Transboundary Natural Resources, Externalities, and Firm Preferences for Regulation*

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Abstract

This paper analyzes a common property resource shared by two countries in the presence of two forms of bilateral externalities: the tragedy of the commons and the environmental damage resulting from the exploitation of the resource. We demonstrate that both cooperative and non-cooperative forms of regulation produce a negative effect on firms' profits, as they increase firms' unit production costs. However, regulation can also entail a positive effect on profits by mitigating industry overproduction. We show that the magnitude of these two effects depends not only on the type of regulatory instrument, but also on the rate of resource extraction and the environmental damage in each country. We identify conditions under which the positive effect of regulation dominates its negative effect, thus increasing firms' profits and ultimately incentivizing them to support the introduction of regulation, either at the national or international level.

Keywords: Common property resource, Bilateral externalities, Transboundary externalities

JEL: H23, Q38, C71, C72

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1 Introduction

Gordon (1954) and Hardin (1968) highlighted early on that, in the absence of property rights, coercive laws or taxes, every rational agent has the incentive to exploit a common property resource (CPR) at a level that is collectively inefficient. The presence of environmental externalities (e.g., environmental and transboundary pollution) associated with the exploitation of the commons complicates the regulators' task, as now the optimal policy has to balance the effects of multiple market failures, which generate different types of distortions, some at the domestic level and others with international scope. The situation becomes even more intricate if a natural resource occupies the geographical territories of two or more independent countries, hence allowing agents in both countries to use the resource. Since in this context the extraction of the resource by one agent reduces the resource available for domestic and foreign agents, even greater pressure will be placed on the stock of natural resources and the environment. While the literature has examined CPRs shared by multiple countries, it has largely overlooked the presence of environmental externalities that can arise from the exploitation of the resource. However, externalities are relatively common in shared CPRs. The Upper Paraná Atlantic Forest (covering the territories of southern Brazil, northeastern Argentina, and eastern Paraguay) and the Aral Sea (between Uzbekistan and Kazakhstan) are two examples of CPRs shared by different countries with different appropriation externalities.[1]

In this paper, we investigate the appropriation and management of CPRs that are located between two countries in the presence of two forms of bilateral externalities: the tragedy of the commons and the environmental damage resulting from the exploitation of the commons.

[1] In the case of the Upper Paraná Atlantic Forest expansion of land use, owing to agriculture, cattle ranching, and extraction of timber for construction, furniture, and biofuel, led to severe forest fragmentation and degradation, with only 7.4% of the original forest cover remaining (Di Bitetti et al., 2003). In the case of the Aral Sea, heavy irrigation for water-intensive crops such as cotton and rice, and construction of hydroelectric dams severely reduced the amount of water flowing into the sea. This ultimately caused the sea to shrink, thereby creating one of the worst ecological disasters in Central Asia. Specifically, the decline of the Aral Sea drastically changed regional climate, landscape, river flow, water level and salinity, fish population dynamics, soil fertility and public health (Glantz, 1999; O'Hara et al., 2000; Whish-Wilson, 2002; and Philip and Aladin, 2008).

We examine a two-stage complete information game where, first, the regulators in two countries set environmental regulations (tax or subsidy), and second, firms, whose production is driven by resource-extraction, select profit-maximizing levels of appropriation given the policy set by the regulator. For completeness, we consider both non-cooperative regulation, where each country independently sets its own environmental policy, and cooperative regulation, where countries select the policy that maximizes their joint welfare as part of an international environmental agreement.

We demonstrate that environmental regulation imposes two opposing effects on firms' profits. On one hand, more stringent regulation increases firms' production costs, thus imposing a *negative effect* on profits. On the other hand, tighter regulation helps firms mitigate aggregate production and thereby increase market prices, yielding a *positive effect* on profits. The magnitude of these two effects depends on the extraction rate and the extent of environmental damage, and are more pronounced with a cooperative policy as it entails stricter regulation relative to a non-cooperative policy.

Comparing the relative sizes of these effects, our findings suggest that when the appropriation rate is relatively high, both cooperative and non-cooperative policies entail stringent taxation, which imposes a negative effect on profits. However, such a strict taxation also helps firms mitigate industry overproduction, thus increasing prices and ultimately producing a positive effect on profits that completely outweighs the negative effect of the regulation. Therefore, firms in this setting earn larger profits when the environmental regulation is present than when it is absent. Since cooperative policy is tighter than non-cooperative policy, the net effect of regulation is going to be larger under the former than the latter. As a consequence, firms support their countries' participation in international environmental agreements that coordinate environmental policies when such cooperation is needed (i.e., when bilateral externalities are high). This may provide a possible explanation for why some oil-rich middle Eastern countries that share oil fields may find it beneficial to be the members of the Organization of the Petroleum Exporting Countries (OPEC), an international organization that ensures stable energy markets, sustainable oil production, and environmental sustainability.[2,3]

In contrast, when the appropriation rate is moderate, regulation entails larger negative than positive effect on firm profits, as laxer policy instruments do not mitigate aggregate production substantially. Hence, profits are lower in the presence of any form of regulation, which incentivizes firms to oppose regulation. Finally, when the appropriation rate is relatively low, firms receive a subsidy under both cooperative and non-cooperative regulation, which produces a large positive effect on profits. As non-cooperative policy is less stringent than cooperative policy, firms receive more generous subsidies with the former than the latter. As a result, firms would actually favor non-cooperative policy (i.e., domestic regulation) in this setting.

From a policy perspective, the theoretical predictions of our analysis allow regulatory agencies to better anticipate the industry reaction to potentially new environmental policies, either domestic or international. In addition, our study highlights the role that non-environmental policies play in influencing industry preferences towards different regulatory settings. Specifically, the dissemination of new technologies that allow firms to appropriate the shared CPR at higher rates would facilitate the emergence of settings where firms support cooperative regulation in international environmental agreements. Intuitively, as the extraction rate increases, more output will be delivered to the market, which entails a downward pressure on the price and thus firms' profits. The environmental tax in this context helps firms alleviate industry overproduction and thereby reverse the price decline. Such effect will be more pronounced with cooperative than non-cooperative policy as the former entails tighter regulation than the latter.

[2]For instance, Iran and Iraq share the Al-Fakkah oil field; Iraq and Kuwait share the Rumaila oil field; and Kuwait and Saudi Arabia share the Khafji oil field; and all four countries are OPEC members.

[3]As part of its effort to support the environment and sustainable development, OPEC requires from its member countries full, effective and sustained implementation of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, which represent coordinated international environmental agreements. For further details, visit http://www.opec.org/opec_web/en/press_room/315.htm.

1.1 Related Literature

Previous studies on CPRs primarily focus on contexts where the natural resource is located within a country or a community and its extraction does not entail environmental externalities.[4] Our paper is motivated by the work of Markusen (1975) who analyzes the dependence and interaction between two countries in the presence of a bilateral externality. In particular, the paper develops a model that separately analyzes natural resource exploitation and international pollution problems, which in turn limits its application to cases where both types of market failures co-exist (as in the case of the Upper Paraná Atlantic Forest and the Aral Sea, for instance). Our paper fills this gap in the literature by examining the consumption and management of shared CPR, where environmental externalities arise from resource extraction.

Lambertini and Leitmann (2013) develop a single country model of an industry that appropriates a natural resource and generates negative environmental externalities. The authors demonstrate that profit motives can facilitate investments in green technologies, and competition may ultimately yield positive long-run welfare effects. When multiple firms in a single country exploit the CPR, the social planner considers the tradeoff between the opposite effects of output expansion on market price on one side, and the intensity of resource exploitation and environmental externality on the other. In contrast, when two or more countries share the same CPR, the planner in each country has to consider not only the tradeoff between the benefits and costs of domestic firms' production, but also the negative externalities imposed by foreign firms' production (i.e., transboundary pollution) and the competition for the use of the CPR.

