Non-uniform Implementation of Uniform Standards

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Abstract

Regulations are frequently based on a uniform standard, which applies to all facilities within a single industry. However, implementation of many of these regulations does not lead to uniform limits due to considerations of local conditions in real policy settings. In this paper, we theoretically examine the relationships among the stringency of effluent limits imposed on individual polluting facilities by permit writers, environmental protection agencies' monitoring decisions, and the ambient quality of the local environment. In particular, we explore the establishment of effluent limits when (1) the national emission standard represents only an upper bound on the local issuance of limits and (2) negotiation efforts expended by regulated polluting facilities and environmentally concerned citizens play a role. We find that the negotiated discharge limit depends on the political weight enjoyed and the negotiation effort costs faced by both citizens and the regulated facility, along with the stringency of the national standard and local ambient quality conditions.

Keywords: effluent limits, monitoring, inspections, environmental permits, wastewater, compliance

JEL codes: K42, L51, Q53, Q58

1. Introduction

Regulatory efforts to control corporate behavior often begin with the issuance of limits, followed by government monitoring of compliance with these limits on the part of regulated facilities and enforcement against non-compliant facilities. Frequently these regulatory limits are based on a uniform standard, which applies to all similar facilities (e.g., same industrial classification). However, the implementation of many of the relevant regulations in place around the world does not lead to uniform limits due to considerations of local conditions.

In this paper, we investigate whether the theoretical disadvantages of using uniform standards such as cost inefficiency would disappear – at least to some extent – in a more realistic policy setting. By developing a model that is close to a real policy setting, we study the interaction between the (supra)national regulator and other entities, such as permit writers and enforcement agencies, within a hierarchical setting. These other entities may pursue different objectives, may possess more or less information regarding abatement costs as well as the seriousness of the environmental problem, and may enjoy access to additional policy instruments that serve as complements to uniform standards. By modeling the decisions of the different entities, we gain insight into the implementation and effectiveness of uniform standards in reality.

As a case in point, implementation of the U.S. Clean Water Act does not lead to uniformly issued effluent limits. Instead, each industry-specific Effluent Limitation Guideline, the nationally set standard, represents only an upper bound on the issuance of any individual limit.[1] The actually issued limit reflects the minimum of the level identified by the Effluent Limitation Guideline and the level identified by an assessment of the ambient surface water quality of the water body receiving the wastewater discharge.[2]

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[1] Since the passage of the 1972 Federal Water Pollution Control Act, which preceded the Clean Water Act, the EPA has developed industry-specific Effluent Limitation Guidelines based on the degree of pollution reduction attainable by facilities in a given industry.

[2] This depiction indicates that permitted effluent limit levels are determined by Effluent Limitation Guidelines, which apply uniformly across all facilities within a particular industry, or ambient water quality concerns, which do not relate to an individual facility's ability to control discharges.

This said, the permit writers who establish the limits possess reasonable discretion in deciding which limit is binding. Once limits are established, the regional offices of the U.S. Environmental Protection Agency and state agencies enjoy great discretion in the selection of facilities to monitor and the timing of this monitoring; the same holds for enforcement decisions. Thus, several authorities play independent roles in implementing the U.S. Clean Water Act.

Although very relevant in practice, the theoretical literature on monitoring and enforcement has not explored the relationships among the stringency of effluent limits imposed on individual polluting facilities, environmental protection agencies' monitoring decisions, and ambient quality conditions (see the literature review in Section 3 below). We are particularly interested in the establishment of effluent limits when the national emission standard represents only an upper bound on the issuance of limits and negotiation efforts expended by regulated polluting facilities and environmentally concerned citizens play a role. Specifically, our research questions are the following: Do inspection agencies base their monitoring decisions on the stringency of limits imposed on individual facilities? If yes, how do limit levels influence these monitoring decisions? How are limits established when the national standard represents only an upper bound on the issuance of limits and negotiation efforts expended by regulated facilities and concerned citizens play a role?

While our theoretical analysis draws upon the context of the U.S. Clean Water Act, our analysis extends to other environmental regulatory contexts meeting these three criteria: (1) legal requirements are constrained asymmetrically by national or supra-national standards, (2) tighter limits are imposed due to local ambient conditions, and (3) a separation exists between the authorities responsible for establishment of the standard, issuance of the effluent limits, and monitoring of compliance with limits. Most obvious, our analysis extends to regulatory efforts to control wastewater discharges from point sources in most developed countries. For instance, the European Water Framework Directive (2000/60/EC) requires a minimal amount of ecological and chemical protection everywhere in the EU by defining a set of ambient water quality standards; yet this same directive obligates member states to establish more stringent requirements for identified zones where more protection is needed to support to particular uses (e.g., source of drinking water).

As important, our analysis extends to regulatory efforts to control air pollutant emissions from stationary sources in most developed countries. For example, the U.S. Clean Air Act dictates that tighter emission limit levels are imposed on stationary sources operating in counties that are out of attainment with National Ambient Air Quality Standards (Greenstone, 2002, 2004). As another example, Belgian environmental protection permits may account for local ambient conditions. Specifically, in Belgium, a regional agency imposes general permit requirements, which include effluent standards that are based on best available technologies or techniques; however, local administrators can impose effluent limits that are stricter, but not laxer, than the effluent standards, as needed in order to protect the local environment as guided by ambient standards (Lavrysen, 2009). Regardless of the permit stringency, the environmental inspectorate is responsible for monitoring and enforcing compliance with the limits.

Our analysis also extends to waste policy. For example, as part of its waste control efforts, the EU determines the minimal collection requirements for products, packaging, and waste associated with electrical and electronic equipment (e.g., WEEE Directive 2012/19/EU). However, EU member states' governments can raise their national or regional collection targets above any EU minimum. Consistent with this differentiation, while countries such as Belgium and the Netherlands impose high collection rates, other countries are struggling to achieve the EU minima (Dubois, 2013). As important, each EU member state is responsible for monitoring and enforcing these collection targets.

Lastly, our analysis also extends to pipeline safety efforts. For example, the U.S. Pipeline and Hazardous Safety Materials Administration (PHMSA) regulates pipelines by setting minimum federal standards with which all pipeline operators must comply, yet the Office of Pipeline Safety (OPS) [which lies within PHMSA], along with approved state regulators, implements the regulatory program by monitoring compliance and taking enforcement actions against non-compliance. Stricter set of controls are imposed in “high consequence” areas where the risk for damage to the environment, including human health, is greater (Stafford, 2012).

To answer the research questions presented above, we build a theoretical model where a national regulator exogenously establishes an effluent standard that constrains the limit level eventually imposed on a representative polluting facility, along with the enforcement policy. A regional administrative body is ultimately responsible for establishing the effluent limit imposed on the regulated facility and the monitoring policy. In particular, two independent branches of the regional body, a permit writer and an inspection agency, discharge these duties. The permit writer endogenously selects the effluent limit level based on negotiation efforts with the regulated polluting facility and environmentally concerned citizens, while the effluent standard established by the national regulator represents an upper bound. Given the effluent limit imposed by the permit writer, the regional inspection agency selects its monitoring policy. Local environmental conditions might influence both of these decisions since environmental degradation generated by wastewater discharges from the polluting facility depends on local environmental conditions. For our analysis, we consider two local environmental settings: strong assimilative capacity, which leads to “good” ambient water quality conditions (hereafter “good quality conditions”), and weak assimilative capacity, which leads to “bad” ambient water quality conditions (hereafter “bad quality conditions”). Given both the effluent limit imposed by the permit writer and the monitoring policy chosen by the regional inspection agency, as well as the enforcement policy established by the national regulator, the representative polluting firm chooses its level of wastewater discharges.

Our theoretical results are twofold. First, we find that variations in the discharge limit influence the regional agency’s inspection decisions. Depending on the stringency of the discharge limit, the monitoring agency chooses either an inspection strategy that is uniform between the two considered settings of ambient water quality conditions – good versus bad – or an inspection strategy that differentiates between these two settings. Second, we identify the conditions under which the effluent limit imposed by the permit writer differs from the national standard. These conditions relate to the political weight enjoyed and the negotiation effort costs faced by both citizens and the regulated facility, along with the stringency of the national standard and ambient quality. In general, we conclude that the application of a discharge limit is able to accommodate heterogeneity when different layers of government, such as local permit writers and monitoring agencies, are taken into account within the theoretical analysis.

