**Discretionary Exemptions from Environmental Regulation:
Flexibility for Good or for Ill**

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Abstract:
Many environmental regulations impose limits on harmful activities yet include discretionary "safety valve" provisions allowing the regulator to grant exemptions that provide relief to regulated parties. We construct a theoretical model and explore cases in which this discretion serves good or ill. We show that when a regulation is otherwise inflexible, exemptions can improve social welfare, and perhaps reduce pollution, by distributing abatement more cost-effectively across polluters. However, these beneficial predictions rely on an unconstrained, fully informed, and benevolent regulator. In other cases, exemptions may not offer such gains; further, the discretionary nature of exemptions allows them to be abused.

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1. Introduction

Environmental protection laws impose strict limits on harmful activities, yet many include "safety valve" provisions giving regulators the discretion to grant exemptions that relax in whole or in part the requirements on some regulated parties. Discretionary exemptions, also known as waivers, variances, or exceptions, can be permanent or temporary and vary in the degree of justification required. For example, in the United States, the Clean Water Act requires regulators to impose limits on dischargers based on local water quality conditions when these limits would be tighter than sector-specific standards. However, the Clean Water Act also allows regulated wastewater dischargers to petition for a temporary exemption from these tighter water quality–based limits. The U.S. Environmental Protection Agency (EPA) has the discretion to grant exemptions when compliance with these tighter limits is expected to cause "substantial and widespread impacts" in the affected community.[1] As another U.S. example, the Endangered Species Act imposes stringent restrictions on landowners' use of land parcels on which endangered species are present, but the Act offers the EPA discretion to grant permanent exemptions when certain conditions are met. And, as the most commonplace example, zoning codes restrict landowners' use of land parcels in myriad ways, but local governments frequently exploit their discretion to issue exemptions when landowners petition for relief from those rules, for example, to allow agriculturally zoned land to be used for commercial purposes.

Despite the prevalence of exemptions in environmental policy, we are unaware of previous studies exploring the relationship between discretionary exemptions from environmental

[1] Clean Water Act 40 C.F.R §131.14, 2015.

regulations and social welfare from an economic perspective. We fill this void in two ways. First, we document the prevalence of discretionary exemptions and their role in various regulatory contexts. More important, we craft a theoretical model of firm and regulator behavior, based on established concepts, and apply this model to various settings in order to examine the use and welfare consequences of regulatory exemptions – both for good and for ill. Our model places a profit-maximizing pollution discharger under the purview of a regulator who may seek to maximize a social welfare function comprising profits accruing to the owners of regulated firms and environmental damages caused by pollution. Using this model, we seek to answer this question: When do discretionary exemptions from environmental regulations increase, decrease, or redistribute social welfare?

We first construct a basic model in which both a regulator and firms possess complete information about firms' current abatement costs but only incomplete information about future abatement costs. Initially, abatement costs are identical across all firms. Consequently, the regulator imposes the same pollution limit on all firms (i.e., a uniform standard). However, firms face idiosyncratic shocks to their future abatement costs. While the regulator has an expectation of the distribution of these shocks, the regulator *ex ante* does not know which firms will receive shocks and how big the shocks will be. After the shocks are revealed, the regulator may have the option to grant one or more exemptions, which allow the firm(s) that receive them to meet a looser standard. However, the regulator cannot issue exemptions that tighten a firm's limit, and may be limited in the number of exemptions it can issue. In this setting, exemptions from the uniform standard can improve social welfare by giving the regulator flexibility to facilitate a more efficient or cost-effective outcome. If there is a chance that shocks will increase abatement costs, then a forward-looking regulator who can grant exemptions may be able to achieve *ex ante* greater social welfare and perhaps lower pollution. However, exemptions prove useless if shocks can only reduce costs. Additionally, we explore the case in which the only exemption that can be granted fully relieves the firm of the responsibility of following the regulation, and provide a rule of thumb for when such exemptions will enhance welfare. Finally, we note that the assumptions underlying these positive impacts of exemptions are quite stringent and likely to be rarely met, and we explore how the discretionary nature of exemptions can render them particularly vulnerable to the types of capture and influence that have been documented in other contexts.

2. Literature Review

Surprisingly little research analyzes the economics of exemptions. The closest study to our analysis is Kaplow (2019), who theoretically explores the question of when it might be efficient to exempt small firms from regulations. Kaplow ranks producers along a continuum based on a parameter that determines the slope of their marginal cost curve. Firms that produce less than a threshold are exempted from the regulation. The exemption of small firms (i.e., firms with high marginal costs) decreases their marginal costs, leading them to increase their output and pollution. The exemption also creates an incentive for some firms with optimal unregulated production above the threshold to reduce their production to this threshold in order to avoid the regulation. Despite this distortionary incentive, Kaplow demonstrates that exemptions can generate benefits that exceed costs, which would justify exemptions on the grounds of economic efficiency. While Kaplow looks at the use of a regulatory exemption, this policy tool is not discretionary in the way that the exemptions we study are; as we describe in the next section, many exemptions issued in environmental regulation, as well as other regulatory areas, are discretionary.

In contrast to the minimal literature on discretionary exemptions, an extensive literature examines how regulatory flexibility in a general sense can increase welfare. Seminal articles on incentive-based mechanisms, such as emissions charges and cap-and-trade schemes, reveal that flexibility granted to regulated entities improves cost-effectiveness relative to performance-based standards (e.g., Montgomery, 1972). Similarly, performance-based standards grant greater flexibility than design-based standards (Field and Field, 2017; Goulder and Parry, 2008). Despite increased interest in using incentive-based mechanisms, inflexible command-and-control policies remain common in environmental regulation (Hahn, 2000; Stavins, 2007), such that exemptions can play an important role in influencing welfare outcomes.

Another related literature explores regulation in contexts where regulatory agencies possess meaningful discretion. For example, environmental policy grants a significant amount of discretion to inspectors and enforcement personnel when monitoring and enforcing regulatory restrictions such as pollution limits. Studies in this area include Deily and Gray (1991), Earnhart (2004b), Earnhart (2016), and Kang and Silveira (2018). Regulatory discretion can be particularly troublesome in cases of regulatory capture (Raff and Earnhart, 2018), wherein firms prod the regulator for weaker enforcement (Maloney and McCormick, 1982). Environmental federalism offers another way for agencies to exercise regulatory discretion by delegating regulatory decisions to decentralized authorities (e.g., Arguedas et al., 2017; Banzhaf and Chupp, 2012). The main difference between environmental federalism and our study's focus is that we consider the granting of flexibility on a polluter-by-polluter basis, whereas environmental federalism allows for regulation to vary across geographic space. Additionally, studies of environmental federalism assume that sub-national regulators possess detailed information about regulated entities and locational parameters (e.g., local environmental quality); accordingly, these sub-national regulators can tailor their regulations to entity- or location-specific features, while higher-level regulators cannot. Our study does not feature this informational asymmetry.

Lastly, our study relates to the economic literature examining the distinction between rules and standards (Diver, 1983; Ehrlich and Posner, 1974).[2,3] According to Kaplow (1992), the important distinction between rules and standards is the timing of legal specificity. Rules specify details *ex ante* (prior to adjudication), while under standards details are worked out *ex post* (in the process of adjudication). Relative to standards, rules require larger upfront costs but lower adjudication costs. Relative to rules, standards offer more flexibility but less clarity for guiding compliance decisions. In a similar way, Battigalli and Maggi (2002) describe the role of discretion held by agents in contracts as a function of, among other things, the difficulty of specifying possible actions and the degree of uncertainty that exists. Some of these elements relate to our study, which considers the case in which a regulatory agency may grant an exemption to one or more regulated firms in a context of uncertainty. We do not model the processes by which a firm applies for an exemption and the agency considers this application, but the decision of whether to grant an exemption is similar to an agent exercising his or her discretion in contract execution and similar to the adjudication of a standard. As the first-best benchmark, we describe a process in which the regulatory agency provides firm-specific limits, which is similar to the establishment of a rule. The rules versus standards literature compares the costs of establishing rules or adjudicating standards (Diver, 1983; Ehrlich and Posner, 1974; Friedman and Wickelgren, 2014); in contrast, our study ignores these administrative costs in order to focus on damage and abatement costs.[4] As

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[2] Legal analysis of the relative desirability between rules and standards precedes this economic literature; see Fuller (1941) and Epstein (1995) for historical and recent legal analyses, respectively.
[3] More recent economic analysis explores specific elements of the contrast between rules and standards. As examples, Johnston (1995) examines the role of bargaining and Friedman and Wickelgren (2014) scrutinize the role of sorting driven by the quality of legal representation.
[4] Relative to rules, standards place a greater burden on private parties to gather sufficient evidence to demonstrate they are compliant with the law (Kaplow, 1992). In our context, agencies would bear a greater

the most important difference, in our context, establishment of a rule and granting (or not granting) of an exemption *precede* a firm's compliance decision so that a regulated firm understands with certainty its legal requirement whether facing a "rule" or "standard." In contrast, the rules versus standards literature highlights that the formulation of rules precedes compliance decisions, while the interpretation of standards follows compliance decisions, implying that certainty is greater under rules (Kaplow, 1992).[5]

Our study contributes to this thin literature in two ways. First, we document the prevalence of discretionary exemptions in various regulatory contexts and use the most common regulatory concerns in these contexts – such as reducing abatement costs – to motivate the development of a theoretical framework that can model the implications of these exemptions on social welfare. Second, while our model breaks limited theoretical ground, it provides a formal structure with which to examine more deeply the most commonly cited reasons for the use of discretionary exemptions in environmental regulation and their potential for serving both good and ill. To achieve these ends, we draw strongly on established theoretical concepts. Still, our study provides a foundation for future work that can extend our theoretical model to accommodate additional complexities, such as asymmetric information, and motivates much needed empirical analysis on

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cost burden if they established firm-specific limits, while regulated firms would bear a greater cost burden if a general rule was set and firms had to apply for a firm-specific exemption, though, again, our present model does not include administrative or application costs.

[5] These differences notwithstanding, the rules versus standards literature offers insights for future research on exemptions that considers the cost of formulating firm-specific limits (similar to "writing costs" in Battigalli and Maggi, 2002) and administrators' cost of granting exemptions. As the proportion of the regulated community that benefits from differentiation rises, the cost advantage of rule formulation (over standard interpretation) increases (Kaplow, 1999); in our context, the cost advantage of *ex ante* firm-specific limit determination over *ex post* issuance of firm-specific exemptions should similarly increase as benefits from differentiation rise.

the magnitude of the positive and negative social welfare implications of discretionary exemptions.

3. Regulatory Context in the United States

Discretionary exemptions are a pervasive feature of regulatory policy in the United States. Government entities have used them in macroeconomic policies (e.g., import tariffs; see Swanson and Hsu, 2018); social policy (e.g., the criminal justice system; see Oliss, 1994); and even in national defense (e.g., Vietnam draft deferments; see Schick, 1975). Our study focuses on the use of such exemptions in environmental policy.

There are many examples of the use of discretionary exemptions in U.S. environmental policy. These examples include temporary waivers for fuel content regulations under the 2005 Energy Policy Act in cases where the rules would impose "disproportionate economic hardship" (US Department of Energy, 2011), rare but high-profile permanent exemptions from the stringent regulations imposed by the Endangered Species Act on parcels of land inhabited by endangered species (Yuknis, 2011), and temporary exemptions from the Renewable Fuel Standard (RFS) (Environmental Protection Agency, 2017). In the first case, Aldy (2017) argues that a discretionary (rather than rule-based) waiver system can reduce social costs by responding flexibly to short-term economic disruptions when the standard is otherwise relatively inflexible.