The present paper also relates to the literature analyzing the effect of regulation on profits and firm preferences towards regulation. Farzin (2003) shows that stricter environmental

[4] See, for example, Ostrom (1992), Ostrom et al. (1994), Bromley (1992), Baland and Platteau (1996) and Berkes and Folke (1998). In particular, this line of literature contends that the lack of cooperation between agents is often associated with over-exploitation of natural resources, whereas cooperative management would lead to an efficient consumption of the resource.

standards can lead firms to improve product quality, which can ultimately increase firm profits. In particular, the author contends that if consumers are sufficiently sensitive to product quality, then higher quality products should in theory allow firms to attract higher demand, thereby increasing profits more than the reduction in them caused by the compliance costs. In line with this study, Porter (1991) and Porter and van der Linder (1995a,b) point out that environmental regulation can also stir R&D and innovation incentives, ultimately increasing firm profits.[5] Firm support for tighter regulation has also been viewed as a form of "market predation," whereby firms, despite being subject to costly regulation, may still lobby in favor of stringent regulation in order to increase their rivals' costs (Salop and Scheffman, 1983, 1987), alleviate their cost-disadvantage (Muñoz-García and Akhundjanov, 2016; Akhundjanov and Muñoz-García, 2016), drive competitors out of the industry (Ordover and Willig, 1981), and deter potential entry into the market (Maloney and McCormick, 1982). We demonstrate that, even if quality, innovation, and "market predation" incentives are absent, firms can still support the introduction of environmental regulation as such regulation can allow firms to mitigate industry overproduction thereby producing a substantial positive effect on their profits.

More recently, Muñoz-García and Akhundjanov (2016), studying optimal emission fees in a polluting duopoly industry, find that emission fees can ameliorate a firm's cost disadvantage relative to its rival, thus giving the former incentives to lobby for the introduction of environmental regulation. Such a regulation, however, happens in a single jurisdiction where both firms operate. In contrast, in the current paper firms operate in different countries thus giving rise to two separate policy settings: one in which every country independently chooses its emission fee to maximize its own social welfare, and another in which both countries coordinate their policies to maximize their joint social welfare. Furthermore, in the present study production generates environmental pollution, similar to Muñoz-García and Akhundjanov (2016); but since the production process in the present paper requires natural

[5]See Heyes (2009) for a review of this literature.

resource extraction, it also entails the tragedy of the commons. Lastly, the current paper considers that several firms operate in each country, thus allowing for a more general setting.

The paper is organized as follows. In the following section, we present the model, and in Sections 3-4 we describe equilibrium firm output levels, profits, and emission standards under different regulatory contexts. Section 5 provides the analysis of output and profit comparisons, while Section 6 presents comparative statics of our results. Section 7 concludes.

2 Model

Consider two neighboring countries, indexed as i for home country and l for foreign country, with n^i and n^l identical firms in each, respectively. Firms produce a homogeneous product within a country, but the type of products can vary across the two countries (e.g., agricultural product and hydroelectric power). We assume that the two products, whose production requires natural resource extraction, are not traded between the two countries and, hence, firms in each country compete only against their domestic rivals a la Cournot.[6] This assumption helps us focus on the effects of bilateral externalities on the interdependence of resource consumption decisions in two countries. For completeness, we discuss the implications of relaxing this assumption in Appendix A, and show that our results are qualitatively unaffected.

We consider inverse linear demand function $p^i = a^i - Q^i$, where $Q^i = \sum_{j=1}^{n_i} q_j^i$, and cost function $C(q_j^i) = c^i q_j^i$, where $c^i \geq 0$ (Lambertini and Leitmann, 2013; Lambertini, 2013).

[6] The two countries under consideration are, for instance, in political dispute or underdeveloped, and hence no significant amount of trade takes place between them. For example, in the context of the Aral Sea, products whose production requires river water (a tributary of the sea) are primarily for self-sufficiency or for trade with non-basin countries. For instance, Tajikistan, where the major part of Central Asia's water resources originates, produces hydroelectricity exclusively for domestic consumption, with hydropower contributing to about 98% of total electricity production in 2009 (Liu et al., 2013). Similarly, Uzbekistan obtained 12% of its total electricity generation from hydropower in 2010, which it consumed domestically (Kochnakyan et al., 2013). In addition, Uzbekistan produces cotton using the river water and exports it mainly to China, Bangladesh, Korea and Russia (International Cotton Advisory Committee, 2011) – countries that are not located in the Aral Sea drainage basin.

The initial stock of the CPR is $\bar{Y}$, while the residual amount is

$$Y = \bar{Y} - z^i Q^i - z^l Q^l, \tag{1}$$

where $z^i, z^l \geq 0$ are the appropriation rates of the CPR; and we allow for rates to be asymmetric, i.e., $z^i > z^l$ or $z^i < z^l$. Hence, firms' production entails a reduction in the CPR's initial stock $\bar{Y}$ by the amount $z^i Q^i + z^l Q^l$. This set-up captures the classical tragedy of the commons problem since firms compete over the natural resource, and their exploitation harms them in the sense that firms appropriate the CPR more intensively than if they were to coordinate their exploitation levels. As a consequence, the resource is depleted faster than if firms coordinated their appropriation levels.

The depletion of the CPR damages the surrounding environment and population health. Since the CPR is located between the two countries, both are affected by its depletion, regardless of each country's appropriation rate. For simplicity, we consider that each country's damage function is additively separable in the two countries' use of the commons. Following Sherstyuk et al. (2016), Duval and Hamilton (2002), Espínola-Arredondo and Zhao (2012), Espínola-Arredondo and Muñoz-García (2012), and Lambertini (2013), the total damage – that is, in addition to loss of a natural resource – borne to country i is captured by a linear function

$$E^i = d^i \left(z^i Q^i + z^l Q^l \right), \tag{2}$$

where $d^i \geq 0$ represents country i's marginal damage from the CPR exploitation. Since the appropriation of the natural resource affects both the stock of the CPR and ensuing environmental damage, the two effects can be written more compactly as $\bar{Y} - (d^i + 1) \left(z^i Q^i + z^l Q^l \right)$.

In our model, environmental damage results from the depletion of the natural resource (the reduction in $\bar{Y}$ in equation (1)), and not necessarily from aggregate production ($Q^i + Q^l$). In particular, if the appropriation rate is insignificant ($z^i, z^l \to 0$), then the pressure on the CPR will be negligible, and hence no environmental damage will ensue ($E^i, E^l \to 0$). Furthermore, our model embodies two standard settings as special cases: first, if the initial stock of the commons is sufficiently large $\bar{Y} \to \infty$, our model analyzes a standard international externality of production without CPR problems; second, if environmental damages are zero $d^i = 0$, the model instead examines a CPR in which firms' activities do not entail environmental pollution.

We analyze a static model of the commons with a two-stage complete information game (Sethi and Somanathan, 1996; McCarthy, 2001; Lambertini, 2013), where the time structure is as follows:[7]

1. The social planners in each country either cooperatively or non-cooperatively set the level of per-unit taxation or subsidy (τ^i) for the optimal appropriation of the CPR;

2. Given the policy set by the regulator, firms in each country simultaneously and independently choose their production levels to maximize profits.

Operating by backward induction, we first investigate firms' production decisions and profits in the second stage of the game.

3 Industry Equilibrium

In the second stage, firm j in country i takes the environmental policy (τ^i) as given and solves

$$\max_{q_j^i \geq 0} \quad \pi_j^i = \left(a^i - q_j^i - Q_{-j}^i\right) q_j^i - \left(c^i + \tau^i\right) q_j^i, \tag{3}$$

where $Q_{-j}^i = \sum_{k \neq j} q_k^i$. In Lemma 1, we present firm's best response function and the corresponding equilibrium output. All proofs are relegated to the appendix (see Appendix C).

[7] Players in the CPR game may collect precise information on payoff functions with repeated interaction, communication, signaling, or inspection. Therefore, the agents may know the mapping between decisions and payoffs. See, for example, Hackett et al. (1994), Ostrom et al. (1994), Gardner et al. (1997), Herr et al. (1997), Keser and Gardner (1999), Walker et al. (2000), and Casari and Plott (2003).

Lemma 1. *Firm j's best response function is* $q_j^i(Q_{-j}^i, \tau^i) = \frac{a^i-(c^i+\tau^i)}{2} - \frac{1}{2}Q_{-j}^i$, *with equilibrium output of* $q_j^i(\tau^i) = \frac{a^i-c^i-\tau^i}{n^i+1}$.