The rest of the paper is organized as follows. In Section 2, we provide some background on the U.S. Clean Water Act. In Section 3, we identify our study's contribution to the economics literature. In Section 4, we describe our theoretical model. In Section 5, we present our results. In Section 6, we offer a discussion on the social welfare implications of the non-uniform implementation of uniform standards, to account for local conditions and facilities' characteristics. In Section 7, we conclude.

2. Background Information on the U.S. Clean Water Act

As mentioned in the introduction, the actually issued limit reflects the minimum of the level identified by the Effluent Limitation Guideline and the level identified by an assessment of the ambient surface water quality of the water body receiving the wastewater discharge.

The state water quality-based standard is designed to ensure that the ambient water quality of the receiving waterbody meets the state-based ambient quality standard, which in turn is designed to support the waterbody's designated use, e.g., fishing, swimming. In other words, the effluent limit is set so that the facility's discharges do not cause the water body's ambient water quality to fall below the acceptable level. Effluent limits identified by state water quality-based standards may differ across facilities and time since state water quality standards differ within a state and across states and ambient water quality conditions differ across space and time. In particular, due to state water quality standards, the same facility may face more stringent limits in different years or in different months of the same year; such monthly or seasonal variation is expected since state water quality standards depend on seasonal stream conditions (e.g., flow) and temperature. For several polluters, the water quality-based limit level becomes the binding effluent limit. Thus, effluent limits differ across regulated polluters in that some limits are tighter than the national standard.

U.S. environmental protection agencies are authorized and obliged to induce compliance with these differing levels of discharge limits using both monitoring inspections and enforcement actions. Yet U.S. environmental regulatory agencies enjoy great discretion over their monitoring decisions, i.e., inspections. Despite this discretion, inspectors do not coordinate with permit writers during the process of establishing effluent limits. As the only meaningful interaction, inspectors communicate with permit writers in order to confirm that they – the inspectors – understand correctly the terms of the Clean Water Act permits before conducting inspections. In simple terms, permit writers write permits, then inspectors work to induce compliance with these permits, at least to some extent. (We glean this insight from discussions with officials at U.S. environmental regulatory agencies, at both the federal and state levels.)

Similar to inspections, permit writers that establish effluent limits under the Clean Water Act enjoy some discretion over the decision whether to impose the national effluent standard or the tighter water quality-based limit as the binding effluent limit. Moreover, the process of permit writing involves a public notice, which is given once a draft permit is developed, followed by a public comment period lasting at least 30 days (Code of Federal Regulations, 40 § 124.10). During this time, any interested parties may submit written comments and/or request a public hearing (Code of Federal Regulations, 40 § 124.11). The state permitting agency must consider the written comments when establishing the final permit and hold a public hearing when a significant public interest exists (Code of Federal Regulations, 40 § 124.11 & 124.12). Thus, interested parties possess ample opportunity to influence the establishment of effluent limits.

Anecdotal evidence reveals that these opportunities can translate into success, sometimes with help from engineering and law firms. For example, a regulated facility in Faribault, Minnesota, hired an engineering firm to negotiate with the Minnesota Pollution Control Agency, which ultimately agreed not to impose a more stringent ammonia-based discharge limit as initially proposed (Donohue and

Associates, 2014). Another regulated facility in Vacaville, California, hired an engineering firm to negotiate with the State Water Resources Control Board, which eventually agreed to remove the more onerous discharge limits that had been proposed (West Yost Associates, 2014). As more general evidence, one U.S. law firm claims that it has "assisted major paper companies in achieving favorable permit limits" (Troutman Sanders, 2014). As for concerned citizens, two examples reveal success at influencing final discharge limits. First, in response to written comments from citizens and citizen groups, a permit writer imposed stricter limits on the discharges of nitrogen and phosphorus from a Massachusetts wastewater treatment plant.[3] Second, a citizen group, the Minnesota Center for Environmental Advocacy, challenged the discharge limit levels being granted to a new wastewater treatment plant serving the cities of Annandale and Maple Lake in Minnesota.[4]

Consistent with our claim of generalizability, the ability of interested parties to influence the establishment of permits extends beyond wastewater discharge limits. Provision of public comment opportunities also apply to the U.S. Clean Air Act (42 USC § 7661a(b)(6)) and Resource Conservation and Recovery Act (42 USC § 7004(b)(2)), as well as wetland permits issued under Section 404 of the Clean Water Act (33 USC § 1344(a),(e)(1)).

3. Contribution to the Literature

The present study contributes to three strands of the literature: one strand that focuses on the interactions between regulatory stringency and enforcement strategies, another strand that investigates the political economy aspects of enforcement, and a third strand that studies the role of public participation in the regulatory decision process.

Firstly, we contribute to the growing literature that theoretically explores the relationship between regulatory stringency and both monitoring and enforcement strategies (e.g., Arguedas and Rousseau, 2015; Arguedas, 2008; Jones and Scotchmer, 1990; Jones, 1989; Keeler, 1995; Harford and

[3] Upper Blackstone Water Pollution Abatement District vs EPA, 690 F.3d 9 (1st Circuit 2011).
[4] Cities of Annandale and Maple Lake NPDES/SDS Permit Issuance for the Discharge of Treated Wastewater, 731 N.W.2d 502 (Minnesota 2007).

Harrington, 1991; Veljanovski, 1984). While all of these previous studies on regulatory stringency and monitoring and enforcement substantially improve our understanding of environmental agency behavior, to the authors' best of knowledge, no previous theoretical study explores variations in effluent limit levels due to factors unrelated to the regulated entities' compliance costs and the effect of these variations on agency behavior.

For example, Veljanovski (1984) and Keeler (1995) examine the influence of effluent limit levels on agency monitoring and/or enforcement behavior. However, in these studies, the limit is assumed to be exogenous, as opposed to the endogenous limit setting considered here. Arguedas (2008) explores the endogenous determination of effluent limits in a setting with costly monitoring and sanctioning, while focusing on the compliance incentives generated by particular policy combinations. However, Arguedas (2008) does not consider the hierarchical approach we take in our study and assumes that all of the policy parameters (the standard, the inspection probability, and the fine for non-compliance) are set by the same regulatory body. Jones and Scotchmer (1990) consider a hierarchical approach but assume that the standard is exogenous and the inspection agency focuses only on deterrence, as opposed to the more general objective function for the inspection agency considered here. Moreover, in Jones and Scotchmer (1990), the instrument used by the national regulator is the size of the budget allocated to the agency, while in our model the instrument used is the effluent standard. Saha and Poole (2000) and Decker (2007) also consider hierarchical settings but construct a federal government that sets the penalty for non-compliance and a local authority that engages in monitoring and enforcement. Particularly, Decker (2007) considers exogenous standards and constructs a setting in which the federal regulator, who is responsible for setting fines, seeks to minimize social costs, yet the local agency, who is responsible for enforcement, seeks to minimize the sum of (1) enforcement costs and (2) the reputational costs stemming from failures to undertake proper enforcement actions.

More recently, Arguedas and Rousseau (2015) consider a hierarchical approach where limits are endogenously determined by the national regulator. In contrast, our study considers a hierarchical approach where limits are endogenously determined by the regional permit writer in negotiation with the regulated facility and concerned citizens.[5] In addition, our study extends the model of Arguedas and Rousseau (2015) by studying the effect of ambient environmental quality on the implementation and monitoring of uniform standards. In particular, our study introduces the option for a tighter pollution limit imposed on a regulated facility due to local environmental concerns. In contrast, Arguedas and Rousseau (2015) explore a national limit imposed uniformly across regulated facilities, regardless of the facility's compliance costs and local environmental conditions. This extension is important because the inspection agency is constrained by the pollution limit imposed on a given regulated facility. Specifically, the inspection agency cannot induce overcompliance; consequently, a tighter locally derived pollution limit gives the inspection agency greater latitude for inducing its desired level of pollution. Our two extensions of the theoretical analysis of Arguedas and Rousseau (2015) relate since the introduced regional permit writer establishes whether the limit imposed on the regulated facility reflects the (looser) national standard or the (tighter) locally derived level, while facing the negotiation efforts of the regulated facility and (local) concerned citizens. Thus, our two extensions not only broaden the theoretical analysis but fit better with the policy and political landscape present in modern, developed economies.

