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

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October 19, 2021

Abstract:
Many environmental regulations impose limits on harmful activities yet include "safety valve" provisions giving the regulator discretion to grant exemptions that provide relief to regulated parties. We use a theoretical model to explore various cases in which this discretion serves good or ill. We show that when a regulation is otherwise inflexible, exemptions can improve social welfare, and in some cases reduce pollution, by allowing abatement to be distributed more cost-effectively across polluters. However, these beneficial impacts of exemptions rely on a fully informed and benevolent regulator; otherwise, the discretionary nature of exemptions allows them to be abused.

JEL codes: D21, D62, K32, Q52, Q53, Q58

Keywords: exemption, variance, regulation, flexibility, discretion, welfare

Declarations of interest: none

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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 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 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 function 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 some chance *ex ante* that shocks will increase abatement costs, a forward-looking regulator who can grant exemptions can, by adjusting the discharge standard and issuing optimal exemptions, achieve *ex ante* greater social welfare and lower pollution, as exemptions allow pollution to be distributed more cost-effectively across dischargers. 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.

In our base model, the regulator seeks to maximize social welfare. In the extended model, we consider a regulator's use of an unequally weighted social welfare function. In this context, we show that the regulator could use exemptions for redistributive ends when the weights reflect normative values or to benefit a narrow constituency if the weights reflect regulatory capture. In the latter case, the use of exemptions is a benefit to some subset of society but a detriment to society in general.

2. Literature Review

Surprisingly little research analyzes the economics of exemptions. The closest study to our analysis is Kaplow (2017), which 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; and, 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 when regulatory agencies possess meaningful discretion over their choices. 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 less strict 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 variation of regulation 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 rely on 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

[2] Legal analysis of the relative desirability between rules and standards precedes the economic analysis. See Fuller (1941) for more historical legal analysis; see Epstein (1995) for more recent legal analysis.

[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.

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 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

[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 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.

[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 the cost of granting exemptions in response to firms' requests. As the proportion of the regulated community that benefits from differentiation rises, the cost advantage of rule formulation increases relative to the cost of interpretation of a standard (Kaplow, 1999); in our context, the cost advantage of *ex ante* firm-specific limit determination increases relative to *ex post* issuance of firm-specific exemptions.

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 between the regulator and regulated firms, and motivates much needed empirical analysis on 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 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 parallel in this study, is the Clean Water Act, which requires writers of discharge permits (within regulatory agencies) to impose 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, EPA does not seek to maximize social welfare when identifying the discharge limit needed to support the designated use and the ability to grant a variance does not alter the relevant 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 shocks and exemptions are not foreseen, the initial standard is not optimized based on the existence of exemptions. The implications for environmental impacts differ greatly 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 model explores both institutions that maximize a uniformly weighted social welfare function and institutions that pursue other objectives, including redistribution or objectives shaped by manipulative forces such as political machinations and rent-seeking.

Lastly, we discuss settings that disallow or circumscribe the use of exemptions. 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 publication in the Federal Register notifying the public of the government's consideration of a species as endangered and (2) the prohibitions will cause undue economic hardship to the person, 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 the liability for investigations and clean-up of hazardous waste sites set by CERCLA. 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 in an independent capacity 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. The regulator may or may not seek to maximize social welfare. The regulator's tools are (a) a limit on pollution, which we refer to as the *discharge limit*, and (b) an exemption that the regulator may grant on an idiosyncratic basis to a firm. 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 – we allow exemptions to include situations in which the regulator requires the firm to partially adhere to the regulation, meeting a less stringent limit.

4.1. Model Foundations

J firms 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, we do not consider 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, including any exempted limit, the firm pays a penalty, which we assume is unavoidable and sufficiently high that no firm exceeds its limit. Consequently, as long as $R_j \le E^{\pi}$, an assumption maintained for all possible limits, including exempted 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 $E = \sum_j E_j$

[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).

$D_i(E)$. Aggregating across households, we write total environmental damages as $D(E)=\sum_i D_i(E)$ with $D'>0$ and $D''>0$. We express environmental damages in monetary units. We further assume that $D'(0)<\sum_k \theta_j \bar{\pi}'(0)$, 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. The regulator's objective is to maximize the benefits to firms less the damages to the public:

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

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 where 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, $S \leq J$

$\theta_j \bar{\pi}'(R_j)$, where $\theta_j>0$.

$\theta_j>1$

$0<\theta_j<1$ 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 $i \leq j \leq S$.

After these shocks in Stage 2, the regulator learns their 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. More important, we 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, $\overline{R}^{11}$ 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 granting exemptions that tighten limits and exemptions to unshocked firms. Yet optimality requires these features, especially to accommodate cost-reducing shocks. 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). The Appendix provides proofs of all results.

4.2. Case 1: 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, $\overline{R}^{00}$, 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 $W = J\pi\left(\overline{R}^{00} \mid \theta = 1\right) - D\left(J\overline{R}^{00}\right)$. Taking the first-order condition with regard to $\overline{R}^{00}$ yields the following:

$$J\pi\left(\overline{R}^{00} \mid \theta = 1\right) = D\left(J\overline{R}^{00}\right). \tag{2}$$

While J could be cancelled out in this expression, we retain it to emphasize that the standard $\overline{R}^{00}$ is chosen considering the profits and discharges of *all* regulated firms.

Obviously, if shocks strike firms' marginal benefits, the $\overline{R}^{00}$ 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 viewing such unanticipated shocks, the regulator could grant exemptions, those exemptions could improve welfare, as shown in subsection 4.4.

In the next subsection, we consider the case in the regulator is still unable to grant exemptions but at least anticipates the shocks.

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 setting 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 $\overline{R}^{10}$ that satisfies the following first-order condition:

$$\left[\mathcal{E}\left(\theta_1 + J - 1\right)\right]\overline{\pi}'\left(\overline{R}^{10}\right) = JD'\left(J\overline{R}^{10}\right). \tag{3}$$

If $\mathcal{E}(\theta_1) > 1$

(2) and (3) imply that $\overline{R}^{00} < \overline{R}^{10}$. 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.

