Green Alliances: Are They Beneficial when Regulated Firms are Asymmetric?*

John C. Strandholm†
George Dean Johnson, Jr. College of Business and Economics
University of South Carolina Upstate
Spartanburg, SC 29306

Ana Espinola-Arredondo‡
School of Economic Sciences
Washington State University
Pullman, WA 99164

Felix Munoz-Garcia§
School of Economic Sciences
Washington State University
Pullman, WA 99164

September 28, 2021

Abstract

In this paper, we analyze the collaboration between environmental groups (EGs) and polluting firms when they are asymmetric in their abatement costs. We find that, as firms become more asymmetric, the EG collaborates more with the firm suffering from an abatement cost disadvantage, but this additional collaboration does not overcome firms' cost asymmetry, producing an overall decrease in total abatement and an increase in total emissions. We also evaluate the welfare effects of introducing an EG and/or a regulator, finding that the latter generally yields larger welfare gains than the former when neither are present. Unlike previous studies, we show that the welfare benefit from a second agent is, under most settings, largest when firms are more asymmetric in their abatement costs.

Keywords: Environmental groups; Green alliances; Abatement; Environmental policy; Welfare gains; Asymmetric firms.
JEL classification: H23, L12, Q58.

*Strandholm thanks the University of South Carolina Upstate Office of Sponsored Awards and Research Support for partial funding of the project.

†Address: George 272, George Dean Johnson, Jr. College of Business and Economics, 160 East St. John Street, Spartanburg, SC 29306. E-mail: jstrandh@uscupstate.edu
‡Address: 101B Hulbert Hall, Washington State University, Pullman, WA 99164. E-mail: anaespinola@wsu.edu
§Address: 103H Hulbert Hall, Washington State University, Pullman, WA 99164. E-mail: fmunoz@wsu.edu

1 Introduction

Environmental groups (EGs) often collaborate with polluting firms to help them reduce their carbon footprint and, generally, to improve their environmental practices. Examples of collaboration between firms and EGs include McDonald's and Environmental Defense Fund,[1] Foron and Greenpeace,[2] and The Conservation Fund and International Paper,[3] among others. See Hartman and Stafford (1997), Stafford et al. (2000), Rondinelli and London (2003), and Seitanidi and Crane (2013) for more examples.

In this paper, we examine how this type of collaboration is affected by firms' asymmetry in their abatement costs, potentially leading the EG to mostly collaborate with one firm. We are also interested in evaluating the welfare gain of having an EG in a polluting industry, and how such a gain is affected by firms' asymmetry, helping us identify in which contexts the precence of an EG, of environmental regulation, or both, generates the largest welfare improvement. Overall, we show that the EG does not yield large welfare gains when firms are relatively symmetric in their initial abatement costs, and in some cases, the EG can produce welfare losses. However, these welfare gains increase as firms become more asymmetric, suggesting that the participation of an EG should be especially facilitated when firms are relatively asymmetric in their abatement costs (e.g., different experience in the industry, R&D units, or access to capital).

Our model considers that, in the first stage, the EG chooses a collaboration level with each firm, which reduces the firm's cost of abatement. In the second stage, every firm observes the EG's collaboration levels and responds selecting its investment in abatement. In the third stage, the regulator observes the EG's collaboration and firms' investment in abatement and responds by setting an emission fee. In the last stage, firms compete in quantities. The structure of the game illustrates industries where the EG is a leader in improving environmental quality or, alternatively, settings where the regulator cannot quickly revise the environmental policy.

In the baseline scenario, where both a regulator and an EG are present, an increase in firm asymmetry induces the EG to collaborate more with the inefficient firm since otherwise it would choose a low abatement level (this is, however, reversed when the EG exhibits a linear environmental benefit in emissions reduction, as we discuss below). Even though the EG collaborates more with the inefficient firm, its collaboration does not eliminate firms' cost asymmetry, driving the more efficient firm to invest more in abatement than its inefficient rival. This intense collaboration, however, does not offset the abatement decrease of the inefficient firm, leading to a decrease in overall abatement. A similar pattern applies to individual and aggregate emissions, yielding an increase in overall emissions, inducing the regulator to set a more stringent emission fee as firm asymmetry increases.

We also evaluate the welfare effects of having one or two agents aiming to reduce pollution. In particular, we examine the welfare impacts of introducing an EG (when a regulator is already present or not) or introducing a regulator (when an EG is already present or not). We find that the introduction of regulation generally yields larger welfare gains than the participation of an EG. When the EG's cost of collaboration is high, the introduction of the EG without the presence of regulation can actually decrease welfare.

[1]For more details visit http://www.edf.org/partnerships/mcdonalds and see Hartman and Stafford (1997) and Levesey (1999).

[2]This collaboration helped replace ozone-destroying chlorofluorocarbons with hydrocarbon in refrigeration technology, visit http://www.greenpeace.org/international/story/15323/how-greenpeace-changed-an-industry-25-years-of-greenfreeze-to-cool-the-planet/.

[3]Visit http://investor.internationalpaper.com/news-releases/press-r/2006/International-Paper-The-Nature-Conservancy-and-The-Conservation-Fund-Protect-218000-Acres-of-US-Forestland-Through-Historic-Land-Acquisition-Project/default.aspx.

Nonetheless, when a second agent is added (regulator or EG), welfare increases under most settings, and welfare gains are the largest when firms are asymmetric. We then evaluate the welfare benefits of adding a second agent. We show that the EG participation in an industry where an environmental regulator (e.g., EPA) already operates or, similarly, introducing regulation in an industry where the EG already operates, is either welfare reducing or yields negligible welfare benefits when firms are relatively symmetric in their initial abatement costs. However, when firms are asymmetric, this welfare gain significantly increases, making the co-existence of both agents (regulator and EG) particularly critical in this type of industries. Therefore, assuming firm symmetry when evaluating the EG's welfare gains can lead policy makers to oppose EG collaboration in a polluting industry, rather than recommending them to enter (stay out) in industries with relatively asymmetric (symmetric) firms.

We also examine how our results are affected by changes in different parameter values, such as the effectiveness of the EG's collaboration effort, its benefit from emission reduction, the environmental damage from pollution, and the public image benefit that firms enjoy when investing in abatement. First, when the collaboration effort of the EG is more effective, its presence becomes more welfare improving, especially in the absence of regulation. When the EG assigns a large value on emissions reduction, it yields small (large) welfare gains when regulation is present (absent, respectively).[4] In these cases, the EG's environmental concerns are enough to make regulation less necessary. In addition, when firms' pollution generates more severe environmental damage, the introduction of the EG yields relatively small welfare gains, but introducing regulation generates large welfare gains both when the EG is already present or not. Indeed, a more severe environmental damage from pollution induces the regulator to set a more stringent emission fee, which begins to "crowd out" the EG's efforts to reduce emissions. Finally, if consumers assign a higher value to the firm's investment in abatement (e.g. public image positively affects demand), the welfare gains from the introduction of either agent decrease, but are still positive. In this case, firms' private benefits from increasing abatement reduce the need of either agent to induce investment in abatement. Our results could, then, help explain empirical findings in the EU car industry, where the introduction of environmental regulation alone (emission standards without EG collaboration) gave rise to small welfare gains, as found by Reynaert (2021).

Our results highlight the role of asymmetry when authorities evaluate whether to promote or hinder EG's partnerships with firms in polluting industries. While EGs should be blocked in markets already subject to environmental regulation when firms are relatively symmetric, EG entry should be facilitated when firms are, instead, asymmetric. In markets not subject to regulation, however, EGs yield welfare gains which are, essentially, unaffected by firms' asymmetry. Finally, our findings suggest that EG participation in regulated industries may be welfare reducing, and thus blocked, when firms already have enough incentives to invest in abatement technologies in the absence of the EG, namely, when consumers assign a high value to the firm's investment in abatement (public image) and when environmental damage is sufficiently high to induce stringent emission fees from the regulator.

For completeness, we also examine how our results are affected when the EG exhibits a linear (instead of concave) benefit from emission reductions. Intuitively, this occurs when the EG is only concerned about the aggregate reduction in emissions due to firms' investment in abatement, regardless of how such reduction is distributed across firms. Alternatively, if firms are geographically distant (or emit different pollutants), this setting represents the case in which the EG does not consider the geographical (chemical) distribution of emissions. In this context, we demonstrate that

[4] EGs often have different goals. The Global Alliance for Health and Pollution, for instance, focuses on collaborating with low- and middle-income countries to deal with toxic hotspots. However, Rainforest Trust focuses on protecting tropical lands to converse threatened species.

the EG focuses its collaboration effort on the most efficient firm, helping it reduce its emissions, while almost abandoning the relatively inefficient firm which receives little collaboration effort. This result entails that, in settings where EG mainly considers aggregate emission reduction, we should observe it collaborating with firms that already exhibit a cost advantage in abatement prior to the entry of the EG. In contrast, when the EG cares about the composition or distribution of emissions across firms, we would expect EGs collaborating with all firms, but mainly with the relatively inefficient firm, with the goal of inducing a more balanced emission reduction across companies. In the case of the Foron-Greenpeace alliance, for instance, Stafford et al. (1998) reports that it was easier for Foron to invest in the new technology than for most appliance manufacturers, leading Greenpeace to target most of its collaboration to Foron. This observation goes in line with our predictions under linear environmental benefits, suggesting that Greenpeace may have preferred to maximize the total emission reduction at that time, instead of promoting a balanced emission reduction across firms.

Finally, we evaluate the profit gains from introducing EGs in order to identify in which industries we should expect firms lobbying or opposing the entry of EGs, and whether this behavior is affected by whether firms already face environmental regulation or not. Overall, we show that, the EG yields negligible effects on profits under most settings, which holds when environmental policy is present and absent, and when firms are relatively symmetric and asymmetric in their abatement costs. However, when the EG's environmental benefit is linear in the emission reduction and environmental regulation is already in place, we demonstrate that both firms can significantly benefit from the EGs collaboration effort, especially the firm with a lower abatement cost, as the EG's collaboration expands its cost advantage. Therefore, collaboration initiatives where the EG focuses its attention on one firm alone, and the firm is publicly open to such collaboration, could indicate that, as described above, the EG is more concerned about aggregate emission reductions than about its composition, and that the collaborating firm already benefited from the lowest abatement cost in its industry. In contrast, firms may oppose the EG, or at least be indifferent, when the EG enters an industry not subject to environmental policy, or when the EG seeks a relatively balanced collaboration effort across firms.[5]

1.1 Related Literature

The literature on EGs largely falls within four categories based on the impact the EG has on polluting firms. First, EGs take a confrontational approach aimed at reducing demand for the firm's good through negative advertising campaigns (Heijnen and Schoonbeek, 2008) or more expansive boycotts (Innes, 2006). Baron and Diermeier (2007) consider that an EG can threaten a monopolist by entering the market and setting up a campaign that influences consumers' perceived environmental damage, hence, incentivizing the monopolist to acquire a cleaner production technology.

Second, EGs invest in campaigns to increase consumers' environmental awareness of the goods firms offer. van der Made and Schoolbeek (2009) show that an EG's campaign can induce entry by a cleaner firm into a polluting industry. However, this entry can increase aggregate pollution as pollution from an increase in aggregate production outweighs the reduction in average pollution per

[5] In 2013, Revlon and the Breast Cancer Fund, for instance, did not collaborate in reducing chemicals deemed to be cancerous, such as DMDM Hydantoin and Quaternium-15. In this period, Revlon was not subject to environmental policy regarding these chemicals in the US, although Quaternium-15 is to be regulated in California in 2025. While other reasons could explain the lack of partnerships, our model identifies an additional source when firms do not face environmental regulation. See February 9, 2015 Guardian article "Under pressure: campaigns that persuaded companies to change the world," www.theguardian.com/sustainable-business/2015/feb/09/corporate-ngo-campaign-environment-climate-change (accessed Sept. 27, 2021).

product from a cleaner producing entrant. Heijnen (2013) follows a similar approach considering that consumers rely on EGs for information regarding a firm's environmental damage, showing that EGs can be beneficial to both consumers and the firm.