The most common exemptions related to environmental policy are almost certainly local zoning variances. Zoning codes restrict landowners' use of land parcels in myriad ways. Municipal governments establish zoning codes that specify, among other things, the allowable use of a parcel (e.g., residential, commercial, or agricultural). These codes consequentially influence the development of zoned areas (Levkovich et al., 2018; Shertzer et al., 2018). Local governments also use zoning for other purposes that affect environmental quality, such as limiting deforestation (Nolte et al., 2017), banning hydraulic fracturing (Hall et al., 2018), limiting housing density

(Zhang et al., 2017), and specifying a minimum setback of construction from a waterway. Local governments that specify zoning regulations receive applications for and grant, at their discretion, variances from these regulations.

While zoning variances have received little attention in the economics literature, Twinam (2018) finds that variances in Seattle were more common in cases where initial zoning was relatively inflexible. In legal studies, zoning variances have a dual reputation. By providing regulatory relief in situations where it is deemed practical and fair to do so, zoning variances can provide flexibility to enhance social welfare and allow landowners reasonable use of their property (Cohen, 1994). However, variances' discretionary nature leaves them open to abuse (Owens, 2004). To be sure, most zoning authorities apply a standard when deciding whether to grant a variance. However, given the simplicity of most zoning rules, relative to the complexity of the zoned landscape, human judgment inevitably enters into variance decisions. Rather than serve as a safety valve for exceptional cases, variances may be used as commonplace tools for circumventing rules meant to protect social welfare; indeed, the approval rate for variances ranges between 58 and 90 percent, according to studies reviewed by Owens (2004). That said, the ability to grant variances may allow zoning authorities to set broader and more stringent zoning rules than would be the case if zoning restrictions applied uniformly across land parcels.

Another example, which we use as our core scenario in this study, is the Clean Water Act, which requires writers of discharge permits (within regulatory agencies) to impose discharge limits based on local water quality conditions whenever these limits would be tighter than sector-specific standards, known as Effluent Limitation Guidelines (Earnhart, 2007). In other words, a national standard sets the maximum wastewater discharge limit. However, permit writers can and frequently do impose limits tighter than the discharge standard with the goal of preserving water quality so that a waterway can support the use (e.g., fishable/swimmable) designated by the relevant state agency. States base this designation not on cost-benefit analysis, but on the goal of rendering waters fishable and swimmable wherever that is achievable. At the same time, the Clean Water Act allows regulated wastewater dischargers to petition for a temporary variance from these tighter water quality–based limits when compliance with these tighter limits is expected to cause "substantial and widespread economic and social impacts" in the affected communities.

Similar to the zoning case, the EPA grants Clean Water Act variances based primarily on applications from affected parties. In certain cases, state agencies may themselves prepare multi-discharger variance application packages on behalf of a group of dischargers facing similarly steep abatement costs (Environmental Protection Agency, 2013). If granted, the variance allows regulated polluters to "press the pause button" until conditions facilitate compliance without problematic impacts. For example, a community may be unable to upgrade its wastewater treatment plant to comply with a water quality standard during an economic recession, but it may anticipate less difficulty in the near future when household incomes recover. In this case, compliance in the near term might be judged to impose a substantial and widespread impact, whereas it will not once the economy recovers.

Clean Water Act variances differ from zoning variances in several important ways. First, Clean Water Act variances are temporary, whereas zoning variances are permanent. Second, a zoning rule is chosen by local planners with the ostensible goal of optimizing local land use, given that some variances will be granted. On the other hand, permit writers set discharge limits under the Clean Water Act so that waterways support their designated uses; variances are merely meant to address short-term bumps in the road toward achieving the level of ambient water quality associated with a designated use. Put differently, the EPA does not seek to maximize social welfare when identifying the discharge limit needed to support the designated use, so the ability to grant a variance cannot alter the regulator's choice of a water quality–based discharge limit. Our theoretical model incorporates cases in which the initial standard is optimally set with the understanding that the regulator may grant exemptions (reflecting backward induction), as well as cases in which, because of legal requirements or because shocks and exemptions are not foreseen, the initial standard is not optimized based on the existence of exemptions. The implications for environmental impacts may differ between these cases. Finally, the Clean Water Act and zoning variance cases also differ in the types of institutions with authority to issue exemptions. While we do not take a stand on how best to represent either case, our core model explores both institutions that maximize a uniformly weighted social welfare function, while in Section 5 we consider regulators that pursue other objectives, including redistribution or the satisfaction of interest groups.

While exemptions are common regulatory tools, some settings disallow or circumscribe their use. As the first example, the Clean Water Act imposes permit requirements for the discharge of dredged or fill material into U.S. waters. Section 404(f)(1)(A) of the Act exempts "discharges associated with normal farming, ranching, and forestry activities" that are part of an "established, ongoing operation" (Wilcher and Page, 1990). However, Section 404(f)(2) revokes this exemption for discharges stemming from activities that (1) change the use of the waters and (2) reduce the accessibility or impair the flow/circulation of regulated waters (including wetlands). As a second example, Section 10(b) of the Endangered Species Act constrains the Act's hardship exemption. Under the Act, a person may be exempt from the prohibitions and penalties in Section 9 if (1) they enter into a contract regarding a species before the public is notified of the government's consideration of a species as endangered and (2) the prohibitions will cause undue economic hardship. However, hardship exemptions are not available for contracts related to the importation or exportation, for commercial purposes, of endangered species. As a third example, the Clean Air Act imposes reporting requirements. The case of Waterkeeper v. EPA circumscribes application of the *de minimis* doctrine, which lets agencies create categorical exemptions to statues when the burden of regulation yields a trivial gain (Stender, 2018). The ruling holds that the EPA cannot exempt farms from air pollution reporting requirements through the *de minimis* doctrine (Stender, 2018). As a fourth example, the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as identified in 42 U.S.C. §§9607(n)(2)-(3), constrains the federal exemption embedded within the Department of Defense (DOD) Appropriations Act (H.R. 3610, P.L. 104-208). This exemption relates to liability for investigations and clean-up of hazardous waste sites. Specifically, the DOD Appropriations Act exempts fiduciaries and lenders from personal liability (Bannon and Bannon, 1996). However, this exemption does not apply if the fiduciary (1) is liable independent of its role as a fiduciary, (2) is negligent in a way that contributes to the release of hazardous waste, (3) acts independently and directly benefits from its fiduciary role, or (4) is also a beneficiary and receives excessive benefits (Bannon and Bannon, 1996). Lastly, the Price Anderson Amendments of 2005 modify Title VI of the Energy Policy Act, which covers nuclear matters; these amendments repeal the exemption from liability for penalties affecting certain universities, corporations, and their subcontractors and suppliers.

While these examples demonstrate that laws certainly circumscribe agencies' use of exemptions, we note no patterns driving the cases in which exemptions are and are not allowed or are or are not circumscribed. Therefore, no such empirical facts can drive our model design.

4. Basic Model

Our model includes three types of economic agents: (1) firms that sell products and generate pollution; (2) households that bear the consequences of pollution generated by firms; and (3) a regulator who legally constrains firms' pollution levels. We initially assume the regulator seeks to maximize social welfare, but relax that assumption in Section 5. The regulator's tools are (a) a limit on pollution, which we refer to as the *discharge limit*, and (b) exemptions that the regulator may grant on an idiosyncratic basis to firms. An exemption allows a firm to meet a limit that is less stringent than the discharge limit. While the word *exemption* is often used as a discrete choice variable – complete dispensation from a regulation – here it refers to a partial dispensation, and specifically, it is a less stringent limit a firm is granted. In Section 4.7, we discuss full waivers, which completely eliminate firms' obligations to comply with a restriction.

4.1. Model Foundations

The J firms in our model produce products that they sell on output markets and generate a single type of pollution. We assume that pollution is a continuous variable. Constrained by its production and abatement technologies, firm j chooses a level of pollutant discharges, E_j, to maximize profits, $\pi\left(E_j \mid \theta_j\right)$, where θ_j is a parameter that determines a firm j's marginal abatement cost curve position, as we discuss below. While social welfare functions typically do not represent firms directly, we assume that each firm's profit accrues to a single risk-neutral owner so that changes in a firm's profits map directly to changes in welfare. We do not allow entry of new firms; therefore, in our model, firms can earn positive profits in their competitive markets. This condition is equivalent to assuming that the fixed costs of entry exceed the present value of profits of a potential entrant. Similarly, our model excludes fixed costs of a firm's operation so that we can ignore concerns about firm exit.

We assume that the cost parameter linearly scales marginal abatement costs. To make explicit this functional form assumption, we define the new single-argument function $\overline{\pi}'\left(E_j\right) > 0$ to represent the baseline profit function's first derivative. We then define the marginal benefit of discharges (i.e., marginal abatement cost) to the j^{th} firm as $\theta_j\overline{\pi}'\left(E_j\right)$. This marginal benefit function reaches zero at the profit-maximizing level of discharges, E^{π}. We assume $\overline{\pi}''\left(E_j\right) < 0$. Each firm faces a discharge limit, R_j, imposed by the regulator. If a firm exceeds its discharge limit, whether the baseline discharge limit or an exemption, the firm pays a penalty, which we assume is unavoidable and sufficiently high that no firm exceeds its limit. Consequently, as long as $R_j \leq E^{\pi}$, an assumption maintained for all possible limits, the firm's discharge level equals the limit, $E_j = R_j$.[6] Therefore, we can express the firm's profit function as $\pi\left(R_j \mid \theta_j\right)$.

The I households' welfare depends on environmental damage caused by pollution. We assume that pollution is uniformly dispersed, which implies that each household experiences damages as a function of the level of aggregate pollution, denoted as $E = \sum_j E_j$. Household i experiences environmental damages, denoted as $D_i\left(E\right)$. Aggregating across households, we write total environmental damages as $D\left(E\right) = \sum_i D_i\left(E\right)$ with $D' > 0$ and $D'' > 0$. We express

[6] We model discharges as a deterministic outcome. In reality, discharges stem from a stochastic process. This uncertainty may cause polluters to choose to over-comply with discharge limits (Beavis and Walker, 1983a, b).

environmental damages in monetary units. We further assume that $D'(0) < \sum_j \theta_j \bar{\pi}'(0)$, which ensures it is socially optimal for this industry to exist and discharge positive amounts of pollution.

We model the regulatory process in two stages. In Stage 1, the regulator observes homogeneous firms and sets discharge limits; in Stage 2, firms receive heterogeneous shocks to their marginal benefit curves and make their discharge decisions. In the latter stage, the regulator may be able to issue exemptions to firms and may choose to do so. (As noted above, we define an exemption as a relaxed limit for an individual firm, rather than as a marginal adjustment to the baseline discharge limit.)

The regulator's objective is to maximize the benefits to firms less the damages to the public:

$$W = \sum_{j=1}^{J} \pi\left(R_j \mid \theta_j\right) - D\left(E\right). \qquad (1)$$

In the social welfare function of our base model, captured by Equation (1), the weights placed on firms and households are implicitly equal. Section 5 explores the case in which the regulator maximizes an optimand other than an equally weighted social welfare function.

In Stage 1, the regulator views the firms as homogeneous with $\theta_j = 1$ for all *j*. As a result of this homogeneity, the regulator sets a uniform discharge limit for all firms. We represent this uniform discharge limit as $\bar{R}$ and refer to it as the *discharge standard*.

In Stage 2, after the discharge standard is set, $S \leq J$ firms each receive firm-specific shocks to their marginal benefit curves so their new marginal benefits are $\theta_j \bar{\pi}'\left(R_j\right)$, where $\theta_j > 0$. $\theta_j > 1$ indicates a positive (cost-increasing) shock to marginal benefits from pollution (marginal abatement costs), while $0 < \theta_j < 1$ indicates a negative (cost-reducing) shock. The form of this shock ensures that all firms stay in business and discharge positive amounts of pollution in the social optimum. This shock can be interpreted as either an actual change or a revelation of firm-specific marginal benefits to the regulator, allowing the regulator to update its beliefs about firm costs. For notational simplicity, we order shocked firms by the magnitude of their shocks from highest to lowest; i.e., $\theta_i \geq \theta_j$ for all $i \leq j \leq S$.