These comparisons are similar if $S > 1$ firms are shocked with no possibility of exemptions. The regulator sets standard $\overline{R}^{S0}$ to solve the following first-order condition:

$$\left[\mathcal{E}\left(\sum_{s \le S} \theta_s\right) + J - S\right] \overline{\pi}'\left(\overline{R}^{S0}\right) = JD'\left(J\overline{R}^{S0}\right). \tag{4}$$

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 <u>not</u> 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.

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 into account (in the Stage 1 limit-setting decision) the exemptions prompted by the shocks. In this case, the regulator sets the standard in Stage 1 equal to $\overline{R}^{00}$, 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:

$$\theta_1 \overline{\pi}'(R_1) = D'\left((J-1)\overline{R}^{00} + R_1\right). \tag{5}$$

Equation (5) demonstrates that the optimal exemption R_1 depends on the standard $\overline{R}^{00}$. Accordingly, we establish an optimal exemption function, $R_1\left(\overline{R}^{00}\right)$, 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 $dR_1\left(\overline{R}^{00}\right)/d\overline{R}^{00} < 0$. In other words, the optimal exemption for the shocked firm becomes less generous as $\overline{R}^{00}$ 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.

If the shock is positive, increasing the firm's marginal benefits of discharges, then the optimal exemption leads to an increase in aggregate discharges, $R_1\left(\overline{R}^{00}\right) > \overline{R}^{00}$

(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: $R_1\left(\overline{R}^{00}\right) < \overline{R}^{00}$. 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. We consider the setting in which the regulator may be restricted as to how many firms can receive exemptions, $K \leq S$,[7] rather than focusing solely on the less interesting case in which the regulator can grant exemptions to all shocked firms, $K = S$. (If only positive shocks strike firms, when $K = S$, the regulator can achieve the optimal discharge allocation.) In this setting, the regulator must select which firms to grant exemptions to and choose 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, this logic means that 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). In what follows, we use *K* for the number of exemptions granted, noting that *K* may either reflect the administrative cap on the number of exemptions or the number of positively shocked firms. The optimal exemptions' magnitudes are again set where the first-order conditions are satisfied for the relevant firms:

$$\theta_k \overline{\pi}'\left(R_k\right) = D'\left(\left(J-K\right)\overline{R}^{00} + \sum_{j=1}^{K} R_j\right), \text{ for all } k \leq K. \tag{6}$$

[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.

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, 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. Additionally, abatement is still not optimal since the exemptions do not achieve equimarginality. The equality of marginal profits shown in equation (6) applies only to the exempted firms. Marginal profits for the firms without exemptions differ from those of the exempted firms: (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 arbitrarily different. In particular, any firm receiving a pollution benefit- (abatement cost-) reducing 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 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.

4.5. Case 4: Anticipated Shocks with Anticipated Exemptions

Clearly, if the regulator anticipates granting exemptions in Stage 2, then the regulator

[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.

should take these exemptions into account when setting the discharge standard in Stage 1. To evaluate this problem, we use backward induction.

We again consider first the scenario in which only Firm 1 is shocked. Suppose a discharge standard $\bar{R}^{11}$ is set in Stage 1. Following Equation (5) and substituting $\bar{R}^{11}$ for the myopic standard, $\bar{R}^{00}$, we can write the optimal exemption granted to Firm 1 in Stage 2 as $R_1\left(\bar{R}^{11}\right)$. The forward-looking regulator sets $\bar{R}^{11}$ 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.

We assume that, if $\theta_1 > 1$, then the regulator sets optimally the exemption, R_1. We consider the possibility of a negative shock, $0 < \theta_1 < 1$, which may be nonzero even when $\mathcal{E}\left(\theta_1\right) > 1$. We define ω^- as the probability of a negative shock and $\mathcal{E}^-$ as the expectation operator conditional on $0 < \theta_1 < 1$. As shown in the Appendix, we can use an envelope condition to simplify the first-order condition to the following:

$$\left[(J-1)+\omega^-\mathcal{E}^-\left(\theta_1\right)\right]\bar{\pi}'\left(\bar{R}^{11}\right)=\mathcal{E}\left[(J-1)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]+\omega^-D'\left(J\bar{R}^{11}\right). \quad (7)$$

If shocks only increase abatement costs, then $\omega^- = 0$ and Equation (7) simplifies to the following:

$$\bar{\pi}'\left(\bar{R}^{11}\right)=\mathcal{E}\left[D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right], \quad (8)$$

from which we obtain Result 3.

Result 4: 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 5 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 exempted firm to marginal damages as well.

Recall that the regulator grants no exemptions in Stage 2 if $0 < \theta_1 < 1$ (i.e., the shock is negative) yet grants exemption $R_1\left(\overline{R}^{11} \mid \theta_1\right) > \overline{R}^{11}$ 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 positive, $\mathcal{E}\left(R_1\left(\overline{R}^{11}\right) \mid \theta_1\right) > \overline{R}^{11}$. This logic leads to Result 6:

Result 7: The regulator who anticipates a single shock and granting an exemption in Stage 2 sets a tighter discharge standard than the regulator who anticipates granting no exemptions: $\overline{R}^{11} \leq \overline{R}^{10}$.

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

Result 4 and the 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, $K = S = J$ and $\omega^+ = 1$, 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 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 8: If $K = S = J$ and $\omega^{+} = 1$, the optimal discharge standard $\overline{R}^{JJ}$ 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.

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, $R_j = \overline{R}^{00}$ for all j; (2) a situation (subsection 4.3) in which the regulator anticipates a shock but is unable to grant exemptions: here, $R_j = \overline{R}^{10}$ 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, $R_1\left(\overline{R}^{00}\right)$ and $R_j = \overline{R}^{00}$ 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, $R_1\left(\overline{R}^{11}\right)$ and $R_j = \overline{R}^{11}$ for $j > 1$.

Comparing the four policy settings, we can ascribe some relative welfare rankings among the four cases. For this comparison, 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 welfare using improved information available in Stage 1, yet (2) the regulator increases welfare in Case 3 by granting in Stage 2 an unanticipated exemption.

