Tax versus Regulations: Robustness to Polluter Lobbying Against Near-Zero Emission Targets

Hirose, Kosuke and Ishihara, Akifumi and Matsumura, Toshihiro

Osaka University of Economics, Institute of Social Science, University of Tokyo, Institute of Social Science, University of Tokyo

20 June 2021

Tax versus Regulations: Robustness to Polluter Lobbying Against Near-Zero Emission Targets*

Kosuke Hirose[†] Akifumi Ishihara[‡] Toshihiro Matsumura[§]

June 21, 2021

Abstract

We investigate polluter lobbying against near-zero emission targets in a monopoly market. To this end, we compare three typical environmental policies—an emission cap regulation that restricts total emissions, an emission intensity regulation that restricts emissions per output unit, and an emission tax. We presume a policy to be most robust to lobbying when a lesser strict emission target (i.e., an increase in the targeted emission level) imposed by the government to the industry increases the firms' profit least significantly among the three policies. We find that the emission tax is the most robust in the presence of lobbying if the government aims for a net-zero emission society. However, the emission tax is the least robust if the emission target is loose or the government is weak against lobbying.

JEL classification codes: Q52, L13, L51

Keywords: net-zero emission industry, emission cap, emission intensity, emission tax, emission equivalence, profit ranking

---

[*] We are grateful to Chanyoung Lee. Sang-Ho Lee, and the participants of seminar at Chonnam National University for their helpful comments and suggestions. This work was supported by JSPS KAKENHI (19K13703, 21K01398).

[†] Corresponding author: Osaka University of Economics, 2-2-8, Ohsumi, Higashiyodogawa-Ku, Osaka 533-8533, Japan. E-mail: hirose@osaka-ue.ac.jp

[‡] Institute of Social Science, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. Phone:(81)-3-5841-4937. Fax:(81)-3-5841-4905. E-mail:akishihara@iss.u-tokyo.ac.jp

[§] Institute of Social Science, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. Phone:(81)-3-5841-4932. Fax:(81)-3-5841-4905. E-mail:matsumur@iss.u-tokyo.ac.jp, ORCID:0000-0003-0572-6516

1 Introduction

Currently, global warming is one of the most serious risks that societies face. As such, many countries have voluntarily committed to reducing their CO2 emissions under the Paris Agreement on climate change. Moreover, several European countries declared that they aim to achieve net-zero emission societies and China and Japan have followed suit.[1] To reach this goal, several industries that emit huge CO2 amounts, such as electric power, steel, and transportation, may face near-zero emission constraints imposed by the authorities. For example, US president Joe Biden signed a new executive order for the commitment to build a carbon pollution-free electricity sector by 2035 and reach net zero emissions by 2050 in the national level.[2] However, such strict policies may substantially reduce firm profits and, thus, firms may have strong incentives to lobby against restrictions and in favor of weaker regulations that increase the upper limit of an industry's emissions. Environmental policies affect industry-level profits, which is why firms often try to influence policymakers (Lowry, 1992; Engel, 1997). Therefore, ambitious environmental policies may not be easily implementable in the presence of polluter lobbying.

In this study, we investigate the robustness of environmental policies to industry lobbying under three environmental policies that are intensively discussed in the literature: an emission cap regulation, an emission intensity regulation, and an emission tax. To this end, we consider a monopoly industry and derive the relationship between the targeted emission level and monopoly profit.[3] We presume that firms have stronger lobbying incentives to manipulate emission targets when a lesser strict emission policy (i.e., an increase in the upper limit of emissions) increases firms' profits more significantly and also clarify under

---

[1] Reuters, https://jp.reuters.com/article/japan-politics-suga/japan-aims-for-zero-emissions-carbon-neutral-society-by-2050-pm-idUSKBN27B0FB

[2] Energy live news, https://www.energylivenews.com/2021/01/28/biden-wants-carbon-free-electricity-by-2035/

[3] Under the standard assumptions in this field, we can derive similar policy implications under symmetric Cournot oligopolies or a symmetric Bertrand oligopoly in a differentiated product market.

which typical environmental policies are firms' lobbying incentives strongest or weakest (i.e., the policy is the most vulnerable or robust to polluter lobbying).

We find that, when the targeted emission level is close to zero, an increase in this level most (least) significantly raises the monopoly profit under the emission cap (emission tax) regulation. In this case, for a near-zero emission target, the emission tax is the most robust to polluter lobbying because firms have the weakest incentives for manipulating targets. By contrast, when the targeted emission level is far from the zero-emission case, the emission tax policy is the most vulnerable to polluter lobbying.

Our results are consistent with the environmental policies adopted in Japan. Until recently, emission targets were significantly less strict in Japan than in European countries. The Japanese government has mainly used emission cap and intensity regulations as environmental policy tools and did not introduce an effective emission tax in the presence of aggressive lobbying by major industry groups. Recently, the new Japanese Cabinet—the Suga Cabinet–declared a net-zero emissions goal by 2050 for Japan and also initiated intensive discussions about the introduction of carbon pricing.[4] Our results support these policy choices in terms of robustness to industry lobbying.