Third, EGs use a lobbying approach for or against projects with environmental impacts and relative effectiveness. Liston-Heyes (2001) show that, in a rent seeking contest, the presence of an EG partially reduces the potential environmental damage of a proposed project as the firm wishes to avoid a later contest from an EG. Empirically, Riddel (2003) takes a directly political angle, finding that environmental political action committees (E-PACs) are successful in donating to candidates that both are likely to win election and continue to advocate for environmental positions after their election.

Fourth, EGs provide green certificates to indicate certain environmental attributes of the good, see Heyes and Maxwell (2004). When adding a government label in addition to the EG label, Harbaugh et al. (2011) show that this can be welfare reducing. Their model also considers that the addition of a label on a product with a bad reputation may have no effect on demand, which can induce equilibria where products with labels and no labels coexist. Fischer and Lyon (2014) show that in the presence of both an EG's label and an industry label that the EG's label alone reduces environmental damage more than with both labels.

Our model builds on Stathopoulou and Gautier (2019), which allows for EGs to either collaborate with or be in conflict against a firm. The decision impacts both the firm's demand and abatement in a discrete matter. Espinola-Arredondo et al. (2021) extend the model in the previous paper to allow for firms, in collaboration with the EG, to invest in abatement technology to investigate the role that EGs have on the abatement decision. Our paper extends their model to a setting with asymmetric firms, evaluating collaboration efforts, abatement investments, and social welfare impacts of markets with asymmetric firms. We show that, while EGs may bring small welfare gains when firms are symmetric, their presence can yield large welfare benefits in industries with asymmetric firms.

2 Model

Consider a polluting industry with two firms, each facing an inverse demand function $p_i(Q) = (1 + \lambda z_i) - Q$, 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.[6] Every unit of output, q_i, generates e_i units of emissions, implying that net emissions are $e_i = q_i - z_i$.

In addition, every firm's marginal cost of production is symmetric and normalized to zero, but its abatement cost is $\frac{1}{2}(\gamma_i - \theta b_i)(z_i)^2$, where $\gamma_i \geq 0$ denotes firm i's initial cost of investing in abatement, while term $\gamma_i - \theta b_i$ represents firm i's net cost of abatement after reducing it by the EG's collaboration effort, b_i.[7] Intuitively, when $\theta = 0$ firms' abatement costs are unaffected by the EG activity, while when $\theta > 0$ these 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.[8] In addition, to examine the role of cost asymmetry,

[6]Alternatively, $\lambda = 0$ can apply for an upstream firm whereas $\lambda > 0$ is more relevant for a downstream firm that directly deals with end-consumer markets.

[7]For comparison purposes, we assume that the EG's collaboration produces the same cost-reducing effect as in Espinola-Arredondo et al. (2021), helping us isolate the effect of firm heterogeneity in equilibrium results.

[8]This implies that firms receive specialized technical expertise from the EG, as suggested by Baron (2012), about environmentally superior technologies, as in Yaziji and Doh (2009).

and without loss of generality, we consider that $\gamma_i > \gamma_j$, indicating that firm i has a higher initial cost of abatement, which may arise from different access to capital markets, experience in the industry, or geographical differences.

The regulator chooses an emission fee, t, to solve,

$$\max_t CS(t) + PS(t) + T - Env(t)$$

which includes consumer and producer surplus ($CS(t) + PS(t)$), emission fee revenue (T), and the environmental damage from aggregate net emissions, $Env(t) \equiv d[Q - Z]^2$, where d represents the weight of the environmental damage, which satisfies $d > 1/2$ to guarantee positive emission fees in all regulatory settings, and $Z = z_i + z_j$.

For comparison purposes, we consider the same time structure as in Espinola-Arredondo et al. (2021), which assumes that the EG acts in the first stage to identify how the EG's collaboration effort affects the regulator's environmental policy decision in a later stage of the game. Hence, the time structure of the game is:

1. In the first stage, the EG chooses a collaboration level with every firm i, b_i.
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.

3 Equilibrium analysis

Let us solve the sequential game using backward induction, starting from the last stage.

3.1 Fourth stage - Output

In the fourth stage, firms observe the emission fee $t > 0$, their own abatement efforts in the second stage, z_i and z_j, and the EG's collaboration effort. Every firm i then solves

$$\max_{q_i \geq 0} \ (1 + \lambda z_i - Q)q_i - t(q_i - z_i). \tag{1}$$

where the last term, $q_i - z_i$, denotes emissions. The next lemma identifies equilibrium output and profits. All proofs are relegated to the appendix.

Lemma 1. *In the fourth stage, every firm i chooses output $q_i(t) = \frac{1}{3}(a - t + \lambda(2z_i - z_j))$, and earns profits $\pi_i(t) = (q_i(t))^2 + tz_i$. Output $q_i(t)$ is positive if and only if $z_i > \frac{1}{2}z_j - \frac{a-t}{2\lambda}$.*

Equilibrium output increases in firm i's own abatement but decreases in its rival's. Output is positive if $z_i > \frac{1}{2}z_j - \frac{a-t}{2\lambda}$, that is, if its abatement is significantly larger than that of its rival. The next corollary discusses the comparative statics on the firm's profits in the fourth stage.

Corollary 1. *Profits $\pi_i(t)$ 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, and in the emission fee t if abatement effort is sufficiently low such that $z_i < \frac{2(a-t-\lambda z_j)}{9-4\lambda}$.*

An increase in the public image parameter λ increases demand for the firm's good, thus increasing profits. And increase in abatement effort both increases demand through a better public image and decreases the emission fee incurred by the firm (total tax, for a given t), which act together in increasing profits. An increase in the rival firm's abatement decreases firm i's profit as the rival firm benefits from a better public image which reduces firm i's sales, i.e., a business stealing effect.

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

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

The next lemma identifies the equilibrium emission fee.

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

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

which is positive if and only if $Z < \frac{2a(4d-1)}{\lambda+4d(3-\lambda)} \equiv \tilde{Z}$. *The emission fee* $t(Z)$ *is decreasing in* Z *and increasing in* λ. *The emission fee is increasing in* d *if and only if* $Z < \frac{2a}{2-\lambda} \equiv \bar{Z}$, *where cutoff* $\bar{Z}$ *satisfies* $\bar{Z} > \tilde{Z}$ *under all parameter conditions.*

The emission fee is positive if aggregate abatement, Z, is not too high, and the fee increases as the regulator assigns a greater weight on environmental damage. If firms sufficiently reduce their emissions, the emission fee becomes negative (a subsidy) as the market failure from the duopoly outweighs the environmental damage, implying that, in this context, the regulator seeks to increase output. An increase in the public image parameter, λ, increases the demand (and subsequent output) for the good, which increases environmental damage and results in a more stringent fee.

3.3 Second stage - Abatement

In the second stage, every firm i chooses its abatement effort anticipating fourth-stage profit $\pi_i(z_i, z_j)$ and the emission fee set by the regulator in the third stage. Each firm i's problem is

$$\max_{z_i\geq 0} \pi_i(z_i, z_j) - \frac{1}{2}(\gamma_i - \theta b_i)(z_i)^2,$$

Differentiating with respect to z_i yields firm i's best response function, as we identify in the next lemma.

Lemma 3. *Firm i's best response function is*

$$z_i(z_j) = \frac{8ad(4d+\lambda+2) + 6a\lambda - 4a}{A} - \frac{2\lambda + (4d+3)\left[\lambda^2 + 4d(2+\lambda(\lambda-1))\right]}{A} z_j,$$

where A *is defined in the proof of lemma 3. Term* A *increases as* γ_i *increases, which decreases the vertical intercept and absolute value of the slope of the best response function. Firm i's best response function is unaffected by firm j's abatement cost* γ_j.

When $\gamma_i = \gamma_j$, the response functions simplifies to that in Espinola-Arredondo et al. (2021), and thus exhibits the same properties. Firms have symmetric best response functions up to their abatement cost parameters (γ_i and γ_j).

Figure 1 illustrates the effect of an increase in γ_i on firm i's best response function $z_i(z_j)$, leaving γ_j unaffected. This best response function rotates counterclockwise, reducing the degree to which firm i regards its rival's abatement as a strategic substitute. Intuitively, when firm i's initial abatement cost increases, it invests less in abatement (depicted in the downward shift in the vertical intercept) but it also free-rides less intensively from its rival's abatement (flatter best

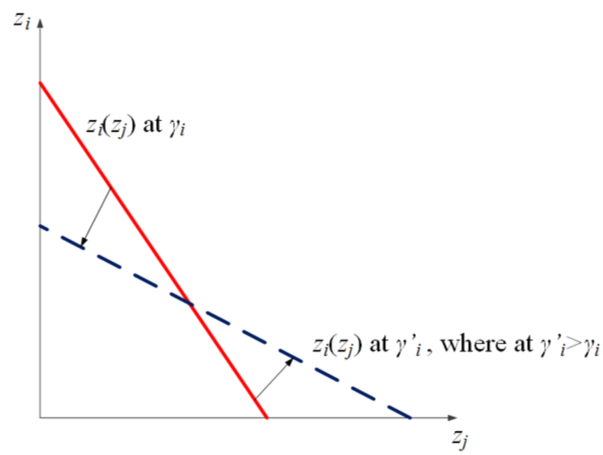


Figure 1

response function). Since firm j's best response function is unaffected by the increase in γ_i, best response functions $z_i(z_j)$ and $z_j(z_i)$ are now likely to cross at lower levels of z_i (lowering firm i's investment in abatement) but higher levels of z_j (higher abatement by firm j), as we analyze in Proposition 1 below.

Interestingly, figure 1 identifies a new effect in best response functions, solely due to abatement cost asymmetry, which is absent in Espinola-Arredondo et al. (2021). First, when firms are symmetric, best response function $z_i(z_j)$ is unambiguously decreasing in z_j when the EG is absent and consumers do not value abatement, $b_i = 0$ and $\lambda = 0$. In this context, an increase in z_j only produces a tax-saving benefit, since an increase in abatement efforts today decreases the emission fee in the next period on both firms, leading firm i to reduce its own abatement, z_i, free-riding its rival's effort. Second, when consumers assign a value to abatement ($\lambda > 0$), but EG are still absent, firm j's abatement effort generates an additional, negative, effect on firm i's profits, as some customers are attracted to firm j because of its improved public image (business-stealing effect). When the tax-saving benefit dominates this business-stealing effect, abatement efforts are still strategic substitutes, but otherwise their abatement become strategic complements. Third, adding the EG augments the above business-stealing effect, making best response function less likely to be negatively sloped. Finally, the addition of asymmetry in firms' initial abatement cost emphasizes this effect, as shown in Lemma 3 and figure 1, expanding the range of parameter values for which abatement efforts z_i and z_j are strategic complements.

The following proposition identifies the equilibrium abatement effort by each firm.

Proposition 1. *In the second stage, each firm i chooses (interior) equilibrium abatement effort*

$$z_i(b_i, b_j) = \frac{1}{B}\left[a(4d(4d+\lambda+2)+3\lambda-2)\left(4d(3+2(\gamma_j-\theta b_j)-\lambda(2\lambda+3))+4(\gamma_j-\theta b_j)-6\lambda^2+\lambda\right)\right]$$

where B is defined, for compactness, in the proof. Firm j's abatement effort is larger if $\gamma_i - \theta b_i > \gamma_j - \theta b_j$.

