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Regulators and Environmental Groups: Better Together or Apart?*

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Abstract

This paper examines green alliances between environmental groups (EGs) and polluting firms, which have become more common in the last decades, and analyzes how they affect policy design. We first show that the activities of regulators and EGs are strategic substitutes, giving rise to free-riding incentives on both agents. Nonetheless, the presence of the EG yields smaller welfare benefits when firms are subject to regulation than when they are not. In addition, the introduction of environmental policy yields large welfare gains when the EG is absent but small benefits when the EG is already present.

KEYWORDS: Environmental groups; Green alliances; Abatement; Environmental policy; Strategic substitutes; Welfare gains.

JEL CLASSIFICATION: H23, L12, Q58.

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1 Introduction

In the last two decades, the relationship of environmental groups (EGs) towards businesses has evolved, from antagonistic —such as campaigns disclosing firms' practices and lobbying to promote stringent environmental regulation[1]— to more constructive partnerships, commonly known as "green alliances;" see Rondinelli and London (2003). Prominent examples include the joint effort by McDonald's and Environmental Defense Fund to evaluate and redesign packaging materials and food processing methods[2]; the pioneering effort of Greenpeace and the German company Foron to create and popularize hydrocarbon refrigeration technology to address ozone-destroying chlorofluorocarbons[3]; the joint effort of International Paper and The Conservation Fund to protect natural habitats, see Hartman and Stafford (1997); and the partnership between Starbucks Coffee and Alliance for Environmental Innovation to find new ways for Starbucks to serve coffee with disposable beverage cups.

In the above examples, firms and EGs directly collaborate in new technologies and processes, rather than just in the credibility of a label or the endorsement from the EG. For instance, in the call for eliminating ozone-destroying CFCs, Greenpeace created a team of engineers who, within a few months, developed a refrigerator prototype using natural hydrocarbons that was efficient and good for the ozone layer and the climate. Greenpeace then collaborated with Foron who started designing GreenFreeze refrigerators based on the knowledge shared by Greenpeace. Similarly, the Alliance for Environmental Innovation partnered with Norm Thompson Outfitters in 2000 to test and use recycled content paper in actual catalog distributions. The Alliance shared its extensive expertise in paper, the third most energy-intensive of all manufacturing industries, its functionality in major paper grades, and its the environmental impact through the full lifecycle of paper.[4]

These partnerships are also common in developing countries, such as Mars and Danone's 3F Livelihoods Fund for Family Farming, with initiatives to improve the ecosystems and productivity of rural farming communities, investing more than €120 million and working with 200,000 farmers, see Nelson (2017). Similarly, the United Nations developed the National Cleaner Production Centres Programme, which aims at improving efficiency of resource use and enhancing industrial

[1] For examples of disclosing campaigns, see Heijnen and Schoonbeek (2008), Friehe (2013), Heijnen (2013), and van der Made (2014), among others. For examples of lobbying to promote stringent policies, see Fredriksson (1997), Aidt (1998), and Fredriksson et al. (2005).

[2] Environmental Defense Fund proposed a 42-step action plan on how McDonald's can reduce its ecological footprint caused by the lack of waste management techniques (Hartman and Stafford, 1997). In particular, McDonald's switched from polystyrene foam "clamshells" to paper-based wraps resulting in a 70-90% reduction in sandwich packaging volume, reducing landfill space consumed, energy used and pollutant releases over the lifecycle of the package. They also converted to bleached paper carry-out bags, coffee filters and Big Mac wraps and reduced paper use by 21% in napkins. In the decade following the partnership, McDonald's eliminated over 300 million pounds of packaging, recycled 1 million tons of corrugated boxes, and reduced restaurant waste by 30%.

[3] For more information, visit https://www.greenpeace.org/international/story/15323/how-greenpeace-changed-an-industry-25-years-of-greenfreeze-to-cool-the-planet/.

[4] This expertise is grounded in the work of the Paper Task Force, a private-sector initiative convened by the Alliance's parent organization, Environmental Defense Fund (EDF). The Paper Task Force has examined paper economics and functionality, and has identified ways to integrate environmental criteria into paper purchasing decisions. Since its founding in 1994, the Alliance for Environmental Innovation has worked with companies such as United Parcel Service and Bristol-Myers Squibb to reduce the environmental impact of their paper use and packaging.

productivity in 47 developing countries.

Firms can benefit from these partnerships since the EG offers specialized technical expertise, Baron (2012). Indeed, the EG is often aware of environmentally superior technologies that firms overlook; see Yaziji and Doh (2009).[5] Alliances with EGs may help firms identify new environmentally friendly products and technologies, since firms' internal development may be too costly, and acquiring the EG is highly unlikely; see Rondinelli and London (2003). In addition, the programmes that firms develop with EGs can provide greater credibility and commitment than self-developed initiatives (improved public image); see Hartman and Stafford (1997). Furthermore, firms consider many regulations problematic, as these are generally too broadly formulated, too costly from an economic point of view, and do not always stimulate best practices and most innovative technologies; see Livesey (1999) and Kolk (2000).

EGs can also benefit from these partnerships, often originated out of frustration with government policies setting too lax or bureaucratic environmental regulations. As World Wide Fund for Nature (WWF) Francis Sullivan said, while emphasizing the need for green alliances, "You cannot just sit back and wait for governments to agree, because this could take forever," Bendell and Murphy (2000, p. 69).[6] Additionally, EGs expect "ripple effects" from some partnerships, where a firm's competitors follow the lead adopting a similar practice, thus strengthening the environmental benefits of the partnership.[7]

Green alliances are then regarded as a good alternative to standard environmental policy since firms themselves design and implement the program; see Arts (2002). But, are they welfare improving regardless of the regulatory regime? We examine their policy implications by first exploring whether green alliances are a substitute or complement of environmental regulation. In the first case, free-riding incentives would arise, implying that regulatory agencies respond with less stringent policies when green alliances are present. If free-riding incentives are strong enough, environmental policy could be completely replaced by green alliances between EGs and firms. While alliances are often more flexible and cost-effective than regulation, EGs represent a specific pool of individuals within a society, potentially giving rise to representability problems. If, in contrast, green alliances are complementary to environmental policy, regulation would become more effective at curbing pollution when the EGs are present than otherwise. Our paper seeks to answer this question and identify if the presence of EGs, regulators, or both, yields the highest social welfare. Understanding the interaction between regulators and EGs in the context of green alliances can help us provide

[5] The partnership between Greenpeace and Foron illustrates this argument. After the Montreal Protocol called for the elimination of CFCs, the chemical industry encouraged appliance makers to replace CFCs with HCFCs, a less-harmful gas. While DuPont and ICI invested more than 500 million in research into HCFCs, Greenpeace developed a refrigerator prototype in a few months using a mix of natural hydrocarbons which was efficient and good for the ozone layer and the climate. In 1994, most German manufactures started to employ this technology and today this type of refrigerators are common in many European countries.

[6] A coordinator at WWF expected more direct results from agreements made with companies than with officials when he said "The government can develop policy, but that is always subject to long-term implementation. The private sector can actually get something meaningful off the ground."

[7] This was the case, for instance, of the McDonald's-EDF partnership where Burger King and other fast food chains followed McDonald's lead by adopting a comparable wrapping.

policy recommendations about the role of EGs in polluting industries.

We consider a sequential-move game where, in the first stage, the EG chooses a collaboration level with each firm, reducing the firm's abatement cost. In the second stage, every firm responds selecting its abatement level. In the third stage, the regulator sets an emission fee, responding to firms' abatement decisions; while in the last stage firms compete in quantities.

In our setting, a firm experiences two benefits from investing in abatement: (1) an increase in its demand, as its product becomes more attractive to customers (which we refer as "public image"); and (2) a reduction in the emission fee that the regulator sets in the subsequent stage since abatement decreases emissions (which we refer as "tax savings"). Public image works as a private good, since only the firm investing in abatement benefits from it, but tax savings work as a public good, since every firm enjoys a lower emission fee regardless of which firm invested in abatement. The public good nature of tax savings introduces free-riding incentives in abatement which are, however, ameliorated by the public image benefit. We show that, when the former effect dominates the latter, firms' abatement decisions are strategic substitutes, but otherwise abatement efforts can become strategic complements. Interestingly, the EG can promote this relationship with its collaboration effort in the first stage. Specifically, the EG can increase its collaboration with firms by a relatively small amount in the first period to make abatement efforts strategic complements (or less strategic substitutable), inducing firms to significantly increase their abatement. This abatement reduces emissions, thus benefiting both the EG and the regulator, who responds setting a less stringent emission fee.

The above results suggest that green alliances may be welfare enhancing, since they help firms invest more in abatement, or welfare reducing, as emission fees are less stringent. To answer this question, we evaluate the welfare gain from having an EG in a polluting industry, showing that its presence yields an unambiguous welfare gain, both when firms are subject to environmental regulation and when they are not, since the EG helps ameliorate free-riding incentives in abatement (tax-saving effects).

We then identify the welfare gain from introducing environmental policy, showing that it is positive when the EG is absent, and thus pollution was not being addressed by any agent. When the EG is present, however, the introduction of emission fees gives rise to free-riding incentives in abatement, leading firms to decrease their investment, a corresponding increase in pollution, ultimately yielding small welfare gains (negligible under some parameters). Therefore, welfare gains from regulation are larger when there is no EG active in that industry.

Our results also contribute to the policy debate about EGs being a potential replacement of environmental policy, since regulation is often criticized by several groups, including EGs, as ineffective. We demonstrate that EGs provide welfare gains in the absence of regulation, but their presence in regulated markets can only yield small welfare improvements. Nonetheless, our results also suggest that unregulated industries where EGs actively collaborate with firms may be left unregulated, as in developing countries with no environmental regulation but an active international EG. Otherwise, free-riding incentives in abatement lead to an increase in overall emissions.

Related literature. The literature on EGs is relatively recent and connects to the wider literature of private politics, in the form of activism by private interests, see Baron and Diermeier (2007), leading to corporate self-regulation when government policies are present or absent.[8]

The studies on EGs can be essentially grouped according to the effect that the EG's activity has on polluting firms. First, several articles assume that EGs take a confrontational approach against firms, reducing market demand for the firm's good (e.g., negative advertising campaigns) or boycotting their sales; see, respectively, Innes (2006), Baron and Diermeier (2007), and Heijnen and Schoonbeek (2008).[9] Heyes and Oestreich (2018) develop a delegation model with the EPA auditing the firms and the EG investing in whipping up "community hostility" against the firm's product. They show that, when the EG represents a hostile society, the actions of the EPA and EG are strategic substitutes; but they can become strategic complements when this hostility is low enough. In a different context, we also show that the actions of regulator and EG are strategic substitutes but their coexistence can be welfare improving.