The three environmental policies investigated in this paper are also intensively discussed in the literature (Amir et al., 2018; Alesina and Passarelli, 2014; Barnett, 1980; Baumol and Oates, 1988; Besanko, 1987; Helfand, 1991; Holland, 2012; Katsoulacos and Xepapadeas, 1996; Lahiri and Ono, 2007; Lee, 1999). Further, several studies have examined the welfare ranking of these environmental policy measures. In perfectly competitive markets, Pigovian taxes yield the first best (Pigou, 1932), as opposed to emission intensity regulations (Holland, 2012; Holland et al., 2009). This implies that emission taxes are best for welfare. However, in imperfectly competitive markets, the first best is not implementable by emission taxes,

---

[4] Reuters, https://www.reuters.com/article/japan-economy-climate-change/japan-advisers-urge-quick-adoption-of-carbon-pricing-to-hit-emissions-goal-idINL4N2KU3H6

owing to underproduction (Buchanan, 1969; Katsoulacos and Xepapadeas, 1996), which is why emission regulations may be better for welfare than an emission tax (Amir et al., 2018; Helfand, 1991; Holland, 2009; Kiyono and Ishikawa, 2013; Li and Shi 2015; Montero, 2002). Lahiri and Ono (2007) consider the case in which emission targets are close to the business-as-usual levels, and show that an emission intensity regulation may be better than an emission tax. Hirose and Matsumura (2020) show that, when emission targets are close to zero, the emission intensity regulation dominates the emission cap regulation and emission tax, whereas the inverse may hold when emission targets are moderate. However, the above-mentioned studies did not consider the threat of polluter lobbying.

Further, Aidt (1998, 2010) and Cai and Li (2020) adopt the approach of Grossman and Helpman (1994) to investigate polluters' lobbying activities in imperfectly competitive markets. They prove that there exists a relationship between lobbying intensity and firm characteristics, but do not compare lobbying activities under the typical environmental policy measures discussed in this study. Moreover, to the best of our knowledge, no study has hitherto presented a clear policy ranking against polluter lobbying when the implementing government aims to achieve near-zero emissions.

The rest of this paper is organized as follows. Section 2 formulates the basic model. Section 3 compares three environmental policies and shows that the emission tax policy is the most robust among them in the presence of lobbying if the government aims for a net-zero emission society. Section 4 uses parametric analysis and draws further policy implications. Section 5 concludes the paper. The appendix provides the proofs.

2 The Model

We consider an industry with a polluting monopolist. This firm produces a single commodity, for which the inverse demand function is given by $P : \mathbb{R}_+ \mapsto \mathbb{R}_+$. Let $c(q, x) : \mathbb{R}^2_+ \mapsto \mathbb{R}^2_+$

be the cost function, where q is the output and x the abatement level. Further, let $e(q, x) : \mathbb{R}_+^2 \mapsto \mathbb{R}_+^2$ be the pollution emission level. We assume that P, c, and e are twice continuously differentiable and satisfy $P' < 0$ as long as $P > 0$, $P' + P''q < 0$, $c_q > 0$, $c_x > 0$, $c_{qq} \geq 0$, $c_{xx} > 0$, $e_q > 0$, $e_x < 0$, $e_{qq} \geq 0$, and $e_{xx} > 0$ for $q, x > 0$, where the subscripts denote derivatives (e.g., $c_q = \partial c/\partial q$ and $c_{qq} = \partial^2 c/\partial q^2$). We also assume that $P(0) - c_q(0, x)$ is sufficiently large, $c_x(q, 0)$ is sufficiently small, and $|c_{qx}|$ and $|e_{qx}|$ are sufficiently small relative to c_{qq}, c_{xx}, e_{qq}, or e_{xx}, which ensures that the solutions are interior and that the second-order conditions are satisfied. These are standard assumptions in the literature (Carraro et al., 1996).

We consider three environmental policies that aim to restrict total emissions below the emission target E. The first is an *emission cap regulation*, under which the monopolist chooses q and x under constraint $e \leq E$. The second policy is an *emission intensity regulation*, under which the monopolist chooses q and x under constraint $e/q \leq \alpha$ and the government chooses α, such that the equilibrium emission is equal to E. The last policy is an *emission tax*, under which the government chooses emission tax rate t, such that the equilibrium emission is equal to E. The firm's profit is $P(q)q - c(q, x)$ when the emission cap or emission intensity regulation are imposed and $P(q)q - c(q, x) - te$ when the emission tax is adopted.

Let $\pi^C(E)$, $\pi^I(E)$, and $\pi^T(E)$ be the firm's optimal profits when the emission target is E under the emission cap regulation, the emission intensity regulation, and the emission tax, respectively. If the emission target is initially $E = E_o$ and is then relaxed to $E_r (> E_o)$, under policy $i (= C, I, T)$, the firm increases its profit by $\pi^i(E_r) - \pi^i(E_o)$. This implies that, if the firm can manipulate the emission target from E_o to E_r through lobbying, it is willing to pay $\pi^i(E_r) - \pi^i(E_o)$ for lobbying.[5] Hence, we presume that the incremental profit is

---

[5] In lobbying models such as that of Grossman and Helpman (1994), to pay the incremental increase in the payoff is an equilibrium behavior.

the firm's lobbying incentive and consider that the policy is more robust to lobbying as the incremental profit decreases. In Section 4, we explicitly introduce lobbying costs and derive further implications.

Let E^B be the emissions when the firm maximizes its profit, without either type of emission regulation or the emission tax (superscript B means "business-as-usual"). If $E \geq E^B$, the constraint is not effective (non-binding). Throughout the analysis, we assume that $E_o \in [0, E^B)$.