We can also compare expected aggregate discharges across the policy settings. This requires knowing 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. As shown in Result 6, *ex ante* aggregate discharges are lower in Case 4, when an exemption is possible. This result might seem ambiguous since, in Case 4, the discharge standard is tighter but the exemption is looser. Intuitively, however, the aggregate costs of achieving any aggregate pollution level are lower because of the exemptions. Therefore, exemptions allow society to optimize at a lower level of aggregate pollution.

Result 9: If the regulator anticipates a shock, expected aggregate discharges are weakly lower if the regulator is able to grant (and anticipates, in Stage 1, being able to grant) an exemption in Stage 2 than if the regulator cannot grant exemptions.

While we have only shown these to be true for the case of a single shocked firm, they should also hold if an arbitrary number of firms are 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, often referred to as a waiver. 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 does not exceed the privately optimal level ($R_j \le E^{\pi}$ for all *j*), a full waiver is not socially optimal. Marginal damages always 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 exempted firm's profits exceeds the increment in damages caused by higher discharges.

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 Firm 1's discharges increasing from the standard $\bar{R}$ to the profit-maximizing level, E^{π}, using a first-order approximation that averages the slopes at $\bar{R}$ and E^{π}:

$$\Delta W = \frac{1}{2}\left[\theta_1 \bar{\pi}'\left(\bar{R}\right) + \theta_1 \bar{\pi}'\left(E^{\pi}\right)\right]\left(E^{\pi} - \bar{R}\right) - \frac{1}{2}\left[D'\left(J\bar{R}\right) + D'\left(\left(J-1\right)\bar{R} + E^{\pi}\right)\right]\left(E^{\pi} - \bar{R}\right) > 0. \tag{9}$$

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

$$\Delta W=\frac{1}{2}\left(\theta_1\overline{\pi}'\left(\overline{R}\right)\right)\left(E^{\pi}-\overline{R}\right)-D'\left(J\overline{R}\right)\left(E^{\pi}-\overline{R}\right)>0. \tag{10}$$

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. Flexible Weights in Regulator's Optimand

In the preceding sections, we assume the regulator makes decisions to maximize a social welfare function composed of equally weighted benefits and costs accruing to firms and households. However, this need not be the regulator's optimand. A growing literature questions the equal treatment of values of all benefits and costs (Coate, 2001; Fleurbaey and Abi-Rafeh, 2016; Hendren, 2017) and argues that regulators should weigh values accruing to members of society differently if society is more concerned about the welfare of disadvantaged or vulnerable people. Alternatively, a regulator might weight welfare function components unequally if the regulator is particularly answerable (or beholden) to some subset of society.

We explore these cases by adding weights to the regulator's optimand. Let α and δ represent the weights placed by the regulator on profits enjoyed by firm owners and environmental damage costs, respectively, and let γ_n represent the weight that the regulator puts on the welfare that accrues to community n out of communities 1 to N. With these weights, we can rewrite the regulator's optimand, which we still denote as W even though it need not represent social welfare:

$$W = \sum_n \gamma_n \left[\alpha \sum_{j=1}^{J_n} \pi\left(R_j \mid \theta_j\right) - \delta D_n\left(E\right) \right], \tag{11}$$

where J_n is the set of firms in community n and D_n is the damage costs borne by the n^{th} community.

In general, these weights change the marginal conditions that drive the regulator's decision; if the weight on profits exceeds the weight on households' pollution damages, then the likelihood of an exemption is greater than in the case of an equally weighted welfare function, and vice versa.

Practically speaking, why would unequal weights arise in a regulator's optimand, and what are their implications? First, across communities, society might weight households more heavily than firms (so $\delta > \alpha$) because households in general might represent more vulnerable populations as compared to firm owners. This weighting decreases the likelihood of an exemption, particularly if the exemption is not anticipated so that the discharge standard is not optimally lowered for firms that do not receive an exemption. If society weights firms more heavily (so $\alpha > \delta$), then the opposite holds.

If an unequally weighted optimand represents the social welfare function, then, by definition, a policy that increases the optimand improves welfare. However, the regulator's optimand could be unequally weighted for reasons that make the optimand differ from the social welfare function. Regulators might be biased in favor of the industry that they regulate for a variety of reasons: from the deplorable case of outright bribery to the common practice of hiring as regulators a particular client group of individuals who have close ties to that group (Prendergast, 2007). In these cases, the optimand of the regulator diverges from that of society; thus, the regulator's discretion can create exemptions that decrease welfare.[9]

If the regulator is captured by industry, firm profits are weighted more heavily than household outcomes by the regulator even though society does not share those weights; in the extreme, the regulator might place no weight on household outcomes ($\delta = 0$). 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.

If the regulator favors only some firms, rather than all of them, then not only is the aggregate amount of pollution excessive, but the allocation across the polluting firms is also inefficient. Equimarginality does not hold due to favoritism.

If the regulator is parochially focused, having jurisdiction in only the regulator's own community, say $n = 1$, then $\gamma_1 = 1$ and $\gamma_n = 0 \ \forall n \neq 1$. For example, zoning variances are granted by local boards charged with considering only local welfare. Similarly, under the Clean Water Act, EPA's consideration of costs focuses exclusively on locally borne costs (Environmental Protection Agency, 1995). Moreover, 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). A parochially focused regulator issues the same exemptions as a regulator with a broader perspective if regulatory costs and benefits accrue only in community $n = 1$. However, if some costs or benefits are exported, the story changes. Commonly, pollution is exported, as is the case of nonuniformly mixed water

[9] In this section, we do not consider the case in which a forward-looking regulator tightens the discharge standard imposed on firms in Stage 1 in anticipation of exemptions. If the non-social-welfare-maximizing regulator has great discretion with regard to the discharge standard, they could simply set a loose standard instead of granting exemptions to allow more pollution.

pollution 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 too much pollution affecting downstream communities outside the regulator's jurisdiction.