Still using a demand approach, a second branch of the literature focuses on EGs investing in advertising and educational campaigns to increase consumers' environmental awareness, so individuals can identify the environmental impact of different products; see van der Made and Schoonbeek (2009).[10] Heijnen (2013) considers a similar problem, where consumers cannot perfectly observe a monopolistic firm's environmental damage, and rely on the advertising campaigns of an EG to infer this information, showing that the EG's presence can be beneficial for both consumers and firm.[11]

A third line of articles examines the EG's role, and its interaction with environmental regulation, using a lobbying rent-seeking approach, where polluting firms (EGs) lobby in favor of (against) projects with environmental implications and, depending on their relative lobbying intensity and effectiveness, the regulator responds approving or denying the project; see Liston-Heyes (2001)[12] and, for an empirical approach, Riddel (2003).[13]

Finally, a fourth branch of the literature considers EGs as providers of green certificates that

[8] Without an active regulator, firms self-regulate to preempt or stop a boycott, whereas in the presence of a regulator firms self-regulate to preempt public regulation; Egorov and Harstad (2017).

[9] In Heijnen and Schoonbeek's (2008), an environmental group can enter a monopolistic market and set up a campaign to influence consumers' perceived environmental damage. The article finds that the group's campaign might threaten the monopolist to produce employing a cleaner production technology. Similarly, in Innes (2006), an environmental group threatens firms with a boycott in order to promote green production techniques.

[10] In this paper, the EG increases consumers environmental concerns, helping entry in the industry (which newcomers are assumed to use less polluting technologies than incumbents). Entrants are then attracted to the market when the EG is present but stay out when the EG is absent, and aggregate pollution may actually increase when the EG is present depending on the entrant's pollution intensity.

[11] This connects with the literature examining firms' decisions to use EGs as providers of eco-label certifications, when for-profit private certifiers are also available; see, for instance, Bottega and De Freitas (2009).

[12] Using a rent-seeking contest, the paper finds that the firm developing the polluting project, anticipating the contest it will face in a subsequent stage against the EG, partially reduces the potential environmental damage of the project; approaching the equilibrium outcome to the first best. As a consequence, lobbying expenditure is lower in equilibrium than in a setting where the project characteristics are exogeneous, reducing wasteful lobbying efforts.

[13] This paper finds that environmental political action committees (E-PACs) choose to donate to candidates that are both likely to win the election and to advocate environmental positions once elected. Examples include the Sierra Club and the League of Conservation Voters.

firms can place in their packaging to signal certain attributes to consumers; see Heyes and Maxwell (2004). This literature has also examined whether government standards, industry standards and eco-labels, or EGs eco-labels are more effective at reducing pollution. Fisher and Lyon (2014), for instance, show that even when labels provide perfectly reliable information to consumers, environmental damages may be worse when both industry and EGs provide labels to the same product than when only the EG offers the label.[14] Harbaugh et al. (2011) suggest that the addition of a government label into a market with an EG label can be welfare reducing. Similarly, we show that the introduction of emission fees in an industry where the EG already operates can lead to insignificant welfare gains.

We also consider the interaction of EGs, polluting firms, and regulators, but within a constructive setting. As described in the above examples, EGs often collaborate with a polluting firm to develop a green technology that the firm would not develop otherwise. Our model is then similar to Stathopoulou and Gautier (2019), but we allow for firms to invest in abatement and analyze how the EGs collaboration affect emission fees, free-riding in abatement, and welfare. We show that, even in the absence of lobbying or green certificates, EGs may have incentives to collaborate with firms to reduce aggregate emissions via green R&D development. In other words, we identify an additional rationale for EGs to collaborate with firms, potentially reinforcing their collaboration incentives stemming from the reasons considered by the previous literature. In addition, we show that the EG's collaboration acts as a strategic substitute of environmental policy, but the EG becomes critically important in the absence of this policy.

The remainder of the paper is organized as follows. Section 2 outlines the model. Section 3 analyzes equilibrium behavior solving for equilibrium output, collaboration effort, abatement levels, and emission tax. In Section 4, we isolate the EG's effect, analyzing the case where there is only an EG in the market without a regulator, as well as the case with only a regulator and no EG; exploring the welfare implications in each case. Section 5 discusses our results and conclusions. Appendix 1 shows that the results remain qualitatively unaffected when we allow for an alternative timing of the game.

2 Model

Consider a polluting industry with two firms, each facing an inverse demand function $p_i(Q) = (a + \lambda z_i) - Q$, where $Q \equiv q_i + q_j$ denotes aggregate output and $\lambda \in [0, 1]$ measures how firm i's abatement z_i increases its demand. When $\lambda = 0$, demand is unaffected by abatement indicating that consumers ignore firm's clean practices, while when $\lambda = 1$ every unit of investment in abatement increases demand proportionally. Alternatively, $\lambda = 0$ can apply for an upstream firm whereas

[14] Our paper also connects with the literature analyzing firms' investment decisions in new technology and how regulators, anticipating these decisions, adjust their policies; see, for instance, Laffont and Tirole (1996) and Jaffe et al. (2002).

$\lambda > 0$ is more relevant for a downstream firm that directly deals with end-consumer markets.[15] Firms have a symmetric marginal cost of production c, and $a > c > 0$. Every unit of output, q_i, generates e_i units of emissions, where $e_i = q_i - z_i$. We consider the following time structure:

1. In the first stage, the EG chooses a collaboration level with firm i, b_i.[16]
2. In the second stage, every firm i independently and simultaneously chooses its abatement level, z_i.
3. In the third stage, the regulator sets an emission fee t.
4. In the fourth stage, every firm i independently and simultaneously selects its output level, q_i.

Therefore, our time structure considers that the EG and firm have already agreed to collaborate with each other. This represents the role of EGs in developing countries, where EGs have collaborated with local firms for years before any environmental regulation was implemented. For completeness, Appendix 1 examines how our equilibrium results are affected if stages 2 and 3 are switched, so the regulator sets emission fee t in the second stage and firms respond with their abatement effort z_i in the third stage. This may be the case in some developed countries where emission fees cannot be easily revised based on the EG's collaboration effort.

Given the above assumptions, every firm i in the fourth stage solves

$$\max_{q_i \geq 0} \ \pi_i = (a + \lambda z_i - Q)q_i - cq_i - t(q_i - z_i) \tag{1}$$

where the first term represents revenue, the second denotes costs, and the last term captures emission fees given that that the firm generates emissions $e_i \equiv q_i - z_i$. In the third stage, the regulator maximizes social welfare, as follows,

$$\max_{t \geq 0} \ CS(t) + PS(t) + T - Env(t) \tag{2}$$

where term $CS(t) + PS(t)$ denotes the sum of consumer and producer surplus, $T \equiv t \times [Q(t) - Z]$ represents total tax collection on net emission[17], and $Env(t) \equiv d\,[Q(t) - Z]^2$ measures the environmental damage from aggregate net emissions, where $Q(t) = q_i(t) + q_j(t)$ and $Z = z_i + z_i$

[15] Public image benefits are mainly appropriated by the firm investing in abatement, that is, $p_i(Q)$ increases in z_i but is unaffected by z_j. For instance, when McDonalds announced an increase in abatement efforts, such as investing in recyclable packaging materials and beverage cups, its rival (Burger King) did not experience an increase in sales. For public image to affect consumer demand, we assume that firms' abatement efforts are observable and verifiable.

[16] The green alliance between McDonald's and Environmental Defense Fund (EDF) started in 1990 and is still in place. We could not find records of EDF not carrying out its announced collaborations with McDonalds, suggesting that EGs tend to commit to a collaboration level once they announce it to the public. A similar argument applies to EDF's collaboration with FedEx, which collaborated since 2010 in developing one of the largest hybrid fleets in the industry; and to the collaboration of Greenpeace in Foron to produce ten prototype hydrocarbon refrigerators (Stafford et al., 2000; Seitanidi and Crane, 2013).

[17] Emission fees are then revenue neutral. Intuitively, while fees induce firms to alter their production (and pollution) decisions, tax collection is completely returned to society in the form of a lump-sum subsidy, implying that tax revenue does not increase social welfare.

denote aggregate output and abatement, respectively[18], and $d > 1/2$ represents the weight that the regulator assigns on environmental damages.[19]

The next section analyzes equilibrium behavior in this sequential-move game, starting from the last stage, providing the payoff function for each player where appropriate.

3 Equilibrium analysis

3.1 Fourth stage - Output

In this period, firms observe the emission fee $t > 0$ that the regulator sets in the third stage, their own abatement efforts in the second stage, z_i and z_j, and the EG's collaboration effort. Every firm i then solves problem (1). The next lemma identifies equilibrium output and profits in this stage.

Lemma 1. *In the fourth stage, every firm i chooses individual output $q_i(t) = \frac{[a+\lambda(2z_i - z_j)]-(c+t)}{3}$, earning profits $\pi_i(t) = (q_i(t))^2 + tz_i$. Output $q_i(t)$ is positive if and only if $z_i > \frac{\lambda z_j + t - (a-c)}{2\lambda}$, and net emissions decrease in z_i for all admissible values of λ. In addition, profits are increasing in firm i's abatement effort, z_i, and in public image, λ, but decreasing in firm j's abatement effort, z_j, in production cost, c, and in the emission fee t if abatement effort is sufficiently low, i.e., $z_i < \frac{2[a-\lambda z_j - (c+t)]}{9-4\lambda}$.*

Intuitively, profits are increasing in the abatement effort that the firm chooses in the third stage, z_i, given that abatement provides: (i) a tax-saving benefit, since z_i reduces emissions for a given emission fee t; and (ii) a public image benefit, since a cleaner production attracts more customers. Similarly, an increase in public image, λ, increases profits, since the firm's demand increases. In contrast, profits decrease in the abatement effort from firm i's rival, z_j, since a better public image reduces firm i's sales, i.e., a business stealing effect. Finally, note that firm i's output $q_i(t)$ is positive as long as its abatement is relatively larger than its rival's.

When analyzing the EG's collaboration effort in the first stage of the game, we show that it chooses a symmetric collaboration profile, $b_i = b_j$, which entails that both firms invest the same amount in abatement, $z_i = z_j$. Inserting this property in our results from Lemma 1, we can claim that, along the equilibrium path, every firm chooses an output level $q_i(t) = \frac{a+\lambda z_i - (c+t)}{3}$, which is positive if and only if $z_i > \frac{t-(a-c)}{\lambda}$.[20]

Firms' output decisions in the last stage are not directly affected by the presence of the EG in previous periods. However, the EG affects the firm's incentives to invest in green R&D in the

[18] We write $Q(t)$ since firms respond with their output to the emission fee t set in the third stage. However, we write aggregate abatement as Z, rather than $Z(t)$, since firms do not respond to t with their abatement efforts, as these are chosen in the second stage.