Secondly, our analysis contributes to the literature that uses political economy models to study enforcement strategies (e.g., Makowsky and Stratmann, 2009; Garoupa and Klerman, 2010; Cheng and Lai, 2012; Ovaere et al. 2013).[6] The study by Cheng and Lai (2012) is particularly relevant since it investigates the impact of interest groups on the regulatory stringency, while taking account of

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[5] Recent theoretical studies explore the interaction between state and federal governments in the environmental regulatory realm (see, for instance, Revesz and Stavins, 2007; Goulder and Stavins, 2011, 2012; Banzhaf and Chupp, 2012; Williams, 2012).

[6] Political economy models are used by many studies to explore various environmental policy settings, such as those relating to climate protection and trade. Several of these studies explore the effects of institutional changes on the stringency of environmental regulation, with some studies considering the role of lobbying: Fredriksson (1997), Damania et al. (2003), Binder and Neumayer (2005), Markussen and Svendsen (2005), and Gullberg (2008). However, these papers all assume full compliance and ignore the role played by the enforcement policy.

incomplete compliance. In the theoretical model, both shareholders of the polluting firms and environmentalists engage in lobbying and offer political contributions to the policymaker in order to influence the level of an emission tax. A somewhat surprising result of Cheng and Lai (2012) is that a stricter enforcement policy can lead to a higher actual emission level, particularly when the polluting firms have a relatively large political influence. Our model differs in several respects from the model presented in Cheng and Lai (2012): [1] we explore an emission limit rather than an emission tax; [2] we endogenously determine the monitoring strategy, while Cheng and Lai (2012) assume monitoring and sanctioning is exogenous; [3] we impose a binding upper standard on the emission limit, while Cheng and Lai (2012) do not constrain the regulatory agent's choice of the emission tax level; and [4] we allow a hierarchical structure of the regulating government, while Cheng and Lai (2012) model a single-layered government.

Thirdly, we allow for public participation in the environmental decision making process in our model. Public or stakeholder involvement is part of environmental policy making in the United States through the US Negotiated Rulemaking Act and in most European countries through the Aarhus Convention. Public participation takes various forms (Wesselink et al., 2011; Luyet et al., 2012). In particular, Videra et al. (2006) and Luyet et al. (2012) identify five different forms of participation: (1) information provision to stakeholders, (2) consultation of stakeholders and then decision making with or without taking into account stakeholder input, (3) collaboration with stakeholders and then decision making taking into account stakeholder input, (4) co-decision making when stakeholders actively help with decision making and implementation, and (5) empowerment that entails the full delegation of decision making and implementation to stakeholders. Our model is an example of the second form, namely, consultation of stakeholders without the guarantee that their input will be used in the final policy decision. An example of such a set-up is the formation of Community Advisory Groups (CAG) within the US Superfund program (EPA, n.d.). Another example is the requirement for public participation embedded within the EU Water Framework Directive (Videira et al., 2006). According to Article 14 of the directive, the public (including users) has the rights to be informed before and during the planning process, to comment, and to access the background documentation and information on the future River Basin Management Plans. On this EU directive, Videira et al. (2006) discusses case studies from five European countries; the authors conclude that, in most cases, stakeholder participation took the form of reactive hearings and consultations rather than active involvement and collaboration. Moreover, public participation can be regarded as a form of regulatory capture. As Dal Bo (2006, p.203) states, "according to the broad interpretation, regulatory capture is the process through which special interests affect state intervention in any of its forms". Regulatory capture in environmental enforcement settings has previously been studied by May and Winter (1999) for the Danish agri-environmental policy and by Zinn (2002) for the US from a more legal perspective.

4. The Model

Since our analysis focuses on the regulatory context of wastewater pollution, hereafter we use the more accurate technical terms of "discharges" and "discharge limits".

We consider a regional district subject to environmental regulation where decisions are made at the national, regional, and facility levels. In this district, a representative facility discharges pollution into a water body, while a national regulator and a regional agency interact to address the environmental problem. The national regulator sets a discharge standard to restrict discharges from the facility operating in the particular region, as well as a fine structure that applies if the facility is discovered exceeding the limit. The regional administrative body includes two independent branches, namely (1) an inspection agency, which is responsible for enforcing the discharge limit and selects the frequency of inspections, i.e., inspection probability, and (2) a permit writer, who is ultimately responsible for establishing the discharge limit imposed on the regulated facility.

For example, within the US National Pollutant Discharge Elimination System (NPDES) permit program, the EPA Office of Wastewater Management – which is a subdivision of the Office of Water – is responsible for writing permits, while the Office of Enforcement and Compliance Assurance is responsible for enforcing these permits. As another example, in Flanders environmental permits for class 2 facilities are written by the mayor and enforced by the local policy, while permits for class 1 – more polluting – facilities are written by the Environmental Permit Administration and enforced by the Environmental Inspectorate.

The national regulator establishes a discharge standard that represents an upper bound on the discharge limit eventually imposed on the facility. In this context, the permit writer must decide whether to impose a discharge limit equaling the national standard or to tighten the discharge limit to a level below the national standard. The permit writer's decision depends on negotiations with both concerned citizens and the regulated facility.

Figure 1 depicts the decision-makers, their decisions, and connections from one decision-maker's decisions to other decision-makers.

[INSERT FIGURE 1 ABOUT HERE]

The facility can reduce its discharges from a *business as usual* discharge level at a cost, which depends on the discharge level, denoted as e, and the facility's type. For simplicity, we assume that the facility can be one of two possible types, either a high-abatement cost facility (H) or a low-abatement cost facility (L). The abatement costs are represented by the function $c_i(e)$, $i \in \{H, L\}$, with the usual assumptions $c_i'(e) < 0$ and $c_i''(e) > 0$. We further assume $c_H(e) > c_L(e)$, $c_H'(e) < c_L'(e)$, and $c_H''(e) \leq c_L''(e)$. Then, a high abatement cost facility faces higher total and marginal abatement costs than a low abatement cost facility.

The facility's discharges cause local environmental damages in the water body. We assume that the water body can possess one of two possible types of assimilative capacity: strong assimilative capacity, which leads to good quality conditions (G), or weak assimilative capacity, which leads to bad quality conditions (B). Environmental damages are then represented by the function $d_j(e)$, $j \in \{G, B\}$, with $d_j'(e) > 0$ and $d_j''(e) \geq 0$. We also assume $d_B(e) > d_G(e)$ and $d_B'(e) \geq d_G'(e)$, which means that both total and marginal damages are greater under bad water quality conditions than under good water quality conditions.

In the first stage of the game, the national regulator establishes the discharge standard, denoted as $\bar{e}$, and a fine per unit of violation, denoted as *f*. We treat this phase as exogenous.

In the second stage of the game, the regional permit writer assesses the discharge limit to be imposed on the facility. (We purposively use the term "standard" for the upper bound discharge level set by the national regulator and the term "limit" for the legally binding discharge level imposed by the permit writer.) We label this phase as the permit hearing and writing phase. Specifically, the permit writer gathers information from the citizens and the regulated facility and hears the concerns of both parties. Based on this information and these concerns, the permit writer may decide to tighten the discharge limit to a level below the national standard. The negotiated discharge limit is denoted as e_{ij}^{w}, as it may depend both on the type of the facility $i \in \{H, L\}$ and the quality of the water body $j \in \{G, B\}$, as we describe below.

Denoting as e_{ij} the level of pollution discharged by a facility of type i into the water body of quality j, we define the fine for exceeding the negotiated discharge limit as follows:[7]

$$F = f \cdot max\{0, e_{ij} - e_{ij}^{w}\}, \text{ where } f > 0. \qquad (1)$$

In the third stage of the game, the regional inspection agency is responsible for enforcing the imposed discharge limit, e_{ij}^{w}, and sets an inspection probability for a facility of type i discharging into a water body of quality j. This probability is denoted as p_{ij}, such that $0 \leq p_{ij} \leq 1$. The cost *per* inspection is $m > 0$. We assume that the regional agency has perfect information on the category to which a facility belongs; thus, the agency can perfectly infer discharges without inspection. However, monitoring is still needed to document formally a violation.