Firm j's abatement exceeds that of its rivals if its effective cost of investing in the technology is less than that of its rival, $\gamma_i - \theta b_i > \gamma_j - \theta b_j$ or, alternatively, if

$$b_j > b_i - \frac{\gamma_i - \gamma_j}{\theta}.$$

As depicted in figure 2, since firm j is more efficient at investing in abatement technology, $\gamma_j < \gamma_i$, in order for firm i to invest more in abatement, the EG's collaboration with firm i must be great enough to overcome the initial cost disadvantage, as captured by $\gamma_i - \gamma_j$.[9]

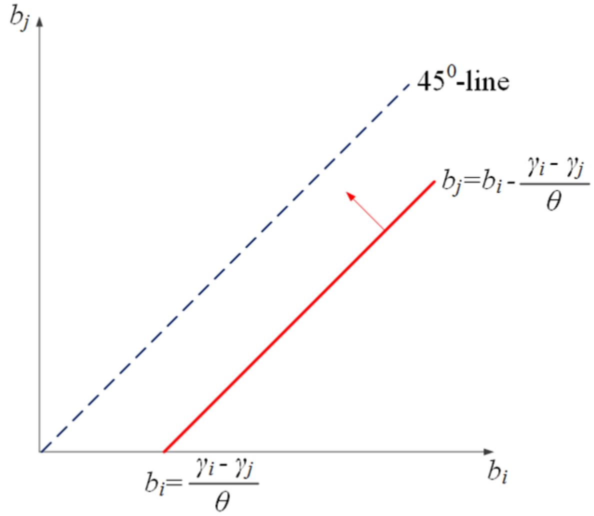


Figure 2

We can alternatively understand this inequality by considering the extreme cases where the EG only collaborates with one firm. If $b_j = 0$ and $b_i > 0$, in the horizontal axis of figure 2 the above condition becomes $b_i < \frac{\gamma_i - \gamma_j}{\theta}$, indicating that firm j invests more in abatement, despite not being supported by the EG, if the EG's collaboration with firm i is relatively low. In contrast, if $b_i = 0$ and $b_j > 0$, in the vertical axis of figure 2, the condition becomes $b_j > -\frac{\gamma_i - \gamma_j}{\theta}$, which holds for all values of b_j, implying that firm j invests more intensively than firm i if the EG does not collaborate with firm i, regardless of its collaboration level with firm j. Finally, if both firms are equally supported by the EG, $b_i = b_j = b$, the above condition simplifies to $0 > -\frac{(\gamma_i - \gamma_j)}{\theta}$, which holds since $\gamma_i > \gamma_j$ by assumption. Intuitively, when both firms receive the same collaboration from the EG, the firm with an initial advantage in investing in abatement (firm j) invests more intensively than its rival. When the EG is absent, or $b_i = b_j = 0$, each firm i's equilibrium abatement effort is

$$z_i(0,0) = \frac{1}{C}\left[a(4d(4d + \lambda + 2) + 3\lambda - 2)\left(4\gamma_j + 4d(2\gamma_j - \lambda(2\lambda + 3) + 3) - 6\lambda^2 + \lambda\right)\right],$$

where C is defined at the end of the proof of Proposition 1. Evaluating the above condition on $b_i = b_j = 0$, we obtain that firm j invests more in abatement than its rival, which is a special case of symmetric collaboration efforts, $b_i = b_j = b$, discussed above.

3.4 First stage - Collaboration effort

In the first stage, the EG anticipates the decisions in subsequent stages and uses that information to decide collaboration levels with each firm, b_i and b_j. The EG's benefit is the decrease in emissions that results from its collaboration. To find this, we define each firm i's net emissions as $e_i^{EG} \equiv q^*(b_i, b_j) - z_i(b_i, b_j)$ where $q^*(b_i, b_j)$ comes from the fourth stage results, and $z_i(b_i, b_j)$ comes from Proposition 1. Firm i's emissions when the EG is absent are $e_i^{NoEG} \equiv q^*(0,0) - z_i(0,0)$. Therefore,

[9]The denominator term B for every firm i depends on both its cost of investing and that of its rival's, γ_i and γ_j.

firm i's reduction in emissions due to the EG's collaboration effort is

$$ER_i = e_i^{NoEG} - e_i^{EG}.$$

The EG solves the following maximization problem

$$\max_{b_i, b_j \geq 0} \underbrace{[\beta(ER_i)^{\frac{1}{2}} - c_{EG}(b_i)^2]}_{\text{Firm } i} + \underbrace{[\beta(ER_j)^{\frac{1}{2}} - c_{EG}(b_j)^2]}_{\text{Firm } j}$$

The benefit from the EG's collaboration is the first term in each set of brackets, which is increasing and concave in ER_i (ER_j, respectively) and scaled by parameter $\beta > 0$ which measures the weight that the EG assigns on emissions reduction. (For completeness, section 6 examines how the equilibrium results are affected if the EG's environmental benefit is, instead, linear in emissions reduction.) The second term within each set of brackets is the EG's cost of collaborating, which is increasing and convex in its efforts b_i and b_j, and $c_{EG} > 0$ represents the effort's cost.

The first-order conditions for the EG's problem do not allow for an explicit solution to b_i^* and b_j^*. We next discuss the analytic first-order conditions to the EG's problem. Starting with the EG's marginal cost of collaboration effort, $MC_i = 2c_{EG}b_i$, is unambiguously positive and increasing in b_i. The next proposition presents the marginal benefit.

Proposition 2. *The EG's marginal benefit from increasing collaboration b_i is*

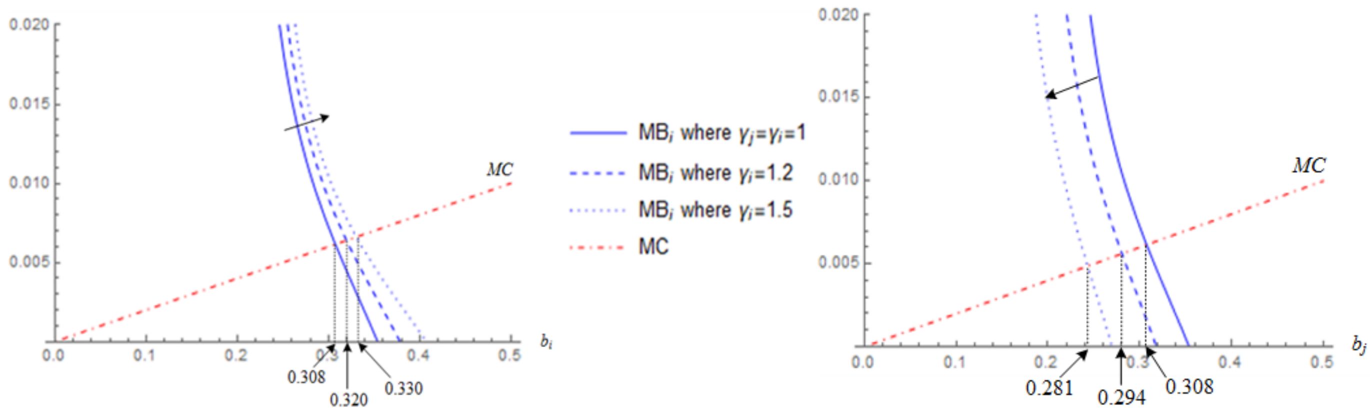
$$MB_i \equiv \frac{1}{2}\beta(ER_i)^{-\frac{1}{2}}\left[\frac{\partial z_i}{\partial b_i} - \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\left(\frac{\partial z_i}{\partial b_i} + \frac{\partial z_j}{\partial b_i}\right)\right] + \frac{1}{2}\beta(ER_j)^{-\frac{1}{2}}\left[\frac{\partial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

The marginal benefit from collaborating with firm i originates from the firm's increase in abatement, which reduces emissions. However, MB_i also considers the change in firm j's abatement (and resulting emissions reduction) from collaborating more intensively with firm i. Importantly, an increase in the initial cost of abatement, γ_i, produces an increase in $\frac{\partial z_i}{\partial b_i}$, without affecting any of the other terms in MB_i.[10] Therefore, a larger value of γ_i (making firms more asymmetric in their initial cost of abatement) yields an unambiguous upward shift in MB_i, inducing the EG to increase its collaboration effort with the firm suffering from a relatively larger initial abatement cost. We illustrate this result below.

The marginal cost of collaboration effort coincides when firms are symmetric and asymmetric in their abatement efforts, but the marginal benefit does not. At higher levels of asymmetry, the marginal benefit of collaborating with the inefficient firm grows, as it induces this firm to increase its investment in abatement, thus reducing emissions.

For illustration purposes, figure 3a plots MB_i and MC_i considering parameter values $a = d = 1$, $\beta = \lambda = 0.1$, $\theta = 0.25$, and $c_{EG} = 0.01$. The figure shows that, when firms are symmetric, $\gamma_i = \gamma_j = 1$, the crossing point between MB_i and MC_i (the EG's collaboration effort) lies at $b_i^* = 0.308$. However, when firm i's initial abatement cost increases (while that of firm j remains unchanged), the MB_i curve shifts rightward (see figure 3a), increasing the point where MB_i and MC_i cross and, as a consequence, the equilibrium collaboration effort, to $b_i^* = 0.320$ when γ_i increases to $\gamma_i = 1.2$, and to $b_i^* = 0.330$ when this cost further increases to $\gamma_i = 1.5$. In figure 3b, MB_j shifts to the left as firm i's abatement cost increases, as well as the intersection of MB_j and MC_j. For instance, when $\gamma_i = 1.2$, the EG's collaboration effort with firm j decreases to $b_j^* = 0.294$, and when $\gamma_i = 1.5$ the equilibrium collaboration effort decreases further to $b_j^* = 0.281$.

[10] As shown in Lemma 3, best response function $z_j(z_i)$ is unaffected by γ_i, thus not changing equilibrium abatement $z_j(b_i, b_j)$.



(a) Inefficient firm i (b) Efficient firm j

Figure 3: EG's marginal benefits and costs for different asymmetries in abatement costs.

3.5 Numerical Simulations

Table 1 evaluates the EG's equilibrium levels of collaboration, b_i^* and b_j^*, the resulting abatement, z_i^* and z_j^*, emission fee, t^*, and emissions, e_i^* and e_j^*, at different levels of asymmetry in the initial abatement costs (the difference between γ_i and γ_j increases in rows). For comparison purposes, table 1 considers the same parameter values as figures 3a and 3b.

	γ_j	γ_i	b_j^*	b_i^*	$\gamma_j - \theta b_j$	$\gamma_i - \theta b_i$	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.308	0.308	0.923	0.923	0.190	0.190	0.129	0.106	0.106	0.348
	1	1.1	0.294	0.314	0.927	1.021	0.192	0.182	0.134	0.103	0.112	0.345
	1	1.2	0.281	0.320	0.930	1.120	0.194	0.176	0.139	0.100	0.116	0.342
	1	1.3	0.268	0.324	0.933	1.219	0.196	0.169	0.144	0.097	0.121	0.339
	1	1.4	0.255	0.328	0.936	1.318	0.197	0.163	0.149	0.094	0.125	0.337
	1	1.5	0.243	0.330	0.939	1.417	0.199	0.158	0.153	0.092	0.129	0.334

TABLE 1A. Equilibrium collaboration efforts when the EG is present.

	γ_j	γ_i	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.186	0.186	0.137	0.108	0.108	0.345
	1	1.1	0.188	0.179	0.142	0.104	0.113	0.342
	1	1.2	0.190	0.172	0.147	0.101	0.118	0.339
	1	1.3	0.192	0.166	0.152	0.098	0.122	0.336
	1	1.4	0.193	0.160	0.156	0.096	0.126	0.334
	1	1.5	0.195	0.154	0.159	0.093	0.130	0.332

TABLE 1B. Equilibrium collaboration efforts in the absence of the EG.

Table 1A shows that as firms become more asymmetric in their abatement costs (larger difference between γ_i and γ_j), the EG collaborates more intensively with the most inefficient firm. This asymmetric collaboration helps to partially reduce the differential in effective cost of abatement between firms, as reported in columns 5 and 6. In the absence of the EG (see table 1B), however, this cost asymmetry would be higher, entailing a more differentiated abatement profile across firms.