[19] For simplicity, we do not include the EG's objective function into the above social welfare as, otherwise, net emissions would be double counted. Intuitively, this can be rationalized by assuming that the EG is a foreign entity seeking to reduce emissions in every country where it operates or, alternatively, by considering that the regulator puts a small weight on the EG's objective function if it represents fringe voters.

[20] We describe here behavior along the equilibrium path, but we do not assume that $b_i = b_j$ or that $z_i = z_j$ in our subsequent analysis.

second stage, thus impacting its equilibrium profits in the fourth stage.

3.2 Third stage - Emission fee

In the third stage, the regulator anticipates the output function $q_i(t)$ that firms will choose in the subsequent stage, and solves problem (2). The next lemma identifies the equilibrium emission fee.

Lemma 2. *In the third stage, the regulator sets an emission fee*

$$t(Z) = \frac{2(a-c)(4d-1) - Z\left[\lambda + 4d(3-\lambda)\right]}{4(1+2d)}$$

which is positive if and only if $Z < \frac{(a-c)(4d-1)}{4d(3-\lambda)+\lambda} \equiv \tilde{Z}$. *In addition,* $t(Z)$ *is unambiguously decreasing in the production cost,* c, *and in aggregate abatement,* Z, *unambiguously increasing in public image,* λ, *but increasing in the regulator's weight on environmental damage,* d, *if and only if* $Z < \frac{2(a-c)}{2-\lambda} \equiv \overline{Z}$, *where cutoff* $\overline{Z}$ *satisfies* $\overline{Z} > \tilde{Z}$ *under all parameter conditions.*

Therefore, the emission fee $t(Z)$ becomes less stringent in the aggregate investment in abatement, Z. Intuitively, the regulator anticipates that a higher abatement reduces net emissions in the subsequent stage, thus requiring a less stringent emission fee.[21] This result gives rise to free-riding incentives in firms' abatement decisions, as every firm can benefit from the tax-savings effect of other firms' abatement.

In addition, the emission fee is decreasing when firms become more inefficient (higher c), since in that context the regulator expects lower production (and pollution) levels in the subsequent stage, calling for less stringent policies. The opposite argument applies when the regulator assigns a larger weight on environmental damage (higher d), inducing her to set a more stringent emission fee.[22] Finally, $t(Z)$ increases in public image since, for a given aggregate abatement Z, a higher value of λ expands demand. A stronger demand leads firms to increase output in the last stage of the game, thus increasing net emissions. Anticipating this output expansion due to public image, the regulator sets a more stringent fee in the third stage.

3.3 Second stage - Abatement

Every firm i anticipates the equilibrium profits it obtains in the fourth stage, $\pi_i(t) = (q_i(t))^2 + tz_i$, and evaluates them at the equilibrium emission fee that the regulator sets in the third stage, $t(Z)$, to obtain equilibrium profit $\pi_i(Z) \equiv \pi_i(t(Z))$. We can now insert $\pi_i(Z)$ in the firm's problem in

[21] Lemma 2 also identifies that, when aggregate abatement is sufficiently large, $Z \geq \tilde{Z}$, the emission fee becomes negative (i.e., a subsidy). This goes in line with standard models of polluting oligopolies, where the optimal emission fee is positive if the market failure from environmental damage dominates that originating from a socially insufficient production, yielding a socially excessive output level. Otherwise, aggregate output is insufficient, leading the regulator to offer production subsidies.

[22] This property holds when $Z < \overline{Z}$. The following section restricts firm abatement choices in the second stage to satisfy this property.

this stage, as follows

$$\max_{z_i \geq 0} \; \pi_i(Z) - \frac{1}{2}\left(\gamma - \theta b_i\right)(z_i)^2 . \tag{3}$$

where $z_i + z_j < \overline{Z}$, to guarantee that the emission fee is increasing in d. Parameter $\gamma \geq 1$ denotes firm i's initial cost of investing in abatement, while term $\gamma - \theta b_i$ represents firm i's final (or net) cost of abatement; after reducing it by the EG's collaboration effort, b_i. Intuitively, when $\theta = 0$ firms' abatement costs are unaffected by the EG activity, while when $\theta > 0$ firms' abatement costs decrease in the EG's collaboration effort b_i. Therefore, parameter θ captures how sensitive the firm's abatement costs are to the EG's collaboration effort or, alternatively, how effective collaboration is. Finally, note that abatement costs are increasing and convex in z_i.

Differentiating with respect to z_i in problem (3) yields

$$\frac{\partial \pi_i}{\partial t}\frac{\partial t}{\partial Z} = \left(\gamma - \theta b_i\right) z_i$$

since $\frac{\partial Z}{\partial z_i} = 1$ given that $Z \equiv z_i + z_j$. Intuitively, firm i increases its abatement until its marginal profit gain (tax savings) coincides with the marginal cost of investing in abatement.

To investigate how firm i's abatement is affected by its rival's decision, z_j, we differentiate this expression with respect to z_j, to obtain $\frac{\partial \pi_i}{\partial t}\frac{\partial t}{\partial Z}$, where $\frac{\partial t}{\partial Z}$ is unambiguously negative (see Lemma 2) but $\frac{\partial \pi_i}{\partial t}$ is also negative, as shown in Lemma 1, if and only if z_j is sufficiently low. Therefore, every firm i increases its abatement when its rival increases its own (implying abatement decisions are strategic complements) when z_j is relatively low. In this setting, a more severe fee makes firm j less competitive, inducing firm i to further increase z_i. In contrast, when z_j is relatively high, firm i responds to a marginal increase in z_j by decreasing its investment in abatement, entailing that investment decisions are strategic substitutes.

We next identify firm i's best response function $z_i(z_j)$ and examine whether abatement efforts are strategic substitutes or complements.

Lemma 3. *Firm i's best response function in the second stage is*

$$z_i(z_j) = \frac{2(a-c)\left[4d(2A+\lambda) - 2 + 3\lambda\right] - \left[2\lambda + \widehat{A}\left[\lambda^2 + 4d(2+\lambda(\lambda-1))\right]\right] z_j}{16d\left[3+5d+2(1+d)\gamma\right] - 32dA\lambda - \widehat{A}^2\lambda^2 + 4(2\gamma+\lambda) - 8A^2\theta b_i}$$

where $A \equiv 1+2d$ and $\widehat{A} \equiv 3+4d$. In addition:

1. *when $b_i = 0$ and $\lambda = 0$, $z_i(z_j)$ is unambiguously decreasing in z_j;*

2. *when $b_i = 0$ and $\lambda > 0$, $z_i(z_j)$ is decreasing in z_j if and only if $\gamma > \overline{\gamma}$; and*

3. *when $b_i, \lambda > 0$, $z_i(z_j)$ is decreasing in z_j if and only if $\gamma > \overline{\gamma} + \theta b_i$ when $b_i, \lambda > 0$,*

where $\overline{\gamma} \equiv \frac{\lambda(9\lambda-4)+8d[\lambda(4+3\lambda)-6]-16d^2(1-\lambda)(5+\lambda)}{8(1+2d)^2}$. Cutoff $\overline{\gamma}$ decreases in the weight that the regulator assigns to environmental damage, d, but increases in public image λ.

Therefore, when the EG is absent and consumers ignore public image, $b_i = 0$ and $\lambda = 0$, firms' abatement efforts are strategic substitutes for all parameter values. In this setting, an increase in firm j's abatement, z_j, only produces a benefit on firm i's profits (tax savings), since an increase in abatement efforts today reduce emission fees tomorrow on both firms. Firm i, hence, responds to an increase in z_j reducing its own abatement z_i, indicating that firms free-ride each other's abatement efforts.

When the EG is absent but there are public image effects, $b_i = 0$ and $\lambda > 0$, abatement efforts are strategic substitutes if the initial abatement cost is sufficiently high, $\gamma > \overline{\gamma}$. In this context, an increase in z_j produces two opposite effects on firm i's profits: (i) a positive tax-savings effect as discussed above; and (ii) a negative business-stealing effect since $\lambda > 0$. Hence, when the positive effect in (i) is larger than the negative effect in (ii), abatement efforts remain strategic substitutes. This occurs, in particular, when firms face a relatively high initial abatement cost, yielding a minor business-stealing effect. Otherwise, firms' abatement become strategic complements. A similar argument applies when both EG and public image are present, but abatement efforts are now strategic substitutes under more restrictive conditions. Intuitively, the EG's collaboration effort enlarges the business-stealing effect, making less likely that free-riding incentives dominate.

Finally, abatement efforts become strategic substitutes under larger conditions when d increases. In this context, the regulator sets a more stringent emission fee, enlarging the tax saving benefits, which ultimately makes free riding more pervasive. The opposite argument applies when λ increases, as the business stealing effect is more significant, making more difficult for abatement efforts to be strategic substitutes.

The following proposition identifies the equilibrium abatement effort.

Proposition 1. *In the second stage, every firm i selects an equilibrium abatement effort*

$$z_i(b_i, b_j) = \frac{(a-c)\left[4d(2A+\lambda)+3\lambda-2\right]\left[4\gamma+\lambda(1-6\lambda)+B-4A\theta b_j\right]}{\left[4\gamma+\lambda(1-6\lambda)+B\right]F-2A\theta\left[\left[D-32dA\lambda+C\right]b_j+b_i\left[D-32dA\lambda+C-8A^2\theta b_j\right]\right]}.$$

where $A \equiv 1+2d$, $B \equiv 4d\left[3+2\gamma-\lambda(3+2\lambda)\right]$, $C \equiv 4(2\gamma+\lambda)-(3+4d)^2\lambda^2$, $D \equiv 16d(3+5d+2(1+d)\gamma)$ and $F \equiv 4\gamma+8d^2(7+2\gamma-5\lambda)+3\lambda(1-\lambda)+2d\left[18+8\gamma-\lambda(11+2\lambda)\right]$. In addition, $z_i(b_i, b_j) + z_j(b_i, b_j) < \overline{Z}$, which guarantees that the emission fee increases in d, holds if $b_i < \overline{b}_i$, where cutoff $\overline{b}_i$ is provided, for compactness, in the appendix.