3 Analysis of Three Environmental Policies

3.1 Emission cap regulation

First, we consider the emission cap regulation. The government imposes the upper total emission bound, $E \in [0, E^B)$. The firm then chooses q and x to maximize its profit under constraint $e(q,x) \leq E$. The firm's optimization problem is

$$\begin{aligned} &\max_{q,x} P(q)q - c(q,x), \\ &s.t. \;\; e(q,x) \leq E. \end{aligned} \tag{1}$$

Because we assume that $E < E^B$, the constraint must be binding (i.e., $e(q,x) = E$ at equilibrium). Consequently, once the firm chooses q, x is automatically determined by constraint $e(q,x) = E$. Let $\hat{x}(q,E)$ be the value that satisfies $e(q, \hat{x}(q,E)) \equiv E$. As the firm chooses $x = \hat{x}(q,E)$ mechanically, given q, substituting this constraint into the profit function yields

$$P(q)q - c(q, \hat{x}(q,E)). \tag{2}$$

Note that due to the implicit function theorem, $\partial \hat{x}/\partial q = -e_q/e_x$. Here, the optimal choice, denoted by (q^C, x^C), is characterized by the following first-order condition:

$$P + P'q - c_q + c_x \frac{e_q}{e_x} = 0 \tag{3}$$

and $e(q,x) = E$.

For the first-order condition, the marginal production cost is $c_q + c_x(-e_q/e_x)$. A marginal increase in q increases e by e_q. To cancel this increase in emissions, the firm must increase x by $(-e_q/e_x)$, which in turn increases cost by $c_x(-e_q/e_x)$.

3.2 Emission intensity regulation

Next, we consider the emission intensity regulation. The government imposes the upper emission bound per unit of output, α. The firm chooses q and x to maximize its profit under constraint $e(q,x) \leq \alpha q$.

The firm's optimization problem is

$$\begin{aligned} &\max_{q,x} P(q)q - c(q,x), \\ &s.t. \;\; e(q,x) \leq \alpha q. \end{aligned} \tag{4}$$

When the constraint is binding, similar to the emission cap regulation, the abatement level is determined as $x = \hat{x}(q, \alpha q)$, given α and q. Substituting this constraint into the profit function yields $p(q)q - c(q, \hat{x}(q, \alpha q))$. By taking the derivative with respect to q, the firm's optimal choice, denoted by $(\hat{q}^I(\alpha), \hat{x}^I(\alpha))$, satisfies the following single first-order condition:

$$P'\hat{q}^I + P - c_q - c_x \frac{\alpha - e_q}{e_x} = 0 \tag{5}$$

and constraint $e(\hat{q}^I(\alpha), \hat{x}^I(\alpha)) = \alpha \hat{q}^I(\alpha)$.

The government chooses α to induce the emission to $E \in (0, E^B)$. Therefore, the equilibrium intensity, denoted by α^I, satisfies $e(\hat{q}^I(\alpha^I), \hat{x}^I(\alpha^I)) = \alpha^I \hat{q}^I(\alpha^I) = E$ as well. Henceforth, we express $(q^I, x^I) \equiv (\hat{q}^I(\alpha^I), \hat{x}^I(\alpha^I))$.

The difference from the emission cap regulation is characterized as follows:

Lemma 1. *(i)* $\alpha^I = 0$ *and* $(q^C, x^C) = (q^I, x^I)$ *for* $E = 0$. *(ii)* $\alpha^I < E/q^C$ *for* $E \in (0, E^B)$.

When $E = 0$, the per-output emission level is $\alpha^I = 0$ under the emission intensity regulation. Thus, the emission level becomes $\alpha^I q = 0$, which is independent of the output and the same as that for the emission cap regulation. Therefore, the firm faces the same constraint under the emission cap and emission intensity regulations, given $E = 0$.

However, as long as $E > 0$, under the emission intensity regulation, $\alpha^I > 0$ and the firm chooses q and x, given α, not E. Total emission αq is increasing in q, in contrast to the emission cap regulation case. Therefore, the firm has a stronger incentive to increase q under the emission intensity regulation than under the emission cap regulation (Holland et al., 2009; Ino and Matsumura, 2019). As such, if the government sets $\alpha = E/q^C$, the resulting emission exceeds E. Given the firm's expected choice, the government chooses a lower emission intensity (i.e., $\alpha^I < E/q^C$) to realize emission target E (Hirose and Matsumura, 2020).

3.3 Emission tax

Finally, we consider the emission tax. Given that the government imposes emission tax t, the firm chooses q and x to maximize its after-tax profit. The firm's optimization problem is

$$\max_{q,x} P(Q)q - c(q,x) - te(q,x). \tag{6}$$

The firm's optimal choice, denoted by $(\hat{q}^T(t), \hat{x}^T(t))$, satisfies the following first-order conditions:

$$\frac{\partial \pi}{\partial q} = P'\hat{q}^T + P - c_q - te_q = 0, \tag{7}$$

$$\frac{\partial \pi}{\partial x} = -c_x - te_x = 0. \tag{8}$$

The government attempts to induce the total emission equal to E. Therefore, the emission tax t^T is determined to satisfy $e(\hat{q}^T(t^T), \hat{x}^T(t^T)) = E$. Henceforth, we express $(q^T, x^T) \equiv (\hat{q}^T(t^T), \hat{x}^T(t^T))$.

Lemma 2 below is a straightforward application of the well-known tariff-quota equivalence.