[7] In the concluding section, we assess the implications of a convex fine structure.

In the fourth and final stage of the game, the facility selects its discharge level e_{ij} as its best response to the multi-faceted environmental policy $\{e_{ij}^{w}, f, p_{ij}\}$.

The objective of the (risk-neutral) facility is to choose the discharge level that minimizes the sum of abatement costs and expected fines. Therefore, for a given regulatory policy $\{e_{ij}^{w}, f, p_{ij}\}$, a facility of type i discharging into a water body of quality j solves the following problem:

$$\min_{\{e_{ij}\}} \left[c_i(e_{ij}) + p_{ij} f max\{0, e_{ij} - e_{ij}^{w}\}\right]. \qquad (2)$$

The inspection agency chooses inspection probabilities while considering abatement costs, environmental damages, and monitoring costs. Specifically, we assume that the agency's objective function is the following:[8]

$$\min_{\{p_{ij}\}} \left[\psi c_i(e_{ij}) + d_j(e_{ij}) + m p_{ij}\right], \qquad (3)$$

where e_{ij} is the facility's optimal choice of the discharge limit, as shown in (2). Parameter $\psi \geq 0$ reflects the importance given by the inspection agency to abatement costs, relative to the sum of environmental damages and monitoring costs.[9]

The regional permit writer selects the legally binding discharge limit in negotiation with the regulated facility and interested citizens while considering its own effort costs of tightening the discharge limit below the national standard and the costs of being confronted with negotiation efforts by the facility and citizens. The permit writer's effort costs of tightening the discharge limit are represented by $Z = Z(\bar{e} - e_{ij}^{w})$, such that $Z(0) = 0$, $Z(\bar{e} - e_{ij}^{w}) > 0$ for $\bar{e} > e_{ij}^{w}$, and $Z'(\bar{e} - e_{ij}^{w}) > 0$ for $\bar{e} \geq e_{ij}^{w}$. This

[8] The choice of the objective function of the inspection agency has already been the subject of debate. Cohen (2000), Firestone (2002, 2003) and Heyes and Kapur (2009) provide extensive summaries of the different arguments and assumptions made in various studies. Overall, evidence seems to support the conclusion that national environmental inspection agencies are mainly concerned with deterrence and less concerned with the compliance cost burden placed on the regulated industry. However, at the local level, the enforcing authorities might have different priorities that emphasize the economic concerns of the local community over compliance with nationally imposed regulations.

[9] Keeler (1995) introduces this same parameter ψ. If $0 < \psi < 1$, abatement costs matter but enjoy a lower priority than environmental damages and monitoring costs. If $\psi > 1$, then the agency's concerns about facilities' abatement costs dominate the other concerns.

function represents the costs of obtaining information to prove that a tighter discharge limit might be needed in the region due to the region's idiosyncratic environmental circumstances.

The regional permit writer also considers citizens and facility's costs of their respective negotiation efforts. First, let $g_{ij} = g(e_{ij}^{w}, u)$ denote the citizens' amount of negotiation effort, which decreases with the cost of negotiation, u, but (weakly) increases with the discharge limit, e_{ij}^{w}, that is, $g_{e_{ij}^{w}}(e_{ij}^{w}, u) \geq 0$ and $g_u(e_{ij}^{w}, u) < 0$.[10]

Second, the facility pressures the permit writer so that he/she does not tighten the discharge limit since the sum of abatement costs and expected fines for non-compliance is decreasing in the discharge limit. If $\mathrm{v} > 0$ denotes the unit cost of the facility's negotiation effort, then the amount of negotiation effort expended by the facility is a function of the discharge limit and the facility's cost of negotiation, denoted as $h_{ij} = h(e_{ij}^{w}, v)$, such that $h_{e_{ij}^{w}}(e_{ij}^{w}, v) < 0$ and $h_v(e_{ij}^{w}, v) < 0$.[11]

We assume that the permit writer's unit cost of being confronted with negotiation efforts by the citizens and the facility are respectively denoted as $\beta_g > 0$ and $\beta_h > 0$. A low value for β_g and a large value for β_h suggest that the permit writer is more prone to accept the facility´s entreaties, since the confrontation costs with the industry in this case are larger. Conversely, a large value for β_g and a low value for β_h suggest that the permit writer is more inclined to accept citizens´ demands. Similar values for the two parameters suggest that the permit writer equally balances the demands by the two parties.

The permit writer chooses the discharge limit level in order to minimize the sum of its tightening effort costs and confrontational costs subject to the restriction that the discharge limit level may not exceed the national standard and the response functions of the citizens and regulated facility:

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[10] One way to interpret citizens' negotiation effort is to assume that citizens act as a collective environmental advocacy group. In this capacity, citizens aim to minimize the sum of expected environmental damages and the costs of their negotiation effort. Thus, citizens' objective is captured as $\min_{\{g\}} \left[d_j\left(\mathrm{e_{ij}}\left(\mathrm{e_{ij}^{w}(g)}\right)\right) + \mathrm{ug}\right]$.

[11] One way to interpret the facility's negotiation effort is to assume that the facility minimizes the sum of abatement costs, expected fines for non-compliance, and its own negotiation costs. Thus, the facility's objective is captured as follows: $\min_{\{h\}} \left[c_i(\mathrm{e_{ij}}) + \mathrm{p_{ij}f}\max\{0, \mathrm{e_{ij}} - \mathrm{e_{ij}^{w}(h)}\} + \mathrm{vh}\right]$.

$$\min_{\{e_{ij}^w\}}\left[Z\left(\bar{e}-e_{ij}^w\right)+\beta_g g_{ij}+\beta_h h_{ij}\right] \tag{4a}$$

$$\text{s.t. } e_{ij}^w \le \bar{e};\, g_{ij}=g\left(e_{ij}^w,u\right);\, h_{ij}=h\left(e_{ij}^w,v\right), \tag{4b}$$

After the limit e_{ij}^w and the fine parameter f are made public, the agency announces the inspection probability p_{ij} for facility type $i \in \{H, L\}$ and water quality type $j \in \{G, B\}$. The facility then reacts to the environmental policy $\{e_{ij}^w, f, p_{ij}\}$ by selecting its discharge level.

Figure 2 presents the timing of the interaction involving the national regulator, the permit writer, the inspection agency, and the facility. [12]

[INSERT FIGURE 2 ABOUT HERE]

We solve the model backwards in order to identify the subgame perfect equilibrium.

5. Results

Since the problem is solved using backward induction, we discuss the decisions made by the facility, the regional inspection agency, and the regional permit writer in that order.

5.1. Facility

Given the policy $\{e_{ij}^w, f, p_{ij}\}$, the objective of the (risk-neutral) facility of type i into a water body of quality j is to choose the discharge level e_{ij} that minimizes the sum of abatement costs and expected fines, as expressed in (2). The optimal discharge level, denoted as $\tilde{e}_{ij}$, satisfies the following conditions:

$$c_i'\left(\tilde{e}_{ij}\right)+p_{ij}f \ge 0, \tag{5a}$$

$$\tilde{e}_{ij} \ge e_{ij}^w, \tag{5b}$$

$$\left[c_i'\left(\tilde{e}_{ij}\right)+p_{ij}f\right]\left[\tilde{e}_{ij}-e_{ij}^w\right]=0. \tag{5c}$$

Therefore, the facility's optimal response to the regulatory policy is to comply with the discharge limit (i.e., $\tilde{e}_{ij}=e_{ij}^w$) when the marginal expected fine for non-compliance is larger than the marginal

[12] We do not explicitly model the standard and fine setting decisions of the national regulator. However, we allow the stringency of the discharge limit to be endogenously determined by the permit writer in negotiation with the regulated facility and concerned citizens.

abatement cost savings of exceeding the limit, i.e., when $p_{ij}f \geq -c_i'(e_{ij}^w)$.[13] However, the optimal response of the facility is to exceed the limit ($\tilde{e}_{ij} > e_{ij}^w$) if the marginal expected fine lies below the marginal abatement cost savings evaluated at the limit. In that case, the facility chooses the discharge level that equates the marginal abatement cost savings and marginal expected fine, that is, $c_i'(\tilde{e}_{ij}) + p_{ij}f = 0$.