In addition, a parochially focused regulator likely undermines cost-effectiveness. For uniformly mixed pollutants, discharges should be distributed across firms so that marginal abatement costs are equal across firms. If the regulator in community $n=1$ grants an exemption from a regulation that affects its operations or at least its discharges in other jurisdictions, then the equimarginal criterion is unlikely to be met in those other communities.[10]

Finally, even if a regulator has jurisdiction over multiple communities, the regulator might weight some of them more heavily than others. The set of weights, γ_n, might now reflect communities' 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.

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

[10] 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 likely would generate too much pollution relative to the optimum.

study, we explore the impact of exemptions to demonstrate that the discretion to grant exemptions can improve social welfare by providing flexibility, though it need not. We demonstrate this welfare-improving outcome by assuming that the regulator seeks to maximize social welfare with equal weights. However, the discretion granted to a regulator may harm social welfare if the regulator does not apply equal weights to the social welfare function.

As our core model, we consider a simple two-stage decision-making context in which the regulator is assumed to maximize a standard social welfare function. As our extended model, we explore a differentiated social welfare function that allows separate weights for firms and households that are specific to an individual community. In all contexts, we show that an exemption can increase social welfare, or serve other social goals, 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, however, 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.

The identified cases in which 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 exemption applications to reduce their regulatory burdens. If firms can misrepresent their costs to the regulator, then the identified welfare gains may not arise. 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). To capture these failures, we also consider cases in which the elements in the regulator's optimand are not weighted equally, either across components (firm profits and environmental damages) or across communities. If the regulator is captured by an industry, focuses only on a local jurisdiction, or cares only about the interests of certain communities, exemptions undermine efficiency and perhaps cost-effectiveness. In these cases, the regulator uses regulatory discretion against society's best interests.

We made a number of critical assumptions with regard to functional forms, information, and the temporal structure of the problem. An analysis that relaxes these restrictions could offer different results from those we present here, and in so doing could reveal many important insights. Furthermore, many questions adjacent to those studied in this paper merit study, such as the following: Do regulators grant exemptions in ways that maximize social welfare or to benefit one community (or constituency) at the expense of society as a whole? Does the granting of exemptions demonstrate a regulator's information asymmetry with regard to grantees? Do exemptions create progressive or regressive impacts? How is the surplus generated by an exemption shared between producers and households? Do regulated firms face exemption application costs, and do regulators bear costs when granting exemptions? Since exemptions are common in environmental policy, further theoretical study of exemptions, as well as empirical analysis, along these lines is needed.

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 <u>not</u> 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:

According to Equation (4), the optimal standard is set where

$\left[\mathcal{E}\left(\sum_{s\leq S}\theta_s\right)+J-S\right]\bar{\pi}'\left(\bar{R}^{S0}\right)=JD'\left(J\bar{R}^{S0}\right)$. When no shock is anticipated, $\mathcal{E}\left(\theta_j\right)=1$ for all j, and therefore $\mathcal{E}\left(\sum_{s\leq S}\theta_s\right)=S$, so the expression becomes $J\bar{\pi}'\left(\bar{R}^{S0}\right)=JD'\left(J\bar{R}^{S0}\right)$. By Equation (2), this requires $\bar{R}^{S0}=\bar{R}^{00}$. The left-hand side of Equation (4) (the marginal benefit to firms of loosening their limit) is increasing in expected shock size $\mathcal{E}\left(\sum_{s\leq S}\theta_s\right)$ and, since $D'\left(E\right)$ is monotonically increasing, higher levels of $\mathcal{E}\left(\sum_{s\leq S}\theta_s\right)$ must be accompanied by higher levels of total discharges $\bar{R}^{S0}$, that is, a looser standard. Relative to the no-shock scenario, therefore, an expected shock that is greater than 1 yields a higher discharge standard and an expected shock less than 1 yields a lower discharge standard.

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 $dR_1 / d\overline{R}^{00}$ is negative for any standard $\overline{R}^{00}$. Equation (5) states that the optimal exemption for $\theta_1 > 1$ is defined by the condition:

$$\theta_1 \overline{\pi}'\left(R_1\right) = D'\left(\left(J-1\right)\overline{R}^{00} + R_1\right).$$

The total differential of this expression follows:

$$\theta_1 \overline{\pi}''\left(R_1\right) dR_1 = D''\left(\left(J-1\right)\overline{R}^{00} + R_1\right)\left(\left(J-1\right) d\overline{R}^{00} + dR_1\right),$$

which rearranges to the following:

$$\frac{dR_1}{d\overline{R}^{00}} = \frac{D''\left(\left(J-1\right)\overline{R}^{00} + R_1\right)}{\theta_1 \overline{\pi}'' - D''}.$$

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

A.3. Derivation of Equation (7)**:**

$$\left[\left(J-1\right) + \omega^{-} \mathcal{E}^{-}\left(\theta_1\right)\right] \overline{\pi}'\left(\overline{R}^{11}\right) = \mathcal{E}\left[\left(J-1\right) D'\left(\left(J-1\right)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right] + \omega^{-} D'\left(J\overline{R}^{11}\right)$$

Proof:

If one exemption is granted and the regulator anticipates this exemption, *ex ante* welfare from the regulator's perspective follows:

$$W=(J-1)\pi\left(\bar{R}^{11}\mid\theta=1\right)+\mathcal{E}\left[\pi\left(R_1\left(\bar{R}^{11}\right)\mid\theta_1\right)\right]-D\left((J-1)\bar{R}^{11}+\mathcal{E}\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right)$$