Next, the regulator learns the shocks' incidence and magnitudes and may grant exemptions to $K \leq J$ firms. Then firms bear abatement costs and generate discharges. We define an exemption granted to firm k as R_k, the level at which the firm is allowed to discharge under the exemption. We assume that the exemption process is costless for both the regulator and firms. We also assume that the regulator can only issue exemptions that allow firms to pollute *more*. The regulator cannot grant exemptions that tighten a firm's discharge limit. This assumption is consistent with the use of exemptions in environmental regulation; with rare exceptions (e.g., 2009 California Clean Car regulations), regulators only use exemptions to loosen pollution control requirements. Finally, we assume that only shocked firms can receive exemptions, as only those firms can claim and document new circumstances to the regulator.

We apply a two-digit superscript to $\overline{R}$, where the first digit refers to the number of firms the regulator anticipates being shocked in Stage 2 and the second digit refers to the number of exemptions the regulator anticipates granting in Stage 2. For example, $\overline{R}^{1,1}$ captures the discharge standard when the regulator anticipates a single shocked firm and a single exemption.

The first-best optimum occurs if the regulator grants exemptions to firms such that the marginal damage cost, $D'(E)$, equals the marginal benefit of increasing each firm's discharge limit, which requires equimarginality across all firms: $D'(E) = \overline{\pi}'(\overline{R}) = \theta_k \overline{\pi}'(R_k)$ for all shocked firms k, where the middle term represents unshocked firms. However, this equimarginality requires a custom optimal exemption for each shocked firm, which, due to informational, administrative, and/or legal constraints, is not likely in practice. More important, as already noted, we assume that the regulatory landscape disallows exemptions that tighten limits and exemptions to unshocked firms. Yet optimality requires these features. Thus, we proceed by examining settings in which the first-best optimum is not possible.

In what follows, we implement the base model in increasing levels of complexity in terms of the regulator's decision. We start with the case in which the regulator does not foresee shocks and cannot issue exemptions (Case 1). Then we move to the case in which the regulator anticipates shocks when setting the discharge standard in Stage 1 but is not able to grant exemptions in Stage 2 (Case 2). Next, we examine the case in which the regulator does not anticipate shocks when setting the discharge standard in Stage 1 (or is not allowed to base the discharge standard on anticipated shocks) but can grant exemptions in Stage 2 (Case 3). Finally, we consider the fully forward-looking case in which the regulator optimally sets the discharge standard in Stage 1 with knowledge that shocks will occur and exemptions will be issued in Stage 2 (Case 4). As we identify important implications of these cases, we label the conclusions that follow logically from our model as "Results" and provide their proofs in the Appendix. Even though some of these Results are intuitively obvious, this Result-proof structure improves transparency and clarity.

4.2. Case 1: Myopic Standard with Unanticipated Shocks and No Exemptions

Consider the case in which the regulator chooses a discharge standard in Stage 1 without anticipating any shocks and without the ability to grant exemptions. In this case, the regulator chooses the standard, $\overline{R}^{0,0}$, to maximize welfare as defined in Equation (1). Since the regulator views J firms' profit functions as homogenous in Stage 1, the regulator's objective function is

$W = J\pi\left(\bar{R}^{0,0} \mid \theta = 1\right) - D\left(J\bar{R}^{0,0}\right)$. Taking the first-order condition with regard to $\bar{R}^{0,0}$ yields the following:

$$J\pi'\left(\bar{R}^{0,0} \mid \theta = 1\right) = JD'\left(J\bar{R}^{0,0}\right). \tag{2}$$

While J could be cancelled out in this expression, we retain it to emphasize that the standard $\bar{R}^{0,0}$ is chosen considering the profits and discharges of *all* regulated firms.

Obviously, if shocks strike firms' marginal benefits, the $\bar{R}^{0,0}$ chosen by the regulator to meet condition (2) generally ceases to be optimal, as we show in Subsection 4.3. On the other hand, if, after unanticipated shocks are realized, the regulator could grant exemptions, those exemptions could improve welfare, as shown in Subsection 4.4.

4.3. Case 2: Anticipated Shocks but No Exemptions

Suppose now that the regulator anticipates that firms will experience shocks but lacks the opportunity to grant exemptions. Consider first the case in which only firm $j = 1$ experiences a shock. Let $\mathcal{E}(\cdot)$ represent an operator that captures the regulator's (possibly subjective) expectations over the distribution of shocks that occur in Stage 2 after the discharge standard is set. Anticipating a shock to one (as yet unidentified) firm, the regulator sets discharge standard $\bar{R}^{1,0}$ that satisfies the following first-order condition:

$$\left[\mathcal{E}(\theta_1) - 1 + J\right]\bar{\pi}'\left(\bar{R}^{1,0}\right) = JD'\left(J\bar{R}^{1,0}\right). \tag{3}$$

If $\mathcal{E}(\theta_1) > 1$, meaning the regulator expects the shock to be marginal benefit-increasing (i.e., increase marginal abatement costs), then Equations (2) and (3) imply that $\bar{R}^{0,0} < \bar{R}^{1,0}$. Put differently, a discharge standard that does not anticipate a positive shock is too strict. Likewise, if $\mathcal{E}(\theta_1) < 1$, a myopic standard is looser than the second-best standard, $\overline{R}^{0,0} > \overline{R}^{1,0}$.

These comparisons are similar if $S > 1$ firms are shocked with no possibility of exemptions. The regulator sets standard $\overline{R}^{S,0}$ to solve the following first-order condition:

$$\left[\mathcal{E}\left(\sum_{s \le S} \theta_s\right) + J - S\right]\overline{\pi}'\left(\overline{R}^{S,0}\right) = JD'\left(J\overline{R}^{S,0}\right). \tag{4}$$

Again, if regulator expects the shocks to increase marginal abatement costs, $\mathcal{E}\left(\sum_{s \le S} \theta_s\right) > S$, then the myopic discharge standard is tighter than the second-best discharge standard; if the regulator expects shocks to decrease marginal abatement costs, the myopic standard is looser. Result 1 summarizes this insight.

Result 1: In the absence of exemptions, as compared to the discharge standard set in the case in which the regulator does *not* anticipate shocks (i.e., the myopic discharge standard), the optimal discharge standard is looser if the regulator anticipates positive shocks to marginal benefit curves and tighter if the regulator anticipates negative shocks.

Put differently, Result 1 shows that, if the regulator underestimates how much a standard hurts firms' profits, the regulator sets the standard too tightly, and vice versa.

While we show that a different discharge standard enhances welfare if the regulator anticipates shocks to firms' marginal benefit curves, in practice, it may be legally or politically challenging for a regulator to set discharge standards based on such expectations. For example, a regulator may anticipate a negative shock in the form of future improvements in abatement technology, but realistic regulatory contexts may disallow the stringency of current discharge limits to be influenced by speculation regarding future pollution control costs. Therefore, we next examine cases in which the regulator does not, or cannot, anticipate shocks when setting the discharge standard but can still grant exemptions after the shocks take place.

4.4. Case 3: Unanticipated Shocks with Exemptions Possible but Unanticipated

Now consider what happens if the regulator has the ability to grant exemptions in Stage 2 yet fails to anticipate shocks or lacks the authority to take the possibility of shocks into account when setting the discharge standard in Stage 1. In this case, the regulator sets the standard in Stage 1 equal to $\overline{R}^{0,0}$, as in Subsection 4.2.

Again, we start with the setting in which only firm $j=1$ experiences a shock. If the marginal benefit curve of Firm 1 is shocked to $\theta_1\overline{\pi}'(R_1)$, with $\theta_1>1$, then the optimal exemption yields an individual standard R_1 for Firm 1 satisfying the following first-order condition:

$$\theta_1\overline{\pi}'(R_1)=D'\left((J-1)\overline{R}^{0,0}+R_1\right). \tag{5}$$

Equation (5) demonstrates that the optimal exemption R_1 depends on the standard $\overline{R}^{0,0}$. Accordingly, we establish an optimal exemption function, $R_1\left(\overline{R}^{0,0}\right)$, that captures this relationship. Taking a total derivative of Equation (5) and noting that, by assumption, $\overline{\pi}''(R)<0$ and $D''(E)>0$, it follows that $dR_1\left(\overline{R}^{0,0}\right)/d\overline{R}^{0,0}<0$. In other words, the optimal exemption for the shocked firm becomes less generous as $\overline{R}^{0,0}$ increases, as summarized in Result 2.

Result 2: The magnitude of the optimal exemption is inversely related to the standard set in Stage 1; i.e., as the standard tightens, the exemption grows more generous.

Result 2 reflects the intuition that, since damages are convex, a loose Stage 1 standard raises the marginal damage cost associated with a marginal increase in the exemption.

If the shock to Firm 1 is positive, increasing the firm's marginal benefits of discharges, then the optimal exemption leads to an increase in aggregate discharges, $R_1\left(\bar{R}^{0,0}\right) > \bar{R}^{0,0}$. However, since the exemption satisfies condition (5), by definition, the gain to Firm 1 exceeds the increased damage costs it causes, yielding a net welfare gain. However, if the shock is negative, $0 < \theta_1 < 1$, the solution to Equation (5) requires a tighter limit for the shocked firm: $R_1\left(\bar{R}^{0,0}\right) < \bar{R}^{0,0}$. Since, by assumption, an exemption can only increase a firm's discharge limit, a cost-reducing shock does not affect aggregate discharges but creates a situation in which pollution exceeds the optimal level.

We now examine the setting in which $S > 1$, that is, multiple firms are shocked. The regulator may be restricted as to how many firms can receive exemptions, so they can grant $K \leq S$ exemptions.[7] (This nests the special case in which $K = S$ and only positive shocks strike firms, which allows the regulator to achieve the optimal discharge allocation.) In this setting, the regulator must choose which firms will receive exemptions and the magnitude of each exemption. The regulator maximizes welfare gains by granting exemptions to the firms with the largest cost-increasing shocks. Since we order shocked firms by shock size, the regulator maximizes welfare by issuing exemptions to firms 1 through *K* (or through the number of positively shocked firms if that number is smaller). The optimal exemptions' magnitudes are again set where the first-order conditions are satisfied for the relevant firms:

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[7] While a regulator is unlikely to face an arbitrary numerical cap on the number of exemptions to grant, in practice, regulators may issue a limited number of exemptions instead of fully reoptimizing discharge standards for reasons such as administrative costs.

$$\theta_k \bar{\pi}'(R_k) = D'\left((J-K)\bar{R}^{0,0} + \sum_{j=1}^{K} R_j \right), \text{ for all } k \leq K. \tag{6}$$

If the regulator grants exemptions based on Equation (6), welfare is increased relative to the case with no exemptions, despite the fact that discharges and environmental damages rise, because the increase in abatement costs stemming from the shocks yields a higher optimal aggregate amount of pollution. If $K = S$ and all shocks are positive, as noted, the regulator issues a customized exemption to every shocked firm so that each of them discharges at a level that is optimal. If fewer exemptions can be granted, only those firms that receive exemptions get the optimal discharge limit and abatement is not optimal since the equality of marginal profits shown in equation (6) applies only to the firms that receive exemptions. Marginal profits for firms without exemptions differ from those of firms with exemptions: (1) the marginal profits of the $J - S$ unshocked firms remain equalized to the expectation of the marginal damages without exemptions, and (2) the marginal profits of the $S - K$ shocked firms without exemptions are different. In particular, any firm receiving a negative shock, $0 < \theta_k < 1$, by assumption, cannot receive a tighter limit; thus, these firms face marginal profits lower than the unshocked firms.[8]

Since the condition for optimal exemptions is the same for multiple shocked firms as for a single shocked firm, the logic for Result 2 still holds for the setting in which $S > 1$: the tighter is the initial standard, the looser are the exemptions.

[8] This comparison fails to hold only when the marginal benefit-reducing shock drives a firm's profit-maximizing level of discharges below the level desired by the regulator; we do not consider this extreme scenario because the assumed functional form for the shocks eliminates the possibility.