We can readily see that equilibrium output is decreasing in environmental policy τ^i and in the number of competing firms in the industry.

4 The Planning Problem

In what follows, we analyze the social planner's problem in the first stage of the game under three different regulatory settings.

4.1 No Regulation

In the absence of government intervention, $\tau^i = 0$, firms do not internalize the negative externalities of their production. Lemma 2 describes firms' production decisions in the unregulated market environment.

Lemma 2. *In the absence of environmental regulation, firm j in country i produces* $q_j^{i,U} = \frac{a^i-c^i}{n^i+1}$, *earning profits of* $\pi_j^{i,U} = \left(\frac{a^i-c^i}{n^i+1}\right)^2$, *which yields aggregate output of* $Q^{i,U} = \frac{n^i(a^i-c^i)}{n^i+1}$.

The equilibrium aggregate output $Q^{i,U}$, where U denotes "unregulated," increases in the number of firms n^i in the market, whilst the individual firm's equilibrium output $q^{i,U}$ decreases in n^i. We next discuss our results when the government designs an appropriate environmental policy (taxation or subsidy) to induce efficient production.

4.2 Non-Cooperative Regulation

In this section, we consider the case where the social planners in each country act non-cooperatively, and hence maximize domestic welfare while ignoring the externalities imposed by domestic firms on the neighboring country. Such a non-cooperative regulation, therefore, does not achieve a first-best outcome (which we explore in the next section), but a second-best.

Each country individually maximizes its social welfare function defined as

$$\max_{\{q_j^i\}_{j=1}^{n^i}} \quad SW^i = PS^i + CS^i + T^i + Y - E^i, \tag{4}$$

where $PS^i = n^i \pi_j^i$ is the producer surplus, $CS^i = \frac{1}{2}\left(q_j^i + Q_{-j}^i\right)^2$ is the consumer surplus, $T^i = Q^i \tau^i$ is the total tax revenue, $Y = \bar{Y} - z^i(q_j^i + Q_{-j}^i) - z^l Q^l$ is the residual amount of the CPR, and $E^i = d^i\left(z^i(q_j^i + Q_{-j}^i) + z^l Q^l\right)$ is the aggregate environmental damage ensuing the exploitation of the CPR. Notice that the appropriation rate z^i of the commons affects the social welfare through two connected channels: (i) z^i determines how fast the natural resource is exhausted, thus affecting the residual stock of the CPR, $Y = \bar{Y} - z^i Q^i - z^l Q^l$; and (ii) z^i determines the extent of environmental damage resulting from the exploitation of the CPR, $E^i = d^i(z^i Q^i + z^l Q^l)$.

In the following proposition, we specify the regulator's choice of environmental policy, and the individual firm's equilibrium production.

Proposition 1. *Under non-cooperative (NC) regulation, every country i sets*

$$\tau^{i,NC} = \frac{z^i(n^i+1)(1+d^i) - n^i(a^i - c^i)}{(n^i)^2}, \tag{5}$$

which yields an equilibrium output of $q_j^{i,NC} = \frac{n^i(a^i-c^i)-z^i(1+d^i)}{(n^i)^2}$ for every firm j.

As with Pigovian taxes, the non-cooperative policy ensures that the marginal benefit of domestic firms' production is equal to the marginal social cost borne domestically. In addition, $\tau^{i,NC}$ increases in both the appropriation rate z^i and damage parameter d^i. Intuitively, when firms' production becomes more intensive in the use of the natural resource or inflicts larger social costs (resulting from the associated environmental damage), the social planner imposes a more stringent environmental policy so firms reduce their production to a sustainable level. As a consequence, the individual firm's equilibrium output $q_j^{i,NC}$ decreases in z^i and d^i. Let us next analyze under which conditions the social planner sets a tax or a subsidy policy.

Corollary 1. *The non-cooperative policy is a tax,* $\tau^{i,NC} > 0$*, if and only if the appropriation rate satisfies* $z^i > \frac{n^i(a^i - c^i)}{(n^i+1)(1+d^i)} \equiv \bar{z}_1$*. Furthermore,* $\frac{\partial \bar{z}_1}{\partial d^i} < 0$*.*

Figure 1 depicts cutoff $\bar{z}_1$ as a function of d^i. When the appropriation rate z^i is relatively small, $z^i < \bar{z}_1$, firms' production imposes an insignificant pressure on the CPR, leading the planner to provide subsidies to domestic firms to bring up their production to an efficient level. In contrast, when the appropriation rate is relatively high, $z^i > \bar{z}_1$, firms' production exerts a significant effect on the residual amount of the CPR, leading the planner to choose a tax policy to curb a socially excessive production. Moreover, cutoff $\bar{z}_1$ decreases in d^i, implying that for a given appropriation rate z^i firms are subject to a more stringent environmental policy as the environmental damage parameter d^i rises.

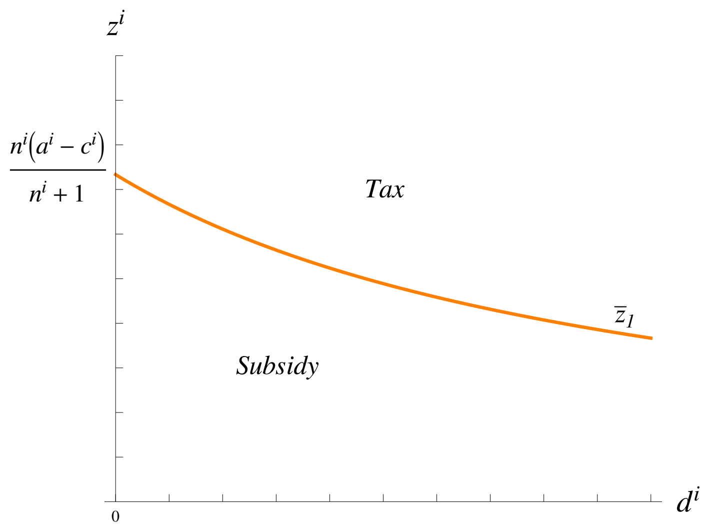

Figure 1: The optimal environmental policy

4.3 Cooperative Regulation

In this section, we investigate the case where countries coordinate their policy design, e.g., by participating in international agreements. In the design of an environmental policy, countries now fully internalize not only the internal effects of their home firms' production, but also their external (transboundary) effects. As a consequence, environmental regulation achieves a first-best outcome.

In this context, countries maximize their joint social welfare by solving

$$\max_{\{q_j^i\}_{j=1}^{n^i}, \{q_j^l\}_{j=1}^{n^l}} \quad SW = SW^i + SW^l, \tag{6}$$

where SW^i and SW^l are defined as in equation (4).[8] The following proposition identifies the environmental policy that solves the above joint welfare maximization problem, and the output level that such policy induces each firm to produce.

Proposition 2. *Under cooperative (C) regulation, every country i sets*

$$\tau^{i,C} = \frac{z^i(n^i+1)(2+d^i+d^l) - n^i(a^i-c^i)}{(n^i)^2}, \tag{7}$$

which yields an equilibrium output of $q_j^{i,C} = \frac{n^i(a^i-c^i)-z^i(2+d^i+d^l)}{(n^i)^2}$ *for every firm j.*

Similar to the non-cooperative setting, the optimal environmental policy $\tau^{i,C}$ increases in d^i, that is $\frac{\partial \tau^{i,C}}{\partial d^i} = \frac{\partial \tau^{i,NC}}{\partial d^i} = \frac{z^i(n^i+1)}{(n^i)^2}$, whilst the optimal cooperative output $q_j^{i,C}$ decreases in d^i, that is $\frac{\partial q_j^{i,C}}{\partial d^i} = \frac{\partial q_j^{i,NC}}{\partial d^i} = -\frac{z^i}{(n^i)^2}$. However, unlike in the non-cooperative setting, cooperative environmental policy (equilibrium output) is also increasing (decreasing, respectively) in the foreign damage parameter d^l, which reflects country i's accountability for the transboundary effects of its domestic production. Intuitively, if the depletion of the CPR entails severe environmental damage in country l, then, under cooperative social planning, country i implements a tighter policy in order to disincentivize its domestic firms from producing large aggregate output, thereby mitigating the transboundary effects of their production. Moreover, notice that both environmental policy and optimal output are more sensitive to domestic appropriation rate under cooperative than non-cooperative planning, i.e., $\frac{\partial \tau^{i,C}}{\partial z^i} = \frac{(n^i+1)(2+d^i+d^l)}{(n^i)^2} > \frac{(n^i+1)(1+d^i)}{(n^i)^2} = \frac{\partial \tau^{i,NC}}{\partial z^i}$ and $\frac{\partial q_j^{i,C}}{\partial z^i} = -\frac{(2+d^i+d^l)}{(n^i)^2} < -\frac{(1+d^i)}{(n^i)^2} = \frac{\partial q_j^{i,NC}}{\partial z^i}$.