Despite the EG's collaboration, the inefficient firm still has a larger effective cost than its efficient rival, inducing the former to invest less in abatement than the latter. The decrease in abatement increases emissions and environmental damage, which increases the fee, ultimately producing an overall welfare reduction (we provide more welfare comparisons in the next section).

In the absence of the EG, as shown in table 1B, both firms exhibit lower levels of abatement and higher levels of emissions than when the EG is present, while social welfare is lower. However, the same patterns as in Table 1A emerge: the efficient firm increases its abatement as the cost asymmetry grows while the inefficient firm decreases its abatement. Emissions move in the opposite direction.

	γ_j	γ_i	ε_{b_j}	ε_{b_i}	ε_{z_j}	ε_{z_i}	ε_t	$\varepsilon_{e_i+e_j}$	ε_{e_j}	ε_{e_i}	ε_{SW}
Benchmark	1	1.1	-0.44	0.22	0.10	-0.40	0.43	0.08	-0.32	0.49	-0.09
	1	1.2	-0.50	0.19	0.10	-0.42	0.42	0.08	-0.33	0.47	-0.10
	1	1.3	-0.55	0.17	0.10	-0.44	0.41	0.09	-0.35	0.46	-0.10
	1	1.4	-0.61	0.14	0.10	-0.46	0.40	0.09	-0.36	0.44	-0.10
	1	1.5	-0.66	0.12	0.10	-0.48	0.39	0.09	-0.37	0.43	-0.10

Table 2: Equilibrium collaboration efforts and elasticities when the EG is present.

Table 2 evaluates the equilibrium results of table 1a in elasticity terms.[11] This table shows that a one-percent increase in firms' asymmetry produces a 0.44 percent decrease in the EG's collaboration effort with the most efficient firm and 0.22 percent increase in collaboration effort with the inefficient firm. The efficient firm j responds to this reduction in the EG's collaboration effort by increasing its investment in abatement, z_j, but to a small extent, while the inefficient firm i responds by significantly decreasing its abatement, z_i. Overall aggregate abatement is then decreased when firms are more asymmetric, which induces the regulator to increase the emission fee. Specifically, a one-percent increase in firms' asymmetry leads to a 0.43 percent increase in the emission fee. In this setting, the efficient firm j decreases its emissions when firms become more asymmetric, while firm i increases its own emissions. However, the latter effect dominates, yielding an overall increase in aggregate emissions and ultimately reducing social welfare.

3.6 Robustness Checks

Appendix A.7 provides robustness checks where we vary each of the parameter values, which also serve as comparative statics of our baseline estimates. We next discuss each of them.

More effective collaboration. When firms are more sensitive to the EG's collaboration efforts (higher θ), the collaboration efforts b_i^* and b_j^* increase, which induces firms to increase their abatement efforts and decrease overall emissions, leading to higher social welfare.

More environmentally conscious EG. An increase in the weight that the EG assigns to emissions reduction (higher β) increases collaboration efforts, and has a similar, but smaller, effect on abatement, emissions, and social welfare than an increase in θ.

More costly collaboration. An increase in the EG's costs of collaboration, c_{EG}, has the opposite effect as θ and β, decreasing the EG's collaboration effort in equilibrium, which decreases the firms' investment in abatement and increases emissions, resulting in a decrease in social welfare.

More damaging emissions. An increase in the severity of environmental damage, d, increases the emissions fee that firms face, which the EG anticipates in the first stage of the game, reducing

[11]For example, elasticities at $\gamma_i = 1.1$ are calculated as $\varepsilon_x = \dfrac{[x(1.1) - x(1)]/x(1)}{(1.1-1)/1}$.

its own collaboration effort. This leads to an increase in firms' abatement effort and a decrease in overall emissions. However, social welfare decreases as the severity of environmental damage is higher, and the reduction in emissions is not enough to overcome the increased damage.

More environmentally conscious consumers. An increase in the responsiveness of consumers to abatement effort, λ, increases the EG's collaboration effort and firms' investment in abatement, which induces the regulator to set a less stringent fee, yielding an overall decrease in emissions and a higher social welfare.

4 Welfare effects across regulatory settings

As shown in the last column of table 1A, when firms become more asymmetric in their initial abatement cost, welfare decreases. This occurs, importantly, in all regulatory settings (with and without EG, and with and without environmental policy), as aggregate abatement weakly decreases when firms become more asymmetric.[12] We next investigate under which regulatory context this welfare loss is the smallest.

	Introducing regulation			Introducing EG		
$\gamma_i - \gamma_j$	when EG is absent	when EG is present	difference	when reg. is absent	when reg. is present	difference
0	0.235	0.232	-0.003	0.007	0.003	-0.004
0.1	0.232	0.234	0.002	0.006	0.008	0.002
0.2	0.228	0.236	0.008	0.005	0.013	0.008
0.3	0.223	0.237	0.014	0.004	0.018	0.014
0.4	0.219	0.238	0.019	0.004	0.022	0.018
0.5	0.215	0.238	0.023	0.004	0.027	0.023

Table 3: Welfare gains from regulation and from EG.

Table 3 shows that introducing regulation when the EG is absent (see first column) yields a welfare gain that decreases as firms become more asymmetric (that is, as we move to lower rows in the table). A similar argument applies when introducing the EG alone when the regulator is absent (see fourth column) Intuitively, the regulator alone (first column) or the EG alone (fourth column) cannot induce a sufficient shift in abatement levels across firms in response to asymmetric costs, ultimately entailing smaller welfare gains from this agent's presence. However, when the EG is already present, the introduction of regulation (see the second column in Table 3) produces a welfare gain that increases in firms' asymmetry. A similar argument applies when the EG is introduced and regulation is already present, as reported in the fifth column. In this case, emission fees and collaboration effort shift the abatement levels between the two firms, yielding a larger welfare gain when firms become more asymmetric. The introduction of the second agent complements the incentives to abate of the first agent, especially for the inefficient firm, which closes the abatement difference between the two firms, increasing social welfare.[13]

The column "difference" in table 3 reports the welfare gain of adding one more agent (EG

[12]Firms continue to invest in abatement without the regulator or EG present because of the increase in demand abatement provides through parameter λ. Appendices A4-A6 examine how our equilibrium results are affected if only the EG is present, only the regulator is present, or if neither of them is present.

[13]Tables analogous to tables 3-8 which evaluates the elasticity of the welfare gains or losses with respect to marginal increases in firm asymmetry are available upon request. In the baseline case, percentage changes in the welfare gains from introducing environmental regulation or EGs diminish as firms become more asymmetric in their cost of investing in abatement, and the welfare losses become more severe.

or regulator) when another agent was already present, that is, the difference in welfare benefit of adding a second agent. Our results show that, when firms are relatively symmetric in their abatement costs, this welfare benefit is negative (entailing that society is better off with one of the two agents alone rather than both) or positive but negligible. However, as firms become more asymmetric in their abatement costs, this welfare gain increases, making the presence of the second agent (EG or regulator) more welfare improving.

4.1 Welfare Analysis - Comparative statics

We next turn our attention to how the welfare gains from the EG and/or regulator change at different levels of relevant parameters.

	Introducing regulation			Introducing EG		
$\gamma_i - \gamma_j$	when EG is absent	when EG is present	difference	when reg. is absent	when reg. is present	difference
0	0.000	-0.024	-0.027	0.029	0.006	-0.027
0.1	0.000	-0.018	-0.016	0.023	0.006	-0.015
0.2	0.000	-0.017	-0.009	0.022	0.005	-0.009
0.3	0.000	-0.016	-0.002	0.021	0.005	-0.002
0.4	0.000	-0.016	0.003	0.020	0.005	0.003
0.5	0.000	-0.016	0.007	0.020	0.004	0.007

Table 4: Change in welfare gains from regulation and from EG when θ increases to 0.45.

More effective collaboration. Table 4 shows that an increase in the effectiveness of the collaboration effort at reducing abatement costs, θ, produces the same welfare gain from introducing regulation when no EG is present, as expected (see first column).[14] However, it yields a smaller welfare gain from regulation when the EG is already present. Similarly, introducing the EG yields a larger welfare gain, which holds both when regulation is present and absent.

	Introducing regulation			Introducing EG		
$\gamma_i - \gamma_j$	when EG is absent	when EG is present	difference	when reg. is absent	when reg. is present	difference
0	0.000	-0.003	-0.006	0.003	0.000	-0.007
0.1	0.000	-0.002	0.000	0.002	0.000	0.000
0.2	0.000	-0.002	0.006	0.002	0.000	0.006
0.3	0.000	-0.002	0.012	0.002	0.000	0.012
0.4	0.000	-0.002	0.017	0.002	0.000	0.016
0.5	0.000	-0.002	0.021	0.001	0.000	0.022

Table 5: Change in welfare gains from regulation and from EG when β increases to 0.2.

More valuable emission reduction for the EG. Table 5 examines how welfare gains are affected by an increase in the value that the EG assigns to emission reductions, β, showing that it produces the same welfare gains of introducing regulation when the EG is absent (first column), but unambiguously smaller gains when the EG is already present. However, the introduction of the EG yields smaller (same) welfare gains when regulation is absent (present). An increase in β increases

[14] This is the case for each of the parameters that only impact the EG's decision (θ, β, and c_{EG}).

the EG's collaboration effort with both firms as it increases the marginal benefit of collaboration, which holds both when firms are symmetric and asymmetric. In this case, the introduction of regulation, when firms are already collaborating with the EG has a smaller impact on welfare as some of the welfare gains now come from the EG's increased collaboration effort. In short, an EG with more environmental concerns makes regulation less necessary.

	Introducing regulation			Introducing EG		
$\gamma_i - \gamma_j$	when EG is absent	when EG is present	difference	when reg. is absent	when reg. is present	difference
0	0.080	0.077	-0.006	0.003	0.000	-0.007
0.1	0.080	0.078	0.000	0.002	-0.005	-0.005
0.2	0.080	0.079	0.007	0.002	-0.010	-0.004
0.3	0.081	0.080	0.013	0.002	-0.016	-0.004
0.4	0.082	0.080	0.017	0.002	-0.020	-0.004
0.5	0.082	0.080	0.021	0.002	-0.025	-0.004

Table 6: Change in welfare gains from regulation and from EG when d increases to 1.25.

More damaging pollution. Table 6 shows that an increase in the environmental damage, d, produces larger welfare gains when regulation is introduced or the EG participates in the absence of the regulator. The increase in environmental damage leads to larger increases in social welfare as emissions are abated, thus the impact of introducing the regulator is amplified. However, the presence of the regulator reduces the welfare impact that the EG carries relative to lower levels of environmental damage as the regulator "crowds out" the EG in incentivizing abatement.

	Introducing regulation			Introducing EG		
$\gamma_i - \gamma_j$	when EG is absent	when EG is present	difference	when reg. is absent	when reg. is present	difference
0	0.000	0.005	0.002	-0.008	-0.003	0.001
0.1	0.000	0.004	0.006	-0.007	-0.003	0.006
0.2	0.000	0.003	0.011	-0.006	-0.003	0.011
0.3	0.000	0.003	0.017	-0.005	-0.003	0.016
0.4	0.000	0.003	0.022	-0.005	-0.002	0.021
0.5	0.000	0.003	0.026	-0.005	-0.002	0.026

Table 7: Change in welfare gains from regulation and from EG when c_{EG} increases to 0.1.

More costly collaboration. Table 7 shows that an increase in the EG's collaboration cost, c_{EG}, still yields the same welfare gain of introducing regulation when the EG is absent, but entails larger welfare gains of introducing regulation when the EG was already present. Introducing the EG when regulation is absent, however, now generates a welfare loss, rather than a gain, since the EG reduces its collaboration effort under all parameter conditions. Similarly, introducing the EG when regulation is already present yields a smaller welfare gain than when the EG faces lower collaboration costs, making the EG less beneficial.