From the above expression, we can easily define the minimum (or threshold) inspection probability that induces the facility of type *i* to comply with the legal limit as follows:

$$\bar{p}_{ij} = -\frac{c_i'(e_{ij}^w)}{f}. \tag{6}$$

In the event that both facility types are confronted with the same legal limit, i.e., $e_{Hj}^w = e_{Lj}^w$, our assumptions ensure that $\bar{p}_{Hj} > \bar{p}_{Lj}$ since $c_H'(e) < c_L'(e)$. Moreover, for the case where the discharge limit does not depend on water quality ($e_{iG}^w = e_{iB}^w$), the threshold inspection probability for facility type *i* does not depend on water quality either ($\bar{p}_{iG} = \bar{p}_{iB}$) since water quality does not affect abatement costs.

5.2. Regional Inspection Agency

The objective of the regional agency is to choose inspection probabilities that minimize the weighted sum of abatement costs, environmental damages, and monitoring costs, as expressed in (3), while taking into account the facility's best response, the legal discharge limit, and the fine:

$$\min_{\{p_{ij}\}} \left[\psi c_i(e_{ij}) + d_j(e_{ij}) + mp_{ij}\right]$$

$$s.t. \quad c_i'(e_{ij}) + p_{ij}f \geq 0; e_{ij} \geq e_{ij}^w. \tag{7}$$

Throughout the paper we abstract from the consideration of a monitoring budget constraint. While this abstraction is obviously a drastic simplification of reality, our main results remain qualitatively the same under a budget constraint, as we explain in the concluding section.[14]

[13] In a static model with deterministic discharges such as ours, the facility never chooses to reduce its discharge level strictly below the limit. This reduction merely increases abatement costs without any fine savings.

[14] Consult Fredriksson et al. (2011) as an example of a study exploring how elected officials can alter budgets for local environmental agencies. As another example, Jones and Scotchmer (1990) used the size of the budget

In order to describe the agency's inspection decisions, we identify e_{ij}^{a} as the inspection agency's preferred discharge level of a facility of type i discharging into a water body of quality j. This discharge level satisfies the optimality condition:

$$\psi c_i'\left(e_{ij}^{a}\right) + d_j'\left(e_{ij}^{a}\right) - m\frac{c_i''\left(e_{ij}^{a}\right)}{f} = 0. \quad (8)$$

Our assumptions guarantee the following ranking of the agency's preferred discharge levels: $e_{Lj}^{a} < e_{Hj}^{a}$ for all $j \in \{G, B\}$ and $e_{iB}^{a} < e_{iG}^{a}$ for all $i \in \{H, L\}$. Also, the larger is ψ (i.e., the larger is the weight the regional agency places on the facility's abatement costs), the larger is the preferred discharge levels e_{ij}^{a}, and vice versa. Based on the facility's optimal decision analyzed in the previous subsection, the inspection probability p_{ij}^{a} that induces each of these identified discharge levels is simply:

$$p_{ij}^{a} = -\frac{c_i'\left(e_{ij}^{a}\right)}{f}. \quad (9)$$

Thus, the regional agency's optimal inspection strategy, denoted as $\tilde{p}_{ij}$, depends on the level of the discharge limit as follows:

$$\tilde{p}_{ij} = \begin{cases} p_{ij}^{a}, & e_{ij}^{w} \leq e_{ij}^{a} \\ \bar{p}_{ij}, & e_{ij}^{w} > e_{ij}^{a} \end{cases} \quad (10)$$

where p_{ij}^{a} and $\bar{p}_{ij}$ are respectively given by equations (9) and (6).

Therefore, as long as the legal discharge limit e_{ij}^{w} is sufficiently strict (i.e., when the legal limit lies below the agency's preferred discharge level), the regional agency can implement its preferred discharge level by setting $\tilde{p}_{ij} = p_{ij}^{a}$. In this case, the facility exceeds the legal limit by selecting its discharges to equal the regional agency's preferred discharge level. However, for a sufficiently lax legal limit (i.e., when the legal limit lies above the agency's preferred discharge level), the optimal inspection strategy is $\tilde{p}_{ij} = \bar{p}_{ij}$, which leads the facility to comply with the limit.

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allocated to the agency to influence monitoring strategies. However, in contrast to our study, the standard is exogenous in their model.

The optimal inspection strategies and the induced discharge levels are depicted in Figures 3 and 4. Each figure shows how the optimal inspection probability and the induced discharge level change as the discharge limit varies. Specifically, the upper graph of each figure shows the relationship between the stringency of the limit and the optimal inspection probability, while the lower graph of each figure shows the resulting facility's best response to both the legal limit and the inspection probability. Figure 3 displays how these relationships differ between the two different water quality levels while considering the same facility cost type. Figure 4 displays how these relationships differ between the two facility cost types while considering the same level of water quality.

[INSERT FIGURES 3 AND 4 ABOUT HERE]

Figure 3 illustrates that the optimal inspection strategy depends on both the stringency of the discharge limit and the level of the water quality. As shown in the upper graph, when the discharge limit lies at or below the agency's preferred level of discharges under bad water quality conditions (e_{iB}^{a}), the agency inspects more frequently when the facility is operating under bad water quality conditions than when the facility is operating under good water quality conditions. The extra monitoring pressure under bad conditions is needed to induce the agency's lower preferred discharge level. As shown in the lower graph, the agency's preferred discharges under bad water quality conditions, e_{iB}^{a}, are clearly less than the agency's preferred discharges under good quality conditions, e_{iG}^{a}. As long as the discharge limit lies below e_{iB}^{a}, both inspection probabilities and both discharge levels are independent of the discharge limit because the limit does not constrain the agency's choice.

When the discharge limit lies between e_{iB}^{a} and e_{iG}^{a}, the optimal inspection probability under bad water quality exceeds the optimal inspection probability under good water quality conditions. Even though the agency is constrained to induce only exact compliance under bad water quality conditions, so the inspection probability is lower than otherwise desired, the monitoring pressure needed to induce compliance exceeds the monitoring pressure needed to induce the agency's preferred discharge level under good quality conditions. Consistent with this difference, discharges under bad water quality conditions are lower than discharges under good water quality conditions.

Once the discharge limit lies above the agency's preferred discharge level under good water quality conditions ($e_{ij}^{w} > e_{iG}^{a}$), the discharge limit binds the agency's choice regardless of the water quality conditions. In this case, the agency is constrained to induce exact compliance whether quality conditions are good or bad, as shown in the lower graph. Consistently, the extent of monitoring pressure does not depend on water quality conditions, as shown in the upper graph.

Most interesting, the upper graph of Figure 3 shows that the regional agency implements a differentiated inspection strategy, under which the agency applies greater monitoring pressure under bad water quality conditions, as long as the discharge limit does not bind under good water quality conditions ($e_{ij}^{w} < e_{iG}^{a}$). Once the discharge limit binds under both bad and good water quality conditions ($e_{ij}^{w} \geq e_{iG}^{a}$), the regional agency implements a uniform inspection strategy under which the agency does not condition its monitoring pressure on water quality conditions.

Moreover, the lower graph of Figure 3 shows that the agency does not always induce compliance. When the discharge limit is sufficiently loose ($e_{ij}^{w} > e_{iG}^{a}$), the facility is compliant regardless of water quality conditions. However, when the discharge limit is sufficiently tight ($e_{ij}^{w} < e_{iB}^{a}$), the facility is non-compliant regardless of water quality conditions. In between these two extremes ($e_{iB}^{a} < e_{ij}^{w} < e_{iG}^{a}$), the facility is compliant only under bad water quality conditions and non-compliant under good water quality conditions.