Taking a first order condition yields the following condition:

$$(J-1)\bar{\pi}'\left(\bar{R}^{11}\right)+\mathcal{E}\left[\theta_1\frac{\partial R_1}{\partial\bar{R}^{11}}\bar{\pi}'\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]=\left(J-1+\mathcal{E}\left(\frac{\partial R_1}{\partial\bar{R}^{11}}\right)\right)D'\left((J-1)\bar{R}^{11}+\mathcal{E}\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right)$$

where we invoke our assumption that the shock to Firm 1's profit function is represented as changing marginal profits according to $\theta_1\bar{\pi}'\left(R_1\right)$.We rearrange this expression to the following:

$$(J-1)\bar{\pi}'\left(\bar{R}^{11}\right)=\mathcal{E}\left[\left(J-1+\frac{\partial R_1}{\partial\bar{R}^{11}}\right)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)-\theta_1\frac{\partial R_1}{\partial\bar{R}^{11}}\bar{\pi}'\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right],$$

and then further rearrange to the following:

$$(J-1)\bar{\pi}'\left(\bar{R}^{11}\right)=\mathcal{E}\left[\begin{array}{r}(J-1)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)+\frac{\partial R_1}{\partial\bar{R}^{11}}D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\\-\theta_1\frac{\partial R_1}{\partial\bar{R}^{11}}\bar{\pi}'\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\end{array}\right],$$

which we rewrite as follows:

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

However, in Stage 2, if $\theta_1>1$ (i.e., the shock to Firm 1 increases marginal profits from pollution or marginal abatement costs), the exemption R_1 is set such that:

$$\theta_1\bar{\pi}'\left(R_1\right)=D'\left((J-1)\bar{R}^{11}+R_1\right).$$

This expression follows the logic of Equation (5) and still holds even though the regulator responds to a different discharge standard set in Stage 1. These are also trivially equalized if $\theta_1 = 1$ with no exemption granted so $R_1 = \overline{R}^{11}$ and this is optimal. Thus, when $\theta_1 \geq 1$, the difference in the last term of the equation above equals zero.

Now, consider the case in which the firm receives a marginal profit-decreasing shock $0 < \theta_1 < 1$. The optimal response by the regulator would be to tighten the standard on that firm with an "exemption" that allows less pollution, but by assumption this is not allowed, so $R_1 = \overline{R}^{11}$. This does not satisfy optimality and $\theta_1 \overline{\pi}'(R_1) < D'\left((J-1)\overline{R}^{11} + R_1\right)$. Thus, when $0 < \theta_1 < 1$, the difference in the last term of the equation above is non-zero, but we can note that $\frac{\partial R_1}{\partial \overline{R}^{11}} = 1$ because $R_1 = \overline{R}^{11}$.

We define ω^+ and ω^- as the regulator's believed probabilities that the shock is marginal profit-increasing and -decreasing respectively, and $\mathcal{E}^-$ as the regulator's expectation conditional on the shock being a negative. We can then write the condition as the following:

$$\begin{aligned}(J-1)\overline{\pi}'\left(\overline{R}^{11}\right) = \mathcal{E}\left[(J-1)D'\left((J-1)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right] \\ +\omega^- \mathcal{E}^-\left[D'\left((J-1)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right] - \mathcal{E}^-\left[\theta_1 \overline{\pi}'\left(R_1\left(\overline{R}^{11} \mid \theta\right)\right)\right]\end{aligned}.$$

Note that this is true because we have also assumed that the regulator can only issue exemptions to firms that have received shocks; otherwise, if Firm 1 receives a negative shock, then given the injunction against standard-tightening exemptions, the regulator should set the baseline standard tighter and issue an exemption to an unshocked firm.

Since $R_1 = \overline{R}^{11}$ when the shock reduces marginal profits, we can rewrite the condition as the following:

$$(J-1)\overline{\pi}'\left(\overline{R}^{11}\right) = \mathcal{E}\left[(J-1)D'\left((J-1)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right] + \omega^- \left(D'\left((J-1)\overline{R}^{11} + \overline{R}^{11}\right) - \mathcal{E}^-(\theta_1)\overline{\pi}'\left(\overline{R}^{11}\right)\right)$$

which simplifies as follows:

$$(J-1)\overline{\pi}'\left(\overline{R}^{11}\right) = \mathcal{E}\left[(J-1)D'\left((J-1)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right] + \omega^- \left(D'\left(J\overline{R}^{11}\right) - \mathcal{E}^-(\theta_1)\overline{\pi}'\left(\overline{R}^{11}\right)\right).$$

We rearrange this expression to the following:

$$(J-1)\overline{\pi}'\left(\overline{R}^{11}\right) + \omega^- \mathcal{E}^-(\theta_1)\overline{\pi}'\left(\overline{R}^{11}\right) = \mathcal{E}\left[(J-1)D'\left((J-1)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right] + \omega^- D'\left(J\overline{R}^{11}\right).$$

Then we combine terms to reveal the following:

$$\left[(J-1) + \omega^- \mathcal{E}^-(\theta_1)\right]\overline{\pi}'\left(\overline{R}^{11}\right) = \mathcal{E}\left[(J-1)D'\left((J-1)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right] + \omega^- D'\left(J\overline{R}^{11}\right).$$

This expression is Equation (7).

A.4. 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.

From Equation (7), if the regulator anticipates one positive shock, which implies $\omega^- = 0$, and anticipates granting one exemption, the regulator chooses optimal standard, $\overline{R}^{11}$, based on this condition:

$$\overline{\pi}'\left(\overline{R}^{11}\right) = \mathcal{E}\left[D'\left((J-1)\overline{R}^{11} + R_1\left(\overline{R}^{11} \mid \theta_1\right)\right)\right]. \tag{A.1}$$

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

$$\theta_1 \bar{\pi}'(R_1) = D'\left((J-1)\bar{R}^{11} + R_1\right). \tag{A.2}$$

Since the right-hand side of Equation (A.1) is simply the expectation of the right-hand side of Equation (A.2) as anticipated in Stage 1, the following holds:

$$\bar{\pi}'\left(\bar{R}^{11}\right) = \mathcal{E}(\theta_1)\bar{\pi}'\left(\bar{R}^{11}\right) = \mathcal{E}\left[D'\left((J-1)\bar{R}^{11} + R_1\left(\bar{R}^{11} \mid \theta_1\right)\right)\right].$$

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.5. Proof for Result 4

Result 4: The regulator who anticipates a single shock and granting an exemption in Stage 2 sets a tighter discharge standard than the regulator who anticipates granting no exemptions: $\bar{R}^{11} \leq \bar{R}^{10}$.