Lemma 2. *$q^T = q^C$ and $x^T = x^C$ for all E.*

3.4 Results

We now investigate the firm's lobbying incentives when the government aims at $E = 0$ to realize a net-zero emission society (i.e., $E_o = 0$). Under policy $i(= C, I, T)$, if the firm lobbies to manipulate the target to E_r, it can increase profit by $\pi^i(E_r) - \pi^i(0)$, which represents its lobbying incentive. Lobbying incentives can be ranked by the following proposition:

Proposition 1. *(i) $\pi^C(0) = \pi^I(0) = \pi^T(0)$; (ii) $\pi^C(E) > \pi^I(E)$ and $\pi^C(E) > \pi^T(E)$ for $E \in (0, E^B)$; (iii) There exists $\hat{E}_0 > 0$, such that $\pi^I(E) > \pi^T(E)$ for all $E \in (0, \hat{E}_0)$.*

Proposition 1(i,ii) states that an increase in E from $E = 0$ increases the firm's profit most under the emission cap regulation.

The comparison between $\pi^C(E)$ and $\pi^I(E)$ is implied by Lemma 1. When $E = 0$, both regulations yield the same outcome. When $E > 0$, relative to the emission cap regulation, the emission intensity regulation yields a strong incentive for the firm to expand its output. Expecting this ex-post aggressive behavior of the firm under the emission intensity regulation, the government sets a strict regulation (i.e., $\alpha^I < E/q^C$), which leads to $\pi^C(E) > \pi^I(E)$ for $E \in (0, E^B)$.

The comparison between $\pi^C(E)$ and $\pi^T(E)$ is implied by the equivalence result of Lemma 2. Since the emission cap regulation and emission tax have the same outcomes, the difference in profit between the two policies is te^T, which is zero when $E = 0$ and becomes positive when $E = e^T > 0$. These lead to $\pi^C(0) = \pi^T(0)$ and $\pi^C(E) > \pi^T(E)$ for $E \in (0, E^B)$.

To demonstrate Proposition 1(iii), we can use the property on derivative $d\pi^i/dE$. The lobbying incentive can be expressed as $\pi^i(E_r) - \pi^i(E_o) = \int_{E_o}^{E_r} (d\pi^i/dE)dE$. By the envelope theorem

$$\begin{aligned} \frac{d\pi^C}{dE} &= -\frac{c_x(q^C, \hat{x}(q^C, E))}{e_x(q^C, \hat{x}(q^C, E))}, \\ \frac{d\pi^I}{dE} &= -\frac{c_x(q^I, \hat{x}(q^I, \alpha^I q^I))}{e_x(q^I, \hat{x}(q^I, \alpha^I q^I))}, \\ \frac{d\pi^T}{dE} &= -e(q^T, x^T)\frac{dt}{dE}. \end{aligned} \tag{9}$$

Under the emission cap and emission intensity regulations, a marginal increase in E improves profit through a marginal reduction in the abatement level, that is, c_x/e_x. When $E = 0$, since the abatement level is positive, the marginal abatement cost is also positive, which implies that a marginal increase in profit is positive at $E = 0$. By contrast, under the emission tax, a marginal increase in E improves profit through a marginal reduction in the tax rate. Nevertheless, when $E = 0$, since the firm has zero emissions and, thus, the tax payment is zero, the marginal increase in profit becomes zero. Accordingly, we obtain the following supplementary result that leads directly to Proposition 1(iii).

Lemma 3.

$$\frac{d\pi^C}{dE}\Big|_{E=0} = \frac{d\pi^I}{dE}\Big|_{E=0} > \frac{d\pi^T}{dE}\Big|_{E=0} = 0.$$

The analysis has hitherto shown that, when $E_o = 0$ and E_r is relatively small, the emission tax policy yields the smallest lobbying incentive among the three policies. Nevertheless, the case of large E_o or E_r is not yet investigated. More importantly, the firm may be able to choose E_r endogenously. Although the general analysis of lobbying incentives for $E_o \in (0, E^B)$ and for the endogenous E_r is intractable, the parametric assumptions in the next section provide further insights on lobbying incentives.

4 Parametric Analysis

In the following, we assume that $P = a - bQ$, $c = \beta q + \gamma x^2/2$, and $e = \kappa q - x$, where a is sufficiently large to ensure the interior solution (i.e., $q > 0$ at equilibrium). Under this parametric specification, the profit under the emission intensity regulation is greater than that under the emission tax for all $E \in (0, E^B)$.

Proposition 2. *$\pi^C(E) > \pi^I(E) > \pi^T(E)$ for all $E \in (0, E^B)$.*

Figure 1 graphically describes Proposition 2 using a numerical example. Because $\pi^C(E^B) = \pi^I(E^B) = \pi^T(E^B)$ for $E = E^B$, Proposition 2 implies that $\pi^C(E^B) - \pi^C(E) < \pi^I(E^B) - \pi^I(E) < \pi^T(E^B) - \pi^T(E)$. Therefore, in contrast to the lobbying incentive in the zero-emission target case, if the initial emission target is loose and close to the business-as-usual level, E^B, an increase in the emission target increases the firm's profit most significantly under the emission tax policy and, thus, the emission tax policy is the most vulnerable to lobbying.