4.5. Case 4: Anticipated Shocks with Anticipated Exemptions

Clearly, if the regulator anticipates granting exemptions in Stage 2, then the regulator should take these exemptions into account when setting the discharge standard in Stage 1. To evaluate this decision problem, we use backward induction.

We again consider first the scenario in which only Firm 1 is shocked. Suppose a discharge standard $\overline{R}^{1,1}$ is set in Stage 1. Following Equation (5) and substituting $\overline{R}^{1,1}$ for the myopic standard, $\overline{R}^{0,0}$, we can write the optimal exemption granted to Firm 1 in Stage 2 as $R_1^*\left(\overline{R}^{1,1}\right)$. The forward-looking regulator sets $\overline{R}^{1,1}$ to maximize welfare taking into account (1) the direct effect of the standard on the $S-1$ unshocked firms, and (2) the indirect effect on the shocked firm.

If $\theta_1 > 1$, then the regulator grants the optimal exemption $R_1^*\left(\overline{R}^{1,1}\right)$. A negative shock, $0 < \theta_1 < 1$, may be possible even when $\mathcal{E}\left(\theta_1\right) > 1$. If that possibility is excluded and the regulator only anticipates positive shocks, then the optimum can be achieved.

Result 3: The regulator who anticipates a single positive shock and anticipates granting an exemption in Stage 2 achieves an *ex ante* optimal aggregate level and allocation of discharges.

Result 3 follows from these points. Unshocked firms, in expectation, have marginal profits equal to marginal damages. The regulator establishes a forward-looking discharge standard and grants an exemption as determined by a relationship that is otherwise like Equation (5). This relationship equates the marginal profits of the shocked and exemption-receiving firm to marginal damages as well. While Result 3 essentially indicates the basic outcome that optimization ensures that the marginal benefits of discharges equal marginal costs, the result demonstrates that this equality holds *ex ante* in the context of this particular two-stage framework.

Recall that the regulator grants no exemptions in Stage 2 if $0 < \theta_1 < 1$ (i.e., the shock is negative) yet grants exemption $R_1\left(\bar{R}^{1,1} \mid \theta_1\right) > \bar{R}^{1,1}$ if $\theta_1 > 1$. This asymmetry means that, if the regulator expects an uncertain but mean zero shock, i.e., $\mathcal{E}\left(\theta_1\right) = 1$, the expected exemption is still discharge-increasing, $\mathcal{E}\left(R_1\left(\bar{R}^{1,1}\right) \mid \theta_1\right) > \bar{R}^{1,1}$. This logic leads to Result 4:

Result 4: The regulator who anticipates a single shock and granting an exemption in Stage 2 sets a strictly tighter discharge standard than the regulator who anticipates granting no exemptions: $\bar{R}^{1,1} < \bar{R}^{1,0}$.

Corollary: The regulator who anticipates *S* shocks and *K* exemptions in Stage 2 sets a strictly tighter discharge standard than the regulator who anticipates granting fewer than *K* exemptions: $\bar{R}^{S,K} < \bar{R}^{S,L}$ for $0 \leq L < K$.

Result 4 and its corollary offer important implications for policy: the ability to grant exemptions allows a stricter discharge standard to be set.

Now consider what happens as the number of shocks and exemptions rise. Exemptions have two key advantages over discharge standards: exemptions are set *ex post* instead of *ex ante* and can be individualized to each firm. Taken to the extreme, if all firms receive marginal profit-increasing shocks and are subsequently granted exemptions, $K = S = J$, then the regulator sets the optimal exemptions at the first-best levels where each firm's marginal benefit from discharges equals the marginal damage caused by the aggregate discharges. To achieve this result, the regulator must set a discharge standard that is so strict that every firm would receive an exemption, as summarized in Result 5.

Result 5: If $K = S = J$ and the regulator only expects positive shocks, the optimal discharge standard $\bar{R}^{J,J}$ is sufficiently strict that all firms receive an exemption in Stage 2 and the regulator grants exemptions to all firms to achieve the optimal aggregate amount of pollution and the first-best allocation of pollution across firms.

The regulator's expectation of only positive shocks might seem irrational. After all, in typical cases, expectations should prove correct on average based on the law of iterated expectations. However, in this context, the temporal separation of the regulatory actions – setting the discharge standard first and later granting an exemption – renders the constructed scenario quite plausible. In Stage 1, a regulator could expect an array of shocks that would all increase costs in Stage 2. For example, the regulator may set the standard for wastewater treatment facilities based on normal operating conditions but be willing to grant exemptions under abnormally bad weather events that increase the facilities' costs of managing their discharges.

4.6. Comparison of Outcomes with and without Exemptions

Focusing on the scenario in which a single firm is shocked, we consider four policy settings: (1) a situation (like in Subsection 4.2) in which the regulator is completely myopic, setting a standard without anticipating any shocks and without the ability to issue exemptions: here, $R_j = \overline{R}^{0,0}$ for all j; (2) a situation (Subsection 4.3) in which the regulator anticipates a shock but is unable to grant exemptions: here, $R_j = \overline{R}^{1,0}$ for all j; (3) a situation (Subsection 4.4) in which the regulator does not anticipate shocks in Stage 1 yet is still able to grant exemptions in Stage 2: here, $R_1 = R_1\left(\overline{R}^{0,0}\right)$ and $R_j = \overline{R}^{0,0}$ for $j > 1$; and (4) a situation (Subsection 4.5) in which the regulator anticipates a shock and the ability to grant an exemption to the shocked firm: here, $R_1 = R_1\left(\overline{R}^{1,1}\right)$ and $R_j = \overline{R}^{1,1}$ for $j > 1$.

Comparing the four policy settings, we can establish some relative welfare rankings among the four cases. Let W_i denote the *ex ante* welfare associated with each situation *i*. Relative to Case 1, welfare is improved in any of the other settings since, in each of the other cases, the regulator takes into account, to some extent, the differential marginal benefits of pollution for the shocked firm. Further, because in Case 4, the regulator is maximally able to optimize, that must be the case with the highest welfare. As a result, $W_4 \geq W_2 \geq W_1$ and $W_4 \geq W_3 \geq W_1$. If shocks are always marginal profit-increasing, these inequalities are strict. Only W_2 and W_3 are not unambiguously comparable because (1) the regulator increases welfare in Case 2 using improved information available in Stage 1, yet (2) the regulator increases welfare in Case 3 by granting in Stage 2 an unanticipated and *ex post* optimized exemption.

We can also compare expected aggregate discharges across the policy settings. This depends on whether the regulator anticipates a positive or negative shock to the firm's marginal benefits. If the anticipated shock is positive, aggregate discharges in Cases 2 and 3 are greater than in Case 1. For the comparison involving Case 2, the ranking follows because, in Cases 1 and 2, the regulator grants no exemptions but sets a looser discharge standard in Case 2. For the comparison involving Case 3, the ranking follows because the regulator sets an identical discharge standard in Cases 1 and 3 yet grant exemptions to some firms in Case 3, allowing them to discharge more. Thus, anticipating positive shocks raises aggregate discharges relative to the case in which the shocks are unanticipated, regardless of whether the regulator is able to issue exemptions. If the anticipated shock is negative, aggregate pollution is the same across Cases 1, 2, and 3, since the regulator grants no exemptions regardless.

Case 4 offers a more interesting comparison, particularly relative to Case 2. The regulator is equally informed in Cases 2 and 4, yet only grants exemptions in Case 4. *Ex ante* aggregate discharges may be higher or lower in Case 4, when an exemption is possible, since the discharge standard is tighter but the exemption is looser. Still, one might expect total discharges to often decline because the aggregate costs of achieving any aggregate pollution level should prove lower since exemptions allow for greater cost-effectiveness. When this is the case, exemptions allow society to optimize at a lower level of aggregate pollution.

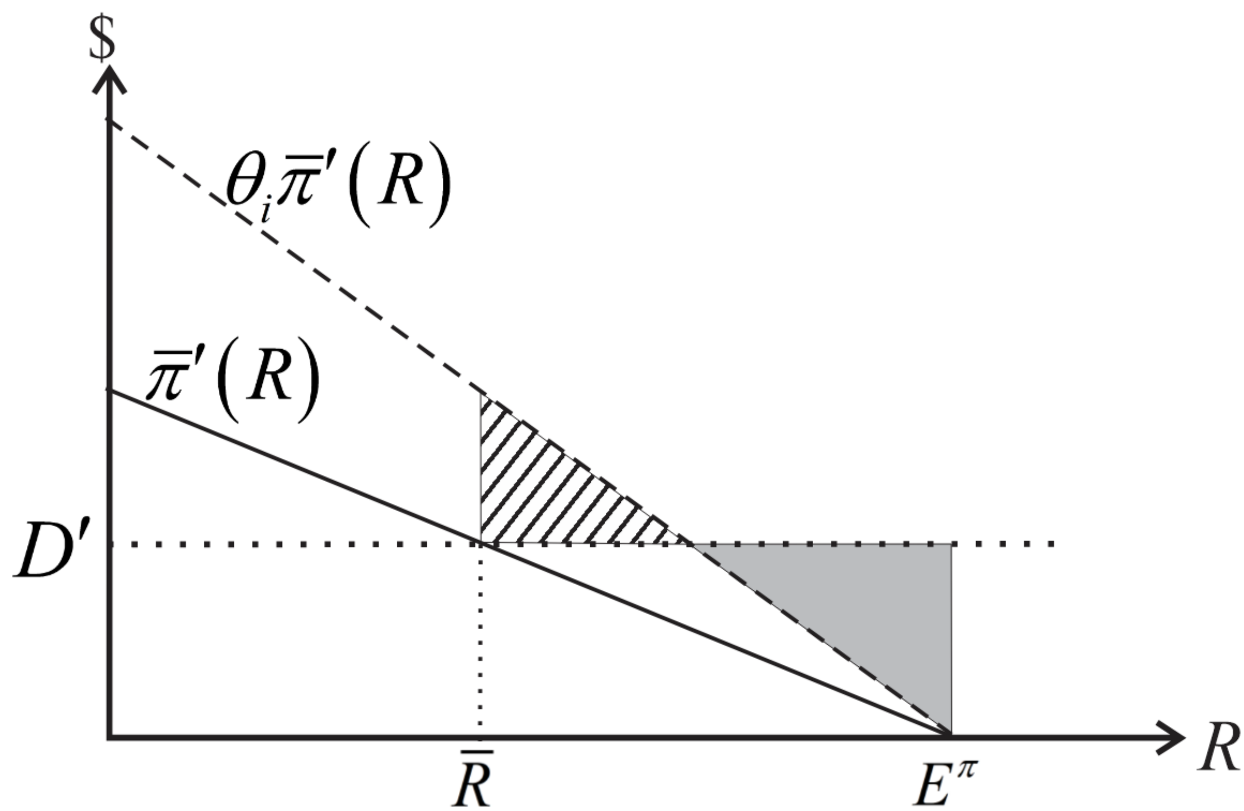
While we have only shown these comparisons to be true for the case of a single shocked firm, they should also hold if an arbitrary number of firms is shocked.

4.7. Full Waivers

Up to this point, we have assumed that the regulator has the discretion to grant an exemption of any magnitude. However, regulators do not always possess such discretion. In some cases, they can only grant a complete exemption from the regulation in the sense of releasing the firm from being bound by it at all. We call this type of exemption a "full waiver." In the context of our model, a full waiver grants a firm the right to discharge at any level. Consequently, the firm chooses the privately optimal level, E^{π}, where $\theta_j \bar{\pi}'\left(E^{\pi}\right) = 0$. Since $D' > 0$ and, by assumption, the optimally set discharge limit is no greater than the privately optimal level ($R_j \leq E^{\pi}$ for all *j*), a full waiver is not socially optimal. Marginal damages always weakly exceed the marginal benefit to a firm receiving a full waiver. Nonetheless, full waivers can enhance welfare if firms are otherwise subject to a uniform discharge standard that is so tight that the increment to the profits of the firm receiving the exemption exceeds the increment in damages caused by higher discharges. Figure 1 displays this tradeoff, with marginal damages now assumed to be constant for easier visualization. The shock drives up the firm's abatement costs from the solid to the dashed line. A full waiver would relieve the firm of all abatement costs by moving right on the horizontal axis to

E^{π}. Of course, the full waiver also increases damage costs, visible as the area under the marginal damage curve D'. In Figure 1, the diagonally-hatched triangle is the value of reduced abatement costs not neutralized by higher damage costs, and the shaded triangle represents increased damage costs not compensated by reduced abatement cots. The full waiver proves welfare-improving if the diagonally-hatched triangle is larger than the shaded triangle.