When we analyze the EG's collaboration effort, we demonstrate that it selects a symmetric collaboration across firms, $b_i = b_j = b$ (see section 3.4). Inserting this property into our results from Proposition 1, we can state that, along the equilibrium path, abatement effort simplifies to

$$z_i(b, b) = \frac{(a-c)\left[2-3\lambda-4d(2+4d+\lambda)\right]}{(3+4d)\lambda^2+(40d^2+22d-3)+4b\theta(1+2d)^2-4d\left[9+14d+4\gamma(1+d)\right]-4\gamma}.$$

Equilibrium abatement is clearly decreasing in the firm's production cost, c. Comparative statics for the EG's collaboration efforts, b_i and b_j, and the public image effect, λ, are, however, less tractable; so figure 1 evaluates equilibrium abatement $z_i(b_i, b_j)$ at parameter values $a = \gamma = d = 1$, $c = 0$, $\theta = 0.25$, $b_j = 1$ and $\lambda = 0.1$.[23] The positive slope of $z_i(b_i, b_j)$ in figure 1a indicates that firm i increases its abatement in the EG's collaboration, b_i. In addition, the upward shift in this figure illustrates that, as public image increases (from $\lambda = 0.1$ to $\lambda = 0.2$), individual abatement effort also increases. Figure 1b indicates that firm i decreases its abatement effort when its rival is more generously helped by the EG (higher b_j).

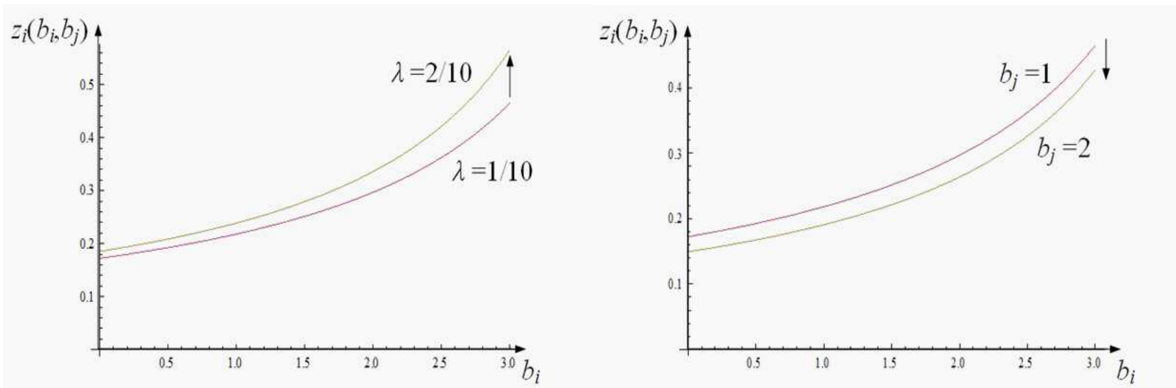

Fig. 1a. Effect of λ on $z_i(b_i, b_j)$ Fig. 1b. Effect of b_j on $z_i(b_i, b_j)$

In the previous section, we found that the optimal emission fee $t(Z)$ is decreasing in aggregate abatement Z. Since $z_i(b_i, b_j)$ is increasing in the EG's collaboration effort b_i, emission fee $t(Z)$ is then decreasing in b_i. In short, a more generous collaboration effort from the EG induces a less stringent emission fee or, in other words, collaboration effort and emission fees are strategic substitutes.

3.4 First stage - Collaboration effort

In the first stage, the EG anticipates the equilibrium abatement $z_i(b_i, b_j)$ from Proposition 1, and inserts it into the regulator's emission fee from Lemma 2, $t(Z)$, obtaining, $t^* \equiv t(z_i(b_i, b_j), z_j(b_i, b_j))$. We can then insert this emission fee t^* into firm i's output function from Lemma 1, yielding $q^*(b_i, b_j) \equiv q_i(t^*)$. Firm i's net emissions when EG is present can then be expressed as $e_i^{EG} \equiv q^*(b_i, b_j) - z_i(b_i, b_j)$. We also consider firm i's net emissions when EG is absent, $e_i^{NoEG} \equiv q^*(t^{NoEG}) - z_i(t^{NoEG})$, where emission fee and abatement effort are evaluated at $b_i = b_j = 0$ and superscript $NoEG$ denotes that the EG is absent. The difference

$$ER_i \equiv e_i^{NoEG} - e_i^{EG}$$

[23]Other parameter values yield similar results and can be provided by the authors upon request.

represents the emission reduction in firm i's pollution that can be attributed to the EG's presence. Therefore, the EG chooses a collaboration level b_i and b_j towards firms i and j that solve

$$\max_{\frac{\gamma}{\theta}\geq b_i, b_j\geq 0} \quad \left[\beta\left(ER_i\right)^{\frac{1}{2}} - c_{EG}\left(b_i\right)^2\right] + \left[\beta\left(ER_j\right)^{\frac{1}{2}} - c_{EG}\left(b_j\right)^2\right] \tag{4}$$

where the first term captures the benefit to the EG in the form of emissions reduction from firm i, which is increasing and concave in ER_i, indicating that the emission reduction benefit from a larger collaboration effort are increasing in b_i, but at a decreasing rate. This benefit is scaled by $\beta > 0$, which denotes the weight that the EG assigns to emission reduction. The second term measures the cost of exerting collaboration effort, which is increasing and convex in b_i, and $c_{EG} > 0$ represents the cost of effort. To guarantee weakly positive abatement costs, $\gamma - \theta b_i \geq 0$, we set an upper bound on the collaboration effort so that b_i cannot exceed $\frac{\gamma}{\theta}$.

Differentiating with respect to b_i in problem (4) yields an intractable expression, which does not allow for an explicit solution of b_i^*. We, nonetheless, provide an analytical discussion of the first-order conditions. The EG's marginal cost of increasing b_i is $MC_i = 2c_{EG}b_i$, which is unambiguously positive and increasing in b_i. The marginal benefit is

$$\begin{aligned} MB_i &\equiv \frac{\partial\left[\beta\left((ER_i)^{\frac{1}{2}} + (ER_j)^{\frac{1}{2}}\right)\right]}{\partial b_i} \\ &= \frac{\beta}{2}\left[\frac{\partial z_i}{\partial b_i} - \frac{\partial q^*}{\partial t}\left(\frac{\partial t}{\partial z_i}\frac{\partial z_i}{\partial b_i} + \frac{\partial t}{\partial z_j}\frac{\partial z_j}{\partial b_i}\right)\right]^{-3/2} \\ &\quad + \frac{\beta}{2}\left[\frac{\partial z_j}{\partial b_i} - \frac{\partial q^*}{\partial t}\left(\frac{\partial t}{\partial z_j}\frac{\partial z_j}{\partial b_i} + \frac{\partial t}{\partial z_i}\frac{\partial z_i}{\partial b_i}\right)\right]^{-3/2} \end{aligned}$$

since $e_i^{NoEG} = q(t^{NoEG}) - z_i(t^{NoEG})$ do not depend on b_i. Because $Z \equiv z_i + z_j$, we have that $\frac{\partial t}{\partial z_i} = \frac{\partial t}{\partial z_j}$, which helps us simplify the above expression of MB_i to

$$\begin{aligned} MB_i &= \frac{\beta}{2}\left[\frac{\partial z_i}{\partial b_i} - \frac{\partial q^*}{\partial t}\frac{\partial t}{\partial z_i}\left(\frac{\partial z_i}{\partial b_i} + \frac{\partial z_j}{\partial b_i}\right)\right]^{-3/2} \\ &\quad + \frac{\beta}{2}\left[\frac{\partial z_j}{\partial b_i} - \frac{\partial q^*}{\partial t}\frac{\partial t}{\partial z_j}\left(\frac{\partial z_j}{\partial b_i} + \frac{\partial z_i}{\partial b_i}\right)\right]^{-3/2}. \end{aligned}$$

In a symmetric equilibrium, $z_i = z_j$, so MB_i simplifies to

$$MB_i = \beta\left[\frac{\partial z_i}{\partial b_i}\left(1 - 2\frac{\partial q^*}{\partial t}\frac{\partial t}{\partial z_i}\right)\right]^{-3/2}$$

where $\frac{\partial q^*}{\partial t} < 0$ from Lemma 1 and $\frac{\partial t}{\partial z_i} < 0$ from Lemma 2, implying that $1 - 2\frac{\partial q^*}{\partial t}\frac{\partial t}{\partial z_i} > 0$. Therefore, if z_i increases in b_i, as shown in section 3.3, MB_i is positive.

Intuitively, the first term captures the direct effect of a marginal increase in b_i, as b_i produces an increase in z_i. The second term, however, measures the indirect effect of b_i, since it affects both

z_i and z_j, which then change the emission fee t, and ultimately firms' output decisions in the last stage. The indirect effect is positive if the increase in z_i is smaller (in absolute value) than the decrease in z_j, implying that the sum of the first and second terms is positive.

To understand if MB_i is decreasing in b_i, we next differentiate it with respect to b_i, finding

$$\frac{\partial MB_i}{\partial b_i} = -\frac{3\beta}{4}\left[\frac{\partial^2 z_i}{\partial b_i^2}\left(1-2\frac{\partial q^*}{\partial t}\frac{\partial t}{\partial z_i}\right)\right]^{-5/2}.$$

If firm i's abatement, z_i, is convex in b_i, $\frac{\partial^2 z_i}{\partial b_i^2} > 0$, as suggested in figure 1, the MB_i is decreasing in b_i, suggesting that the EG's help exhibits diminishing returns, which guarantees a unique crossing point with the marginal cost, MC_i.

Figure 2 considers the same parameter values as in figure 1, and depicts the marginal benefit that the EG obtains from collaborating with firm i, MB_i (the derivative of the first term in (4) with respect to b_i), and the marginal cost of its collaboration effort, MC_i (the derivative of the second term in (4) with respect to b_i).[24]

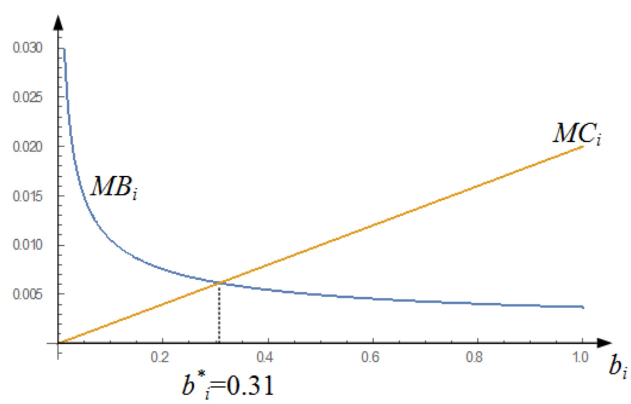

Fig. 2. MB and MC of the EG.

Marginal benefit MB_i is positive but decreasing in b_i, but marginal cost MC_i is increasing in b_i, suggesting that additional units of effort become more costly for the EG. In our parametric example, MB_i and MC_i cross at $b_i^* = 0.31$, and similar results emerge for other parameter values as reported in Table 1.[25] Other parameter values yield similar result and can be provided by the authors upon request.

Table 1. Equilibrium collaboration effort.