Figure 4 displays the relationships involving the optimal inspection strategy, the induced discharge level, and the imposed discharge limit for the two facility types and a given water quality level. Here, the upper graph of Figure 4 shows that the regional agency always implements a differentiated inspection strategy when both facility types are confronted with the same discharge limit, applying greater monitoring pressure under high costs. The lower graph of Figure 4 shows that each facility type is compliant when the discharge limit is sufficiently loose ($e_{ij}^w \geq e_{ij}^a$) and non-compliant when the discharge limit is sufficiently tight ($e_{ij}^w < e_{ij}^a$). Therefore, both facility types are non-compliant if the corresponding discharge limits e_{Hj}^w and e_{Lj}^w are lower than e_{Lj}^a, while both facility types are compliant if the discharge limits are larger than e_{Hj}^a. In the intermediate region between e_{Lj}^a and e_{Hj}^a, only the low cost facility is compliant, while the high cost facility is non-compliant.

5.3. Permit Writer

As described in equation (4), the permit writer seeks to minimize the sum of effort costs and confrontational costs, constrained by the national regulator's upper bound standard on the discharge limit and the response functions of the citizens and facility. Given this objective and these constraints, the permit writer's optimal discharge limit satisfies the following conditions:

$$Z'\left(\bar{e} - e_{ij}^w\right) - \beta_h h_{e_{ij}^w}\left(e_{ij}^w, v\right) \geq \beta_g g_{e_{ij}^w}\left(e_{ij}^w, u\right), \tag{11a}$$

$$\bar{e} \geq e_{ij}^w, \tag{11b}$$

$$\left[Z'\left(\bar{e} - e_{ij}^w\right) - \beta_h h_{e_{ij}^w}\left(e_{ij}^w, v\right) - \beta_g g_{e_{ij}^w}\left(e_{ij}^w, u_g\right)\right]\left[\bar{e} - e_{ij}^w\right] = 0. \tag{11c}$$

We explore these three conditions. Consider the first optimality condition – equation (11a). The term $Z'\left(\bar{e} - e_{ij}^w\right) - \beta_h h_{e_{ij}^w}\left(e_{ij}^w, v\right)$ lies on the left hand side of equation (11a). This term represents the marginal cost of tightening the discharge limit, which is composed, respectively, of the marginal cost of the administrative effort needed to tighten the limit and the marginal cost of being confronted with increased negotiation effort by the regulated facility. The term $\beta_g g_{e_{ij}^w}\left(e_{ij}^w, u\right)$ lies on the right hand side of equation (11a). This term represents the marginal benefit of tightening the discharge limit as captured by the permit writer's marginal cost savings of being confronted with less effort by citizens. The second optimality condition – equation (11b) – simply reflects the binding nature of the national regulator's discharge standard, which represents an upper bound on the discharge limit. The third optimality condition – equation (11c) – combines the first two components as part of the Kuhn-Tucker conditions.

In sum, it is optimal for the permit writer not to tighten the discharge limit, so that e_{ij}^{w} remains equal to $\bar{e}$, as long as $Z'(0) - \beta_h h_{e_{ij}^{w}}(\bar{e}, v) \geq \beta_g g_{e_{ij}^{w}}(\bar{e}, u)$. This condition holds when the marginal costs of tightening the limit outweigh the corresponding marginal benefits, evaluated at $e_{ij}^{w} = \bar{e}$. On the other hand, it is optimal to tighten the limit, so that $e_{ij}^{w} < \bar{e}$, when the opposite condition is met. This condition holds when the marginal costs of tightening the limit are lower than the corresponding marginal benefits, evaluated at $e_{ij}^{w} = \bar{e}$. In this latter case, the optimal discharge limit set by the permit writer satisfies the first optimality condition by equating marginal costs and marginal benefits: $Z'\left(\bar{e} - e_{ij}^{w}\right) - \beta_h h_{e_{ij}^{w}}\left(e_{ij}^{w}, v\right) = \beta_g g_{e_{ij}^{w}}\left(e_{ij}^{w}, u\right)$.

Based on our assessment of the optimality conditions shown in equation (11), we now identify the conditions under which the discharge limit imposed by the permit writer equals the national standard (the contrary conditions lead to the limit lying below the national standard). Basically, the chosen discharge limit depends on the political weight granted to citizens and the regulated facility by the permit writer, the negotiation effort costs borne by the citizens and regulated facility, the stringency of the national standard relative to the agency's preferred discharge levels, and water quality conditions. The specific conditions are intuitive as follows:

(i). Citizens possess insufficient political weight. In the extreme case where citizens have zero political weight, β_g= 0, the marginal benefits of tightening the limit below the standard become zero. This case may correspond to a situation where the permit writer is not aligned with the citizens' desire to minimize environmental damages and the confrontational costs against citizens are negligible.

(ii). The facility enjoys a large political weight. This case may correspond to a situation where the permit writer aligns with the facility, because the confrontational costs are large. If β_g is large, this implies that the marginal costs of tightening the limit below the standard are large.

(iii). Citizens' negotiation effort costs are large enough or the facility's negotiation effort costs are small enough. These elements result in low negotiation effort on the part of citizens and high negotiation effort on the part of the facility, which raises the likelihood that inequality (11a) is met.

(iv). The national standard is already sufficiently strict, that is, $\bar{e} \leq e_{ij}^{a}$. In this case, tightening the discharge limit even more has no effect on environmental damages, since the facility does not reduce its discharges when the limit lies below e_{ij}^{a}, because the agency does not exert the monitoring pressure needed to induce discharges below e_{ij}^{a}. As a result of the agency's choice, it is worthless for citizens to exert any negotiation effort. Given a particular standard $\bar{e}$, the greater is the importance given by the inspection agency to the facility's abatement costs (i.e., the larger is ψ), the larger is e_{ij}^{a}, and, therefore, the condition of $\bar{e} \leq e_{ij}^{a}$ is more likely met in this case.

(v). Water quality conditions are good rather than bad. By assessing Figure 3, since $e_{iB}^{a} < e_{iG}^{a}$, the national standard is more likely to lie below e_{iG}^{a} than below e_{iB}^{a}. Therefore, citizens enjoy more leverage to exert negotiation effort under bad water quality conditions than under good water quality conditions, everything else equal. Under bad conditions, citizens are better able to reduce environmental damages by prompting the permit writer to tighten the discharge limit in the event that the national standard is set above e_{iB}^{a}.

(vi). Abatement costs are sufficiently large. The high abatement cost type is more likely to exert more effort against a tighter limit than the low abatement cost type, since the additional costs borne by the high cost type of a tighter limit are larger.

An assessment of these conditions easily identifies the more likely outcome when the monitoring agency and the permit writer have converging interests. If the permit writer's and the monitoring agency's objectives are closer to the facility´s objective than the citizens' objective (small β_g, large β_h, and large ψ), then conditions (i), (ii) and (iv) are more likely to be met. As shown, all of these conditions result in a discharge limit that equals the national standard. The opposite conclusion holds under converging objectives that are closer to the citizens' objective. If both the monitoring agency and the permit writer are aligned with the citizens, the permit writer is more likely to tighten the discharge limit.

Less evident is the case where the monitoring agency and the permit writer have diverging interests. In this situation, we can deduce that the permit writer is less likely to set a discharge limit tighter than the standard, independent of which entity supports the facility's interest. The explanation follows. The permit writer can impose a tighter discharge limit, to which the monitoring agency induces compliance, as long as the national standard is not sufficiently strict (i.e., $\bar{e} > e_{ij}^{a}$, the opposite ordering shown in condition (iv)). For this case to happen, ψ must be small enough, which applies when the monitoring agency's objective is not particularly aligned with the facility´s objective. However, if the permit writer's interest were close to the facility´s interest, the permit writer would have no incentive to tighten the limit below the standard. In the opposite scenario where the monitoring agency's objective is close to the facility´s objective (i.e., ψ is large), condition (iv) is more likely to be met. However, the permit writer gains nothing by tightening the limit below the standard (even if the permit writer's interest is aligned with the citizens' interest) because, in this case, the monitoring agency is able to implement its preferred pollution level, e_{ij}^{a}. As a result, the limit is less likely set tighter than the standard when the monitoring agency and the permit writer have diverging objectives, independent of which entity supports the facility's interest.

As a final remark, a tightening of the discharge limit is more likely only when both the monitoring agency's and the permit writer's objectives are aligned with the citizens' objective. If one of these two government entity's objective is closer to the facility's objective, no matter which one, then the permit writer is not expected to tighten the discharge limit below the standard.