Figure 1: Welfare consequences of a full waiver to firm *i* from $\bar{R}$ to E^{π}



Note: The reduction in abatement costs that is not neutralized by higher damage costs is the diagonally-hatched triangle and the increase in damage costs not compensated by lower abatement costs is the shaded triangle.

Consider a marginal profit-increasing (marginal abatement cost-increasing) shock to a single firm (Firm 1). We focus on the regulator's Stage 2 decision to grant the firm a full waiver.

We can approximate the welfare change stemming from the increase in Firm 1's discharges from the standard $\overline{R}$ to the profit-maximizing level E^{π} using a first-order approximation that averages the slopes for the cases in which Firm 1's emissions are $\overline{R}$ and E^{π}:

$$\Delta W = \frac{1}{2}\left[\theta_1 \overline{\pi}'\left(\overline{R}\right) + \theta_1 \overline{\pi}'\left(E^{\pi}\right)\right]\left(E^{\pi} - \overline{R}\right) - \frac{1}{2}\left[D'\left(J\overline{R}\right) + D'\left(\left(J-1\right)\overline{R} + E^{\pi}\right)\right]\left(E^{\pi} - \overline{R}\right) > 0. \quad (7)$$

If we assume that the D' is approximately constant over this range, which is likely if J is large so that each firm's share of total discharges is small, then $D'\left(J\overline{R}\right) + D'\left(\left(J-1\right)\overline{R} + E^{\pi}\right) \cong 2D'\left(J\overline{R}\right)$. Since $\overline{\pi}'\left(E^{\pi}\right) = 0$, this expression implies the following:

$$\Delta W = \frac{1}{2}\left(\theta_1 \overline{\pi}'\left(\overline{R}\right)\right)\left(E^{\pi} - \overline{R}\right) - D'\left(J\overline{R}\right)\left(E^{\pi} - \overline{R}\right) > 0. \quad (8)$$

This inequality holds if $\frac{1}{2}\theta_1 \overline{\pi}'\left(\overline{R}\right) > D'\left(J\overline{R}\right)$. If the standard $\overline{R}$ is set optimally so that $\overline{\pi}'\left(\overline{R}\right)$ approximately equals $D'\left(J\overline{R}\right)$ (again, assuming Firm 1 is small), then the inequality in (8) further simplifies to: $\Delta W > 0$ if $\theta_1 > 2$. As a rule of thumb, therefore, a full waiver enhances welfare only if the shock doubles the marginal benefit of discharges for the shocked firm.

5. Exemptions for Ill

In the preceding sections, we show that exemptions can improve social welfare, and, in some cases, reduce pollution. We also show that these beneficial outcomes only arise under strong assumptions regarding the regulator's ability to issue exemptions. Yet many of these assumptions, including (1) the ability to set discharge limits in Stage 1 based on expectations regarding shocks to the marginal benefits of discharges in Stage 2 and (2) the ability to issue customized exemptions to individual firms in Stage 2 based on perfect information, are unlikely to hold in real-world contexts. Thus, it may be difficult for regulators to use exemptions "for good" in practice.

In addition, our analysis thus far has assumed that the regulator makes decisions to maximize a social welfare function composed of equally weighted benefits and costs accruing to firms and households. While this setup is standard in the literature, in practice, this construction need not prove relevant. A growing literature in welfare economics questions the equal treatment of values of all benefits and costs (Coate, 2001; Fleurbaey and Abi-Rafeh, 2016; Hendren, 2020). For example, Fleurbaey and Abi-Rafeh (2016) argue that regulators should weight values accruing to members of society differently if society is more concerned about the welfare of disadvantaged or vulnerable people; in other words, the social welfare function need not be equally weighted. As long as the regulator uses the true social welfare function as its optimand, the presence of unequal weights changes our marginal conditions but not the general functioning or optimality of exemptions.

One implication of such unequal weighting, however, is that, if an exemption simply redistributes benefits, it ceases to be welfare-neutral. For example, if a regulator weights households damaged by pollution most heavily, then an exemption that provides a benefit to polluters similar in dollar value to the cost imposed on pollution-affected households actually harms social welfare, whereas an exemption that redistributes welfare from high-income elites who would bear pollution damages to low-wage workers who benefit from pollution-fueled development improves social welfare.

Alternatively, a regulator might weight welfare function components unequally if the regulator is particularly beholden to some subset of society such that the regulator's optimand diverges from the social welfare function. This setting proves more consequential: exemptions are no longer guaranteed to increase welfare and may even decrease it. Whether the regulator's optimand reflects the social welfare function is especially salient in the context of regulations that allow for exemptions because exemptions are generally granted on a discretionary basis and the exemption process frequently lacks the transparency and public input that are common when environmental standards are set.

As one common situation, the regulator is often parochially focused, having jurisdiction in only its own community. For example, zoning variances are granted by local boards charged with considering only local welfare. Similarly, under the Clean Water Act, the EPA's consideration of costs focuses exclusively on locally borne costs (Environmental Protection Agency, 1995), and as a result, when a state agency prepares an application for a multiple discharger variance from Clean Water Act water quality-based limits, the agency focuses exclusively on costs borne within that state (Environmental Protection Agency, 2013).

As important, previous studies provide evidence on the role of special interest groups formed along community lines and their influence on environmental policy decisions (Oates and Portney, 2003). As one example, zoning is seen by many as a tool "used to quietly grant special favors to the politically connected" (Owens, 2004). As another example, Pashigian (1985) finds that the interests of certain regions shaped a U.S. environmental policy that limited increases in pollution in high environmental quality areas, concluding that self-interest favoring local economic actors and sources of political pressure drives legislators' positions on environmental policy. Thus, there is evidence that regulators may make policy choices to favor either their local area in general or specific pressure groups in it.

The regulator may instead unequally weight economic sectors within a community. Regulators may be biased in favor of the industry they regulate for reasons ranging from the deplorable case of outright bribery to the common practice of hiring as regulators individuals who have close ties to that group, among others (Prendergast, 2007).

Previous empirical studies provide evidence on the influence of special interest groups on environmental protection policy measures including regulatory agency decisions. Oates and Portney (2003) offer a useful framework for assessing this influence empirically, guided by the positive theory of environmental regulation (Peltzman, 1976; Stigler, 1971). These studies attempt to examine the "revealed preferences" of environmental regulatory agencies, i.e., to infer the criteria guiding the agencies' choices (McFadden, 1976). In general, the studies estimate a relationship between an agency's decisions and these explanatory factors: interest groups' behavior, expected environmental damages, and expected abatement costs (Oates and Portney, 2003).[9] This literature shows that interest groups shape the design and implementation of environmental measures, including the use of exemptions (Oates and Portney, 2003). Interest groups have been found to influence environmental policy relating to wastewater effluent management (Magat et al., 1986), pesticide regulations (Cropper et al., 1992; Nadaï, 1996), the sale of leases for offshore gas and oil drilling (Hoagland and Farrow, 1996), Superfund remediation efforts (Hird, 1990; Sigman, 2001), and sustainability policies adopted by U.S. cities (Berry and Portney, 2013).[10, 11] Oates and Portney (2003) note that these results imply that *both* social welfare and the desires of interest groups influence regulators' work. To our knowledge, no

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[9] Other studies econometrically infer the influence of special interest groups using indirect measures like local employment conditions; see Deily and Gray (1991) and Earnhart (2004c).

[10] In addition to these econometric studies, case studies reveal the influence of special interest groups on environmental policy. As examples, Ackerman and Hassler (1981) examine the U.S. Clean Air Act and Lévêque (1996) examines various E.U. environmental policies.

[11] A broader empirical literature explores the influence of special interest groups on government agency decisions in general (e.g., Yackee and Yackee, 2006).

empirical studies show this influence on environmental exemptions, but exemptions' dependence on the discretion of individuals and lack of transparency render them vulnerable to it.

If a regulator's optimand differs from the social welfare function, exemptions are not socially optimal. For example, a parochially-focused regulator may oversee firms generating pollution that is exported, e.g., water pollutants carried downstream out of a community, while abatement costs accrue locally. In this case, the parochially-focused regulator may issue too many exemptions, resulting in inefficiently high levels of downstream pollution. Alternatively, if the regulator is captured by industry, firm profits are weighted too heavily by the regulator; in the extreme, the regulator might place no weight on household outcomes. Since an exemption increases firms' profits, a regulator captured by industry is more likely to issue an exemption than one serving the public good, resulting in too much pollution relative to the optimal.

In addition, a regulator not allocating exemptions based on the social welfare function likely undermines cost-effectiveness by sabotaging equimarginality. For uniformly mixed pollutants, discharges should be distributed across firms so that marginal abatement costs are equal across firms. If the regulator in one community grants an exemption that is not granted to firms in other communities, then the equimarginal criterion is unlikely to be met.[12] If instead the regulator favors only some firms within a community, then this favoritism also renders the allocation across the polluting firms inefficient. Finally, a regulator with jurisdiction over multiple communities might weight some of them more heavily than others, perhaps reflecting communities' different

[12] Other communities may also grant parochially driven exemptions, especially if firms can relocate based on regulatory costs. This "race to the bottom" could result in a cost-effective allocation if regulations are relaxed to the same level; however, in this scenario, the relaxed discharge limits would likely generate far too much pollution relative to the optimum.

capacities to exert political pressure, as in Earnhart (2004a). If greater power rests in communities with firm owners or communities far from pollution damage, the regulator is likely to grant too many exemptions. If greater power rests with elites who do not receive firm profits but are affected by pollution, the regulator issues too few exemptions.

Overall, therefore, there is significant potential for the exemption process to result in deviations from the social optimum. Given the strong assumptions required by our model showing exemptions' efficiency, as well as the empirical evidence from the literature that regulatory decisions are frequently influenced by particular parties, sectors, or regions, along with the structural elements of the exemption process that render it vulnerable to similar influence, common uses of exemptions in environmental policy could undermine social welfare. If true, exemptions prove a force for ill rather than for good. Thus, communities that are considering using exemptions as part of their regulatory toolkit should carefully consider whether the idealized conditions required for the maximization of societal net benefits are actually reflected in the relevant regulatory context.

6. Conclusions

Many laws grant government agencies the discretion to grant exemptions – known also as variances, exceptions, and waivers – as a safety valve that can loosen the stringency of protective restrictions. Government agencies commonly use exemptions in the realm of environmental protection (and other settings), but the implications of this tool have been understudied. In this study, we explore the impact of exemptions to demonstrate that, under the right conditions, the discretion to grant exemptions can improve social welfare by providing flexibility.

In our core model, we consider a two-stage decision-making context in which the regulator maximizes a standard social welfare function. We show that an exemption can increase social welfare by giving the regulator discretion to relax a limit that is too tight: discretion begets flexibility, which yields cost-effectiveness. This reduction in the cost of fighting pollution relative to a strict uniform discharge standard may even reduce the aggregate amount of pollution. These results are similar to the welfare-improving effects of other forms of policy flexibility, such as emissions charges.

Exemptions contrast strongly with other policies in the way they offer flexibility. Emissions charges, for example, offer flexibility to polluters, allowing them to take advantage of private information about their own abatement costs. Exemptions, in contrast, offer discretion to regulatory agencies, allowing for flexible adjustments to otherwise uniformly imposed limits. Under an exemption, polluters still lack flexibility over their emissions levels – polluters may not legally exceed even adjusted limits and gain no legal benefits by over-complying with limits.