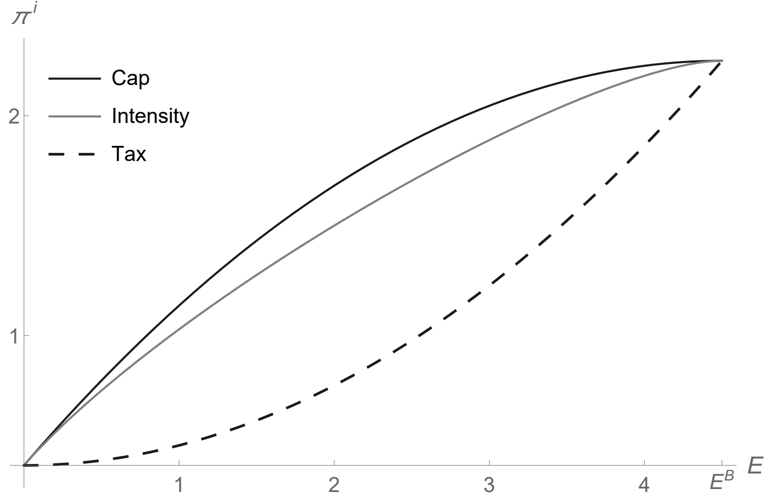


Figure 1: $\pi^i(E)$ ($a = 5$, $b = 1$, $\beta = 2$, $\gamma = 1$, and $\kappa = 3$)

So far, we have implicitly assumed that the initial target level E_o and manipulated level E_r are exogenously given and investigated the difference in profit as the firm's lobbying incentive. The parametric assumptions allow us to conduct further analyses to clarify the emission target that the firm optimally attempts to achieve. To investigate the optimal emission target for the firm, we assume that the firm bears a lobbying cost defined by function $L(\Delta E)$, where the government initially wants to implement emission target E_o, the realized emission target after lobbying is E_r, and $\Delta E \equiv E_r - E_o$.

In the following, we consider a scenario under which, given policy $i(= C, I, T)$ and E_o, the firm chooses manipulated level E_r to maximize $\pi^i(E_r) - L(\Delta E)$. For each $i = C, I, T$, we denote the firm's optimal manipulated level by E_r^i. Here, the policy inducing the least E_r^i is most robust, in that the realized target is closest to the initial policy. We assume that $L(\Delta E)$ is twice differentiable, increasing, and convex. We further assume that $L'(0) = 0$ and L'' is sufficiently large, so that $\pi^i(E_r) - L(\Delta E)$ is strictly concave in E_r. Under these conditions, the realized E_r is determined by the first-order condition with respect to E_r, that is, $d\pi^i/dE \geq L'(\Delta E)$, where the strict inequality holds only if $E_r = E^B$.

Since L'' is positive, the first-order condition implies that the firm is more willing to increase E_r if $d\pi^i/dE$ is larger. The ranking of $d\pi^i/dE$ at $E = 0$ is shown in Lemma 3. Under the parametric assumption, the ranking is characterized for each $E \in (0, E^B)$ as follows:

Lemma 4. *(i) There exists $\hat{E}_1 \in (0, E^B)$ such that $d\pi^C/dE = d\pi^I/dE = d\pi^T/dE$ when $E = \hat{E}_1$, $d\pi^C/dE > d\pi^I/dE > d\pi^T/dE$ for $E \in (0, \hat{E}_1)$, and $d\pi^C/dE < d\pi^I/dE < d\pi^T/dE$ for $E \in (\hat{E}_1, E^B)$. (ii) $d\pi^C/dE = d\pi^I/dE = 0$ and $d\pi^T/dE > 0$ at $E = E^B$.*

Figure 2 graphically describes Lemma 4 using a numerical example. From the figure, for a small E, the derivative of π^i is the largest under the emission cap. By contrast, for a large E, the derivative is the largest under the emission tax.

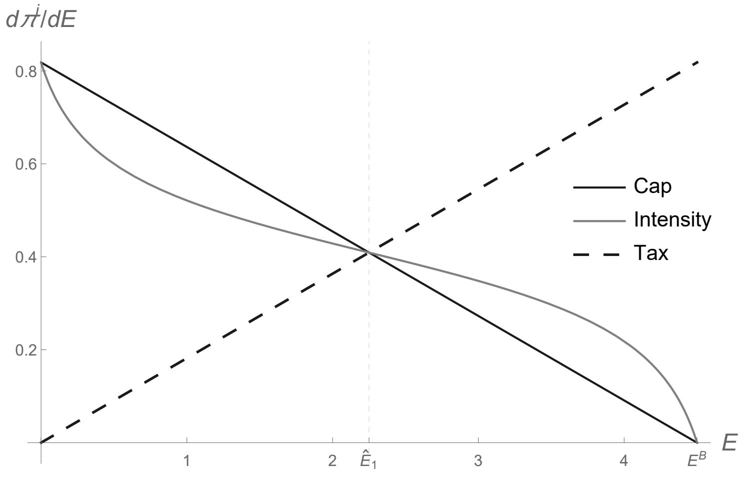


Figure 2: $d\pi^i/dE$ ($a = 5$, $b = 1$, $\beta = 2$, $\gamma = 1$, and $\kappa = 3$)

By relating the results in Lemma 4 to the first-order condition, we observe that the ranking of E_r^i depends on the initial target, E_o.