Proof:

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 $\left(\omega^{+} + \omega^{-} = 1\right)$.

The regulator's Stage 1 first-order condition, as noted in the third equation within the derivation above in Section A.3, yields:

$$(J-1)\bar{\pi}'\left(\bar{R}^{11}\right) = \mathcal{E}\left[\left(J-1+\frac{\partial R_1}{\partial \bar{R}^{11}}\right)D'\left((J-1)\bar{R}^{11} + R_1\left(\bar{R}^{11} \mid \theta_1\right)\right) - \theta_1 \frac{\partial R_1}{\partial \bar{R}^{11}} \bar{\pi}'\left(R_1\left(\bar{R}^{11} \mid \theta_1\right)\right)\right].$$

We can move the last term on the right to the left side of the equation and use the fact that $\omega^{+} + \omega^{-} = 1$ to expand the expression as follows:

$$
\begin{aligned}
&(J-1)\bar{\pi}'\left(\bar{R}^{11}\right)+\omega^{+}\mathcal{E}^{+}\left[\theta_1\frac{\partial R_1}{\partial \bar{R}^{11}}\bar{\pi}'\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]+\omega^{-}\mathcal{E}^{-}\left[\theta_1\frac{\partial R_1}{\partial \bar{R}^{11}}\bar{\pi}'\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]\\
&\quad=\omega^{+}\mathcal{E}^{+}\left[\left(J-1+\frac{\partial R_1}{\partial \bar{R}^{11}}\right)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]\\
&\quad+\omega^{-}\mathcal{E}^{-}\left[\left(J-1+\frac{\partial R_1}{\partial \bar{R}^{11}}\right)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]
\end{aligned}.
$$

When a shock reduces abatement costs, the regulator grants no exemption; consequently, in that case, $R_1=\bar{R}^{11}$ and $\frac{\partial R_1}{\partial \bar{R}^{11}}=1$. Thus, we can write the above condition as follows:

$$
\begin{aligned}
&(J-1)\bar{\pi}'\left(\bar{R}^{11}\right)+\omega^{+}\mathcal{E}^{+}\left[\theta_1\frac{\partial R_1}{\partial \bar{R}^{11}}\bar{\pi}'\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]+\omega^{-}\mathcal{E}^{-}\left[\theta_1\bar{\pi}'\left(\bar{R}^{11}\right)\right]\\
&\quad=\omega^{+}\mathcal{E}^{+}\left[\left(J-1+\frac{\partial R_1}{\partial \bar{R}^{11}}\right)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]\\
&\quad+\omega^{-}\mathcal{E}^{-}\left[JD'\left(J\bar{R}^{11}\right)\right]
\end{aligned}.
$$

We rearrange terms and apply expectations only to uncertain elements to yield the following:

$$
\begin{aligned}
&(J-1)\bar{\pi}'\left(\bar{R}^{11}\right)+\omega^{-}\mathcal{E}^{-}(\theta_1)\bar{\pi}'\left(\bar{R}^{11}\right)\\
&\quad=\omega^{+}\mathcal{E}^{+}\left[\frac{\partial R_1}{\partial \bar{R}^{11}}\left(D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)-\theta_1\bar{\pi}'\left(R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right)\right].\\
&\quad+\omega^{+}\mathcal{E}^{+}\left[(J-1)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]+\omega^{-}JD'\left(J\bar{R}^{11}\right)
\end{aligned}
$$

Per the envelope condition logic used in the derivation of Equation (7), the first term on the right-hand side equals zero at the optimal exemption choice $R_1\left(\bar{R}^{11}\mid\theta_1\right)$. Thus, the expression becomes the following:

$$
\begin{aligned}
&(J-1)\bar{\pi}'\left(\bar{R}^{11}\right)+\omega^{-}\mathcal{E}^{-}(\theta_1)\bar{\pi}'\left(\bar{R}^{11}\right)\\
&\quad=\omega^{+}\mathcal{E}^{+}\left[(J-1)D'\left((J-1)\bar{R}^{11}+R_1\left(\bar{R}^{11}\mid\theta_1\right)\right)\right]+\omega^{-}JD'\left(J\bar{R}^{11}\right)
\end{aligned}. \tag{A3}
$$

We know from Equation (3) that, if the regulator anticipates a shock but does not anticipate the ability to grant an exemption, the discharge standard is set to satisfy:

$$\left(\mathcal{E}\left(\theta_1\right)+J-1\right)\bar{\pi}'\left(\bar{R}^{10}\right)=JD'\left(J\bar{R}^{10}\right).$$

We rewrite the left-hand side of this expression as follows:

$$\left(J-1\right)\bar{\pi}'\left(\bar{R}^{10}\right)+\omega^{+}\mathcal{E}^{+}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)+\omega^{-}\mathcal{E}^{-}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)=JD'\left(J\bar{R}^{10}\right), \tag{A4}$$

and then rearrange further to yield the following:

$$\left(J-1\right)\bar{\pi}'\left(\bar{R}^{10}\right)+\omega^{-}\mathcal{E}^{-}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)=JD'\left(J\bar{R}^{10}\right)-\omega^{+}\mathcal{E}^{+}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right). \tag{A5}$$

Our aim is to show that the forward-looking regulator who is able to grant an exemption sets a tighter discharge standard than the regulator who is not able to grant an exemption, that is, that $\bar{R}^{11}$ satisfying Equation (A3) is less than $\bar{R}^{10}$ satisfying Equation (A5). To this end, we assume that the discharge standard set by a forward-looking regulator that grants an exemption is not less but the same as the standard set by a regulator lacking this ability. This would imply that Equation (A3) is satisfied with the same $\bar{R}^{10}$ that satisfies Equation (A5). We then show that a contradiction arises unless the regulator who grants an exemption sets a tighter standard.