[8]Note that when countries coordinate their policies in expression (6), each enjoys the residual stock of the CPR, i.e., Y can be enjoyed by both countries, since it is non-rival in consumption.

The reason for this is because the commons is shared between the two countries, and hence the appropriation of the commons by domestic country reduces the resource availability not only for domestic, but also for foreign country. And vice versa. Consequently, cooperative policy accounts for the disutility caused to the foreign country from reduction in the quantity of the resource owing to the domestic country's consumption.

While each country obtains a larger social welfare when both countries coordinate their policies (as analyzed in this section) than when none of them do (studied in the previous section), every country can have incentives to unilaterally deviate to an independent policy while its neighbor cooperates selecting the coordinated policy. Appendix B evaluates the social welfare from this unilateral deviation, and compares it against that from maintaining cooperation.

Similarly as in Corollary 1, we next identify conditions under which the environmental policy in Proposition 2 is a tax or a subsidy.

Corollary 2. *The optimal policy is a tax, i.e.,* $\tau^{i,C} > 0$*, if and only if the appropriation rate satisfies* $z^i > \frac{n^i(a^i - c^i)}{(n^i+1)(2+d^i+d^l)} \equiv \bar{z}_2$*, where* $\bar{z}_2 < \bar{z}_1$ *for all parameter values. Furthermore,* $\frac{\partial \bar{z}_2}{\partial d^i} = \frac{\partial \bar{z}_2}{\partial d^l} < 0$.

Similar to the non-cooperative scenario, when the appropriation rate of the commons is relatively low, $z^i < \bar{z}_2$, the social planner offers a subsidy to stimulate larger production from his domestic industry. In contrast, if domestic production is relatively intensive in the use of the CPR, $z^i > \bar{z}_2$, the planner introduces a tax policy in order to internalize the costs of firms' negative externalities. As depicted in Figure 2, cutoff $\bar{z}_2$ lies strictly below cutoff $\bar{z}_1$ for all $d^l > 0$, implying that the cooperative regulator chooses a tax policy under larger parameter conditions than the non-cooperative regulator. This is because the first-best policy $\tau^{i,C}$ internalizes the transboundary effects of resource extraction which are ignored by the second-best policy $\tau^{i,NC}$.

Both cutoffs are decreasing in d^i, reflecting that the set of appropriation rates for which firms receive subsidy (taxation) shrinks (expands, respectively) as the magnitude of the ensuing environmental damage increases. In addition, since only cutoff $\bar{z}_2$ is responsive to transboundary externalities, it shifts downwards (upwards) when the foreign damage parameter d^l increases (decreases, respectively). In the extreme case when $d^l \to 0$, the vertical intercept of cutoff $\bar{z}_2$ does not converge to that of cutoff $\bar{z}_1$. The reason for the persistence of the distinction between the two regulatory regimes even with $d^l \to 0$ is because cooperative policy accounts for not only transboundary environmental damage but also the disutility caused to the neighboring country from a reduction in the size of the shared CPR. Hence, so long as the countries appropriate the commons, $z^i > 0$, there will be at least one form of transboundary externality that the cooperative policy addresses (namely, the CPR exploitation).

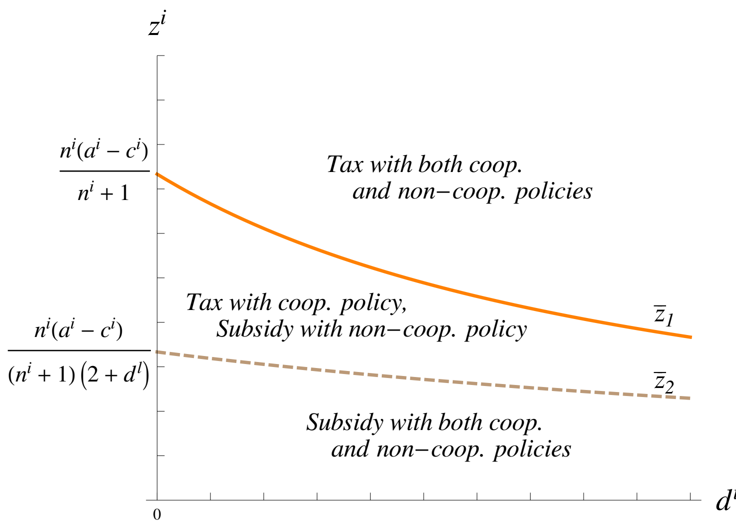

Figure 2: Cutoffs $\bar{z}_1$ and $\bar{z}_2$

When countries cooperate they maximize their joint welfare. In the absence of CPR externalities, cooperative and non-cooperative regulation coincide (as shown in Section 6), thus yielding the same welfare levels. In this context, country i obtains the same welfare when cooperating and not cooperating with its neighboring country l. In the presence of CPR externalities, however, cooperative and non-cooperative regulation do not coincide. Every country tends to impose a laxer emission fee on the firms located in its jurisdiction when it independently sets its own emission fees than when it cooperates with its neighboring country.[9]

5 Analysis

Let us next compare our results from unregulated and regulated (cooperative and non-cooperative) market environments. We first contrast environmental policies arising under cooperative and non-cooperative regulations.

Lemma 3. *Cooperative regulation is more stringent than non-cooperative regulation,* $\tau^{i,C} > \tau^{i,NC}$*. Furthermore, the stringency premium* $\tau^{i,C} - \tau^{i,NC}$ *is increasing in both the appropriation rate* z^i *and the damage in country* l*,* d^l*, but unaffected by the damage in country* i*,* d^i*.*

The cooperative social planner choosing a stricter policy than the non-cooperative planner reflects the fact that the former curbs over-exploitation of the commons by inducing the output level that is jointly socially preferable. When z^i or d^i increases, *ceteris paribus*, there will be a proportionate increase in both of these policy instruments. However, the wedge between non-cooperative and cooperative policy instruments increases in the domestic appropriation rate z^i and foreign damage parameter d^l as the values of these parameters determine the extent of transboundary externalities (i.e., depletion of the commons and the resulting environmental damage in a foreign country), which are only considered in the design of a cooperative policy but ignored in the non-cooperative case.

We next compare equilibrium output across different regulatory contexts.

Lemma 4. *Equilibrium output levels satisfy:*

- $q_j^{i,U} > q_j^{i,NC} > q_j^{i,C}$ *if and only if* $z^i > \bar{z}_1$*, i.e.,* $\tau^{i,NC}, \tau^{i,C} > 0$*;*

[9] As a consequence, pollution is above the optimum (as well as the exploitation of the resource) ultimately yielding a lower welfare level when countries do not coordinate their policies than when they do. This result is relatively standard, and analogous to that in oligopoly games, where firms are better off coordinating their output choices than independently choosing their individual output.

- $q_j^{i,NC} > q_j^{i,U} > q_j^{i,C}$ *if and only if* $\bar{z}_2 < z^i < \bar{z}_1$*, i.e.,* $\tau^{i,NC} < 0$ *and* $\tau^{i,C} > 0$*;*
- $q_j^{i,NC} > q_j^{i,C} > q_j^{i,U}$ *if and only if* $z^i < \bar{z}_2$*, i.e.,* $\tau^{i,NC}, \tau^{i,C} < 0$.