Proposition 3. *If* $E_o \geq \hat{E}_1$ *or* $(d\pi^T/dE)(\hat{E}_1) > L'(\hat{E}_1 - E_o)$*, then* $E_r^C < E_r^I < E_r^T$*. If* $E_o < \hat{E}_1$ *and* $(d\pi^T/dE)(\hat{E}_1) = L'(\hat{E}_1 - E_o)$*, then* $E_r^C = E_r^I = E_r^T$*. Otherwise,* $E_r^C > E_r^I > E_r^T$*.*

The following result is directly derived from Proposition 3 because $L'' > 0$ and, thus, L' is decreasing in E_o.

Corollary 1. *Let* $\hat{E}_2 (< \hat{E}_1)$ *be the value that satisfies* $(d\pi^T/dE)(\hat{E}_1) = L'(\hat{E}_1 - \hat{E}_2)$*. Then,* $E_r^C \lesseqqgtr E_r^I \lesseqqgtr E_r^T$ *if* $E_o \gtreqqless \hat{E}_2$*.*

Figure 3 describes the arguments in Proposition 3 and Corollary 1 using a numerical example with $L(\Delta E) = h(\Delta E)^2/2$.[6] The horizontal axis is the initial target and the vertical axis is the optimal manipulated target. When the initial emission target E_o is small (i.e., the government initially sets a strict target), the realized emission target E_r must be small as well. In this case, because $d\pi^i/dE$ is smallest under the emission tax policy, this policy

---

[6] $\pi^i(E_r) - L(\Delta E)$ is strictly concave in E_r for $i = C, I$ as long as $h > 0$. $\pi^T(E_r) - L(\Delta E)$ is strictly concave in E_r if $h > (2b\gamma)/(2b + \gamma\kappa^2)$. This inequality holds under the parameter values used in Figure 3.

induces the smallest manipulated target and is thus the most robust to polluter lobbying. By contrast, when the initial emission target is large (i.e., the government initially sets a loose target), the realized emission target must be large as well. In this case, since the emission tax policy yields the largest E_r, this policy is the most vulnerable to polluter lobbying.

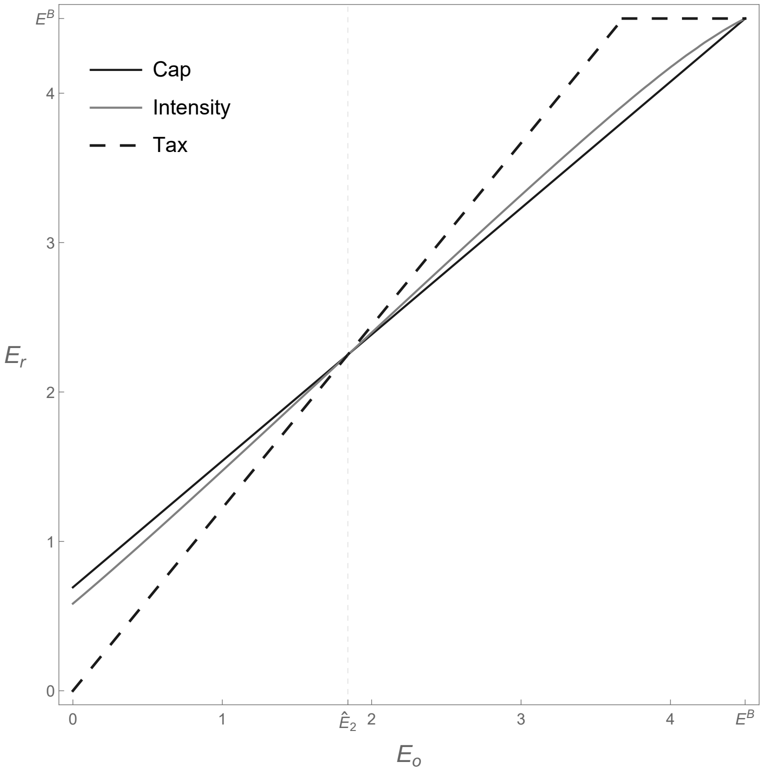
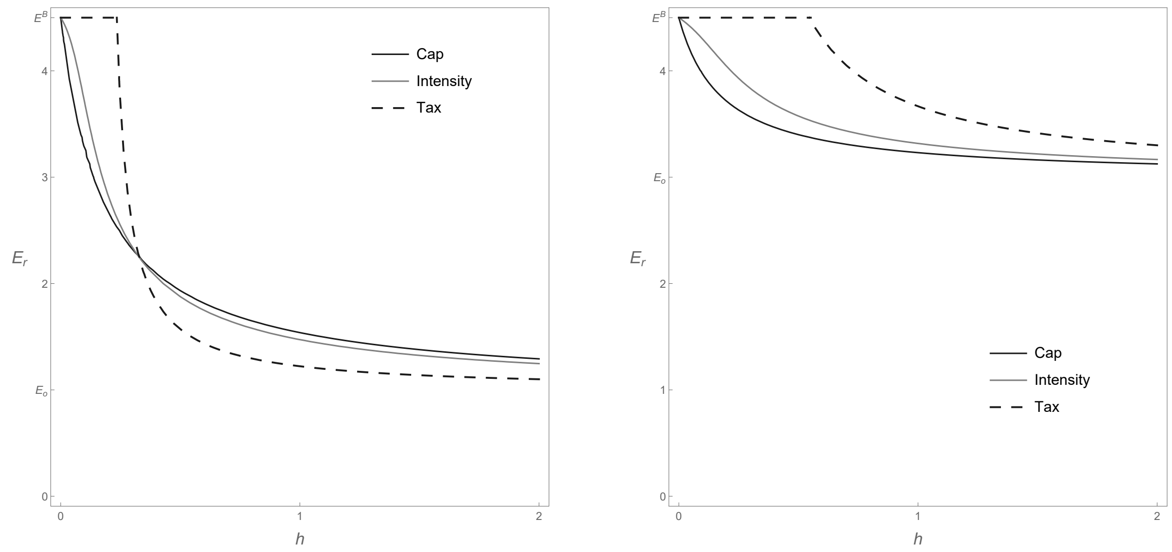