Our model makes a number of critical assumptions about functional forms, information, the temporal structure of the problem, and the actions available to the regulator. The cases in which we showed that exemptions improve welfare assume a great deal of information on the part of the regulator. To make optimal exemption decisions, the regulator eventually requires perfect knowledge of the costs of each polluting firm and the damage costs associated with pollution. In reality, the regulator is unlikely to possess all this information. Indeed, in most cases, firms must submit applications to be considered for exemptions. If firms can misrepresent their costs to the regulator, then exemptions need not be beneficial and could even be welfare reducing. Worse yet, a regulator may exploit regulatory discretion by granting an exemption when it is not merited, reducing welfare by either granting too many exemptions (reducing efficiency) or by granting them to the wrong entities (reducing cost-effectiveness). These welfare-harming exemptions may occur because the regulator is captured by an industry, focuses only on a local jurisdiction, or cares only about the interests of certain groups or communities. In these cases, the regulator uses regulatory discretion against society's best interests. Thus, while our formal model shows exemptions' use "for good," failures of our technical or behavioral assumptions could make exemptions a force "for ill."

Despite the idealized conditions under which we examine exemptions, our theoretical analysis contributes to the literature on the economics of environmental regulation by presenting a framework that links the behavior of firms and a regulator to welfare consequences under various constraints on how the regulator issues these exemptions. Extensions to our theoretical model could answer additional questions that merit study, such as the following: Do exemptions have progressive or regressive impacts? How is the surplus generated by an exemption shared between producers and households? What are the impacts on outcomes if regulated firms face exemption application costs and/or regulators bear costs when processing or granting exemptions? Our theoretical setup may also serve as a foundation for empirical analysis of the use of exemptions within environmental policy. Empirical analysis could study whether observed discharge standards set by real-world pollution control policies reflect exemptions that were issued in ways consistent with our model's predictions. Future empirical work building on our theory could also assess whether regulators grant exemptions in ways that maximize social welfare or benefit one constituency at the expense of society as a whole. This work is akin to previous empirical work estimating the influence of special interest groups on regulatory actions (e.g., Cropper et al., 1992; Magat et al., 1986), as described in Section 5. Similarly, empirical analysis can explore whether the granting of exemptions demonstrates a regulator's information asymmetry with regard to grantees.

Appendix: Proofs

A.1. Proof for Result 1

Result 1: In the absence of exemptions, as compared to the discharge standard set in the case in which the regulator does *not* anticipate shocks (i.e., the myopic discharge standard), the optimal discharge standard is looser if the regulator anticipates positive shocks to marginal benefit curves and tighter if the regulator anticipates negative shocks.

Proof:

The standard, $\overline{R}^{S,0}$, in which the regulator anticipates S shocks but cannot grant exemptions, is found by maximizing Equation (3) with first order condition as expressed in Equation (4):

$$\left[\mathcal{E}\left(\sum_{s\le S}\theta_s\right)+J-S\right]\overline{\pi}'\left(\overline{R}^{S,0}\right)=JD'\left(J\overline{R}^{S,0}\right).$$

Let $\Theta_s=\mathcal{E}\left(\sum_{s\le S}\theta_s\right)+J-S$, so that $\Theta_s>J$ implies that shocks are anticipated to be positive on average while $\Theta_s<J$ implies they are anticipated to be negative on average.

By the implicit function theorem:

$$\frac{d\overline{R}}{d\Theta_s}=-\frac{\overline{\pi}'\left(\overline{R}\right)}{\Theta_s\overline{\pi}''\left(\overline{R}\right)-J^2D''\left(J\overline{R}\right)}.$$

This expression is positive because π' and D'' are positive and $\Theta_s\overline{\pi}''$ is negative. Hence, relative to the case in which no shocks or mean zero shocks are anticipated, the optimal standard $\overline{R}^{S,0}$ rises (i.e., loosens) if the regulator anticipates positive shocks and falls if the regulator anticipates negative shocks.

A.2. Proof for Result 2

Result 2: The magnitude of the optimal exemption is inversely related to the standard set in Stage 1; i.e., as the standard tightens, the exemption grows more generous.

Proof:

The claim is that $dR_1 / d\overline{R}^{0,0}$ is negative for any standard $\overline{R}^{0,0}$. Equation (5) states that the optimal exemption for $\theta_1 > 1$ is defined by the condition:

$$\theta_1 \overline{\pi}'(R_1) = D'\left(\left(J-1\right)\overline{R}^{0,0} + R_1\right).$$

The total differential of this expression is

$$\theta_1 \overline{\pi}''(R_1)\, dR_1 = \left(\left(J-1\right)d\overline{R}^{0,0} + dR_1\right) D''\left(\left(J-1\right)\overline{R}^{0,0} + R_1\right),$$

which rearranges to the following:

$$\frac{dR_1}{d\overline{R}^{0,0}} = \frac{\left(J-1\right) D''\left(\left(J-1\right)\overline{R}^{0,0} + R_1\right)}{\theta_1 \overline{\pi}''(R_1) - D''\left(\left(J-1\right)\overline{R}^{0,0} + R_1\right)}. \tag{A.1}$$

Since by assumption, $D''(\cdot) > 0$ and $\pi''(\cdot) < 0$, the numerator is unambiguously positive and the denominator is unambiguously negative, so the derivative is negative.

A.3. Proof for Result 3

Result 3: The regulator who anticipates a single positive shock and anticipates granting an exemption in Stage 2 achieves an *ex ante* optimal aggregate level and allocation of discharges.

Proof:

In Stage 2, if the shocked firm receives a positive shock, the optimal exemption is set according to following condition:

$$\frac{dW}{dR_1} = \theta_1 \bar{\pi}'\left(R_1\right) - D'\left(\left(J-1\right)\bar{R}^{1,1} + R_1\right) = 0, \tag{A.2}$$

where $\bar{R}^{1,1}$ is the standard set in Stage 1. This condition implicitly defines a function $R_1^{+}\left(\bar{R}^{1,1}\right)$, with the "+" superscript indicating that the shock is positive ($\theta_1 > 1$). If the firm receives a negative shock, then, by assumption, the regulator grants no exemption, i.e., $R_1^{-}\left(\bar{R}^{1,1}\right) = \bar{R}^{1,1}$. We then define a constrained optimal exemption function as follows:

$R^{*}\left(\bar{R}^{1,1}\right) = R_1^{+}\left(\bar{R}^{1,1}\right)$ if $\theta_1 > 1$ and $R_1^{-}\left(\bar{R}^{1,1}\right) = \bar{R}^{1,1}$ if $\theta_1 \le 1$.

In Stage 1, we determine $\bar{R}^{1,1}$ by solving this problem:

$$\max_{\bar{R}^{1,1}} W = \left(J-1\right)\bar{\pi}\left(\bar{R}^{1,1}\right) + \mathcal{E}\left[\theta_1 \bar{\pi}\left(R_1^{*}\left(\bar{R}^{1,1}\right)\right) - D\left(\left(J-1\right)\bar{R}^{1,1} + R_1^{*}\left(\bar{R}^{1,1}\right)\right)\right],$$

which has first-order condition

$$\begin{aligned}\frac{dW}{d\bar{R}^{11}} &= \left(J-1\right)\bar{\pi}'\left(\bar{R}^{1,1}\right) \\ &+ \mathcal{E}\left[\theta_1 \frac{dR_1^{*}}{d\bar{R}^{1,1}} \bar{\pi}'\left(R_1^{*}\left(\bar{R}^{1,1}\right)\right) - \left(J-1+\frac{dR_1^{*}}{d\bar{R}^{1,1}}\right) D'\left(\left(J-1\right)\bar{R}^{1,1} + R_1^{*}\left(\bar{R}^{1,1}\right)\right)\right] = 0\end{aligned}.$$

Let ω^{+} and ω^{-} represent the regulator's believed probabilities that the shock to θ_1 is positive and negative, respectively, and $\mathcal{E}^{+}$ and $\mathcal{E}^{-}$ represent the expectation operators conditional on positive and negative shocks, respectively.

The first order condition of the Stage 1 problem can, therefore, be written as follows:

$$
\begin{aligned}
0 &= (J-1)\bar{\pi}'\left(\bar{R}^{1,1}\right) \\
&+ \omega^{-}\mathcal{E}^{-}\left[\theta_1\left(\frac{dR_1^{-}}{d\bar{R}^{1,1}} \mid \theta_1 \le 1\right)\bar{\pi}'\left(R_1^{-}\left(\bar{R}^{1,1}\right)\right) - \left(J-1+\left(\frac{dR_1^{-}}{d\bar{R}^{1,1}} \mid \theta_1 \le 1\right)\right)D'\left((J-1)\bar{R}^{1,1} + R_1^{-}\left(\bar{R}^{1,1}\right)\right)\right]. \\
&+ \omega^{+}\mathcal{E}^{+}\left[\theta_1\left(\frac{dR_1^{+}}{d\bar{R}^{1,1}} \mid \theta_1 > 1\right)\bar{\pi}'\left(R_1^{+}\left(\bar{R}^{1,1}\right)\right) - \left(J-1+\left(\frac{dR_1^{+}}{d\bar{R}^{1,1}} \mid \theta_1 > 1\right)\right)D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\right]
\end{aligned}
$$

Using the fact that $R_1^{-}\left(\bar{R}^{1,1}\right) = \bar{R}^{1,1}$, which also implies that $dR_1^{-}/d\bar{R}^{1,1} = 1$, we further simplify and rearrange this expression to the following:

$$
\begin{aligned}
0 &= (J-1)\bar{\pi}'\left(\bar{R}^{1,1}\right) \\
&+ \omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,1}\right) - JD'\left(J\bar{R}^{1,1}\right)\right\} \\
&+ \omega^{+}\mathcal{E}^{+}\left\{\begin{array}{l}\underbrace{\left[\theta_1\bar{\pi}'\left(R_1^{+}\left(\bar{R}^{1,1}\right)\right) - D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\right]}_{=0}\left(\frac{dR_1^{+}}{d\bar{R}^{1,1}} \mid \theta_1 > 1\right) \\ -(J-1)D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\end{array}\right\}
\end{aligned}
\quad . \qquad \text{(A.3)}
$$

Since the term in the square brackets equals zero, as indicated, because of the Stage 2 first-order condition in Equation (A.2), we can simplify and rearrange the expression to the following:

$$
\begin{aligned}
&(J-1)\bar{\pi}'\left(\bar{R}^{1,1}\right) + \omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,1}\right)\right\} = \\
&\quad \omega^{-}\mathcal{E}^{-}\left\{JD'\left(J\bar{R}^{1,1}\right)\right\} + \omega^{+}\mathcal{E}^{+}\left\{(J-1)D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\right\}
\end{aligned}.
$$

If the regulator anticipates one positive shock, which implies that $\omega^{-} = 0$ and $\omega^{+} = 1$ and lets us replace $\mathcal{E}^{+}$ with $\mathcal{E}$, and the regulator anticipates granting one exemption, the regulator chooses the optimal standard, $\bar{R}^{1,1}$, based on this condition:

$$
\bar{\pi}'\left(\bar{R}^{1,1}\right) = \mathcal{E}\left\{D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\right\}. \qquad \text{(A.4)}
$$

Similarly, to Equation (5), the optimal exemption, R_1, is chosen so that the following holds:

$$
\theta_1\bar{\pi}'\left(R_1\right) = D'\left((J-1)\bar{R}^{1,1} + R_1\right). \qquad \text{(A.5)}
$$

Since the right-hand side of Equation (A.4) is simply the expectation of the right-hand side of Equation (A.5) as anticipated in Stage 1, we can take expectations of both sides of Equation (A.5) so the following holds:

$$\bar{\pi}'\left(\bar{R}^{1,1}\right) = \mathcal{E}\left(\theta_1\right)\bar{\pi}'\left(R_1^+\left(\bar{R}^{1,1}\right)\right) = \mathcal{E}\left\{D'\left(\left(J-1\right)\bar{R}^{1,1} + R_1^+\left(\bar{R}^{1,1}\right)\right)\right\}.$$

The first equality represents equimarginality; this equality identifies the *ex ante* efficient allocation of discharges across firms. The second equality ensures that *ex ante* marginal damages equal *ex ante* marginal abatement costs. These conditions are sufficient for *ex ante* optimization.