6. Discussion

The previous section analyzes how a uniform discharge standard can be implemented in a non-uniform fashion to account for local conditions and circumstances. This section discusses whether the theoretical disadvantages of using a uniform discharge limit shrink when the discharge limit is implemented non-uniformly. For this purpose, we compare social welfare under the non-uniform implementation of a discharge limit that reflects local conditions and circumstances ("non-uniform case") and social welfare under the uniform implementation of a uniform discharge limit ("uniform case").

Our more realistic way of modeling a uniform standard (non-uniform case) impacts social welfare by changing abatement costs, monitoring costs, environmental damages, negotiation costs of facilities and citizens, and permit writer effort costs.[15] The following equation depicts the respective change in each cost term generated by a switch from the uniform case to the non-uniform case:

$$\Delta SW = \left[c_i\left(\tilde{e}_{ij}\right) - c_i(\bar{e})\right] + m\left[\tilde{p}_{ij} - \bar{p}_{ij}\right] + \left[d_j\left(\tilde{e}_{ij}\right) - d_j(\bar{e})\right] + h_{ij}\left(e_{ij}^{w}, v\right) + g_{ij}\left(e_{ij}^{w}, u\right) + Z\left(\bar{e} - e_{ij}^{w}\right)$$

To facilitate our welfare comparison, we identify some key insights generated by our model. Firstly, the inspection frequency is weakly decreasing with the level of the national standard. Secondly, the permit writer's decision - and thus the effects of negotiation and lobbying efforts - is bounded by the level of the national standard and by the inspection agency's willingness to enforce the local discharge limit. Finally, the inspection agency's ability to reach the desired level of environmental quality is constrained by the level of the local limit, thus, indirectly by the national standard.

Social welfare in the non-uniform case roughly equals social welfare in the uniform case ($\Delta SW \approx 0$) under a set of restrictive assumptions: the actual (induced) discharge levels are equal across facilities and between cases, negotiation unit costs are so high that neither the regulated facility nor the citizens engage in any meaningful amount of negotiation, and the permit writer effort costs are negligible. These conditions emerge if the national standard is set at a lax level, facilities face the same abatement cost structure, and ambient water conditions do not vary spatially. Since there are no negotiations with stakeholders, the local permit writer sets the local limit equal to the national standard. The inspection

15 For simplicity, we assume that fine payments are welfare-neutral transfers; consequently, these policy changes do not affect consumer surplus.

agency strictly enforces the lax limit, as long as the agency's objective function does not deviate too much from the social welfare function, i.e., $\psi \approx 1$.

The non-uniform case is more likely to reduce social welfare relative to the uniform case ($\Delta SW < 0$) when the inspection agency places different weights on abatement costs and environmental damages (i.e., $\psi \neq 1$), negotiation unit costs are sufficiently low so that the regulated facility and the citizens engage in meaningful amounts of negotiation, and the permit writer effort costs are non-negligible. These conditions drive the level of social welfare in the non-uniform case to fall below the level of social welfare in the uniform case because the non-uniform case involves costs not present in the uniform case, e.g., negotiation costs.

However, the non-uniform case is more likely to increase social welfare relative to the uniform case ($\Delta SW > 0$) when the national standard differs from water condition-specific optimal discharge levels and/or the national standard differs from abatement cost-specific optimal discharge levels. For example, if the national standard is set at a sufficiently strict level, the regional permit writer in the more realistic model does not tighten the local discharge limit to a level below the national standard, yet the induced levels of compliance differ across facilities. Depending on local circumstances, facilities can choose to be non-compliant; these choices improve welfare, as long as the (1) inspection agency's objective function is sufficiently similar to the social welfare function and (2) negotiation efforts by the stakeholders are more or less balanced.

While the differences between the more realistic model and the standard model are fairly clear to identify, exact welfare comparisons are more challenging to provide. Differences in monitoring costs, abatement costs, environmental damages, negotiation costs, and permit writer effort costs depend on several factors. Firstly, comparing the socially optimal discharge limit for each of the facility types and water quality types to the national standard and locally imposed discharge limit is critical. Secondly, the difference between the inspection agency's objective and the social welfare function plays an important role. Thirdly, the levels of abatement costs and environmental damages, as well as the relative unit monitoring costs and unit negotiation costs, impact social welfare.

In conclusion, the more realistic model can increase social welfare relative to the standard model but not always. For example, when the national standard is stricter than the socially optimal discharge levels, our model allows for imperfect compliance by facilities, which increases welfare (up to some point) since the savings in abatement and monitoring costs outweigh the increase in environmental damages. However, if the strict national standard actually represents the socially optimal discharge levels, our model reduces social welfare by allowing facilities to be non-compliant.

7. Conclusions

In this paper, we investigate how a uniform standard can be transformed into a non-uniform level of protection effort through the implementation process of a multi-layered government. We model how protection effort is induced in a bounded framework, where a national standard acts as an upper bound on the limit imposed to constrain the harmful activity, thus, guaranteeing a minimal extent of protection, while the monitoring strategy selected by the regulatory inspector restrains the maximal extent of protection that can be induced.

More specifically, we study the relationships among the stringency of effluent limits imposed on individual polluting facilities, environmental protection agencies' monitoring decisions, and the ambient quality of the local environment. As one interesting feature of our study, our model includes negotiation efforts expended by regulated polluting facilities and environmentally concerned citizens to influence the establishment of the discharge limit by a permit writer.

We find that the monitoring agency chooses either an inspection strategy that is uniform between the two sets of ambient water quality conditions – good versus bad – or an inspection strategy that differentiates between these two sets of conditions, depending on the stringency of the discharge limit. In contrast, the monitoring agency chooses an inspection strategy that differentiates between low cost facilities and high cost facilities for a given discharge limit stringency. In the permit hearing phase, we identify the conditions under which the discharge limit imposed on a regulated polluter differs from a national standard, which represents an upper bound on the limit. In particular, the negotiated discharge limit depends on the political weight granted to citizens and the regulated facility by the permit writer, the negotiation effort costs borne by the citizens and facility, the stringency of the national standard relative to the agency's preferred discharge levels, and water quality conditions. Thus, the application of a discharge limit is able to accommodate heterogeneity when different layers of government, such as local permit writers and monitoring agencies, are taken into account within theoretical analysis.

We next assess the implications of relaxing certain assumptions. As one assumption, we model a linear fine structure. If we were instead to consider a convex fine structure, we would need to modify Figures 3 and 4. The main modification would concern the effect of the discharge limit level on the facility's chosen discharge level. Since the marginal fine would be increasing in the degree of non-compliance, a lower discharge limit would induce a lower discharge level. In terms of Figures 3 and 4, this connection implies that the facility's best response under non-compliance would be no longer horizontal but increasing in the discharge limit, with a slope less than 1, which would reflect the fact that a lower discharge limit leads to a larger degree of non-compliance. Given this relationship under a convex fine structure, concerned citizens would be inclined to negotiate a reduction in the discharge limit below the national standard even when the standard lies below e_{iB}^{a} or e_{Lj}^{a}, depending on circumstances, since the monitoring agency would be able to induce further reductions in the facility's discharge level within the relevant range. Therefore, all else equal, the permit writer would be more likely to tighten the discharge limit below the national standard under a convex fine structure than under a linear fine structure.

As another assumption, we posit that the regional agency's budget constraint is not binding. If we were instead to posit a binding budget, the likelihood of compliance would decrease. In terms of Figures 3 and 4, this decrease would imply that the range of discharge limit values that induce non-compliance would expand. Since the facility's best response is constant under non-compliance, the presence of a binding budget would decrease the likelihood that the permit writer tightens the discharge limit below the national standard, all else equal.

Lastly, we claim that our results apply to other regulatory contexts beyond water quality protection. Besides environmental protection, our results are also applicable to other realms of safety protection where the stringency of safety controls depends on the risk of damage to human safety, such as in the contexts of transportation safety, occupational safety, and product safety. For example, transportation speed limits are tighter in areas where children are likely to be playing, e.g., near schools; tighter occupational safety controls are imposed where pregnant women are working; etc. While our results should apply to these other contexts, future theoretical research should model these contexts explicitly.