Figure 3: E_r ($a = 5$, $b = 1$, $\beta = 2$, $\gamma = 1$, $\kappa = 3$, and $h = 1$)

The robustness of a policy is also determined by the shape of the lobbying cost. Assume again that $L = h(\Delta E)^2/2$. Figure 4 plots the optimal manipulated level, the horizontal axis showing h. Note that, as long as $h > 0$ and $E_o < E^B$, the emission cap and emission intensity regulations always yield interior solutions (i.e., $E_r^C, E_r^I \in (E_o, E^B)$) because $d\pi^C/dE$ and $d\pi^I/dE$ are decreasing in E and are zero at $E = E^B$. By contrast, the emission tax policy may yield a corner solution (i.e., $E_r^T = E^B$) when h is small.[7]

---

[7] As we discussed in footnote 6, the assumption that $\pi^i(E_r) - L(\Delta E)$ is strictly concave in E_r does not



$E_o = 1$ $E_o = 3$

Figure 4: E_r ($a = 5$, $b = 1$, $\beta = 2$, $\gamma = 1$, and $\kappa = 3$)

Figure 4 illustrates how policy robustness is determined by h. When E_o is large (as in the right-hand panel of Figure 4) or h is small, the emission tax policy induces the largest manipulated target and is thus the most vulnerable to polluter lobbying. By contrast, when E_o is small (as in the left-hand panel of Figure 4) and h is large, the emission tax policy is the most robust, since it yields the smallest E_r. The following proposition shows that this property is, in general, valid under the parametric assumptions.

Proposition 4. *Suppose that* $L(\Delta E) = h(\Delta E)^2/2$. *(i) Suppose that* $E_o \in [0, \hat{E}_1)$. *Then,* $E_r^T < \min\{E_r^C, E_r^I\}$ *if and only if*

$$h > \frac{2b(a-\beta)\gamma\kappa}{[(a-\beta)\kappa - 4bE_o](2b + \gamma\kappa^2)}. \tag{10}$$

(ii) Suppose that $E_o \in [\hat{E}_1, E^B)$. *Then,* $E_r^T \geq \min\{E_r^C, E_r^I\}$.

---

holds when $i = T$ and h is small. In this case, $E_r^T = E^B$ holds, whereas the inequalities $E_r^I, E_r^C < E^B$ always hold for $E_o < E^B$. Therefore, the following Proposition 4 holds even when h is so small that $\pi^T(E_r) - L(\Delta E)$ is convex in E_r.

Parameter h is interpreted as the degree of the government's resolve against lobbying. When the initial target level is relatively high (i.e., $E_o \in [\hat{E}_1, E^B)$), the manipulated target level is also high, regardless of h. Therefore, the emission tax is the most vulnerable policy, as argued in Proposition 3. Parameter h is thus important to determine the robustness of the regulation policy when the initial target level is relatively low (i.e., $E_o \in (0, \hat{E}_1)$). When the government is strict against lobbying (i.e., when h is large) and since lobbying is costly, the realized target level is relatively small. In this case, according to Lemma 4, the marginal benefit of manipulation is smallest under the emission tax policy, which becomes the most robust policy to polluter lobbying. By contrast, if the government is relatively weak regarding lobbying (i.e., if h is small), the realized target level is relatively large. Therefore, as opposed to a large h, the emission tax policy allows the firm to induce the largest manipulation among the regulation policies.

We now briefly discuss whether the results in this section would qualitatively hold without the parametric specification. The key property is the slope of $d\pi^i/dE$, as illustrated in Figure 2. From the first and second equations in (9), $d\pi^C/dE$ and $d\pi^I/dE$ are equal to $-c_x/e_x$, which is the effective marginal cost of abatement. Given the reasonable premise that the marginal cost decreases in the allowed emission level, we observe that $d\pi^C/dE$ and $d\pi^I/dE$ are decreasing in E. From the third equation in (9), $d\pi^T/dE$ is proportional to E, given $(-dt/dE)$ fixed. As relaxing the emission level would reduce the emission tax (i.e., $-dt/dE$ is positive), we would obtain that $d\pi^T/dE$ is increasing in E. Therefore, together with Lemma 3, the slope of $d\pi^i/dE$ is as in Figure 2, even without the parametric specification. Although this explanation does not clarify the difference between $d\pi^C/dE$ and $d\pi^I/dE$, it is clear that the shape of $d\pi^T/dE$ is qualitatively different from that of $d\pi^C/dE$ and $d\pi^I/dE$. In this case, in terms of the emission tax policy, the argument would qualitatively hold even without the parametric specification.