Public image from abatement. An increase in the public image parameter, λ, shown in table 8, induces firms to increase their investment in abatement, which boosts their demands, making regulation less necessary. In particular, the welfare gain from introducing regulation decreases, both when the EG is present and absent. However, introducing the EG yields larger welfare gains

$\gamma_i - \gamma_j$	Introducing regulation			Introducing EG		
	when EG is absent	when EG is present	difference	when reg. is absent	when reg. is present	difference
0	-0.075	-0.081	-0.009	0.007	0.001	-0.010
0.1	-0.067	-0.077	-0.010	0.006	-0.005	-0.009
0.2	-0.059	-0.074	-0.007	0.006	-0.010	-0.008
0.3	-0.051	-0.071	-0.006	0.005	-0.015	-0.006
0.4	-0.045	-0.070	-0.006	0.005	-0.019	-0.006
0.5	-0.039	-0.068	-0.006	0.005	-0.024	-0.006

Table 8: Change in welfare gains from regulation and from EG when λ increases to 0.2.

in the absence of regulation and smaller welfare gains when regulation is present. Intuitively, firms are more sensitive to the EG's collaboration when λ increases, making the EG's presence more beneficial without environmental regulation.

5 Linear environmental benefit

In this section, we analyze how our above results are affected when the EG, instead, exhibits a linear environmental benefit function for every firm i's emission reduction, βER_i. In this setting, the EG only cares about aggregate emission reductions, without assigning any importance to its composition (e.g., whether firm i is reducing emissions more or less than firm j does) and applies to industries where firms' pollution is chemically identical or are closely located. The concave environmental damage function considered in previous sections applies, instead, to industries where the EG prefers a balanced emission reduction across firms, which may be relevant when firms generate relatively different emissions or produce them in different locations. In this context, the EG solves the following maximization problem

$$\max_{b_i, b_j \geq 0} \underbrace{[\beta(ER_i) - c_{EG}(b_i)^2]}_{\text{Firm } i} + \underbrace{[\beta(ER_j) - c_{EG}(b_j)^2]}_{\text{Firm } j}$$

While the marginal cost of collaboration coincides with that in section 3, the EG's marginal benefit simplifies, as Proposition 3 describes.

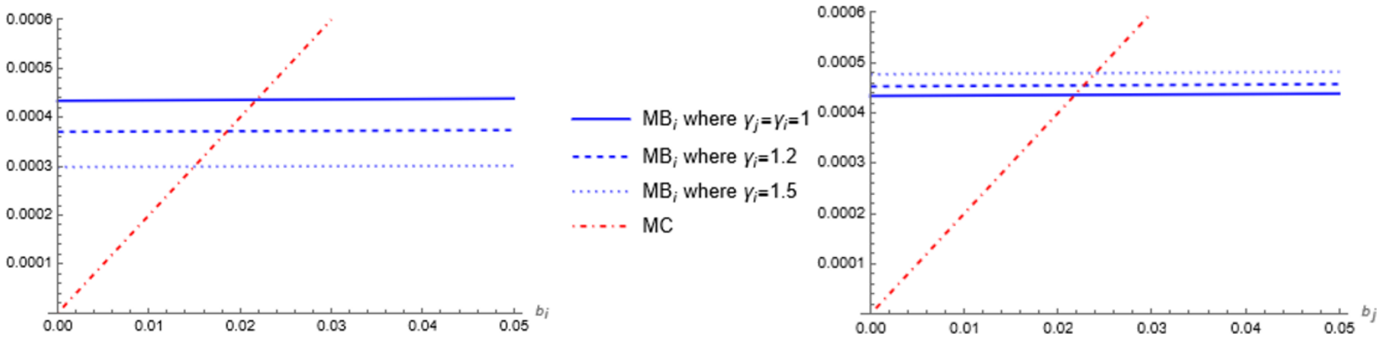
Proposition 3. *The EG's marginal benefit from increasing collaboration b_i is*

$$MB_i \equiv \beta \left[\frac{\partial(z_i + z_j)}{\partial b_i} - 2 \frac{\partial q}{\partial t} \frac{\partial t}{\partial z_i} \frac{\partial(z_i + z_j)}{\partial b_i} \right].$$

Intuitively, the marginal benefit of increasing the collaboration with firm i is now captured by the increase in aggregate abatement, $z_i + z_j$, and in the effect that this additional abatement has on equilibrium output. In this setting, decreasing firm i's investment in abatement can be perfectly offset by a proportional increase in abatement by firm j, leaving the EG with the same environmental benefit.

Figure 4a and 4b plot the EG's marginal benefit and cost of increasing its collaboration effort. For comparison purposes, we consider the same parameter values as in figures 3a and 3b. The upward sloping line representing MC_i is unaffected, but MB_i is now linear in the EG's collaboration effort.

As described in section 3 (see figures 3a and 3b), when the EG's environmental benefits are concave, the EG collaborates more (less) intensively with the firm that becomes relatively less



(a) Inefficient firm i (b) Efficient firm j

Figure 4: EG's marginal benefits and costs for different asymmetries in abatement costs when environmental benefit function is linear.

(more) efficient. When the environmental benefit is linear, however, our findings go in the opposite direction: the EG collaborates more (less) intensively with the firm that becomes relatively more (less) efficient; as summarized in table 9.

	Concave env. benefit	Linear env. benefit
More efficient firm i	∇ in b_i, Δ in b_j	Δ in b_i, ∇ in b_j
Less efficient firm i	Δ in b_i, ∇ in b_j	∇ in b_i, Δ in b_j

Table 9: Comparison of EG's collaboration when its environmental benefit is concave or linear.

This result originates from the EG's ability to substitute collaboration effort across different firms while enjoying the same aggregate environmental benefit. That is, the EG reduces its collaboration with firm i, as this firm would need a more generous collaboration than firm j to induce the same investment in abatement and pollution reduction. We should, then, observe EGs collaborating with the most efficient firm in abatement when the EG is not concerned about abatement composition, that is, when the EG focuses on aggregate abatement irrespective of its origin. In contrast, when the EG values that firms invest similar amounts in abatement, as when environmental benefit enters in a concave fashion, we should expect the EG to exert a positive collaboration effort with all firms, even if this effort is not completely identical. This argument can also be interpreted geographically, if the EG values that all regions abate similarly, when firms are located in different regions; or that all pollutants are reduced similarly, if each firm produces slightly different pollutants.

	γ_j	γ_i	b_j^*	b_i^*	$\gamma_j - \theta b_j$	$\gamma_i - \theta b_i$	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.022	0.022	0.995	0.995	0.186	0.186	0.137	0.108	0.108	0.345
	1	1.1	0.022	0.020	0.994	1.095	0.188	0.179	0.142	0.104	0.113	0.342
	1	1.2	0.023	0.019	0.994	1.195	0.190	0.172	0.147	0.101	0.118	0.339
	1	1.3	0.023	0.017	0.994	1.296	0.192	0.166	0.151	0.098	0.122	0.337
	1	1.4	0.024	0.016	0.994	1.396	0.194	0.160	0.155	0.095	0.126	0.334
	1	1.5	0.024	0.015	0.994	1.496	0.195	0.154	0.159	0.093	0.130	0.332

Table 10: Equilibrium collaboration when the EG is present and the environmental benefit is linear.

Table 10 shows that, relative to concave environmental benefits, collaboration efforts are significantly decreased in the linear case. Here, we see that as the cost asymmetry increases (higher γ_i), the EG increases its collaboration effort with the relatively more efficient firm j and decreases its collaboration effort with the relatively inefficient firm i. The lower level of collaboration effort decreases the investment in abatement by both firms. Under both linear and concave environmental benefits, the efficient firm increases its abatement effort as its rival becomes relatively more inefficient. However, in the linear case, the collaboration effort from the EG reinforces this effect. As the cost asymmetry increases (lower rows), we see the same patterns in firm abatement, emissions, the emission fee, and social welfare as in the concave case.

	Introducing regulation			Introducing EG		
$\gamma_i - \gamma_j$	when EG is absent	when EG is present	difference	when reg. is absent	when reg. is present	difference
0	0.235	0.236	0.001	-0.0006	0.0003	0.0009
0.1	0.232	0.238	0.006	-0.0008	0.0056	0.0064
0.2	0.228	0.239	0.011	-0.0008	0.0107	0.0115
0.3	0.223	0.240	0.017	-0.0008	0.0156	0.0164
0.4	0.219	0.240	0.021	-0.0008	0.0203	0.0211
0.5	0.215	0.241	0.026	-0.0008	0.0248	0.0256

Table 11: Welfare gains from regulation and from EG.

Table 11 is analogous to Table 3, evaluating the welfare gains from regulation and the EG. (The first column, when regulation alone is introduced, coincides with that in Table 3.) When regulation is added and the EG is already present (see the second column), it produces a larger welfare than when environmental benefits are concave. This is a result of the EG's lower collaboration effort resulting in reduced abatement without regulation, and regulation eliciting a larger increase in abatement than in the concave environmental benefits case. The welfare benefits from introducing the EG are now smaller than in the concave case, which is a result of a lower collaboration effort under a linear environmental benefit. When regulation is absent, the introduction of the EG decreases welfare (fourth column). In this case, the cost of the EG's collaboration efforts outweigh the social benefits from the additional reduction in emissions resulting from the EG's collaboration.

6 Profit gains

In this section, we evaluate how the introduction of environmental regulation, the EG's collaboration, or both, affect firms' profits. Table 12 considers the equilibrium results when the EG's environmental benefit is concave (see section 3) and the same parameter values as table 1. In this context, the first (second) column measures the profit gain that can be directly attributed to the EG's collaboration effort, in a setting where the regulator is absent (present, respectively). The third (fourth) column evaluate, instead, the profit gain due to environmental policy when the EG is absent (present, respectively). Overall, our results indicate that the EG yields, essentially, no profit gains, which holds when firms are symmetric in their abatement costs (top row) and when they become more cost asymmetric (bottom rows). Intuitively, this occurs because, when the EG's environmental benefit is concave, it chooses relatively balanced collaboration effort across both firms, which keeps their cost differential mostly unaffected, not increasing their profits substantially. When regulation is added, the profits of both firms decrease, but those of the firm with the highest abatement cost are impacted the most. Unlike the EG's relatively equal impact on both firms, regulation is more costly to the firm that emits more pollution, thus the unequal impact of regulation on profits as firm are more asymmetric.

	Change in Equilibrium Profits							
	No reg, adding EG		Reg, adding EG		No EG, adding Reg		EG, adding Reg	
$\gamma_i - \gamma_j$	Firm j	Firm i	Firm j	Firm i	Firm j	Firm i	Firm j	Firm i
0	0.0000	0.0000	0.0013	0.0013	-0.0166	-0.0166	-0.0153	-0.0153
0.1	0.0000	0.0000	0.0013	0.0012	-0.0166	-0.0181	-0.0153	-0.0169
0.2	0.0000	0.0000	0.0012	0.0012	-0.0166	-0.0196	-0.0154	-0.0184
0.3	0.0001	0.0000	0.0012	0.0012	-0.0165	-0.0210	-0.0154	-0.0198
0.4	0.0000	0.0000	0.0012	0.0011	-0.0165	-0.0222	-0.0153	-0.0211
0.5	0.0001	0.0000	0.0011	0.001	-0.0164	-0.0234	-0.0154	-0.0223

Table 12: Change in equilibrium profit from the introduction of the EG or regulation under concave environmental benefits.

Table 13 reports profit gains, but considering now our equilibrium results when the EG's environmental benefit is linear in emission reductions. As shown in section 5, equilibrium collaboration effort is significantly smaller, but more targeted to the firm that already exhibited a lower abatement cost. In a polluting, unregulated industry, this decreases the profits for the relatively efficient firm while having essentially (due to rounding) no effect on the inefficient firm. When the EG is present, the introduction of regulation has a smaller negative impact on each firm's profits. However, the efficient firm's profits are impacted less as a result of the more targeted collaboration effort, which makes collaboration more attractive for the most efficient firm. If the EG's environmental benefit is linear, firms would be more likely to welcome collaboration from an EG when they are already facing environmental regulation, and reject collaboration in the absence of such policy.