When the appropriation rate is high, $z^i > \bar{z}_1$, the regulator imposes a tax policy under both cooperative and non-cooperative regulation, with the former being stricter than the latter as illustrated in Lemma 3. In this context, firms produce the highest amount of output when regulation is absent, followed by non-cooperative regulation, and finally cooperative regulation. When the appropriation rate is moderate, $\bar{z}_2 < z^i < \bar{z}_1$, non-cooperative regulation now opts for a subsidy policy, while cooperative regulation still chooses a tax. As a result, firms are able to produce the highest amount of output under non-cooperative setting (due to the incentives created by a subsidy), followed by unregulated setting, and finally the cooperative setting, where firms are still subject to a tax. Lastly, when the appropriation rate is relatively low, $z^i < \bar{z}_2$, the regulator provides a subsidy under both cooperative and non-cooperative settings. In this case, firms still produce the highest amount of output with non-cooperative regulation, as such regulation entails a more generous subsidy than under cooperative regulation, followed by cooperative regulation, and finally no regulation.

5.1 Profit Comparison

The introduction of regulation imposes two distinct effects on firms' profits: first, a *negative effect*, since a tax increases firms' marginal production costs $(c^i + \tau^i)$; and second, a *positive effect*, since a tax leads firms to decrease their aggregate output (see Lemma 1), thus increasing prices and profits. Depending on the type of policy instrument (cooperative or non-cooperative), the magnitude of the two effects varies. In particular, the two effects are the most pronounced with cooperative policy as it entails more stringent regulation. In addition, we next show that the relative size of these effects, and thus firm preferences towards the regulatory setting, ultimately depends on the appropriation rate and the damage parameter. We compare firms' profits under each regulatory regime, and identify conditions under which the equilibrium profits can actually increase as a result of regulation.

5.1.1 No Regulation vs. Non-Cooperative Regulation

Proposition 3. *Firm's equilibrium profits under non-cooperative regulation are larger than under no regulation,* $\pi_j^{i,NC} > \pi_j^{i,U}$*, if and only if* $z^i < \bar{z}_1$ *or* $z^i > \bar{z}_3$*, where*

$$\bar{z}_3 \equiv \frac{n^i(a^i - c^i)(1 + 2n^i)}{(n^i + 1)(1 + d^i)}. \tag{8}$$

Furthermore, $\bar{z}_3 > \bar{z}_1$ *for all parameter values.*

As illustrated in Figure 3, when the appropriation rate of the CPR is relatively low, $z^i < \bar{z}_1$, the pressure firms exert on the stock of natural resource and the environment is minimal, which results in the social planner providing subsidies to stimulate a larger production (see Corollary 1). Since the regulation in this context ameliorates firms' marginal production costs, firms, unsurprisingly, generate larger profits in the presence of regulation than in its absence, $\pi_j^{i,NC} > \pi_j^{i,U}$.

On the other hand, when the appropriation rate of the commons is moderate, $\bar{z}_1 < z^i < \bar{z}_3$, the industry production starts to inflict a considerable pressure on the CPR and the environment, which in turn necessitates the imposition of a tax policy. Such policy, however, produces a negative effect on firm profits that outweighs its positive effect (i.e., mitigation of

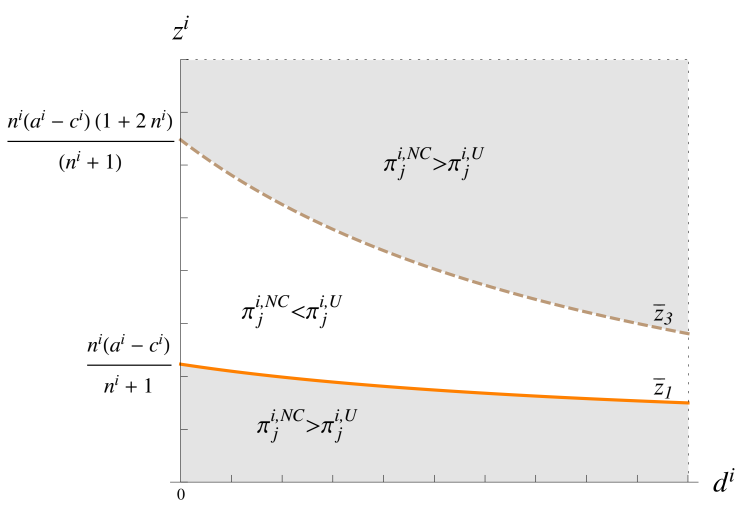

Figure 3: No regulation (U) vs. non-cooperative (NC) regulation

Cournot overproduction), ultimately decreasing firm profits, $\pi_j^{i,NC} < \pi_j^{i,U}$. In other words, the loss firms incur due to compliance costs is greater than the gain firms reap due to a decrease in aggregate production. As a consequence, the regulator faces the opposition of the resource-consuming industries when (z^i, d^i) pairs occur in this region.

Finally, when the appropriation rate of the CPR is relatively high, $z^i > \bar{z}_3$, firms earn larger profits when the regulation is present than when it is absent, $\pi_j^{i,NC} > \pi_j^{i,U}$. Intuitively, the social planner penalizes the resource-intensive industries with a more stringent taxation, which yields a large negative effect on firms' profits. However, such a strict policy substantially lowers aggregate output, which drives prices up, ultimately producing a large positive effect on profits that counterbalances the negative effect of the policy.

5.1.2 No Regulation vs. Cooperative Regulation

Proposition 4. *Firm's equilibrium profits under cooperative regulation are larger than under no regulation, $\pi_j^{i,C} > \pi_j^{i,U}$, if and only if $z^i < \bar{z}_2$ or $z^i > \bar{z}_4$, where*

$$\bar{z}_4 \equiv \frac{n^i(a^i - c^i)(1 + 2n^i)}{(n^i + 1)(2 + d^i + d^l)}. \tag{9}$$

Furthermore, $\bar{z}_2 < \bar{z}_4 < \bar{z}_3$ for all parameter values, and $\bar{z}_4 > \bar{z}_1$ ($\bar{z}_4 < \bar{z}_1$) for all $d^i > \frac{1+d^l}{2n^i} - 1 \equiv \bar{d}$ ($d^i < \bar{d}$, respectively).

Firm preferences towards cooperative regulation thus exhibit a similar pattern as those towards non-cooperative policy (see Figure 4), except for the relative position of cutoffs that determine the set of (d^i, z^i) pairs for which firms either support or oppose regulation.

In particular, firms lobby in favor of the introduction of cooperative regulation when the appropriation rate is low, $z^i < \bar{z}_2$, where firms' enjoy a large positive effect of the subsidy; and when it is relatively high, $z^i > \bar{z}_4$, where the gains from the alleviation of industry overproduction offset the compliance costs of regulation. In contrast, firms oppose regulation when the appropriation rate is relatively moderate, $\bar{z}_2 < z^i < \bar{z}_4$, where now the

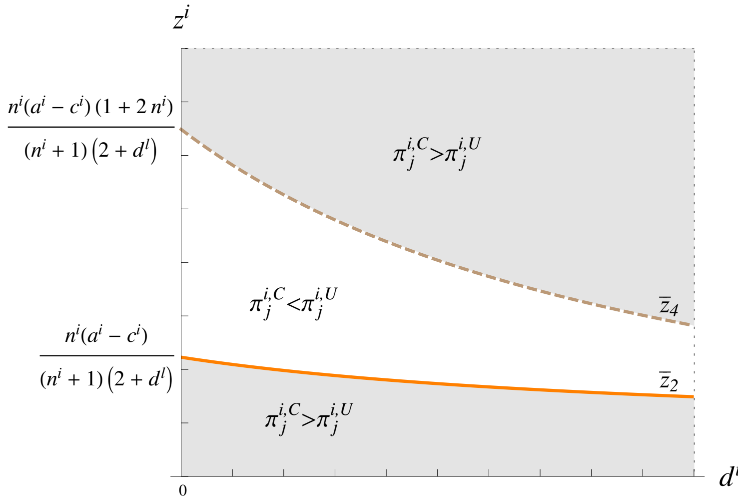

Figure 4: No regulation (U) vs. cooperative (C) regulation

compliance costs outweigh the profit gain.