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Figure 1

Regulation of Discharges under Negotiation over the Discharge Limit

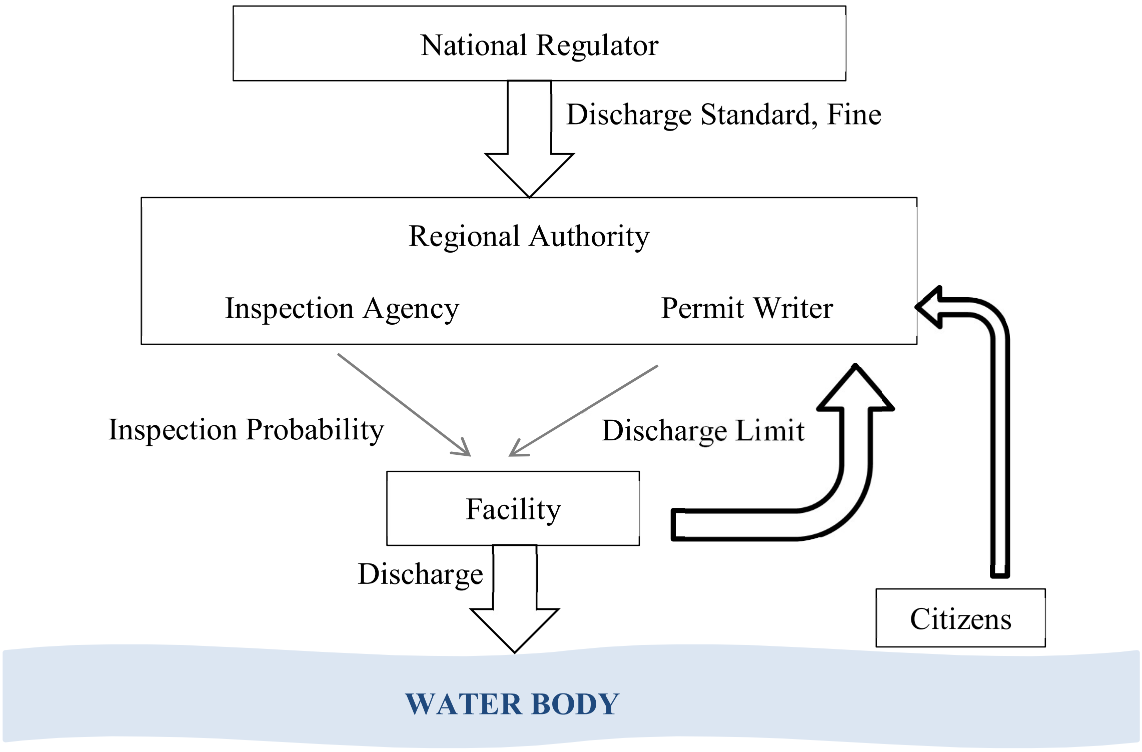

Figure 2

Timing of Decisions

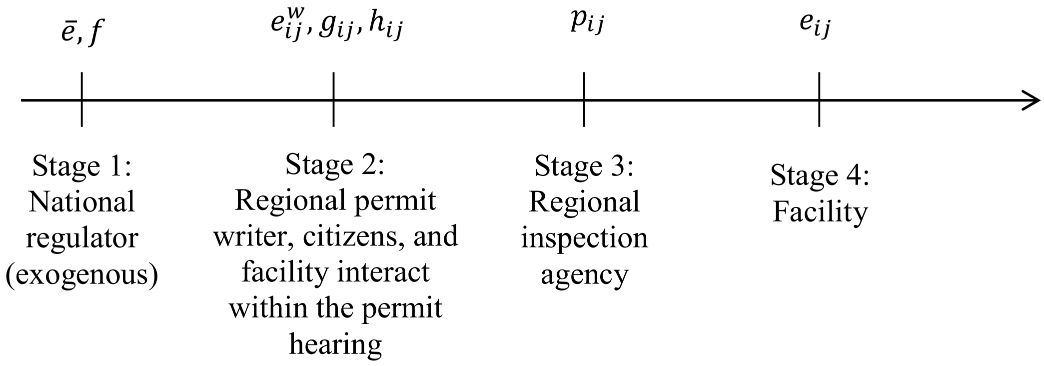

Figure 3
Optimal Inspection Strategy for a Given Facility Cost Type and Different Water Quality Levels

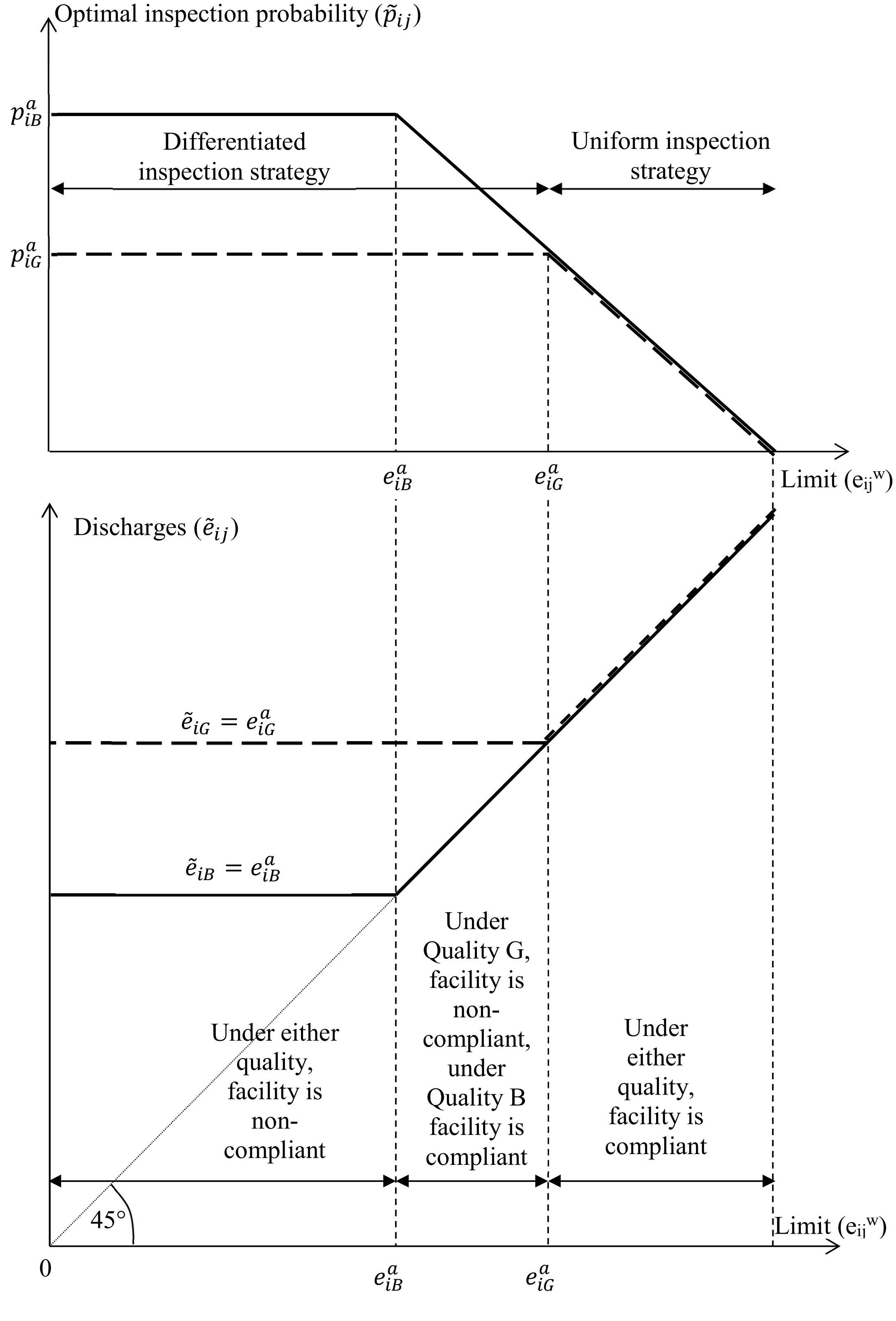

Figure 4
Optimal Inspection Probability for a Given Water Quality Level and Different Facility Types