	Change in Equilibrium Profits							
	No reg, adding EG		Reg, adding EG		No EG, adding Reg		EG, adding Reg	
$\gamma_i - \gamma_j$	Firm j	Firm i	Firm j	Firm i	Firm j	Firm i	Firm j	Firm i
0	0.0000	0.0000	0.0001	0.0001	-0.0166	-0.0166	-0.0165	-0.0165
0.1	-0.0001	0.0000	0.0001	0.0000	-0.0166	-0.0181	-0.0164	-0.0181
0.2	-0.0002	0.0000	0.0001	0.0001	-0.0166	-0.0196	-0.0163	-0.0195
0.3	-0.0002	0.0000	0.0001	0.0001	-0.0165	-0.0210	-0.0162	-0.0209
0.4	-0.0004	0.0000	0.0001	0.0001	-0.0165	-0.0222	-0.0160	-0.0219
0.5	-0.0005	0.0000	0.0002	0.0000	-0.0164	-0.0234	-0.0157	-0.0234

Table 13: Change in equilibrium profit from the introduction of the EG or regulation under linear environmental benefits.

7 Discussion

Balancing investment in abatement. When firms are symmetric in their initial abatement costs, $\gamma_i = \gamma_j$, the EG collaborates equally with both firms, $b_i = b_j$. However, when one of them is more cost-inefficient than its rival, the EG chooses to help the more cost-inefficient firm, yielding a more balanced investment in abatement profile from both firms. In other words, the EG's benefit from emission reduction exhibits a "preference for variety" in investment in abatements, instead of inducing unbalanced abatement profiles. Our above results do not entail that the EG induces identical abatement levels from all firms. Its presence ameliorates the asymmetric abatement profiles that would emerge in equilibrium otherwise (without the EG), but can still lead to $z_i^* \neq z_j^*$.

Asymmetric collaboration profiles. When the EG can more effectively decrease the firms' abatement costs, the EG is more environmentally conscious, or consumers are more environmentally conscious, the EG increases its collaboration efforts with the firms leveraging these effects to further decrease emissions and environmental damage. However, when collaboration is more costly or emissions are more damaging to the environment, the EG reduces its collaboration effort. In the latter case, the increase in environmental damage from emissions increases the emission fee, which induces more abatement from the firms through regulation instead of through collaboration with the EG. As the inefficient firm's abatement costs increase and it becomes extremely less efficient than its rival, the EG's collaboration effort with the efficient firm converges to zero and the EG only collaborates with the inefficient firm.

Welfare gains of two agents. When firms are symmetric in their abatement costs, the welfare gains of adding one more agent (EG or regulator) when another agent was already present is negative, or positive but negligible. This result goes in line with that in Espinola-Arredondo et al. (2021), namely, introducing an EG in an already regulated industry or, similarly, introducing regulation to an industry where the EG already operates, is either welfare decreasing or just produces negligible welfare gains. However, as firms become more asymmetric in their abatement costs, the welfare gains of the introduction of a second agent increase, making their simultaneous presence more welfare improving. Therefore, adding an EG in an already regulated industry is particularly welfare improving when firms are quite asymmetric in their initial abatement costs, such as when they are different in their experience operating in the industry, in their R&D departments, or in their access to capital markets. Even if in asymmetric settings, where the EG mostly collaborates with the cost-inefficient firm, the increase in aggregate abatement (relative to the setting where the EG is absent) can lead to a significant pollution reduction, ultimately yielding large welfare gains.

Impact on firm profits. How the EG values emissions reduction has a impact on the partnered firms' profits. Both efficient and inefficient firms prefer that the EG values relatively balanced emission reduction across firms (concave environmental benefits) rather than aggregate emissions reduction (linear environmental benefits). If the EG values a relatively balanced emission reduction, both firms' profit increase when an EG enters an already regulated market compared to a much smaller increase in profit if the EG values aggregate emissions reduction. Similarly, firms incur a smaller decrease in profit if they are partnered with an EG and firms are then regulated when the EG values more balanced reduction in emissions.

A Appendix

A.1 Proof of Lemma 1

The first-order condition from the firm's problem is

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

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

$$q_i(q_j) = \frac{1}{2}[a + \lambda z_i - t] - \frac{1}{2}q_i.$$

Firm j has a symmetric best response function. Simultaneously solving the best response functions for q_i and q_j, we obtain equilibrium output in the fourth stage of,

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

We find that output is positive if and only if,

$$z_i > \frac{1}{2}z_j - \frac{a-t}{2\lambda}.$$

Inserting equilibrium output in the firm's fourth-stage profits, we find,

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

A.2 Proof of Corollary 1

Taking a derivative of firm i's profit with respect to z_i, λ, z_j, and t we obtain:

$$\begin{aligned}
\frac{\partial \pi_i(t)}{\partial z_i} &= \frac{1}{9}(4\lambda(a + 2\lambda z_i - \lambda z_j) + (9 - 4\lambda)t) > 0, \\
\frac{\partial \pi_i(t)}{\partial \lambda} &= \frac{2}{9}(2z_i - z_j)(a - t + 2\lambda z_i - \lambda z_j) > 0, \\
\frac{\partial \pi_i(t)}{\partial z_j} &= -\frac{2}{9}\lambda(a - t + \lambda(2z_i - z_j)) < 0, \\
\frac{\partial \pi_i(t)}{\partial t} &= -\frac{1}{9}(2(a - t) + 4\lambda z_i - 9z_i - 2\lambda z_j).
\end{aligned}$$

The final comparative static is positive, $\frac{\partial \pi_i(t)}{\partial t} > 0$, if $z_i < \frac{2(a-t-\lambda z_j)}{9-4\lambda}$.

A.3 Proof of Lemma 2

In the third stage, the regulator's problem is,

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

The first-order condition is,

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

Solving for t, we obtain the emission fee,

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

in which $t(Z) > 0$ if and only if $Z < \frac{2a(4d-1)}{\lambda+4d(3-\lambda)} \equiv \tilde{Z}$. The emission fee is unambiguously decreasing in aggregate abatement Z, and increasing in public image λ:

$$\frac{\partial t(Z)}{\partial Z} = \frac{4d(\lambda-3)-\lambda}{8d+4} < 0$$
$$\frac{\partial t(Z)}{\partial \lambda} = \frac{(4d-1)Z}{8d+4} > 0.$$

The comparative static on the emission fee with respect to environmental damage d is,

$$\frac{\partial t(Z)}{\partial d} = \frac{6a + 3(\lambda-2)Z}{2(2d+1)^2},$$

which is positive if and only if $Z < \frac{2a}{2-\lambda} \equiv \bar{Z}$. Comparing $\bar{Z}$ and $\tilde{Z}$, we find that $\bar{Z} > \tilde{Z}$ under all parameter conditions:

$$\bar{Z} \equiv \frac{2a}{2-\lambda} > \frac{2a(4d-1)}{\lambda+4d(3-\lambda)} \equiv \tilde{Z},$$

which simplifies to $d > -\frac{1}{2}$, which always holds as $d > \frac{1}{2}$.

A.4 Proof of Lemma 3

In the second stage, we first evaluate realized equilibrium profits in the fourth stage $\pi_k(z_i, z_j) = \pi_k(t(Z))$, where $t(Z)$ is from Lemma 2. Inserting this into each firm i's problem in the second stage, we have that

$$\max_{z_i \geq 0} \pi_i(z_i, z_j) - \frac{1}{2}(\gamma_i - \theta b_i)(z_i)^2,$$

and differentiating with respect to z_i we find

$$\frac{a(8d-2) + (4d(\lambda-3)-\lambda)(z_i+z_j)}{8d+4} + \frac{(4d(\lambda+1)+3\lambda)(2a + 4d((1+\lambda)z_i + (1-\lambda)z_j) + \lambda(3z_i - z_j))}{8(2d+1)^2}$$
$$+ z_i(b_i\theta_i - \gamma_i) + \frac{z_i(4d(\lambda-3)-\lambda)}{8d+4} = 0$$

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

$$z_i(z_j) = \frac{1}{A}\left[8ad(4d+\lambda+2) + 6a\lambda - 4a\right] - \frac{1}{A}[2\lambda + (4d+3)\left(\lambda^2 + 4d(2+\lambda(\lambda-1))\right)]z_j,$$

where $A \equiv 16d(5d+3+2(d+1)(\gamma_i - b_i\theta)) + 8(\gamma_i - b_i\theta) - (4d+3)^2\lambda^2 - 32d(2d+1)\lambda + 4\lambda$. Taking derivatives of A with respect to γ_i and γ_j yields

$$\frac{\partial A}{\partial \gamma_i} = 8(1+2d)^2,$$
$$\frac{\partial A}{\partial \gamma_j} = 0.$$

Firm j has a symmetric best response function. This best response function has the following properties:

1. when $b_i = 0$ and $\lambda = 0$, the best response function is

$$z_i(z_j) = \frac{a\left(8d^2 + 4d - 1\right) - 2d(4d+3)z_j}{2\gamma_i + 4d(2\gamma_i(d+1) + 5d + 3)},$$

which is unambiguously decreasing in z_j;

2. when $b_i = 0$ and $\lambda > 0$, the best response function is

$$z_i(z_j) = \frac{8ad(4d+\lambda+2) + a(6\lambda - 4) - z_j\left[(4d+3)\left(4d((\lambda-1)\lambda+2)+\lambda^2\right) - 2\lambda\right]}{8\gamma_i + 16d(2\gamma_i(d+1)+5d+3) - (4d+3)^2\lambda^2 - 32d(2d+1)\lambda + 4\lambda},$$

and is decreasing in z_j if and only if $\gamma_i > \bar{\gamma}$;

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

where $\bar{\gamma} \equiv \frac{\lambda(9\lambda-4)+8d[\lambda(3\lambda+4)-6]-16d^2(1-\lambda)(5+\lambda)}{8(1+2d)^2}$. This cutoff decreases in d, and increases in λ as follows:

$$\frac{\partial\bar{\gamma}}{\partial d} = -\frac{(4d+3)(\lambda-2)^2}{2(2d+1)^3} < 0,$$
$$\frac{\partial\bar{\gamma}}{\partial\lambda} = \frac{8d(2d(\lambda+2)+3\lambda+2)+9\lambda-2}{4(2d+1)^2} > 0.$$

A.5 Proof of Proposition 1

Simultaneously solving for z_i and z_j in the best response function $z_i(z_j)$, and $z_j(z_i)$ yields the equilibrium abatement

$$z_i(b_i, b_j) = \frac{1}{B}\left[a(4d(4d+\lambda+2)+3\lambda-2)\left(4d(3+2(\gamma_j - b_j\theta) - \lambda(2\lambda+3)) + 4(\gamma_j - b_j\theta) - 6\lambda^2 + \lambda\right)\right]$$

for each firm i, where the term B is defined as

$$\begin{aligned}
B \equiv\ & 3\lambda^2(6\theta(b_i+b_j) - 6(\gamma_i+\gamma_j)+1) + 8\lambda(-\theta(b_i+b_j)+\gamma_i+\gamma_j) + 16(\gamma_i - b_i\theta)(\gamma_j - b_j\theta) \\
& + 32d^3\left[\lambda^2(2\theta(b_i+b_j) - 2(\gamma_i+\gamma_j+1) - 8\lambda(-\theta(b_i+b_j)+\gamma_i+\gamma_j) + 4b_i\theta b_j\theta - \gamma_j) - 10\theta b_i + b_j)\right. \\
& \left. + 2\gamma_i(2(\gamma_j - b_j\theta)+5) + 10\gamma_j + 10\lambda^3 - 36\lambda + 21\right] + 16d^2\left[-4\lambda^2(-2\theta(b_i+b_j) + 2(\gamma_i+\gamma_j)+7) - \right. \\
& 16\lambda(-\theta(b_i+b_j)+\gamma_i+\gamma_j) + 2(6b_i\theta(b_j\theta - \gamma_j) + \gamma_i(6(\gamma_j - b_j\theta)+11)) - 22\theta(b_i+b_j) + 22\gamma_j + 2\lambda^4 \\
& \left. +29\lambda^3 - 40\lambda + 27\right] + 2d\left[48\left(-\theta(b_i\gamma_j + b_i + b_j\gamma_i + b_j) + b_ib_j\theta^2 + \gamma_i\gamma_j + \gamma_i + \gamma_j\right)\right. \\
& \left. +\lambda^2(42\theta(b_i+b_j) - 42\gamma_i - 42\gamma_j - 155) + 12\lambda(2\theta(b_i+b_j) - 2\gamma_i - 2\gamma_j + 3) + 24\lambda^4 + 70\lambda^3\right] \\
& + 18\lambda^4 - 21\lambda^3.
\end{aligned}$$