We proceed by noting that if we substitute $\bar{R}^{11}=\bar{R}^{10}$ into Equation (A3), the left-hand sides of Equations (A3) and (A5) are the same. If, with this substitution, the right-hand side of Equation (A3) is greater than the right-hand side of Equation (A5), equality is contradicted, and specifically the $\bar{R}^{11}$ that satisfies Equation (A3) must be less than the $\bar{R}^{10}$ that satisfies Equation (A5) because a smaller $\bar{R}^{11}$ will decrease the right-hand side (since $D'(\cdot)$ is increasing) and increase the left-hand side (since $\bar{\pi}'(\cdot)$ is decreasing).

Making that substitution, then, if the following inequality holds, it must be true that $\bar{R}^{11}<\bar{R}^{10}$:

$$\begin{aligned}&\omega^{+}\mathcal{E}^{+}\left[\left(J-1\right)D'\left(\left(J-1\right)\bar{R}^{10}+R_1\left(\bar{R}^{10}\mid\theta_1\right)\right)\right]+\omega^{-}JD'\left(J\bar{R}^{10}\right)\\&\qquad>JD'\left(J\bar{R}^{10}\right)-\omega^{+}\mathcal{E}^{+}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)\end{aligned}. \tag{A6}$$

We again use $\omega^{+}+\omega^{-}=1$ to decompose Equation (A6) into the following:

$$\begin{aligned}&\omega^{+}\mathcal{E}^{+}\left[\left(J-1\right)D'\left(\left(J-1\right)\bar{R}^{10}+R_1\left(\bar{R}^{10}\mid\theta_1\right)\right)\right]+\omega^{-}JD'\left(J\bar{R}^{10}\right)\\&\qquad>\omega^{+}JD'\left(J\bar{R}^{10}\right)+\omega^{-}JD'\left(J\bar{R}^{10}\right)-\omega^{+}\mathcal{E}^{+}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)\end{aligned}.$$

We note that $\omega^{+}J=\omega^{+}\left(J-1\right)+\omega^{+}$. We use this and cancel the term that appears on both sides to craft the following:

$$\begin{aligned}&\omega^{+}\mathcal{E}^{+}\left[\left(J-1\right)D'\left(\left(J-1\right)\bar{R}^{10}+R_1\left(\bar{R}^{10}\mid\theta_1\right)\right)\right]\\&\qquad>\omega^{+}\left(J-1\right)D'\left(J\bar{R}^{10}\right)+\omega^{+}D'\left(J\bar{R}^{10}\right)-\omega^{+}\mathcal{E}^{+}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)\end{aligned}.$$

Moving the last term on the right-hand side to the left and cancelling the (positive) ω^{+} that appears in all terms yields the following:

$$\begin{aligned}&\mathcal{E}^{+}\left[\left(J-1\right)D'\left(\left(J-1\right)\bar{R}^{10}+R_1\left(\bar{R}^{10}\mid\theta_1\right)\right)\right]+\mathcal{E}^{+}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)\\&\qquad>\left(J-1\right)D'\left(J\bar{R}^{10}\right)+D'\left(J\bar{R}^{10}\right)\end{aligned}. \tag{A7}$$

This inequality holds if the following two (sufficient but not necessary) conditions hold:

$$\begin{aligned}&\mathcal{E}^{+}\left[\left(J-1\right)D'\left(\left(J-1\right)\bar{R}^{10}+R_1\left(\bar{R}^{10}\mid\theta_1\right)\right)\right]>\left(J-1\right)D'\left(J\bar{R}^{10}\right)\\&\mathcal{E}^{+}\left(\theta_1\right)\bar{\pi}'\left(\bar{R}^{10}\right)>D'\left(J\bar{R}^{10}\right)\end{aligned}. \tag{A8}$$

In fact, the inequality also strictly holds if one of the conditions in (A8) holds strictly and the other holds weakly, and weakly holds if both hold weakly. The first inequality requires only that $\mathcal{E}^{+}\left[D'\left(\left(J-1\right)\bar{R}^{10}+R_1\left(\bar{R}^{10}\mid\theta_1\right)\right)\right]>D'\left(J\bar{R}^{10}\right)$. $D'(\cdot)$

because an exemption can only grant a higher discharge limit than the discharge standard. Specifically, this strict inequality holds if there is any probability $\omega^{+} > 0$ that there will be a positive shock, because then in expectation $R_1\left(\bar{R}^{10} \mid \theta_1\right) > \bar{R}^{10}$. If there is no chance the shock will be positive, then no exemption can be granted, and the first inequality only weakly holds.

We multiply both terms in the second inequality in (A8) by (positive) J to yield:

$$\mathcal{E}^{+}\left(\theta_1\right) J \bar{\pi}'\left(\bar{R}^{10}\right) > JD'\left(J\bar{R}^{10}\right).$$

The right-hand side of the inequality is the same as the right-hand side of Equation (A4) (based on the optimality condition for the no-exemption case) above, so we substitute the left-hand side of Equation (A4) to get the following:

$$\mathcal{E}^{+}\left(\theta_1\right) J \bar{\pi}'\left(\bar{R}^{10}\right) > \left(J-1\right) \bar{\pi}'\left(\bar{R}^{10}\right) + \omega^{+} \mathcal{E}^{+}\left(\theta_1\right) \bar{\pi}'\left(\bar{R}^{10}\right) + \omega^{-} \mathcal{E}^{-}\left(\theta_1\right) \bar{\pi}'\left(\bar{R}^{10}\right).$$

Since all terms include $\bar{\pi}'\left(\bar{R}^{10}\right)$, which is positive by assumption, we eliminate it. Further, we move the last term on the left to the right and group terms to get:

$$\left(J-\omega^{+}\right) \mathcal{E}^{+}\left(\theta_1\right) > J-1+\omega^{-} \mathcal{E}^{-}\left(\theta_1\right).$$

Again, using $\omega^{+} + \omega^{-} = 1$, we craft the following:

$$\left(J-1+\omega^{-}\right) \mathcal{E}^{+}\left(\theta_1\right) > J-1+\omega^{-} \mathcal{E}^{-}\left(\theta_1\right),$$

which we expand to this expression:

$$\left(J-1\right) \mathcal{E}^{+}\left(\theta_1\right) + \omega^{-} \mathcal{E}^{+}\left(\theta_1\right) > J-1+\omega^{-} \mathcal{E}^{-}\left(\theta_1\right).$$

We know that, by definition, $\left(J-1\right) \mathcal{E}^{+}\left(\theta_1\right) > J-1$

$\mathcal{E}^{+}\left(\theta_1\right) > \mathcal{E}^{-}\left(\theta_1\right)$, which is true by definition. Therefore, this inequality holds, which completes our proof that $\overline{R}^{11} < \overline{R}^{10}$ given that $\omega^{+} > 0$.