In the next subsection, we compare equilibrium profits under cooperative and non-cooperative policy. Since regulation is more stringent in the former than the latter, the magnitude of the negative effect of regulation is stronger under cooperative than non-cooperative policy as we show next.

5.1.3 Cooperative vs. Non-Cooperative Regulation

Proposition 5. *Firm's equilibrium profits under cooperative regulation are larger than under non-cooperative regulation, $\pi_j^{i,C} > \pi_j^{i,NC}$, if and only if $z^i > \bar{z}_5$, where*

$$\bar{z}_5 \equiv \frac{2n^i(a^i - c^i)}{3 + 2d^i + d^l}. \tag{10}$$

Furthermore, $\bar{z}_1 < \bar{z}_5 < \bar{z}_4$ ($\bar{z}_4 < \bar{z}_5 < \bar{z}_1$) for all $d^i > \bar{d}$ ($d^i < \bar{d}$, respectively).

Figure 5 depicts cutoff $\bar{z}_5$ along with $\bar{z}_1$ and $\bar{z}_2$, cutoffs for environmental subsidy/taxation under non-cooperative and cooperative regulation, respectively. The introduction of non-cooperative regulation is beneficial for firm profits relative to cooperative regulation if the appropriation rate is relatively low, $z^i < \bar{z}_5$. In particular, in region I, where $z^i < \bar{z}_2$, both forms of regulation entail a subsidy. Since non-cooperative policy entails a more generous subsidy than cooperative policy (see Lemma 3), the industry unambiguously favors the former policy in this region.

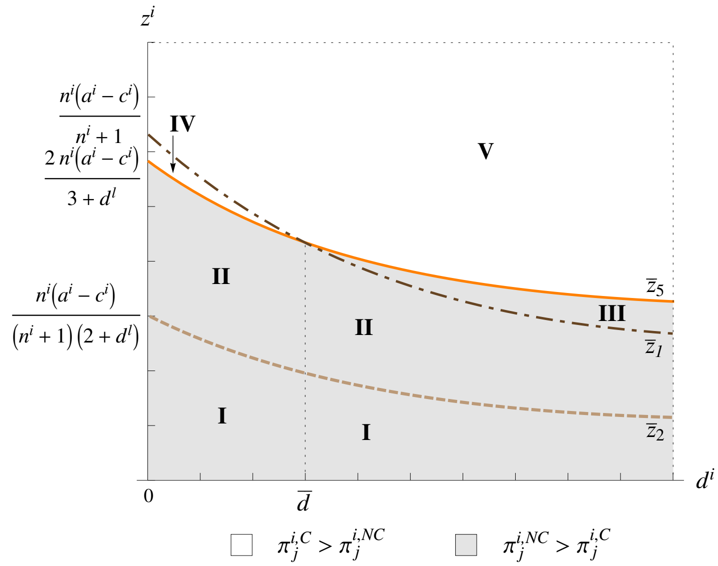

Figure 5: Cooperative (C) vs. non-cooperative (NC) regulation

In region II, where $\bar{z}_2 < z^i < \min\{\bar{z}_1, \bar{z}_5\}$, firms receive a subsidy with non-cooperative regulation, whilst they face taxation under cooperative regulation. Since the appropriation rate in this context is relatively moderate, the cooperative regulation does not yield large enough positive effect (i.e., reduction in aggregate output), so as to outweigh the net effect that non-cooperative subsidy imposes on firm profits. Consequently, firms prefer non-cooperation regulation in this region. Finally, in region III, where $\bar{z}_1 < z^i < \bar{z}_5$, both cooperative and non-cooperative regulation entail taxation. Although the magnitude of positive effect is low under both regulatory settings (due to moderate appropriation rate which results in a laxer taxation), the magnitude of negative effect is nonetheless larger under cooperative than non-cooperative policy. Hence, firms prefer to lobby in favor of the non-cooperative regulation in this region.

In contrast, when $z^i > \bar{z}_5$, cooperative regulation becomes beneficial for firm profits relative to non-cooperative regulation. In region IV, where $\bar{z}_5 < z^i < \bar{z}_1$, even though non-cooperative policy entails a subsidy and cooperative policy assigns a tax, firms prefer the latter form of regulation. Such behavior can be rationalized as follows. Since the appropriation rate is relatively high in this context, the non-cooperative policy does not entail large subsidy (recall that $\tau^{i,NC}$ is decreasing in z^i). Hence, the positive effect of non-cooperative policy on firm profits will be relatively small. On the other hand, a high appropriation rate translates into stricter taxation under cooperative policy. Such policy imposes a large negative effect on firm profits, which forces the industry to significantly lower aggregate production, thus yielding a large positive effect on profits. As a consequence, the net effect of cooperative policy on profits is larger than that of non-cooperative policy.

In region V, where $z^i > \max\{\bar{z}_1, \bar{z}_5\}$, firms are subject to taxation under both regulatory settings. The high extraction rate in this context forces the regulator to impose a stringent environmental policy which substantially depresses the output. As a result, the introduction of an environmental policy helps firms alleviate industry overproduction, and hence produce an upward effect on the price. Such effect will be more pronounced with cooperative than non-cooperative policy as the former entails tighter regulation than the latter. Hence, in this region, firms benefit more from cooperative than non-cooperative regulation.

We summarize firms' preferences towards different regulatory settings in Figure 6, which superimposes cutoffs identified in the paper on the (d^i, z^i)-axis.[10] It is clear that firms are better off with at least one form of regulation (cooperative or non-cooperative) relative to no regulation under a large set of parameter values. The regulation harms firms' profits only when the extraction rate is moderate, $\bar{z}_1 < z^i < \bar{z}_4$, and the environmental damage is sufficiently large, $d^i > \bar{d}$ (i.e., the shaded region). Intuitively, when the rate of the resource consumption is moderate, the social planner imposes a relatively lax tax on the industry. Such a policy, however, does not yield a sizable reduction in aggregate production (a positive

[10] The relative position of the cutoffs and their intersection points are discussed in the proofs of Corollary 2 and Propositions 3, 4 and 5. For profit ranking and firm preferences towards regulation in different regions of the (d^i, z^i) quadrant, see the discussions following the aforementioned propositions.

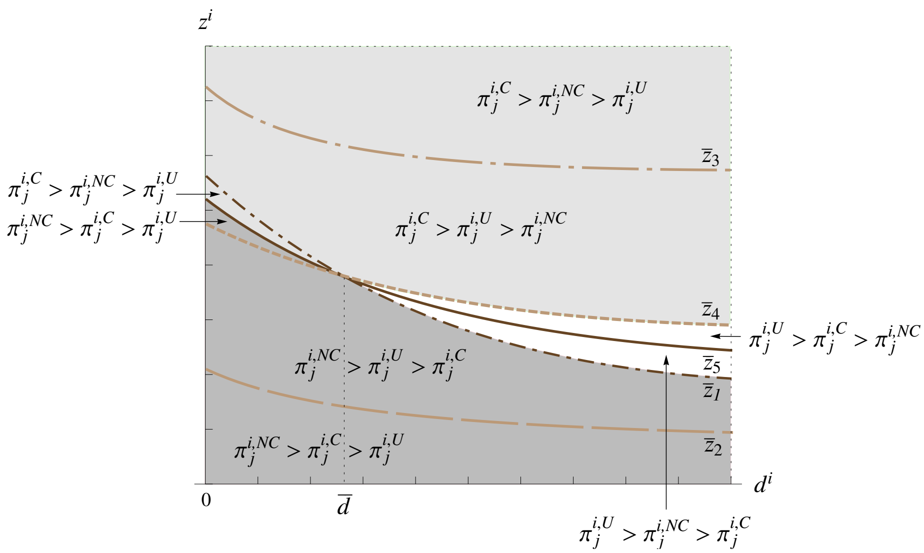

Figure 6: Firm preferences for different regulatory settings

effect), ultimately hurting firms' profits.