A.4. Proof for Result 4

Result 4: The regulator who anticipates a single shock and granting an exemption in Stage 2 sets a strictly tighter discharge standard than the regulator who anticipates granting no exemptions: $\bar{R}^{1,1} < \bar{R}^{1,0}$.

Proof:

We again let $\mathcal{E}^+$ and $\mathcal{E}^-$ be the regulator's expectations conditional on the shock being positive and negative or zero, respectively, and let ω^+ and ω^- be the probabilities for each case $\left(\omega^+ + \omega^- = 1\right)$. To find the optimal standard in Stage 1, the regulator takes the first derivative of W with respect to $\bar{R}^{1,1}$ as noted in Equation (A.3), which can be written as follows:

$$\begin{aligned}\frac{dW}{d\bar{R}^{1,1}} &= \left(J-1\right)\bar{\pi}'\left(\bar{R}^{1,1}\right)\\ &+ \omega^-\mathcal{E}^-\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,1}\right) - JD'\left(J\bar{R}^{1,1}\right)\right\}\\ &+ \omega^+\mathcal{E}^+\left\{\begin{aligned}&\left[\theta_1\bar{\pi}'\left(R_1^+\left(\bar{R}^{1,1}\right)\right) - D'\left(\left(J-1\right)\bar{R}^{1,1} + R_1^+\left(\bar{R}^{1,1}\right)\right)\right]\left(\frac{dR_1^+}{d\bar{R}^{1,1}} \mid \theta_1 > 1\right)\\ &-\left(J-1\right)D'\left(\left(J-1\right)\bar{R}^{1,1} + R_1^+\left(\bar{R}^{1,1}\right)\right)\end{aligned}\right\}\end{aligned}.$$

We rearrange this expression, suppressing the θ_1 condition on the derivative for brevity, to the following:

$$\begin{aligned}\frac{dW}{d\bar{R}^{1,1}} &= (J-1)\bar{\pi}'\left(\bar{R}^{1,1}\right) \\ &+ \omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,1}\right) - JD'\left(J\bar{R}^{1,1}\right)\right\} \\ &+ \omega^{+}\mathcal{E}^{+}\left\{\begin{array}{l}\theta_1\dfrac{dR_1^{+}}{d\bar{R}^{1,1}}\bar{\pi}'\left(R_1^{+}\left(\bar{R}^{1,1}\right)\right) \\ -\dfrac{dR_1^{+}}{d\bar{R}^{1,1}}D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right) - (J-1)D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\end{array}\right\}\end{aligned},$$

and then rearrange further to

$$\begin{aligned}\frac{dW}{d\bar{R}^{1,1}} &= (J-1)\bar{\pi}'\left(\bar{R}^{1,1}\right) \\ &+ \omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,1}\right) - JD'\left(J\bar{R}^{1,1}\right)\right\} \\ &+ \omega^{+}\mathcal{E}^{+}\left\{\theta_1\frac{dR_1^{+}}{d\bar{R}^{1,1}}\bar{\pi}'\left(R_1^{+}\left(\bar{R}^{1,1}\right)\right) - \left(J-1+\frac{dR_1^{+}}{d\bar{R}^{1,1}}\right)D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\right\}, \\ &+ \omega^{+}\mathcal{E}^{+}\left\{\underbrace{\left[\theta_1\bar{\pi}'\left(R_1^{+}\left(\bar{R}^{1,1}\right)\right) - D'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\right]}_{=0}\cdot\left(1-\frac{dR_1^{+}}{d\bar{R}^{1,1}}\right)\right\}\end{aligned}$$

where the final term on the right-hand side can be added because the term equals zero by the first-order condition, per Equation (A.5). We then rearrange and cancel terms to reach the following expression:

$$\begin{aligned}\frac{dW}{d\bar{R}^{1,1}} &= (J-1)\bar{\pi}'\left(\bar{R}^{1,1}\right) \\ &+ \omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,1}\right) - JD'\left(J\bar{R}^{1,1}\right)\right\} \\ &+ \omega^{+}\mathcal{E}^{+}\left\{\theta_1\bar{\pi}'\left(R_1^{+}\left(\bar{R}^{1,1}\right)\right) - JD'\left((J-1)\bar{R}^{1,1} + R_1^{+}\left(\bar{R}^{1,1}\right)\right)\right\}\end{aligned}. \tag{A.6}$$

We next differentiate Equation (A.6):

$$\frac{dW^2}{d\left(\bar{R}^{1,1}\right)^2} = \left(J-1\right)\bar{\pi}''\left(\bar{R}^{1,1}\right)$$
$$+\omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}''\left(\bar{R}^{1,1}\right) - J^2 D''\left(J\bar{R}^{1,1}\right)\right\} \qquad . \text{ (A.7)}$$
$$+\omega^{+}\mathcal{E}^{+}\left\{\theta_1\frac{dR_1^+}{d\bar{R}^{1,1}}\bar{\pi}''\left(R_1^+\left(\bar{R}^{1,1}\right)\right) - J\left(J-1+\frac{dR_1^+}{d\bar{R}^{1,1}}\right)D''\left(\left(J-1\right)\bar{R}^{1,1} + R_1^+\left(\bar{R}^{1,1}\right)\right)\right\}$$

We seek to identify the sign of this second derivative. Since we assume that $\bar{\pi}''(\cdot) < 0$ and $D''(\cdot) > 0$, the first and second terms on the right side of Equation (A.7) are negative. To sign the third term, we recall from Equation (A.1) the following expression:

$$\frac{dR_1}{d\bar{R}^{0,0}} = \frac{\left(J-1\right)D''\left(\left(J-1\right)\bar{R}^{0,0} + R_1\right)}{\theta_1\bar{\pi}''\left(R_1\right) - D''\left(\left(J-1\right)\bar{R}^{0,0} + R_1\right)}.$$

Using this expression and suppressing functional arguments for brevity, we rewrite the contents of the curly brackets in the third term on the right side of Equation (A.7) as the following:

$$\omega^{+}\mathcal{E}^{+}\left\{\theta_1\frac{\left(J-1\right)D''(\cdot)}{\theta_1\bar{\pi}''(\cdot) - D''(\cdot)}\bar{\pi}''(\cdot) - J\left(J-1+\frac{\left(J-1\right)D''(\cdot)}{\theta_1\bar{\pi}''(\cdot) - D''(\cdot)}\right)D''(\cdot)\right\}.$$

Of course, ω^{+} is positive, so we need to know the sign of the contents of the expectation. We can write those contents as follows:

$$\left(J-1\right)D''(\cdot)\left\{\frac{\theta_1\bar{\pi}''(\cdot)}{\theta_1\bar{\pi}''(\cdot) - D''(\cdot)} - J\left(1+\frac{D''(\cdot)}{\theta_1\bar{\pi}''(\cdot) - D''(\cdot)}\right)\right\},$$

which we rewrite again as:

$$\left(J-1\right)D''(\cdot)\left\{\frac{\theta_1\bar{\pi}''(\cdot)}{\theta_1\bar{\pi}''(\cdot) - D''(\cdot)} - J\left(\frac{\theta_1\bar{\pi}''(\cdot)}{\theta_1\bar{\pi}''(\cdot) - D''(\cdot)}\right)\right\}.$$

Combining terms, we sign the expression:

$$\underbrace{-(J-1)^2 D''(\cdot)}_{-}\left\{\frac{\overbrace{\theta_1\bar{\pi}''(\cdot)}^{-}}{\underbrace{\theta_1\bar{\pi}''(\cdot)}_{-}-\underbrace{D''(\cdot)}_{+}}\right\}<0\,.$$

Thus, the second derivative of welfare with regard to the standard is negative since all derivative terms are negative. In other words, the welfare function is strictly concave with regard to the discharge standard.

Recall that we seek to show that $\bar{R}^{1,1}<\bar{R}^{1,0}$. A sufficient condition for this to be true, given the concavity of the welfare function that we have just shown and given that at the optimal $\bar{R}^{1,1}$ by definition $dW/d\bar{R}^{1,1}=0$, is that the slope of W at $\bar{R}^{1,0}$ is strictly negative.

We evaluate whether the slope of W at $\bar{R}^{1,0}$ is strictly negative by constructing the derivative of welfare with respect to $\bar{R}$ from Equation (A.6) but evaluating it at $\bar{R}=\bar{R}^{1,0}$:

$$\begin{aligned}\left.\frac{dW}{d\bar{R}}\right|_{\bar{R}=R^{1,0}} &= (J-1)\bar{\pi}'\left(\bar{R}^{1,0}\right)\\ &+\omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,0}\right)-JD'\left(J\bar{R}^{1,0}\right)\right\}\\ &+\omega^{+}\mathcal{E}^{+}\left\{\theta_1\bar{\pi}'\left(R_1^{+}\left(\bar{R}^{1,0}\right)\right)-JD'\left((J-1)\bar{R}^{1,0}+R_1^{+}\left(\bar{R}^{1,0}\right)\right)\right\}\end{aligned} \tag{A.8}$$

Because $\bar{R}^{1,0}<R_1^{+}\left(\bar{R}^{1,0}\right)$, $(J-1)\bar{R}^{1,0}+R_1^{+}\left(\bar{R}^{10,}\right)>J\bar{R}^{1,0}$. Together with the assumptions that $\bar{\pi}''(\cdot)<0$ and $D''(\cdot)>0$, this implies the derivative of the welfare function is less than the following expression:

$$\begin{aligned}&(J-1)\bar{\pi}'\left(\bar{R}^{1,0}\right)\\ &+\omega^{+}\mathcal{E}^{+}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,0}\right)-JD'\left(J\bar{R}^{1,0}\right)\right\}.\\ &+\omega^{-}\mathcal{E}^{-}\left\{\theta_1\bar{\pi}'\left(\bar{R}^{1,0}\right)-JD'\left(J\bar{R}^{1,0}\right)\right\}\end{aligned}$$

We can combine terms and use the fact that $\left(\omega^{+}+\omega^{-}=1\right)$ to rearrange this expression to:

$$\left(J-1+\mathcal{E}\left(\theta_1\right)\right)\overline{\pi}'\left(\overline{R}^{1,0}\right)-JD'\left(J\overline{R}^{1,0}\right),$$

which equals zero at the optimized $\overline{R}^{1,0}$. Thus, the derivative of the welfare function evaluated at $\overline{R}^{1,0}$, Equation (A.8), must be negative because we have just shown it must be less than an expression that equals zero, which completes the proof that $\overline{R}^{1,1}<\overline{R}^{1,0}$.

A.5. Proof for the Corollary of Result 4

Corollary: The regulator who anticipates S shocks and K exemptions in Stage 2 sets a strictly tighter discharge standard than the regulator who anticipates granting fewer than K exemptions: $\overline{R}^{S,K}<\overline{R}^{S,L}$ for $0\le L<K$.

Proof: We show in the proof of Result 4 that, if the regulator expects a single shock and can grant a single exemption, then the discharge standard must be strictly lower than the case in which the regulator expects a shock but cannot grant an exemption, so that $\overline{R}^{1,1}<\overline{R}^{1,0}$. The same logic applies for any number of shocks and a single exemption, so that $\overline{R}^{S,1}<\overline{R}^{S,0}$. Similarly, starting from any number of exemptions $0\le R\le S-1$ and increasing to $R+1\le S$ exemptions, the same logic used to prove Result 4 shows that $\overline{R}^{S,R}<\overline{R}^{S,(R-1)}$. Therefore, it must be true that $\overline{R}^{S,K}<\overline{R}^{S,L}$ for $0\le L<K$.