If there is no chance there will be a positive shock, both inequalities hold weakly, so the discharge standard is only weakly tighter than if no exemptions are anticipated.

A.6. Proof for Corollary of Result 4

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

Proof: We show in the proof of Result 4 that, if a single shock is expected and a single exemption can be granted, then the discharge standard must be weakly lower than the case in which a shock is expected but no exemption can be granted, so that $\overline{R}^{11} \le \overline{R}^{10}$. The same logic would apply for any number of shocks and a single exemption, so that $\overline{R}^{S1} \le \overline{R}^{S0}$. Similarly, starting from any number of exemptions $0 \le R \le S-1$ and increasing to $R+1 \le S$ exemptions, we could follow the logic of the proof of Result 4 to show that $\overline{R}^{SR} \le \overline{R}^{S(R-1)}$. Therefore, it must be true that $\overline{R}^{SK} \le \overline{R}^{SL}$ for $0 \le L < K$.

A.7. Proof for Result 5

Result 5: If $K = S = J$ and $\omega^{+} = 1$, the optimal discharge standard $\overline{R}^{JJ}$ 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, $\overline{R}^{JJ}$, is sufficiently low that $\mathrm{P}\left(R_k^* < \overline{R}^{JJ}\right) = 0$ for all *k*. In this scenario, the regulator is able to issue up to *J* exemptions as long as those are less strict than the standard. The discharge standard can be ensured to be below the lower bound of the distribution of possible optimal discharge levels because the standard can always be set to $\overline{R}^{JJ} = 0$, and the optimal discharge limit for every firm must be positive by assumption.

A.8. Proof for Result 6

Result 6: If the regulator anticipates a shock, expected aggregate discharges are weakly lower if the regulator is able to grant (and anticipates, in Stage 1, being able to grant) an exemption in Stage 2 than if the regulator cannot grant exemptions.

Proof:

The claim is that given optimizing choices by the regulator, the total expected discharges with an exemption, including the $J-1$ firms discharging at the discharge standard $\overline{R}^{11}$ and the one firm discharging at the exemption limit R_1, will be less than the total expected discharges without an exemption, in which case *J* firms each discharge at the discharge standard $\overline{R}^{10}$:

$$\left(J-1\right)\overline{R}^{11} + \mathcal{E}\left[R_1\left(\overline{R}^{11} \mid \theta_1\right)\right] < J\overline{R}^{10}.$$

We rewrite the right-hand side as:

$$\left(J-1\right)\bar{R}^{11}+\mathcal{E}\left[R_1\left(\bar{R}^{11}\mid\theta_1\right)\right]<\left(J-1\right)\bar{R}^{10}+\bar{R}^{10},$$

and then rearrange terms to the following:

$$\mathcal{E}\left[R_1\left(\bar{R}^{11}\mid\theta_1\right)\right]-\bar{R}^{10}<\left(J-1\right)\left(\bar{R}^{10}-\bar{R}^{11}\right).$$

The left-hand side of this inequality is the expected increase in discharges from the firm receiving the exemption; the right-hand side is the reduction in discharges due to the tightening of discharge standard in anticipation of the exemption. Given that $\bar{R}^{10}>\bar{R}^{11}$, the inequality requires the following:

$$\frac{\mathcal{E}\left[R_1\left(\bar{R}^{11}\mid\theta_1\right)\right]-\bar{R}^{10}}{\bar{R}^{10}-\bar{R}^{11}}<J-1.$$

To demonstrate this inequality holds, we take a total derivative of the first-order condition for the optimal exemption as set in Stage 2 by a forward-looking regulator, $R_1\left(\bar{R}^{11}\mid\theta_1\right)$. This total derivative is equivalent to replacing $\bar{R}^{00}$ with $\bar{R}^{11}$ in Equation (5), and yields the following:

$$\theta_1\bar{\pi}''\left(R_1\right)dR_1=D''\left(\left(J-1\right)\bar{R}^{11}+R_1\right)\left(\left(J-1\right)d\bar{R}^{11}+dR_1\right).$$

Rearranging and dropping arguments for visual clarity generates the following:

$$\frac{dR_1}{d\bar{R}^{11}}=\frac{D''}{\theta_1\bar{\pi}''-D''}\left(J-1\right).$$

By assumption, $D''>0$ and $\bar{\pi}''<0$, so the ratio on the right-hand side of the expression is negative and less than one in absolute value. That is, a marginal decrease in the Stage 1 standard $\bar{R}^{11}$ yields an increase in the exemption granted in Stage 2 to the shocked firm by less than $J-1$ times the size of the standard decrease. This condition ensures that a marginal exemption corresponding to a marginal change in the discharge standard always reduces discharges in expectation. Since this outcome is true for an exemption in response to a marginal shock and would be true in the presence of an additional marginal shock (and so on), this outcome also holds for a non-marginal shock and a non-marginal exemption.

References

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.

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.

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., 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., 2017. Efficient Welfare Weights. NBER Working Paper Series No. 20351.
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., 2017. Optimal Regulation with Exemptions. National Bureau of Economic Research Working Paper Series No. 23887.
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.
Maloney, M.T., McCormick, R.E., 1982. A Positive Theory of Environmental Quality Regulation. The Journal of Law and Economics 25, 99-123.
Montgomery, W.D., 1972. Markets in licenses and efficient pollution control programs. Journal of economic theory 5, 395-418.
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.
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.
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.
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.

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.
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.