Furthermore, firms are better off with cooperative (non-cooperative) regulation when the appropriation rate of the CPR is relatively high (low, respectively). This result has important policy implications. In particular, it shows that when firms exhaust the shared natural resources at a higher rate, and create environmental damages that affect both domestic and foreign countries, then they are actually willing to support their countries' participation in international environmental agreements. In contrast, when firms exhaust the CPR at a relatively lower rate, they are in favor of non-cooperative policy. In other words, firms choose to support cooperative regulation when social costs of resource extraction are high (i.e., fast resource exhaustion and large-scale environmental damage), but go with domestic policies when these costs are relatively low.

6 Comparative Statistics

In this section, we examine the comparative statistics of our above profit comparisons. Specifically, we focus on how firm preferences for regulation are influenced by variations in appropriation rates, environmental damages, and market structure. We first analyze our model in two special cases described in the introduction. First, a setting in which the appropriation rate is zero and thus regulators only face environmental damage. Second, a context in which the appropriation rate is positive but the environmental damage is zero, and thus the regulation only seeks to address the overexploitation of the CPR.

Corollary 3 (No CPR externality). *When the domestic appropriation rate is zero, $z^i = 0$, domestic firms generate zero environmental externalities, and the optimal cooperative and non-cooperative domestic policies set the same subsidy $\tau^{i,NC} = \tau^{i,C} = -\frac{a^i - c^i}{n^i} < 0$.*

Since environmental externalities emerge as a by-product of the appropriation of the commons, and not necessarily from firms' production activities, then when the extraction rate approaches zero, $z^i = 0$, so do the ensuing negative externalities of firm's production activities. As a result, both cooperative and non-cooperative policies entail the same (subsidy) policy for the country that does *not* exploit the CPR. In particular, the optimal policy entails a subsidy so as to raise the underproduction in Cournot competition to a socially efficient level. Notice that the domestic country can still suffer from the transboundary externality, with a total disutility of $(\bar{Y} - z^l Q^l) - d^i(z^l Q^l)$, if firms located in a neighboring country continue to use the CPR in their production process, i.e., $z^l > 0$.[11]

Let us now examine the second extreme case in which appropriation rates are positive but environmental damages are zero.

Corollary 4 (No environmental damage). *When the appropriation of the commons entails no domestic environmental damage, $d^i = 0$, domestic firms face less stringent cooperative and non-cooperative regulation, and earn larger profits than when $d^i > 0$. Furthermore, profits satisfy*

- $\pi_j^{i,NC} > \pi_j^{i,U}$ *if and only if* $z^i < \bar{z}_1(d^i = 0)$ *or* $z^i > \bar{z}_3(d^i = 0)$*;*
- $\pi_j^{i,C} > \pi_j^{i,U}$ *if and only if* $z^i < \bar{z}_2(d^i = 0)$ *or* $z^i > \bar{z}_4(d^i = 0)$*;*

[11] In a special case, when $z^i = z^l = 0$, no environmental externalities (i.e., neither tragedy of the commons nor environmental damage) will be generated.

- $\pi_j^{i,C} > \pi_j^{i,NC}$ *if and only if* $z^i > \bar{z}_5(d^i = 0)$.

In this case, the natural resource is exhausted without creating environmental pollution in the domestic country but it can still cause a transboundary externality if $d^l > 0$.[12] Because domestic firms' production creates fewer market failures in this context (i.e., no domestic environmental damages), the social planner imposes less stringent cooperative and non-cooperative regulation than when $d^i > 0$. Consequently, firms are able to earn larger profits with regulation compared to what they received when domestic damages were present.

The profit ranking of different regulatory settings remains the same as in Figure 6, with all cutoffs evaluated at $d^i = 0$, i.e., the vertical axis of Figure 6. In this context, firms' profits are unambiguously larger with some form of regulation (cooperative or non-cooperative) relative to no regulation at all. Indeed, as illustrated in the vertical axis of Figure 6, firms prefer cooperative regulation for all $z^i > \bar{z}_5$, but non-cooperative policy otherwise.

Let us next evaluate firm preferences for regulation when exploitation of the commons entails a domestic, but not a transboundary externality.

Corollary 5 (No transboundary damage). *When the appropriation of the commons entails no transboundary damage, $d^l = 0$, domestic firms face less stringent cooperative regulation and generate larger profits than when $d^l > 0$. Furthermore, profits satisfy*

- $\pi_j^{i,C} > \pi_j^{i,U}$ *if and only if* $z^i < \bar{z}_2(d^l = 0)$ *or* $z^i > \bar{z}_4(d^l = 0)$*;*
- $\pi_j^{i,C} > \pi_j^{i,NC}$ *if and only if* $z^i > \bar{z}_5(d^l = 0)$*,*

where the regions for which $\pi_j^{i,C} > \pi_j^{i,U}$ ($\pi_j^{i,C} < \pi_j^{i,U}$) and $\pi_j^{i,C} > \pi_j^{i,NC}$ ($\pi_j^{i,C} < \pi_j^{i,NC}$) shrinks (expands, respectively).

In this context, domestic extraction affects the neighboring country only through the disutility arising from the depletion of the shared CPR. As a result, the cooperative policy entails less stringent regulation, thus allowing firms to earn larger profits compared to that

[12] In a special case, when $d^i = d^l = 0$, the consumption of the CPR generates neither internal nor transboundary pollution in two countries, but can still lead to the tragedy of the commons.

when $d^l > 0$. Since non-cooperative policy does not internalize the transboundary externalities, then changes in the foreign damage parameter does not affect domestic non-cooperative policy.

Corollary 6 (Market structure). *When the product market is monopolistic, $n_i = 1$, the area in which firms prefer cooperative (non-cooperative) regulation expands (shrinks, respectively); whereas when the market is perfectly competitive, $n_i \to \infty$, this region shrinks (expands, respectively).*

Intuitively, when the industry consists of a few large firms, the positive effect of environmental regulation (i.e., mitigation of aggregate production) offsets its negative effect (i.e., compliance costs). This is especially true for cooperative policy which induces a larger aggregate output reduction relative to non-cooperative policy. However, as more firms compete in the industry, the positive effect of regulation on each firm shrinks relative to its negative effect (more so with cooperative than non-cooperative policy). As a result, individual firms become less inclined to lobby for cooperative policy in this setting.

7 Conclusion

In the present study, we analyze the cooperative and non-cooperative management of a common property resource shared between two countries in the presence of two forms of bilateral externalities: the depletion of the commons and the environmental damage resulting from the consumption of the resource. We show that regulation can benefit not only the stock of the commons and environmental quality, but also firms' profits, thus inducing them to actually support the introduction of regulation, either cooperative, through bilateral environmental agreements, or non-cooperative, via independent national policies.

The paper demonstrates that the introduction of regulation imposes two opposing effects on profits: a negative effect, due to an increase in marginal production costs, and a positive effect, owing to the mitigation in Cournot overproduction. The magnitude of the two effects depends on the extraction rate and the environmental damage parameter, and are more pronounced with cooperative policy as it entails more stringent regulation relative to non-cooperative policy. Comparing the positive and negative effects of regulation, we show that firms are better off with at least one form of regulation under a large set of appropriation rates. In particular, firms reap the highest profits under cooperative regulation when the appropriation rate is relatively high (meaning high bilateral externalities), thus supporting their countries' participation in bilateral environmental agreements. As the extraction rate decreases, regulation starts to impose smaller positive effect on profits (i.e., mitigation of aggregate production), thus incentivizing firms to oppose all forms of regulation. When the appropriation rate is sufficiently low, firms are better off with non-cooperative regulation as such regulation entails larger positive effect on profits (due to subsidies).

When more countries interact, every country's free-riding incentives to set lax emission fees would increase, ultimately inducing domestic firms to exploit the CPR more intensively. In this setting, coordinated policies would require setting relatively stringent fees, thus providing every country with incentives to unilaterally defect from cooperative policies, i.e., setting a lax fee now yields a large welfare gain. As a consequence, the introduction of more countries could make cooperative policies unstable (i.e., unprofitable for individual countries), limiting our profit comparison to only the unregulated regime and the uncoordinated policy regime. In alternative setting (not analyzed in this paper), a subset of countries can form a coalition (e.g., m countries out of n, $m < n$), and implement a cooperative policy which is more profitable for countries in the coalition than when these countries individually set their regulations.