[24] Figure 2 constrains b_i to its admissible set, $\frac{\gamma}{\theta} \geq b_i \geq 0$, which in this parametric example entails $2 \geq b_i \geq 0$ since $\gamma = 1$ and $\theta = 1/2$.

[25] The first row in Table 1 considers the same parameter values as in figure 2. The second row increases parameter β from $\beta = 0.1$ to $\beta = 0.15$, leaving all other parameter values unchanged. A similar argument applies to all subsequent rows, which change one parameter at a time. Note that all our numerical simulations satisfy condition $z_i + z_j < \overline{Z}$. For instance, at our benchmark, this condition entails $b_i < 3.79$, which holds in equilibrium.

	β	a	c	γ	θ	d	c_{EG}	λ	b_i^*	z_i^*	t_i^*	q_i^*	$e_i^* \equiv q_i^* - z_i^*$
Benchmark	0.10	1	0	1	0.25	1	0.01	0.1	0.31	0.19	0.13	0.29	0.10
Higher β	**0.15**	1	0	1	0.25	1	0.01	0.1	0.19	0.12	0.12	0.29	0.10
Higher a	0.10	**2**	0	1	0.25	1	0.01	0.1	0.39	0.38	0.25	0.60	0.21
Higher c	0.10	1	**0.5**	1	0.25	1	0.01	0.1	0.24	0.09	0.07	0.15	0.05
Higher γ	0.10	1	0	**2**	0.25	1	0.01	0.1	0.26	0.07	0.11	0.13	0.06
Higher θ	0.10	1	0	1	**0.5**	1	0.01	0.1	0.40	0.20	0.11	0.30	0.10
Higher d	0.10	1	0	1	0.25	**2**	0.01	0.1	0.26	0.21	0.20	0.27	0.06
Higher c_{EG}	0.10	1	0	1	0.25	1	**0.1**	0.1	0.07	0.19	0.14	0.29	0.11
Higher λ	0.10	1	0	1	0.25	1	0.01	**0.2**	0.32	0.21	0.11	0.31	0.10
$\lambda = 0$	0.10	1	0	1	0.25	1	0.01	**0**	0.29	0.18	0.15	0.28	0.11

Overall, equilibrium collaboration b_i^* increases in the benefit that the EG obtains from emission reductions, β, in the strength of demand, a, in firm sensitivity to the EG's collaboration, θ, and in the public image, λ. However, b_i^* decreases in the firm's production cost, c, its initial abatement cost, γ, in the weight the regulator assigns on environmental damage, d, and the EG's collaboration cost, c_{EG}.

The last row evaluates equilibrium results in the special case where consumers ignore public image, $\lambda = 0$, showing that the firm has less incentives to invest in abatement, which the regulator responds with a more stringent fee. The EG in this case anticipates that the firm benefits from the tax-saving effect, but does not from business-stealing effects, which makes the firm less receptive to collaborate.

For completeness, the last columns of Table 1 report the equilibrium abatement effort, z_i^*, emission fee, t_i^*, and output level, q_i^*, evaluated at each vector of parameter values. As expected, when the EG's collaboration effort b_i^* increases, the firm responds increasing the investment in abatement, z_i^*, which is subsequently responded by the regulator setting a less stringent fee t_i^* in the third stage, except when the regulator assigns a larger weight on environmental damages (higher d) where fees becomes more stringent.

A natural question is whether collaboration effort and emission fees help reduce net emissions, as evaluated in the last column of Table 1. Overall, net emissions increase in the EG's collaboration cost, c_{EG}, since the EG reduces b_i^*; and in the demand strength, a, since production (and pollution) increase. In contrast, net emissions decrease in the EG's weight on emissions, β, since collaboration effort is more intense; in the firm's sensitivity to the EG's collaboration, θ, as its investment in abatement becomes less costly; and in the regulator's weight on environmental damage, d, since the regulator sets more stringent fees leading the firm to invest more in abatement.

3.4.1 Exclusive contracts

We now explore the EG's collaboration effort in "exclusive contracts," namely, industries where the EG collaborates with only one firm, $b_i > 0$ but $b_j = 0$. In this setting, the EG solves

$$\max_{\frac{\gamma}{\theta} \geq b_i \geq 0} \left[\beta \left(ER_i \right)^{\frac{1}{2}} - c_{EG} \left(b_i \right)^2 \right] + \beta \left(ER_j \right)^{\frac{1}{2}} \tag{4'}$$

which still includes the emission reductions of both firms i and j, but the EG's costs now only originate from collaborating with firm i.

As in Section 3.4, the EG's marginal cost of increasing b_i is $MC_i = 2c_{EG}b_i$, which is unambiguously positive and increasing in b_i. The marginal benefit in this context is still

$$MB_i \equiv \frac{\partial \left[\beta \left(ER_i \right)^{\frac{1}{2}} + \beta \left(ER_j \right)^{\frac{1}{2}} \right]}{\partial b_i}.$$

As shown in Section 3.4, this marginal benefit simplifies to

$$MB_i = \beta \left[\frac{\partial z_i}{\partial b_i} \left(1 - 2 \frac{\partial q^*}{\partial t} \frac{\partial t}{\partial z_i} \right) \right]^{-3/2}.$$

To understand this result, note that the EG's costs of collaborating with each firm are additively separable. While the benefits of this collaboration are not, the EG internalizes the effect of increasing b_i in firm j's emission reduction, yielding the same marginal benefit of increasing b_i as in section 3.4 –which holds both when the EG chooses the collaboration pair (b_i, b_j) and when it only selects b_i. Therefore, the EG chooses the same equilibrium collaboration effort when it helps both firms and when it exclusively helps firm i. As a consequence, the welfare effects that we identify in subsequent sections, apply to exclusive and non-exclusive contracts.

4 Isolating the EG's effect

4.1 Benchmark A - Regulator, but no EG

To better understand the effect of the EG in the setting of an emission fee, we now consider a context where the EG is absent, but still allow firms to invest in abatement, $z_i \geq 0$. That setting is strategically equivalent to our model, but assuming that the EG's collaboration effort is $b_i = 0$. Equilibrium results in the fourth stage (output decisions) and in the third stage (emission fees) are unaffected since they were not a function of collaboration efforts b_i and b_j; while the abatement decision in the second stage, $z_i(b_i, b_j)$, is now evaluated at $b_i = b_j = 0$, yielding

$$z_i^{NoEG} \equiv z_i(0,0) = \frac{(a-c)\left[4d(2+4d+\lambda)+3\lambda-2\right]}{4\gamma+8d^2(7+2\gamma-5\lambda)+3(1-\lambda)\lambda+2d\left[18+8\gamma-\lambda(11+2\lambda)\right]}.$$

Equilibrium abatement when the EG is present, $z_i(b_i, b_j)$, is increasing in b_i but decreasing in

b_j; see section 3.3. As a consequence, we cannot analytically rank abatement levels when the EG is present, $z_i(b_i, b_j)$, and absent, z_i^{NoEG}. In the parameter values considered in previous sections, we find $z_i^{NoEG} = 0.19$ and $z_i(b_i, b_j) = 0.22$, thus indicating that firms invest less in abatement when the EG is absent.

Inserting equilibrium abatement, z_i^{NoEG}, into the regulator's emission fee from Lemma 2, we obtain $t^{NoEG} \equiv t(z_i^{NoEG}, z_j^{NoEG})$. For consistency, figure 3 plots this emission fee considering the same parameter values as in previous figures. For comparison purposes, we also depict the fee when the EG is present, t^*, as found in the previous section. Figure 3 indicates that the presence of the EG induces the regulator to set less stringent emission fees. Intuitively, she free-rides off the EG, as the latter helps curb pollution, making environmental policy less necessary.

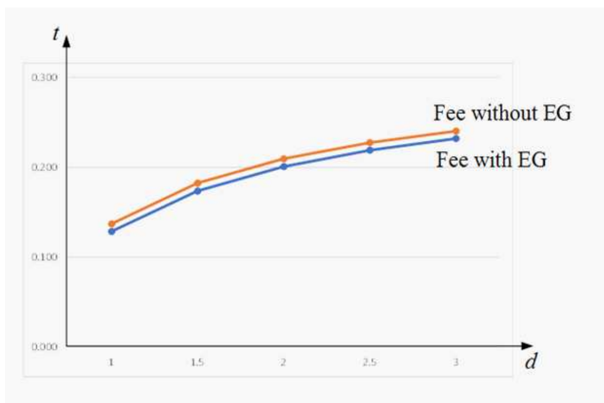

Fig. 3. Effect of EGs on emission fees.

4.2 Benchmark B - EG, but no regulator

Let us now consider an alternative benchmark, where the regulator is absent but the EG is present. In the fourth stage of the game, we obtain the same results as in Section 3.1, but evaluated at an emission fee $t = 0$ since the regulator is absent, i.e., output $q_i(0) = \frac{[a+\lambda(2z_i - z_j)]-c}{3}$ and profits $\pi_i(0) = (q_i(0))^2$. The third stage is inconsequential since the regulator is absent. In the second stage, every firm i chooses its investment in abatement by solving a problem analogous to (3), but without the effect of future taxes, as follows

$$\max_{z_i \geq 0} \; \pi_i(0) - \frac{1}{2}(\gamma - \theta b_i)(z_i)^2 . \tag{3'}$$

Differentiating with respect to z_i we obtain firm i's best response function $z_i(z_j) = \frac{4\lambda(a-c-\lambda z_j)}{9(\gamma - \theta b_i) - 8\lambda^2}$, thus indicating that abatement efforts of firm i and j are strategic substitutes if $\gamma > \frac{8\lambda^2}{9} + \theta b_i$, thus exhibiting a similar interpretation as in Lemma 2. Firm j's best response function, $z_j(z_i)$, is symmetric. Simultaneously solving for z_i and z_j in $z_i(z_j)$ and $z_j(z_i)$, yields abatement effort

$$z_i^{NoReg}(b_i, b_j) = \frac{4\lambda(a-c)\left[3(\gamma-\theta b_j)-4\lambda^2\right]}{27\gamma^2-48\gamma\lambda^2+16\lambda^4+3\theta(8\lambda^2-9\gamma)b_j+3\theta b_i\left[8\lambda^2-9(\gamma-\theta b_j)\right]}$$

which collapses to zero when $\lambda = 0$. Intuitively, when the regulator is absent and public image effects are nil, firms do not experience any of the two possible benefits of investing in abatement (tax savings and public image), leading them to abstain from investing.

In the first stage, the EG anticipates $z_i^{NoReg}(b_i, b_j)$ and solves problem (4) to find the equilibrium collaboration effort with firm i, b_i^*. As in the model with regulator, the EG's first-order condition yields non-linear expressions that do not provide an explicit solution for b_i^*. It is straightforward to numerically show, however, that collaboration efforts are generally higher in this context than when the regulator is present. Intuitively, the EG increases his collaboration to compensate for the void left by the regulator. We use our numerical results below to evaluate welfare gains from regulation alone, from the EG alone, and from both.