A.6. Proof for Result 5

Result 5: If $K = S = J$ and the regulator only expects positive shocks, the optimal discharge standard $\overline{R}^{J,J}$ is sufficiently strict that all firms receive an exemption in Stage 2 and the regulator grants exemptions to all firms to achieve the optimal aggregate amount of pollution and the first-best allocation of pollution across firms.

Proof: Let R_k^* be the first-best optimal discharge for firm *k* defined by the following set of equations:

$$D'\left(\sum_{j=1}^{J} R_j^*\right) = \theta_k \pi'\left(R_k^*\right) \text{ for all } k.$$

These equations determine the Stage 2 outcomes with certainty if the standard $\overline{R}^{J,J}$ is sufficiently low that $\mathrm{P}\left(R_k^* < \overline{R}^{J,J}\right) = 0$ for all *k*. In this scenario, the regulator is able to issue up to *J* exemptions as long as those exemptions are less strict than the standard. The discharge standard is always able to lie below the lower bound of the distribution of possible optimal discharge levels because the standard can be set to $\overline{R}^{J,J} = 0$, yet the optimal discharge limit for every firm must be positive by assumption.

References

Ackerman, B., Hassler, W.T., 1981. Clean Coal/Dirty Air: or How the Clean Air Act Became a Multibillion-Dollar Bail-Out for High-Sulfur Coal Producers. Yale University Press, New Haven, CT.

Aldy, J.E., 2017. Energy Market Shock Absorbers, Policy Digest. Kleinman Center for Energy Policy, University of Pennsylvania.

Arguedas, C., Earnhart, D., Rousseau, S., 2017. Non-uniform implementation of uniform standards. Journal of Regulatory Economics 51, 159-183.

Bannon, R.D., Bannon, A.L., 1996. Congress Passes Fiduciary Exemption from Environmental Liability. ACTEC Notes 22, 222.

Banzhaf, H.S., Chupp, B.A., 2012. Fiscal federalism and interjurisdictional externalities: New results and an application to US Air pollution. Journal of Public Economics 96, 449-464.

Battigalli, P., Maggi, G., 2002. Rigidity, Discretion, and the Costs of Writing Contracts. The American Economic Review 92, 798-817.

Beavis, B., Walker, M., 1983a. Achieving environmental standards with stochastic discharges. Journal of Environmental Economics and Management 10, 103-111.

Beavis, B., Walker, M., 1983b. Random wastes, imperfect monitoring and environmental quality standards. Journal of Public Economics 21, 377-387.

Berry, J.M., Portney, K.E., 2013. Sustainability and Interest Group Participation in City Politics. Sustainability 5, 2077-2097.

Coate, S., 2001. An Efficiency Approach to the Evaluation of Policy Changes. The Economic Journal 110, 437-455.

Cohen, J.E., 1994. A Constitutional Safety Valve: The Variance in Zoning and Land-Use Based Environmental Controls. Boston College Environmental Affairs Law Review 22, 307.

Cropper, M.L., Evans, W.N., Berardi, S.J., Ducla-Soares, M.M., Portney, P.R., 1992. The Determinants of Pesticide Regulation: A Statistical Analysis of EPA Decision Making. Journal of Political Economy 100, 175-197.

Deily, M.E., Gray, W.B., 1991. Enforcement of pollution regulations in a declining industry. Journal of Environmental Economics and Management 21, 260-274.

Diver, C.S., 1983. The Optimal Precision of Administrative Rules. Yale Law Journal, 65-110.

Earnhart, D., 2004a. The Effects of Community Characteristics on Polluter Compliance Levels. Land Economics 80, 408-432.

Earnhart, D., 2004b. Panel Data Analysis of Regulatory Factors Shaping Environmental Performance. The Review of Economics and Statistics 86, 391-401.

Earnhart, D., 2004c. Regulatory factors shaping environmental performance at publicly-owned treatment plants. Journal of Environmental Economics and Management 48, 655-681.

Earnhart, D., 2007. Effects of permitted effluent limits on environmental compliance levels. Ecological Economics 61, 178-193.

Earnhart, D., 2016. Effluent Limits and Monitoring: Do Regulators Inspect Polluters Facing Tighter Limits Less Frequently?, University of Kansas Working Paper.

Ehrlich, I., Posner, R.A., 1974. An Economic Analysis of Legal Rulemaking. The Journal of Legal Studies 3, 257-286.

Environmental Protection Agency, 1995. Interim Economic Guidance for Water Quality Standards, Washington, DC.

Environmental Protection Agency, 2013. Discharger-specific Variances on a Broader Scale: Developing Credible Rationales for Variances that Apply to Multiple Dischargers, Washington, DC.
Environmental Protection Agency, 2017. Renewable Fuel Standard Exemptions for Small Refineries, Washington, DC.
Epstein, R.A., 1995. Simple rules for a complex world. Harvard University Press, Cambridge, MA.
Field, B.C., Field, M.K., 2017. Environmental Economics. McGraw-Hill.
Fleurbaey, M., Abi-Rafeh, R., 2016. The Use of Distributional Weights in Benefit–Cost Analysis: Insights from Welfare Economics. Review of Environmental Economics and Policy 10, 286-307.
Friedman, E., Wickelgren, A.L., 2014. A New Angle on Rules versus Standards. American Law and Economics Review 16, 499-549.
Fuller, L.L., 1941. Consideration and Form. Columbia Law Review 41, 799-824.
Goulder, L.H., Parry, I.W.H., 2008. Instrument Choice in Environmental Policy. Review of Environmental Economics and Policy 2, 152-174.
Hahn, R.W., 2000. The Impact of Economics on Environmental Policy. Journal of Environmental Economics and Management 39, 375-399.
Hall, J.C., Shultz, C., Stephenson, E.F., 2018. The political economy of local fracking bans. Journal of Economics and Finance 42, 397-408.
Hendren, N., 2020. Measuring economic efficiency using inverse-optimum weights. Journal of Public Economics 187, 104198.
Hird, J.A., 1990. Superfund Expenditures and Cleanup Priorities: Distributive Politics or the Public Interest? Journal of Policy Analysis and Management 9, 455-483.
Hoagland, P., Farrow, S., 1996. Planning versus reality: Political and scientific determinants of outer continental shelf lease sales, in: Congleton, R. (Ed.), The political economy of environmental protection. University of Michigan, Ann Arbor, MI, USA, pp. 145-166.
Johnston, J.S., 1995. Bargaining under Rules Versus Standards. Journal of Law, Economics and Organization, 256-281.
Kang, K., Silveira, B.S., 2018. Understanding Disparities in Punishment: Regulator Preferences and Expertise.
Kaplow, L., 1992. Rules Versus Standards: An Economic Analysis. Duke Law Journal, 557-629.
Kaplow, L., 1999. General characteristics of rules, Encyclopedia of law and economics.
Kaplow, L., 2019. Optimal regulation with exemptions. International Journal of Industrial Organization 66, 1-39.
Lévêque, F., 1996. Environmental policy in Europe : industry, competition, and the policy process. Edward Elgar Publishing, Cheltenham, UK.
Levkovich, O., Rouwendal, J., Brugman, L., 2018. Spatial Planning and Segmentation of the Land Market: The Case of the Netherlands. Land Economics 94, 137-154.
Magat, W., Krupnick, A.J., Harrington, W., 1986. Rules in the making: A statistical analysis of regulatory agency behavior. RFF Press, Washington, DC, USA.
Maloney, M.T., McCormick, R.E., 1982. A Positive Theory of Environmental Quality Regulation. The Journal of Law and Economics 25, 99-123.
McFadden, D., 1976. The Revealed Preferences of a Government Bureaucracy: Empirical Evidence. The Bell Journal of Economics 7, 55-72.

Montgomery, W.D., 1972. Markets in licenses and efficient pollution control programs. Journal of economic theory 5, 395-418.
Nadaï, A., 1996. From Environment to Competition—the EU Regulatory Process in Pesticide Regulation, in: Lévêque, F. (Ed.), Environmental Policy in Europe: Industry Competition and the Policy Process. Edward Elgar Publishing, Cheltenham, UK, pp. 53-73.
Nolte, C., Gobbi, B., le Polain de Waroux, Y., Piquer-Rodríguez, M., Butsic, V., Lambin, E.F., 2017. Decentralized Land Use Zoning Reduces Large-scale Deforestation in a Major Agricultural Frontier. Ecological Economics 136, 30-40.
Oates, W.E., Portney, P.R., 2003. The political economy of environmental policy, in: Mäler, K.-G., Vincent, J.R. (Eds.), Handbook of environmental economics. Elsevier, Amsterdam, pp. 325-354.
Oliss, P., 1994. Mandatory minimum sentencing: Discretion, the safety valve, and the sentencing guidelines. University of Cincinnati Law Review 63, 1851-1892.
Owens, D.W., 2004. The Zoning Variance: Reappraisal and Recommendations for Reform of a Much-Maligned Tool. Columbia Journal of Environmental Law 29, 279.
Pashigian, B.P., 1985. Environmental Regulation: Whose Self-Interests Are Being Protected? Economic Inquiry 23, 551-584.
Peltzman, S., 1976. Toward a More General Theory of Regulation. The Journal of Law & Economics 19, 211-240.
Prendergast, C., 2007. The Motivation and Bias of Bureaucrats. American Economic Review 97, 180-196.
Raff, Z., Earnhart, D., 2018. Effect of Cooperative Enforcement Strategies on Wastewater Management. Economic Inquiry 56, 1357-1379.
Schick, A., 1975. The Battle of the Budget. Proceedings of the Academy of Political Science 32, 51-70.
Shertzer, A., Twinam, T., Walsh, R.P., 2018. Zoning and the economic geography of cities. Journal of Urban Economics 105, 20-39.
Sigman, H., 2001. The Pace of Progress at Superfund Sites: Policy Goals and Interest Group Influence. The Journal of Law and Economics 44, 315-343.
Stavins, R.N., 2007. Market-based environmental policies: what can we learn from US experience (and related research)?, in: J. Freeman and C. D. Kolstad (Ed.), Moving to markets in environmental regulation: Lessons from twenty years of experience. Oxford University Press, New York, pp. 19-47.
Stender, B., 2018. When the Exemption Becomes the Rule: Problems That Waterkeeper v. EPA Poses for Advocates of Reporting Requirements and Potential Solutions. Ecology Law Quarterly 45, 395-417.
Stigler, G.J., 1971. The Theory of Economic Regulation. The Bell Journal of Economics and Management Science 2, 3-21.
Swanson, A., Hsu, T., 2018. Companies Get First Tariff Waivers, but Many More Are Left in Limbo, The New York Times. The New York Times Company, New York, NY.
Twinam, T., 2018. The long-run impact of zoning: Institutional hysteresis and durable capital in Seattle, 1920–2015. Regional Science and Urban Economics 73, 155-169.
US Department of Energy, 2011. Small Refinery Exemption Study: An Investigation into Disproportionate Economic Hardship. US Department of Energy, Office of Policy and International Affairs.

Wilcher, L.S., Page, R.W., 1990. Memorandum: Clean Water Act Section 404 Regulatory Program and Agricultural Activities. United States Environmental Protection Agency and United States Department of the Army.
Yackee, J.W., Yackee, S.W., 2006. A Bias Towards Business? Assessing Interest Group Influence on the U.S. Bureaucracy. The Journal of Politics 68, 128-139.
Yuknis, E.M., 2011. Would a God Squad Exemption under the Endangered Species Act Solve the California Water Crisis? Boston College Environmental Affairs Law Review 38, 567-596.
Zhang, W., Wrenn, D.H., Irwin, E.G., 2017. Spatial Heterogeneity, Accessibility, and Zoning: An Empirical Investigation of Leapfrog Development. Journal of Economic Geography 17, 547-570.