When the EG is absent, $b_i = b_j = 0$, each firm i's equilibrium abatement is

$$z_i(0,0) = \frac{1}{C}\left[a(4d(4d+\lambda+2)+3\lambda-2)\left(4\gamma_j + 4d(2\gamma_j - \lambda(2\lambda+3)+3) - 6\lambda^2 + \lambda\right)\right]$$

where the term C is defined as

$$\begin{aligned}
C \equiv\ & -\lambda^2(3(6\gamma_i+6\gamma_j-1) + 2d(42\gamma_i+42\gamma_j+16d(4\gamma_i+4\gamma_j+d(2\gamma_i+2\gamma_j-1)+14)+155)) \\
& + 8\lambda(\gamma_i+\gamma_j - d(6\gamma_i+6\gamma_j+16d(2\gamma_i+2\gamma_j+d(2\gamma_i+2\gamma_j+9)+5)-9)) \\
& + 16(\gamma_j(2d+1)(\gamma_i+2d(2\gamma_i(d+1)+5d+3)) + d(6\gamma_i+d(22\gamma_i+(20\gamma_i+42)d+27))) \\
& + 2(4d+3)^2\lambda^4 + (4d+3)(8d(10d+7)-7)\lambda^3
\end{aligned}$$

A.6 Proof of Proposition 2

The EG's marginal benefit is

$$MB_i \equiv \frac{1}{2}\beta(ER_i)^{-\frac{1}{2}}\left[\frac{\partial ER_i}{\partial b_i}\right] + \frac{1}{2}\beta(ER_j)^{-\frac{1}{2}}\left[\frac{\partial ER_j}{\partial b_i}\right]$$
$$= \frac{1}{2}\beta(ER_i)^{-\frac{1}{2}}\left[\frac{\partial e_i^{NoEG}}{\partial b_i} - \frac{\partial e_i^{EG}}{\partial b_i}\right] + \frac{1}{2}\beta(ER_j)^{-\frac{1}{2}}\left[\frac{\partial e_j^{NoEG}}{\partial b_i} - \frac{\partial e_j^{EG}}{\partial b_i}\right]$$

We can simplify this further since $\frac{\partial e_i^{NoEG}}{\partial b_i} = \frac{\partial e_j^{NoEG}}{\partial b_i} = 0$ and $\frac{\partial e_i^{EG}}{\partial b_i} = \frac{\partial q}{\partial b_i} - \frac{\partial z_i}{\partial b_i}$, where $q(t(z_i(b_i, b_j), z_j(b_i, b_j)))$. Therefore,

$$\frac{\partial q}{\partial b_i} = \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\frac{\partial z_i}{\partial b_i} + \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\frac{\partial z_j}{\partial b_i},$$

which simplifies further to $\frac{\partial q}{\partial b_i} = \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\left(\frac{\partial z_i}{\partial b_i} + \frac{\partial z_j}{\partial b_i}\right)$. We also know that since $t(Z) = t(z_i + z_j)$, then $\frac{\partial t}{\partial z_i} = \frac{\partial t}{\partial z_j}$. Substituting this into MB_i, we obtain

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

A.7 Robustness Checks

A.7.1 Higher $\theta = 0.45$.

Since θ only shows up in the EG's problem, the equilibrium values in the absence of the EG coincide with those in Table 1b.

	γ_j	γ_i	b_j^*	b_i^*	$\gamma_j - \theta b_j$	$\gamma_i - \theta b_i$	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.385	0.385	0.827	0.827	0.196	0.196	0.118	0.105	0.105	0.354
	1	1.1	0.368	0.393	0.834	0.923	0.198	0.188	0.124	0.101	0.109	0.350
	1	1.2	0.351	0.400	0.842	1.020	0.199	0.181	0.129	0.098	0.115	0.347
	1	1.3	0.335	0.405	0.849	1.118	0.201	0.174	0.134	0.095	0.119	0.343
	1	1.4	0.319	0.409	0.856	1.216	0.202	0.168	0.139	0.093	0.124	0.341
	1	1.5	0.304	0.412	0.863	1.314	0.203	0.162	0.144	0.090	0.128	0.339

TABLE A1.Equilibrium collaboration efforts when the EG collaborates with both firms at $\theta = 0.45$.

	γ_j	γ_i	ε_{b_j}	ε_{b_i}	ε_{z_j}	ε_{z_i}	ε_t	$\varepsilon_{e_i+e_j}$	ε_{e_j}	ε_{e_i}	ε_{SW}
Benchmark	1	1.1	-0.04	0.02	0.01	-0.04	0.05	0.00	-0.04	0.04	-0.01
	1	1.2	-0.05	0.02	0.01	-0.04	0.04	0.01	-0.03	0.06	-0.01
	1	1.3	-0.05	0.01	0.01	-0.04	0.04	0.01	-0.03	0.04	-0.01
	1	1.4	-0.05	0.01	0.00	-0.04	0.04	0.01	-0.03	0.04	-0.01
	1	1.5	-0.05	0.01	0.00	-0.04	0.04	0.01	-0.03	0.03	-0.01

TABLE A2.Equilibrium collaboration efforts and elasticities when the EG collaborates with both firms at $\theta = 0.45$.

A.7.2 Higher $\beta = 0.2$.

Since β only affects the EG's problem, the equilibrium values in the absence of the EG coincide with those in Table 1b.

	γ_j	γ_i	b_j^*	b_i^*	$\gamma_j - \theta b_j$	$\gamma_i - \theta b_i$	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.495	0.495	0.876	0.876	0.193	0.193	0.124	0.106	0.106	0.348
	1	1.1	0.473	0.506	0.882	0.974	0.195	0.185	0.129	0.102	0.111	0.345
	1	1.2	0.452	0.514	0.887	1.071	0.197	0.178	0.135	0.099	0.116	0.342
	1	1.3	0.431	0.521	0.892	1.170	0.198	0.172	0.139	0.096	0.120	0.339
	1	1.4	0.410	0.527	0.897	1.268	0.200	0.165	0.144	0.093	0.124	0.336
	1	1.5	0.391	0.531	0.902	1.367	0.201	0.160	0.148	0.091	0.128	0.334

TABLE A3. Equilibrium collaboration efforts when the EG collaborates with both firms at $\beta = 0.2$.

	γ_j	γ_i	ε_{b_j}	ε_{b_i}	ε_{z_j}	ε_{z_i}	ε_t	$\varepsilon_{e_i+e_j}$	ε_{e_j}	ε_{e_i}	ε_{SW}
Benchmark	1	1.1	-0.04	0.02	0.01	-0.04	0.04	0.00	-0.04	0.05	-0.01
	1	1.2	-0.04	0.02	0.01	-0.04	0.05	0.02	-0.03	0.05	-0.01
	1	1.3	-0.04	0.01	0.01	-0.03	0.03	0.00	-0.03	0.03	-0.01
	1	1.4	-0.05	0.01	0.01	-0.04	0.03	0.00	-0.03	0.03	-0.01
	1	1.5	-0.05	0.01	0.01	-0.03	0.03	0.01	-0.02	0.03	-0.01

TABLE A4. Equilibrium collaboration efforts and elasticities when the EG collaborates with both firms at $\beta = 0.2$.

A.7.3 Higher $d = 1.25$.

	γ_j	γ_i	b_j^*	b_i^*	$\gamma_j - \theta b_j$	$\gamma_i - \theta b_i$	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.293	0.293	0.927	0.927	0.200	0.200	0.155	0.089	0.089	0.344
	1	1.1	0.280	0.299	0.930	1.025	0.202	0.192	0.161	0.085	0.094	0.341
	1	1.2	0.267	0.305	0.933	1.124	0.204	0.185	0.166	0.082	0.098	0.337
	1	1.3	0.255	0.309	0.936	1.223	0.205	0.178	0.171	0.079	0.103	0.334
	1	1.4	0.243	0.313	0.939	1.322	0.207	0.172	0.176	0.076	0.107	0.332
	1	1.5	0.231	0.316	0.942	1.421	0.208	0.167	0.180	0.073	0.111	0.329

TABLE A5A. Equilibrium collaboration efforts when the EG collaborates with both firms at $d = 1.25$.

	γ_j	γ_i	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.196	0.196	0.163	0.090	0.090	0.341
	1	1.1	0.197	0.188	0.169	0.086	0.095	0.337
	1	1.2	0.200	0.181	0.174	0.083	0.100	0.334
	1	1.3	0.202	0.175	0.179	0.080	0.104	0.331
	1	1.4	0.203	0.169	0.183	0.077	0.108	0.329
	1	1.5	0.205	0.163	0.187	0.074	0.112	0.327

TABLE A5B. Equilibrium collaboration efforts in the absence of the EG at $d = 1.25$.

	γ_j	γ_i	ε_{b_j}	ε_{b_i}	ε_{z_j}	ε_{z_i}	ε_t	$\varepsilon_{e_i+e_j}$	ε_{e_j}	ε_{e_i}	ε_{SW}
Benchmark	1	1.1	-0.04	0.02	0.01	-0.04	0.04	0.01	-0.04	0.06	-0.01
	1	1.2	-0.04	0.02	0.01	-0.04	0.03	0.01	-0.04	0.04	-0.01
	1	1.3	-0.04	0.01	0.01	-0.04	0.03	0.01	-0.04	0.04	-0.01
	1	1.4	-0.05	0.01	0.01	-0.03	0.03	0.01	-0.04	0.04	-0.01
	1	1.5	-0.05	0.01	0.00	-0.03	0.03	0.01	-0.04	0.04	-0.01

TABLE A6.Equilibrium collaboration efforts and elasticities when the EG collaborates with both firms at $d = 1.25$.

A.7.4 Higher $c_{EG} = 0.1$.

Since c_{EG} only affects the EG's problem, the equilibrium values in the absence of the EG coincide with those in Table 1b.

	γ_j	γ_i	b_j^*	b_i^*	$\gamma_j - \theta b_j$	$\gamma_i - \theta b_i$	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.065	0.065	0.984	0.984	0.187	0.187	0.136	0.107	0.107	0.345
	1	1.1	0.062	0.067	0.984	1.083	0.190	0.180	0.141	0.104	0.113	0.342
	1	1.2	0.059	0.068	0.985	1.183	0.191	0.173	0.146	0.101	0.117	0.339
	1	1.3	0.057	0.069	0.986	1.283	0.193	0.166	0.150	0.098	0.122	0.337
	1	1.4	0.054	0.069	0.986	1.383	0.194	0.160	0.154	0.095	0.126	0.334
	1	1.5	0.052	0.070	0.987	1.482	0.196	0.155	0.158	0.093	0.129	0.332

TABLE A7.Equilibrium collaboration efforts when the EG collaborates with both firms at $c_{EG} = 0.1$.

A.7.5 Higher $\lambda = 0.2$.