4.3 Benchmark C - No EG and no regulator

Finally, we consider a setting in which both the regulator and the EG are absent. In the fourth stage, firms choose the same output as in Benchmark B, that is, $q_i(0) = \frac{[a+\lambda(2z_i-z_j)]-c}{3}$, which yields profits $\pi_i(0) = (q_i(0))^2$.

In the second stage, every firm solves problem (3') but evaluated at $b_i = b_j = 0$ since the EG is absent, which produces a best response function $z_i(z_j) = \frac{4\lambda(a-c-\lambda z_j)}{9\gamma-8\lambda^2}$. Abatement efforts of firm i and j are then strategic substitutes in this setting if $\gamma > \frac{8\lambda^2}{9}$. Firm j's best response function, $z_j(z_i)$, is symmetric. Simultaneously solving for z_i and z_j in $z_i(z_j)$ and $z_j(z_i)$, yields abatement effort $z_i^{NoReg,NoEG} = \frac{4\lambda(a-c)}{9\gamma-4\lambda^2}$, which is increasing in public image, λ, but decreasing in the initial cost of abatement, γ.

4.4 Welfare comparison

In this section, we evaluate the welfare that emerges in equilibrium when the EG is present and absent, to measure the welfare gain of environmental regulation in each context. In particular, when the EG is absent, the welfare gain from the introduction of environmental regulation is

$$WGR_{NoEG} = W_{NoEG,R} - W_{NoEG,NR}$$

where subscript $NoEG$ denotes that the EG is absent, while R (NR) indicates that regulation is present (absent, respectively).[26] A similar definition applies for the welfare benefit from introducing environmental regulation in a setting where the EG is present $WGR_{EG} = W_{EG,R} - W_{EG,NR}$.

Alternatively, we can evaluate the welfare gains of introducing an EG in an industry not subject

[26] All welfare expressions in this section use our welfare definition in Section 3.2.

to regulation

$$WGEG_{NR} = W_{EG,NR} - W_{NoEG,NR},$$

or subject to regulation, $WGEG_R = W_{EG,R} - W_{NoEG,R}$. Evaluating these welfare gains at our ongoing parameter values, we obtain Table 2, which indicates that the introduction of emission fees produces a welfare benefit when the EG is absent, i.e., $WGR_{NoEG} > 0$ in the first column for all values of d. However, introducing environmental regulation in a context where an EG is already present produces a smaller welfare gain, as illustrated in the second column. Intuitively, firms now face free-riding incentives that they did not have in the absence of regulation. Specifically, the abatement of firm i's rivals decreases the emission fee that the regulator sets in the third stage of the game (tax-saving effect), inducing every firm to reduce its investment in abatement.

Table 2. Welfare gains from regulation and from EG.

	Introducing regulation		Introducing EG	
	when EG is absent	when EG is present	when reg. is absent	when reg. is present
d	WGR_{NoEG}	WGR_{EG}	$WGEG_{NR}$	$WGEG_R$
1	0.235	0.227	0.013	0.005
1.5	0.396	0.382	0.020	0.005
2	0.560	0.539	0.026	0.005
2.5	0.726	0.698	0.033	0.005
3	0.892	0.858	0.039	0.005

The third column indicates that introducing an EG in a setting where the regulator is absent improves social welfare since abatement increases. A similar argument applies to the fourth column which examines the welfare gain of introducing an EG where regulation is already present. In this context, the EG's collaboration ameliorates firms' free-riding incentives from tax savings, yielding small welfare gain.

In summary, introducing an EG is welfare improving regardless of whether pollution was being tackled with environmental regulation or not. The welfare gain is, as expected, larger when regulation is absent than when firms were already subject to emission fees; and generally larger than that from introducing environmental regulation. Environmental regulation produces a large welfare gain when no EG was present in the industry, and a small welfare gain when one EG is present, since in this case emission fees introduce new free-riding incentives in abatement that firms did not experience in the absence of regulation. Therefore, while the introduction of emission fees should be promoted in all regulatory settings, the introduction of EGs may only be considered when no environmental regulation exists in that industry or pollution damages are particularly severe.

Comparative statics. Table 3 evaluates our results in Table 2 at a higher public image ($\lambda = 0.2$ rather than $\lambda = 0.1$), showing that the welfare gains of introducing regulation (both when the EG is absent and present) are smaller than in Table 2 (first and second columns). Intuitively, public image provides firms with stronger incentives to invest in abatement, even when regulation and EG are absent, reducing the amount of pollution that regulation needs to curb. In contrast, the introduction of an EG yields larger welfare gains than in Table 2, both when firms are not subject to regulation (third column) and when they are (fourth column).

Table 3. Welfare gains from regulation and from EG, change in λ.

	Introducing regulation		Introducing EG	
	when EG is absent	when EG is present	when reg. is absent	when reg. is present
d	WGR_{NoEG}	WGR_{EG}	$WGEG_{NR}$	$WGEG_{R}$
1	0.161	0.136	0.031	0.006
1.5	0.277	0.238	0.046	0.006
2	0.397	0.339	0.064	0.006
2.5	0.518	0.442	0.083	0.006
3	0.640	0.545	0.101	0.006

Table 4 examines how results are affected when market size increases, from $a = 1$ to $a = 1.5$, showing that welfare gains are augmented relative to Table 2, but maintain their relative ranking, as well as their comparative statics as d increases.

Table 4. Welfare gains from regulation and from EG, change in a.

	Introducing regulation		Introducing EG	
	when EG is absent	when EG is present	when reg. is absent	when reg. is present
d	WGR_{NoEG}	WGR_{EG}	$WGEG_{NR}$	$WGEG_{R}$
1	0.529	0.507	0.036	0.013
1.5	0.891	0.852	0.053	0.014
2	1.260	1.203	0.071	0.013
2.5	1.633	1.558	0.088	0.013
3	2.007	1.914	0.105	0.013

Table 5 considers that marginal production cost c increases, from $c = 0$ to $c = 0.5$, showing that welfare gains are all smaller relative to Table 2. Intuitively, the margin $a - c$ shrinks, for a given a, leading to lower output levels and pollution in the absence of environmental regulation and EGs, implying that the presence of either agent yields smaller welfare effects.

Table 5. Welfare gains from regulation and from EG, change in c.

	Introducing regulation		Introducing EG	
	when EG is absent	when EG is present	when reg. is absent	when reg. is present
d	WGR_{NoEG}	WGR_{EG}	$WGEG_{NR}$	$WGEG_{R}$
1	0.059	0.057	0.002	0.001
1.5	0.099	0.096	0.004	0.001
2	0.140	0.136	0.005	0.001
2.5	0.181	0.176	0.006	0.001
3	0.223	0.217	0.007	0.001

In Table 6, we increase parameter γ in Table 2, from $\gamma = 1$ to $\gamma = 1.5$, keeping all other parameter values unaffected. Table 6 indicates that the welfare gains from introducing regulation are larger than in Table 2 while the welfare gains of the EG are smaller, although all keep their relative ranking unaffected.

Table 6. Welfare gains from regulation and from EG, change in γ.

	Introducing regulation		Introducing EG	
	when EG is absent	when EG is present	when reg. is absent	when reg. is present
d	WGR_{NoEG}	WGR_{EG}	$WGEG_{NR}$	$WGEG_{R}$
1	0.243	0.242	0.004	0.003
1.5	0.417	0.414	0.006	0.003
2	0.596	0.591	0.008	0.003
2.5	0.777	0.771	0.010	0.003
3	0.960	0.951	0.012	0.003

Finally, Table 7 decreases parameter θ, from $\theta = 1/4$ to $\theta = 1/10$. Relative to Table 2, the EG yields lower welfare gains, both when regulation is present and absent. The introduction of regulation produces the same welfare gain when the EG is absent (so θ is inconsequential for the firm's investment decision) but yields a larger welfare gain when the EG is already present than in Table 2. Intuitively, when the effectiveness of the EG's collaboration effort, θ, decreases, the EG collaborates less with the firms, as shown in section 3.4, ultimately making regulation more necessary.

Table 7. Welfare gains from regulation and from EG, change in θ.

	Introducing regulation		Introducing EG	
	when EG is absent	when EG is present	when reg. is absent	when reg. is present
d	WGR_{NoEG}	WGR_{EG}	$WGEG_{NR}$	$WGEG_{R}$
1	0.235	0.233	0.003	0.001
1.5	0.396	0.393	0.005	0.001
2	0.560	0.555	0.006	0.001
2.5	0.726	0.719	0.008	0.001
3	0.892	0.884	0.010	0.001

5 Discussion

Environmental groups and regulation are substitutes. We examine the interplay of the EG and the regulator. Our results show that the collaboration effort from the EG makes the presence of the regulator less necessary, inducing a less stringent emission fee. However, the absence of regulation induces the EG to collaborate more intensively with firms.

Welfare gains from EGs. At first glance, one could interpret the above results as an indication that green alliances can be welfare reducing since they lead to less stringent environmental policies. In contrast, we show that the presence of EGs produce a strict welfare improvement, both when firms are subject to regulation and when they are not, since the EG helps ameliorate free-riding incentives in abatement efforts (tax-saving effects). Our results also contribute to the policy debate about EGs being a potential replacement of environmental policy, since regulation is often criticized by several groups, including EGs, as ineffective. We demonstrate that EGs provide welfare gains, but generally small, especially in markets that are already subject to environmental regulation.

Welfare gains from regulation. We show that environmental policy is welfare improving when pollution is not addressed by any agent, i.e., when the EG is absent. When the EG is present, however, environmental policy introduces free-riding incentives in abatement, leading firms to reduce their investment, which can lead to minor welfare gains relative to the setting where only the EG is active.

Further research. Our model can be extended along different dimensions. First, we could assume the EG is uninformed about the firm's initial abatement cost, thus choosing its collaboration effort in expectation. This could happen, for instance, if the EG has extensive experience in similar industries but does not know the specific cost structure of firms in this market. Second, the regulator and EG could coordinate their decisions (jointly choosing b and t in the first stage) to internalize their free-riding incentives; although to our knowledge EGs rarely coordinate their collaboration efforts with public officials. Third, we could extend the game to allow for a previous stage in which the EG and firms decide whether to collaborate. For instance, the EG could offer a menu of collaboration effort b_i if and only if the firm commits to an abatement level z_i in the next stage. Finally, we consider for simplicity that firms sell homogeneous goods and are symmetric in their production costs, but our setting could be extended to allow for heterogeneous goods and/or cost asymmetries, identifying how our above results and welfare implications are affected.