A number of research questions remain open. Our model considers a complete information setting, whereby information about each country's extraction rate and environmental damages is common knowledge. A natural extension is to consider a setting where each country is privately informed about its appropriation and damages, but not those of foreign countries. Although governments might gather information about their neighbors' appropriation patterns, such information is not necessarily accurate. Furthermore, we use per unit fee/subsidy to regulate industry production. It would be interesting to examine firm preferences towards regulation under other types of policy instruments, such as tradable quotas and nonlinear taxes. Future studies can also extend our analysis by allowing for endogenous firm entry in both or one of the countries. In this context, apart from studying the effect of regulation on profits, it is of interest to examine whether regulation facilitates or hinders potential entry into the industry. Finally, future studies can empirically estimate the parameters in our model to identify industries for which our equilibrium results hold.

References

1. Akhundjanov, S.B. and F. Muñoz-García (2016) "Firm Preferences for Environmental Policy: Industry Uniform or Firm Specific?" *Strategic Behavior and the Environment*, 6(1-2): 135–180.

2. Baland, J.M. and J.P. Platteau (1996) *Halting Degradation of Natural Resources: Is There a Role for Rural Communities?* Cambridge, Cambridge University Press.

3. Berkes, F. and C. Folke (1998) *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience.* Cambridge, Cambridge University Press.

4. Bromley, D. (1992) *Making the Commons Work: Theory, Practice, and Policy.* San Francisco, Institute for Contemporary Studies Press.

5. Casari, M. and C.H. Plott (2003) "Decentralized management of common property resources: experiments with a centuries-old institution." *Journal of Economic Behavior and Organization*, 51: 217–247.

6. Di Bitetti, M.S., G. Placci, and L.A. Dietz (2003) *A biodiversity vision for the Upper Paraná Atlantic Forest ecoregion: Designing a biodiversity conservation landscape and setting priorities for conservation action.* World Wildlife Fund, Washington DC.

7. Duval, Y. and S.F. Hamilton (2002) "Strategic environmental policy and international trade in asymmetric oligopoly markets." *International Tax and Public Finance*, 9(3): 259–271.

8. Espínola-Arredondo, A. and F. Muñoz-García (2012) "When do firms support environmental agreements?" *Journal of Regulatory Economics*, 41: 380–401.

9. Espínola-Arredondo, A. and H. Zhao (2012) "Environmental policy in a linear city model of product differentiation." *Environment and Development Economics*, 17(4): 461–477.

10. Farzin, Y.H. (2003) "The effects of emission standards on industry." *Journal of Regulatory Economics*, 24: 315–327.

11. Gardner, R., M.R. Moore, and J.M. Walker (1997) "Governing a groundwater commons: a strategic and laboratory analysis of western water law." *Economic Inquiry*, 2: 218–234.

12. Glantz, M.H. (1999) *Creeping Environmental Problems and Sustainable Development in the Aral Sea Basin.* Cambridge, Cambridge University Press.

13. Gordon, H.S. (1954) "The economic theory of a common-property resource: The fishery." *Journal of Political Economy*, 62(2): 124–42.

14. Hackett, S., E. Schlager, and J. Walker (1994) "The role of communication in resolving commons dilemmas: experimental evidence with heterogeneous appropriators." *Journal of Environmental Economics and Management*, 27: 99–126.

15. Hardin, G. (1968) "The Tragedy of the Commons." *Science*, 162: 1243–1248.

16. Herr, A., R. Gardner, and J.M. Walker (1997) "An experimental study of time-independent and time-dependent externalities in the commons." *Games and Economic Behavior*, 19: 77–96.

17. Heyes, A. (2009) "Is environmental regulation bad for competition? A survey." *Journal of Regulatory Economics*, 36: 1–28.

18. International Cotton Advisory Committee (2011) "Cotton Fact Sheet: Uzbekistan." Washington, DC. Retrieved from: https://www.icac.org/econ_stats/country_fact_sheets/fact_sheet_uzbekistan_2011.pdf.

19. Keser, C. and R. Gardner (1999) "Strategic behavior of experienced subjects in a common pool resource game." *International Journal of Game Theory*, 28: 241–252.

20. Kochnakyan, A., S.K. Khosla, I. Buranov, K. Hofer, D. Hankinson and J. Finn (2013) "Uzbekistan Energy/Power Sector Issues Note." The World Bank Group, *Report No: ACS4146*. Washington, D.C.

21. Lambertini, L. (2013) *Oligopoly, the Environment and Natural Resources.* pp. 24–75, London, Routledge.

22. Lambertini, L. and G. Leitmann (2013) "Market power, resource extraction and pollution: Some paradoxes and a unified view." In J. Crespo Cuaresma, T. Palokangas, and A. Tarasyev (Eds.), *Green Growth and Sustainable Development.* Berlin, Heidelberg, Springer. 14: 143-164.

23. Liu, H., D. Masera, and L. Esser, eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization and International Center on Small Hydro Power. Retrieved from: https://www.smallhydroworld.org.

24. Maloney, M. and R. McCormick (1982) "A positive theory of environmental quality regulation." *Journal of Law and Economics*, 25(1): 99–124.

25. Markusen, J.R. (1975) "Cooperative control of international pollution and common property resources." *Quarterly Journal of Economics*, 89(4): 618–632.

26. McCarthy, N. (2001) "Common pool resource appropriation under costly cooperation." *Journal of Environmental Economics and Management*, 42: 297–309.

27. Muñoz-García, F. and S.B. Akhundjanov (2016) "Can polluting firms favor regulation?" *The B.E. Journal of Economic Analysis and Policy*, 16(4).

28. O'Hara, S.L., G.F.S. Wiggs, B. Mamedov, G. Davidson, R.B. Hubbard (2000) "Exposure to airborne dust contaminated with pesticide in the Aral Sea region." *The Lancet*, 355(9204): 627–628.

29. Ordover, J.A. and D.R. Willig (1981) "An economic definition of predation: Pricing and product innovation." *The Yale Law Journal*, 91(1): 8–53.

30. Ostrom, E. (1992) *Governing the Commons: The Evolution of Institutions for Collective Action.* New York, Cambridge University Press.

31. Ostrom, E., R. Gardner, and J. Walker (1994) *Rules, Games and Common Pool Resources.* Michigan, University of Michigan Press.

32. Philip, M. and N.V. Aladin (2008) "Reclaiming the Aral Sea." *Scientific American*, 298(4): 64–71.

33. Porter, M.E. (1991) "America's green strategy." *Scientific American*, 264: 168.

34. Porter, M.E. and C. van der Linde (1995a) "Green and competitive: Breaking the stalemate." *Harvard Business Review*, 73: 120–134.

35. Porter, M.E. and C. van der Linde (1995b) "Toward a new conception of the environment-competitiveness relationship." *Journal of Economic Perspectives*, 9(4): 97–118.

36. Salop, S.C., and D.T. Scheffman (1983) "Raising rivals' costs." *American Economic Review*, 73: 267–71.

37. Salop, S.C., and D.T. Scheffman (1987) "Cost-raising strategies." *Journal of Industrial Economics*, 26: 19–34.

38. Sethi, R. and E. Somanathan (1996) "The evolution of social norms in common property resource use." *American Economic Review*, 86: 766–788.

39. Sherstyuk, K., N. Tarui, M.-L.V. Ravago, and T. Saijo (2016) "Intergenerational Games with Dynamic Externalities and Climate Change Experiments." *Journal of the Association of Environmental and Resource Economists*, 3(2): 247–281.

40. Walker, J.M., R. Gardner, A. Herr, and E. Ostrom (2000) "Collective choice in the commons: experimental results on proposed allocation rules and votes." *The Economic Journal*, 110: 212–234.

41. Whish-Wilson, P. (2002) "The Aral Sea environmental health crisis." *Journal of Rural and Remote Environmental Health*, 1(2): 29–34.