	γ_j	γ_i	b_j^*	b_i^*	$\gamma_j - \theta b_j$	$\gamma_i - \theta b_i$	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.316	0.316	0.921	0.921	0.207	0.207	0.107	0.105	0.105	0.370
	1	1.1	0.302	0.323	0.925	1.019	0.209	0.198	0.113	0.101	0.110	0.366
	1	1.2	0.287	0.190	0.928	1.118	0.211	0.190	0.119	0.098	0.115	0.362
	1	1.3	0.274	0.334	0.932	1.217	0.213	0.183	0.124	0.095	0.120	0.359
	1	1.4	0.260	0.337	0.935	1.316	0.215	0.176	0.129	0.092	0.124	0.356
	1	1.5	0.247	0.340	0.938	1.415	0.217	0.169	0.133	0.090	0.128	0.353

TABLE A8A. Equilibrium collaboration efforts when the EG collaborates with both firms at $\lambda = 0.2$.

	γ_j	γ_i	z_j^*	z_i^*	t^*	e_j^*	e_i^*	SW
Benchmark	1	1	0.202	0.202	0.116	0.106	0.106	0.365
	1	1.1	0.204	0.193	0.122	0.102	0.111	0.362
	1	1.2	0.207	0.186	0.127	0.111	0.116	0.358
	1	1.3	0.209	0.178	0.132	0.097	0.121	0.355
	1	1.4	0.211	0.172	0.137	0.094	0.125	0.353
	1	1.5	0.212	0.166	0.141	0.091	0.129	0.350

TABLE A8B. Equilibrium collaboration efforts in the absence of the EG at $\lambda = 0.2$.

A.8 No EG, regulation present

In this case, there is no actor in the first stage and the results from the fourth stage (Lemma 1) and the third stage (Lemma 2) are unchanged:

$$q_i = \frac{1}{3}(a - t + 2\lambda z_i - \lambda z_j),$$
$$t = \frac{2a(4d-1) - (z_i + z_j)[\lambda + 4d(3-\lambda)]}{4(1+2d)}.$$

Second Stage. We can use the result from Proposition 1 where $z_i(b_i, b_j)$ is evaluated at $b_i = b_j = 0$ to obtain each firm i's equilibrium investment in abatement in the absence of the EG,

$$z_i^{NoEG} = \frac{1}{C}\left[a(4d(4d+\lambda+2)+3\lambda-2)\left(4\gamma_j + 4d(2\gamma_j - \lambda(2\lambda+3)+3) - 6\lambda^2 + \lambda\right)\right].$$

which entails equilibrium profits of

$$\pi_i^{NoEG} = \frac{1}{9}\left[a^2 + 2\lambda(a-t)(2z_i^{NoEG} - z_j^{NoEG}) - 2at + t^2 - \lambda^2(2z_i^{NoEG} - z_j^{NoEG})^2\right] + tz_i^{NoEG}.$$

Social welfare in this case is

$$SW = \frac{1}{2}[q_i + q_j]^2 + \pi_i + \pi_j + t[q_i + q_j - z_i - z_j] - d[q_i + q_j - z_i - z_j]^2,$$

where the $NoEG$ superscripts are removed for readability.

A.9 No regulation, EG present

Fourth stage. In this case, the fourth stage remains unchanged except now we treat $t = 0$, and the results from Lemma 1 become,

$$q_i(z_i, z_j) = \frac{1}{3}\left(a + \lambda(2z_i - z_j)\right),$$
$$\pi_i(z_i, z_j) = \left(q_i(z_i, z_j)\right)^2.$$

Second Stage. In the absence of the regulator, there is no player in the third stage, so we proceed to the second stage of the game where each firm i solves

$$\max_{z_i \geq 0} \pi_i(z_i, z_j) - \frac{1}{2}(\gamma_i - \theta b_i)(z_i)^2.$$

The first-order condition is

$$\frac{4}{9}\lambda(a + \lambda(2z_i - z_j)) - (\gamma_i - \theta b_i)z_i = 0,$$

and firm i's best response function is

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

Firm j has a symmetric best response function. Simultaneously solving for z_i and z_j, we find

$$z_i^{NoReg} = \frac{4a\lambda\left(3(\gamma_j - \theta b_j) - 4\lambda^2\right)}{27(\gamma_i - \theta b_i)(\gamma_j - \theta b_j) - 24\lambda^2[(\gamma_i - \theta b_i) + (\gamma_j - \theta b_j)] + 16\lambda^4}.$$

First stage. The EG's problem remains

$$\max_{b_i,b_j\geq 0} \underbrace{[\beta(ER_i)^{\frac{1}{2}} - c_{EG}(b_i)^2]}_{\text{Firm } i} + \underbrace{[\beta(ER_j)^{\frac{1}{2}} - c_{EG}(b_j)^2]}_{\text{Firm } j}.$$

In the absence of the regulator, the firm's abatement is not impacted by an emissions fee (as $t = 0$) and solely incentivized by how abatement impacts demand, λ. The EG anticipates this when choosing its collaboration efforts b_i and b_j.

Social welfare in this case is

$$SW = \frac{1}{2}[q_i + q_j]^2 + \pi_i + \pi_j - d[q_i + q_j - z_i - z_j]^2 - c_{EG}(b_i^2 + b_j^2).$$

A.10 No regulation, no EG

In the absence of both the EG and the regulator, the game only includes stages two and four.

Fourth stage. We again use our result from Lemma A1 where $t = 0$, which yields

$$q_i(z_i, z_j) = \frac{1}{3}\left(a + \lambda(2z_i - z_j)\right),$$
$$\pi_i(z_i, z_j) = \left(q_i(z_i, z_j)\right)^2.$$

Second stage. Each firm i's problem in the second stage is

$$\max_{z_i\geq 0} \frac{1}{9}(a + \lambda(2z_i - z_j))^2 - \frac{1}{2}\gamma_i(z_i)^2,$$

with first-order condition

$$\frac{4}{9}\lambda(a + (\lambda z_i - z_j)) - \gamma_i z_i = 0,$$

and best response function

$$z_i(z_j) = \frac{4a\lambda}{9\gamma_i - 8\lambda^2} - \frac{4\lambda^2}{9\gamma_i - 8\lambda^2} z_j.$$

Firm j has a symmetric best response function. Simultaneously solving for z_i and z_j, we obtain

$$z_i^{NoEG,NoReg} = \frac{4a\lambda\left(3\gamma_j - 4\lambda^2\right)}{27\gamma_i\gamma_j - 24\lambda^2(\gamma_i + \gamma_j) + 16\lambda^4},$$

which coincides with z_i^{NoReg} when evaluated at $b_i = b_j = 0$ (see Appendix A.5). Inserting this equilibrium abatement level into firm i's equilibrium output, we obtain that

$$q_i^{NoEG,NoReg} = \frac{3a\gamma_i\left(3\gamma_j - 4\lambda^2\right)}{27\gamma_i\gamma_j - 24\lambda^2(\gamma_i + \gamma_j) + 16\lambda^4},$$

which entails equilibrium profits of

$$\pi_i^{NoEG,NoReg} = \frac{a^2\gamma_i\left(9\gamma_i - 8\lambda^2\right)\left(3\gamma_j - 4\lambda^2\right)^2}{\left(27\gamma_i\gamma_j - 24\lambda^2(\gamma_i + \gamma_j) + 16\lambda^4\right)^2}.$$

Social welfare in this case is

$$SW = \frac{1}{2}[q_i + q_j]^2 + \pi_i + \pi_j - d[q_i + q_j - z_i - z_j]^2,$$

which, when evaluated at the equilibrium is

$$SW = \frac{1}{\left(27\gamma_i\gamma_j - 24\lambda^2(\gamma_i+\gamma_j)+16\lambda^4\right)^2} 4a^2[-6\lambda^4\left(-9\gamma_i^2 - 22\gamma_i\gamma_j - 9\gamma_j^2 + 2d(\gamma_i+\gamma_j)(3\gamma_i+3\gamma_j-16)\right)$$
$$-72d\lambda^3\left(\gamma_i^2+6\gamma_i\gamma_j+\gamma_j^2\right) - 81\gamma_i^2\gamma_j^2(d-1) - 32\lambda^6(\gamma_i+\gamma_j+8d) + 192d\lambda^5(\gamma_i+\gamma_j)$$
$$+18\lambda^2(\gamma_i+\gamma_j)(-7\gamma_i\gamma_j+\gamma_i(6\gamma_j-2)d - 2\gamma_j d) + 108\gamma_i\gamma_j d\lambda(\gamma_i+\gamma_j)].$$

A.11 Proof of Proposition 3

The EG's marginal benefit is

$$MB_i \equiv \beta\left[\frac{\partial ER_i}{\partial b_i}\right] + \beta\left[\frac{\partial ER_j}{\partial b_i}\right] = \beta\left[\frac{\partial ER_i}{\partial b_i} + \frac{\partial ER_j}{\partial b_i}\right]$$
$$= \beta\left[\frac{\partial e_i^{NoEG}}{\partial b_i} - \frac{\partial e_i^{EG}}{\partial b_i} + \frac{\partial e_j^{NoEG}}{\partial b_i} - \frac{\partial e_j^{EG}}{\partial b_i}\right]$$

We can simplify this further since $\frac{\partial e_i^{NoEG}}{\partial b_i} = \frac{\partial e_j^{NoEG}}{\partial b_i} = 0$ and $\frac{\partial e_i^{EG}}{\partial b_i} = \frac{\partial q}{\partial b_i} - \frac{\partial z_i}{\partial b_i}$, where $q(t(z_i(b_i,b_j), z_j(b_i,b_j)))$. Therefore,

$$\frac{\partial q}{\partial b_i} = \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\frac{\partial z_i}{\partial b_i} + \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\frac{\partial z_j}{\partial b_i},$$

which simplifies further to $\frac{\partial q}{\partial b_i} = \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\left(\frac{\partial z_i}{\partial b_i} + \frac{\partial z_j}{\partial b_i}\right)$. We also know that since $t(Z) = t(z_i + z_j)$, then $\frac{\partial t}{\partial z_i} = \frac{\partial t}{\partial z_j}$. Substituting this into MB_i, we obtain

$$MB_i \equiv \beta\left[\frac{\partial z_i}{\partial b_i} - \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\left(\frac{\partial z_i}{\partial b_i} + \frac{\partial z_j}{\partial b_i}\right) + \frac{\partial z_j}{\partial b_i} - \frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\left(\frac{\partial z_i}{\partial b_i} + \frac{\partial z_j}{\partial b_i}\right)\right],$$
$$= \beta\left[\frac{\partial z_i + z_j}{\partial b_i} - 2\frac{\partial q}{\partial t}\frac{\partial t}{\partial z_i}\left(\frac{\partial z_i + z_j}{\partial b_i}\right)\right].$$

References

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

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

Espinola-Arredondo, A., E. Stathopoulou, and F. Munoz-Garcia (2021) "Regulators and environmental groups: Better together or apart?" forthcoming *Environment and Development Economics.*

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

Harbaugh, R., J.W. Maxwell, and B. Roussillon (2011) "Label confusion: The Groucho effect of uncertain standards" *Management Science* **57**(9), 1512-1527.

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

Heijnen, P. (2013) "Information advertising by an environmental group" *Journal of Economics* **108**(3), 249-272.

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

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), 978-996.

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

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

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), 5-39.

Reynaert, M. (2021) "Abatement Straegies and the Cost of Environmental Regulation: Emission Standards on the European Car Market" *The Review of Economic Studies* **88**(1), pp. 454–488.

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

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), 61-76.

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

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.

Stathopoulou, E. and L. Gautier (2019) "Green alliances and the role of taxation" *Environmental and Resource Economics* **74**(3), 1189-1206.

van der Made, A. and L. Schoonbeek (2009) "Information provision by interest groups" *Environmental and Resource Economics* **43**(4), 457-472.

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