6 Appendix

6.1 Appendix 1 - Alternative time structure

In this appendix, we consider an alternative timing in which the second and third stages are switched, that is, the EG still chooses its collaboration b_i in the first stage, the regulator responds choosing fee t in the second stage, every firm i chooses its abatement effort z_i in the third stage, followed by firms competing a la Cournot in the last stage.

Fourth stage. In the last stage, our results coincide with those in the baseline model, producing output level $q_i(t) = \frac{[a+\lambda(2z_i - z_j)]-(c+t)}{3}$, and earning profits $\pi_i(t) = (q_i(t))^2 + tz_i$.

Third stage. In the third stage, the firm solves

$$\max_{z_i \geq 0} \ \pi_i(t) - \frac{1}{2}(\gamma - \theta b_i)(z_i)^2$$

Relative to problem (3) in the baseline model (section 3.3), the firm now cannot alter the emission fee with its investment in abatement, z_i, since the emission fee is already set by the regulator in the second stage. Differentiating with respect to z_i and solving, yields best response function

$$z_i(z_j) = \frac{4\lambda(a-c-t)+9t}{9(\gamma - \theta b_i) - 8\lambda^2} - \frac{4\lambda}{9(\gamma - \theta b_i) - 8\lambda^2} z_j.$$

While the slope of best response function $z_i(z_j)$ is unaffected by emission fee t, its vertical intercept is increasing in t since

$$\frac{\partial\left(\frac{4\lambda(a-c-t)+9t}{9(\gamma-\theta b_i)-8\lambda^2}\right)}{\partial t} = \frac{9-4\lambda}{9(\gamma-\theta b_i)-8\lambda^2}$$

and $\gamma \geq 1$ by definition. Intuitively, a more stringent emission fee t in the second stage does not alter whether firms regard their investment in abatement as strategic substitutes or complements, yet provides firms with stronger incentives to invest.

The best response function of firm j, $z_j(z_i)$, is symmetric. Simultaneously solving for z_i and z_j in best response functions $z_i(z_j)$ and $z_j(z_i)$, yields an abatement level

$$z_i(t) = \frac{[4\lambda(a-c)+t(9-4\lambda)]\left[3(\gamma-\theta b_j)-4\lambda^2\right]}{27\gamma^2 - 48\gamma\lambda^2 + 16\lambda^4 + 3\theta(8\lambda^2 - 9\gamma)b_j + 3\theta b_i\left[8\lambda^2 - 9(\gamma - \theta b_j)\right]}$$

which is similar to equilibrium abatement when the regulator is absent, $z_i^{NoReg}(b_i, b_j)$, except for term $t(9-4\lambda)$ in the numerator. Firms then invest more significantly when the emission fee is set in the second stage than when the regulator is absent.

Second stage. In this stage, the regulator anticipates the output function $q_i(t)$ that firms will choose in the fourth stage, and their abatement investment $z_i(t)$ in the third stage, solving

$$\max_{t \geq 0} \; CS(t) + PS(t) + T - Env(t)$$

Relative to problem (2) in section 3.2, this welfare function is evaluated at $q_i(t)$ and at $z_i(t)$, while (3) is only evaluated at $q_i(t)$ and a generic z_i. Differentiating with respect to t, and solving we obtain a fee $t(b_i)$ which, relative to the fee in the main body of the paper, $t(Z)$, this fee is not a function of aggregate abatement (since abatement is selected in the subsequent stage), thus being only a function of the EG's collaboration effort, b_i. (The expression of fee $t(b_i)$ is rather large but can be provided by the authors upon request.)

First stage. At the beginning of the game, the EG solves a problem analogous to (4) in section 3.4, but evaluated at a different emission reduction term ER_i. As in problem (4), differentiating with respect to b_i yields a highly non-linear equation which cannot be solved analytically. We next evaluate the first-order condition at the same parameter values as in the main body of the paper (Table 1), obtaining the results in Table A1.

Table A1. Equilibrium collaboration effort.

	β	a	c	γ	θ	d	c_{EG}	λ	b_i^*
Benchmark	0.10	1	0	1	0.5	1	0.01	0.10	1.98
Higher β	**0.15**	1	0	1	0.5	1	0.01	0.10	1.98
Higher a	0.10	**2**	0	1	0.5	1	0.01	0.10	1.98
Higher c	0.10	1	**0.5**	1	0.5	1	0.01	0.10	1.98
Higher γ	0.10	1	0	**2**	0.5	1	0.01	0.10	0.82
Higher θ	0.10	1	0	1	**0.6**	1	0.01	0.10	1.65
Higher d	0.10	1	0	1	0.5	**2**	0.01	0.10	1.98
Higher c_{EG}	0.10	1	0	1	0.5	1	**0.10**	0.10	0.22
Higher λ	0.10	1	0	1	0.5	1	0.01	**0.20**	1.92

Relative to our baseline model, the EG anticipates that the firm will not increase its investment in abatement as significantly, since the firm cannot alter the emission fee by investing in z_i (only its overall tax bill), leading the EG to choose a more intense collaboration effort b_i^* under most parameter conditions.

6.2 *Proof of Lemma 1*

Differentiating the objective function in problem (1) with respect to q_i, yields

$$a + \lambda z_i - 2q_i - q_j - c - t = 0,$$

Solving for q_i, we obtain firm i's best response function

$$q_i(q_j) = \begin{cases} \frac{a+\lambda z_i-(c+t)}{2} - \frac{1}{2}q_j & \text{if } q_j < a+\lambda z_i-(c+t) \\ 0 & \text{otherwise.} \end{cases}$$

A symmetric expression applies when solving problem (1) for firm j. Simultaneously solving for q_i and q_j in $q_i(q_j)$ and $q_j(q_i)$ we obtain equilibrium output

$$q_i(t) = \frac{[a+\lambda(2z_i - z_j)] - (c+t)}{3}$$

and emissions $q_i(t) - z_i$ decrease in abatement effort, z_i, since $\frac{\partial[q_i(t)-z_i]}{\partial z_i} = \frac{2}{3}\lambda - 1 < 0$ given that $\lambda \in [0,1]$ by assumption.

Inserting this equilibrium output into the firm's objective function in (1), we find

$$\begin{aligned} \pi_i(t) &= (a+\lambda z_i - q_i(t) - q_j(t))q_i(t) - cq_i(t) - t(q_i(t) - z_i) \\ &= \left(\frac{[a+\lambda(2z_i - z_j)] - (c+t)}{3}\right)^2 + tz_i. \end{aligned}$$

or, more compactly, $\pi_i(t) = (q_i(t))^2 + tz_i$. Equilibrium profits are then increasing in firm i's abatement effort, z_i, and in public image, λ, but decreasing in firm i's production cost, c, and in its rival's abatement, z_j. Finally, if we differentiate equilibrium profit $\pi_i(t)$ with respect to emission fee t, we obtain

$$\frac{\partial \pi_i(t)}{\partial t} = \frac{(9-4\lambda)z_i - 2(a - \lambda z_j - c - t)}{9}$$

which is negative if z_i satisfies $z_i < \frac{2[a-\lambda z_j-(c+t)]}{9-4\lambda}$.

6.3 *Proof of Lemma 2*

The regulator sets emission fee t to solve

$$\begin{aligned} &\max_{t\geq 0} \frac{1}{2}[q_i(t)+q_j(t)]^2 + [\pi_i(t)+\pi_j(t)] \\ &+t[q_i(t)+q_j(t)-Z] - d[q_i(t)+q_j(t)-Z]^2 \end{aligned}$$

Differentiating with respect to t, we obtain

$$\frac{2(a-c)(4d-1) - 4t(1+2d) - Z[\lambda + 4d(3-\lambda)]}{9} = 0.$$

Solving for t, we find emission fee

$$t(Z) = \frac{2(a-c)(4d-1) - Z[\lambda+4d(3-\lambda)]}{4(1+2d)}$$

where $t(Z) > 0$ if and only if $Z < \frac{(a-c)(4d-1)}{4d(3-\lambda)+\lambda} \equiv \widetilde{Z}$.

In addition, $t(Z)$ is unambiguously decreasing in the production cost, c, and in aggregate abatement, Z. Differentiating $t(Z)$ with respect to the regulator's weight on environmental damage, d, we find

$$\frac{\partial t(Z)}{\partial d} = \frac{3\left[2a - 2(c+Z) + \lambda Z\right]}{2(1+2d)^2}$$

which is positive if and only if $Z < \frac{2(a-c)}{2-\lambda} \equiv \overline{Z}$. Comparing cutoff $\overline{Z}$ against that guaranteeing a positive emission fee, $\widetilde{Z}$, we obtain

$$\frac{2(a-c)}{2-\lambda} - \frac{(a-c)(4d-1)}{4d(3-\lambda)+\lambda} = \frac{4(a-c)(1+2d)}{(2-\lambda)\left[\lambda + 4d(3-\lambda)\right]}$$

which is unambiguously positive since $\lambda \in [0,1]$. Therefore, the cutoffs are ranked as $\overline{Z} > \widetilde{Z}$, implying that three regions of Z arise: (1) when $Z < \widetilde{Z}$, the emission fee is positive and it increases in d; (2) when $\widetilde{Z} \leq Z < \overline{Z}$, the emission fee is negative (a subsidy) but it still increases in d; and (3) when $Z > \overline{Z}$, the emission fee is negative and decreasing in d.

Finally, $t(Z)$ increases in public image since

$$\frac{\partial t(Z)}{\partial \lambda} = \frac{(4d-1)Z}{4(1+2d)}$$

is positive given that $d > 1/2$ by definition.

6.4 *Proof of Lemma 3*

We first evaluate equilibrium profits $\pi_i(Z) \equiv \pi_i(t(Z))$, where $t(Z) = \frac{2(a-c)(4d-1)-Z[\lambda+4d(3-\lambda)]}{4(1+2d)}$ from Lemma 2. Inserting this result into problem (3),

$$\max_{z_i \geq 0} \ \pi_i(Z) - \frac{1}{2}\left(\gamma - \theta b_i\right)(z_i)^2$$

and differentiating with respect to z_i, we find

$$\frac{2(a-c)\left[3\lambda + 2 + 4d(2(1+2d)+\lambda)\right] + z_i\left[8d(\lambda(4+3\lambda)-6) + \lambda(9\lambda-4) - 16d^2(1-\lambda)(5+\lambda)\right]}{8(1+2d)^2}$$

$$-\frac{z_j\left[2\lambda + (3+4d)\left[\lambda^2 + 4d(2+\lambda(\lambda-1))\right]\right]}{8(1+2d)^2} = \left(\gamma - \theta b_i\right) z_i.$$

Solving for z_i, we obtain firm i's best response function $z_i(z_j)$, as follows

$$z_i(z_j) = \frac{2(a-c)\left[4d(2A+\lambda) - 2 + 3\lambda\right] - \left[2\lambda + \widehat{A}\left[\lambda^2 + 4d(2+\lambda(\lambda-1))\right]\right] z_j}{16d\left[3+5d+2(1+d)\gamma\right] - 32dA\lambda - \widehat{A}^2\lambda^2 + 4(2\gamma+\lambda) - 8A^2\theta b_i}$$

where, for compactness, $A \equiv 1+2d$ and $\widehat{A} \equiv 3+4d$. Differentiating $z_i(z_j)$ with respect to z_j, we find the slope of the best response function, as follows

$$\frac{\partial z_i(z_j)}{\partial z_j} = \frac{2\lambda + \widehat{A}\left[\lambda^2 + 4d(2+\lambda(\lambda-1))\right]}{8A^2\theta b_i + \left(\widehat{A}\right)^2 \lambda^2 + 4\lambda\left(8dA-1\right) - 8\left[\gamma + 2d(2+5d+2(1+d)\gamma)\right]}$$

which is positive if γ satisfies $\gamma > \overline{\gamma} + \theta b_i$, where $\overline{\gamma} \equiv \frac{\lambda(9\lambda-4)+8d[\lambda(4+3\lambda)-6]-16d^2(1-\lambda)(5+\lambda)}{8(1+2d)^2}$. When $b_i = 0$ and $\lambda = 0$, condition $\gamma > \overline{\gamma} + \theta b_i$ collapses to $\gamma > -\frac{2d(3+5d)}{(1+2d)^2}$, which holds for all values of d. When $b_i = 0$ but $\lambda > 0$, condition $\gamma > \overline{\gamma} + \theta b_i$ simplifies to $\gamma > \frac{\lambda(9\lambda-4)+8d[\lambda(4+3\lambda)-6]-16d^2(1-\lambda)(5+\lambda)}{8(1+2d)^2}$.

Finally, differentiating cutoff $\overline{\gamma} + \theta b_i$ with respect to d, yields

$$\frac{\partial(\overline{\gamma} + \theta b_i)}{\partial d} = -\frac{(3+4d)(2-\lambda)^2}{2(1+2d)^3}$$

which is unambiguously negative; while differentiating cutoff $\overline{\gamma} + \theta b_i$ with respect to λ, we obtain

$$\frac{\partial(\overline{\gamma} + \theta b_i)}{\partial \lambda} = \frac{9\lambda + 8d[2+3\lambda+2d(2+\lambda)] - 2}{4(1+2d)^2}$$

which is unambiguously positive since $d > 1/2$ and $\lambda \in [0,1]$ by assumption.

6.5 *Proof of Proposition 1*

Simultaneously solving for z_i and z_j in best response functions $z_i(z_j)$ and $z_j(z_i)$, we obtain equilibrium abatement

$$z_i(b_i, b_j) = \frac{(a-c)\left[4d(2A+\lambda)+3\lambda-2\right]\left[4\gamma+\lambda(1-6\lambda)+B-4A\theta b_j\right]}{\left[4\gamma+\lambda(1-6\lambda)+B\right]F - 2A\theta\left[\left[D-32dA\lambda+C\right]b_j + b_i[D-32dA\lambda+C-8A^2\theta b_j]\right]}.$$

where $A \equiv 1+2d$, $B \equiv 4d\left[3+2\gamma-\lambda(3+2\lambda)\right]$, $C \equiv 4(2\gamma+\lambda)-(3+4d)^2\lambda^2$, $D \equiv 16d(3+5d+2(1+d)\gamma)$ and $F \equiv 4\gamma + 8d^2(7+2\gamma-5\lambda) + 3\lambda(1-\lambda) + 2d\left[18+8\gamma-\lambda(11+2\lambda)\right]$. Therefore, condition $z_i + z_j < \overline{Z}$, which guarantees that the emission fee increases in d, holds if and only if

$$\begin{aligned} b_i \quad < \quad \bar{b}_i \equiv & \frac{\left[4(1+\gamma)+4d(3+2\gamma-3\lambda)\right]\left[4\gamma+\lambda-6\lambda^2+B\right]}{4A\theta\left[2+4\gamma-\lambda(2+3\lambda)+4d\left(3+2\gamma-\lambda(3+\lambda)\right)-4A\theta b_j\right]} \\ & -\frac{4A\theta\left[2+4\gamma-\lambda(2+3\lambda)+4d\left(3+2\gamma-\lambda(3+\lambda)\right)\right]b_j}{4A\theta\left[2+4\gamma-\lambda(2+3\lambda)+4d\left(3+2\gamma-\lambda(3+\lambda)\right)-4A\theta b_j\right]}. \end{aligned}$$

References

[1] Aidt, T.S. (1998) "Political internalization of economic externalities and environmental policy." Journal of Public Economics 69, pp. 1-16.

[2] Alliance for Environmental innovation (2000) "Report of the Starbucks Coffee Company/Alliance for Environmental Innovation Joint Task Force." http://business.edf.org/files/2014/03/starbucks-report-april2000.pdf.

[3] Arts, B. (2002) "Green alliances of business and NGOs. New styles of self-regulation or dead-end roads?" Corporate Social Responsibility and Environmental Management 9, pp. 26-36.

[4] Baron, D.P. (2003) "Private politics," Journal of Economics & Management Strategy, 12(1), pp.31-66.

[5] Baron, D.P. (2012) "The industrial organization of private politics," Quarterly Journal of Political Science, 7(2), pp.135-174.

[6] Baron, D.P. and D. Diermeier (2007) "Strategic activism and nonmarket strategy." Journal of Economics & Management Strategy, 16(3), pp. 599-634.

[7] Bendell, J. and D. F. Murphy (2000) "Planting the seeds of change: business – NGO relations on tropical deforestation." In *Terms of Endearment. Business, NGOs and Sustainable Development*, Bendell J. (ed.). Greenleaf: Sheffield; pp. 65-78.

[8] Bottega, L. and J. De Freitas (2009) "Public, private and nonprofit regulation for environmental quality." Journal of Economics and Management Strategy, 18(1), pp.105-123.

[9] Egorov, G. and B. Harstad (2017) "Private politics and public regulation," The Review of Economic Studies, 84(4), pp.1652-82.

[10] Fischer, C. and T. P. Lyon (2014) "Competing environmental labels." Journal of Economics and Management Strategy, 23(3), pp. 692-716.

[11] Friehe, T. (2013) "The role of investment in environmental lobbying contests." Environmental and Resource Economics 56(3), pp. 337-352.

[12] Fredriksson, P. (1997) "The political economy of pollution taxes in a small open economy." Journal of Environmental Economics and Management 33, pp. 44-58.

[13] Fredriksson, P.G., E. Neumayer, R. Damania, and S. Gates (2005) "Environmentalism, democracy, and pollution control." Journal of Environmental Economics and Management, 49(2), pp. 343-365.

[14] Harbaugh, R., J.W. Maxwell, and B. Roussillon (2011) "Label confusion: The Groucho effect of uncertain standards," Management science, 57(9), pp.1512-27.

[15] Hartman, C. and E. Stafford (1997) "Green alliances: building new business with environmental groups." Long Range Planning 30(2), pp. 184-196.

[16] Heijnen, P. (2013) "Informative advertising by an environmental group." Journal of Economics 108(3), pp. 249-272.

[17] Heijnen P. and L. Schoonbeek (2008) "Environmental groups in monopolistic markets." Environmental and Resource Economics 39(4), pp. 379-396.

[18] Heyes, A.G. and J.W. Maxwell (2004) "Private vs. public regulation: political economy of the international environment." Journal of Environmental Economics and Management, 48(2), pp. 978-996.

[19] Heyes, A. and A.M. Oestreich (2018) "A theory of social license when regulatory pressure is jointly produced by an EPA and an NGO." Journal of Regulatory Economics, 54(3), pp. 219-243.

[20] Innes, R. (2006) "A theory of consumer boycotts under symmetric information and imperfect competition." The Economic Journal, 116(511), pp. 355-381.

[21] Jaffe, A., N. Newell, and R. Stavins (2002) "Environmental Policy and Technological Change," Environmental and Resource Economics, 22, pp. 41-70.

[22] Kolk, A. (2000) *Economics of Environmental Management*. Pearson: Edinburgh.

[23] Laffont, J.J. and J. Tirole (1996) "Pollution Permits and Environmental Innovation," Journal of Public Economics, 62, pp. 127-140.

[24] Liston-Heyes, C. (2001) "Setting the stakes in environmental contests." Journal of Environmental Economics and Management, 41(1), pp.1-12.

[25] Livesey, S.M. (1999) "McDonald's and the Environmental Defense Fund: a case study of a green alliance." The Journal of Business Communication 36(1): pp. 5-39.

[26] Lyon, T. P., and J.W. Maxwell (2008) "Corporate social responsibility and the environment: A theoretical perspective." Review of Environmental Economics and Policy, 2(2), pp. 240-260.

[27] Nelson, J. (2017) "Partnerships for Sustainable Development: Collective action by business, governments and civil society to achieve scale and transform markets," Business and Sustainable Development Commission, and Corporate Responsibility Initiative, Harvard Kennedy School. http://s3.amazonaws.com/aws-bsdc/PartnershipsforSD.pdf.

[28] Riddel, M. (2003) "Candidate eco-labeling and senate campaign contributions." Journal of Environmental Economics and Management, 45(2), pp. 177-194.

[29] Rondinelli, D.A. and T. London (2003) "How corporations and environmental groups cooperate: Assessing cross-sector alliances and collaborations." The Academy of Management Executive 17(1), pp. 61-76.

[30] Seitanidi, M. M. and A. Crane (2013) *Social partnerships and responsible business: A research handbook*. Routledge Publishers.

[31] Stafford, E. R., M.J. Polonsky, and C.L. Hartman (2000) “Environmental NGO–Business Collaboration and Strategic Bridging: A Case Analysis of the Greenpeace–Foron Alliance.” Business Strategy and the Environment. 9(2), pp. 122-135.

[32] Stathopoulou, E. and L. Gautier (2019) “Green alliances and the role of taxation,” Environmental and Resource Economics, 74(3), pp.1189-1206.

[33] van der Made, A. (2014) “Information provision by interest groups.” Environmental and Resource Economics 58(4), pp. 649-664.

[34] van der Made, A. and L. Schoonbeek (2009) “Entry facilitation by environmental groups.” Environmental and Resource Economics, 43(4), pp. 457-472.

[35] Yaziji, M. and J. Doh (2009) *NGOs and Corporations: Conflict and collaboration*, Cambridge: Cambridge University Press.