5 Conclusions and Policy Implications

This study compares three environmental policies: an emission cap regulation, an emission intensity regulation, and an emission tax. It also investigates how the emission target in an industry affects a monopoly firm's profits. We find that, when the emission target is close to zero (large), a marginal increase in the emission target yields the least (largest) increase in industry profits under the emission tax. This result implies that, among the three policies, the emission tax gives industry leaders the weakest (strongest) incentives to manipulate the emission target when the initial target level is close to zero (large). Therefore, we conclude that the emission tax is a reasonable policy tool to achieve a near-zero emission society in the presence of polluter lobbying. We also show that, if the government lacks the strong will to implement a near-zero emission society and emission targets are quite loose, emission regulations are reasonable policies to implement.

When an emission tax is imposed, firms may lobby to obtain tax refunds rather than lower the tax rate. As the emission tax revenue can be large when the emission target is intermediate, the firm may not necessarily lobby to reduce the emission target and the government may be able to maintain a desirable emission target even in the presence of polluter lobbying. Incorporating this effect into our analysis will be done in future studies.

We consider three environmental policies and, although these are popular environmental policies, many other policies such as energy conservation regulations and green portfolio standards exist (Holland et al., 2009; Ino and Matsumura, 2021a; Matsumura and Yamagishi, 2017). Moreover, it may be reasonable to combine two or more policies (Cohen and Keiser, 2017; Ino and Matsumura, 2021b). Expanding the range of policy measures would thus be a natural extension of our research.

Appendix

Proof of Lemma 1

(i) Suppose that $E = 0$. Since $\alpha^I q^I = E = 0$ and $q^I > 0$, $\alpha^I = 0$ must hold. Hence, the constraint in Problem (4) becomes $e(q, x) \leq 0$, which is equivalent to the constraint in Problem (1). As (4) is identical to (1), $(q^I, x^I) = (q^C, x^C)$.

(ii) q^I is derived from (5). By substituting $q = q^I$ into the left-hand side of equation (5), we have $P + P'q - c_q + c_x(e_q/e_x) = -c_x\alpha < 0$. Because the second-order conditions are satisfied, we have $q^I > q^C$. Because $\alpha^I q^I = E$ and $q^I > q^C$, we have $\alpha^I < E/q^C$. ■

Proof of Lemma 2

Substituting (8) into (7) to eliminate t, we find that (7) is expressed as (3). This implies that the firm chooses the same output and abatement levels as those under the emission cap regulation. ■

We prove Lemma 3 before Proposition 1.

Proof of Lemma 4

Suppose $E = 0$. Lemma 1 implies that $\alpha^I = 0$ and $(q^I, x^I) = (q^C, x^C)$. Then, (9) implies $d\pi^C/dE = d\pi^I/dE$. Since both $c_x(q^i, x^i)$ and $e_x(q^i, x^i)$ are positive for $q^i > 0$, $d\pi^C/dE = d\pi^I/dE > 0$. Under the emission tax, since $e(q^T, x^T) = 0$, (9) implies $d\pi^T/dE = 0$.■

Proof of Proposition 1

(i) From Lemma 2, we have $\pi^C = p(q^C)q^C - c(q^C, x^C)$ and $\pi^T = p(q^C)q^C - c(q^C, x^C) - t^T e^T$. Because $e^T = 0$ when $E = 0$, we have $\pi^C = \pi^T$ when $E = 0$. When $E = 0$, the maximization problems under the emission cap and emission intensity regulations are the same. Therefore, $q^C = q^I$ and $x^C = x^I$ when $E = 0$, which implies that $\pi^C = \pi^I$ when $E = 0$.

(ii) From Lemma 2, we have $\pi^C = p(q^C)q^C - c(q^C, x^C)$ and $\pi^T = p(q^C)q^C - c(q^C, x^C) - t^T e^T$. Because $e^T = E$ and $t > 0$, when $E > 0$, we have $\pi^C > \pi^T$.

Further, we show $\pi^C > \pi^I$ when $E > 0$. From Lemma 1, we find that the firm can choose $(q, x) = (q^I, x^I)$ under the emission cap constraint. This implies that $\pi^C \geq \pi^I$ and the equality holds only when $(q^C, x^C) = (q^I, x^I)$.

As shown in the proof of Lemma 1, $q^I \neq q^C$ when $\alpha > 0$.

(iii) From Lemma 3, Proposition 1(i), and the continuity of π^I and π^T with respect to E, we have $\pi^I > \pi^T$ when E is sufficiently close to 0. ■

Proofs of Proposition 2 and Lemma 4

Under the parametric assumption, $E^B = (a - \beta)\kappa/2b$. Under the emission cap regulation, given $E \in [0, E^B)$,

$$q^C = \frac{a - \beta + \gamma\kappa E}{2b + \gamma\kappa^2},\ x^C = \frac{(a - \beta)\kappa - 2bE}{2b + \gamma\kappa^2},\ \pi^C = \frac{(a - \beta)^2 - 2b\gamma E^2 + 2(a - \beta)\gamma\kappa E}{2(2b + \gamma\kappa^2)}. \quad (11)$$

Under the emission intensity regulation, given α,

$$\hat{q}^I(\alpha) = \frac{a - \beta}{2b + \gamma(\kappa - \alpha)^2},\ \hat{x}^I(\alpha) = \frac{(a - \beta)(\kappa - \alpha)}{2b + \gamma(\kappa - \alpha)^2},\ \pi^I = \frac{(a - \beta)^2}{2(2b + \gamma(\kappa - \alpha)^2)}, \quad (12)$$

and, given $E \in [0, E^B)$,

$$\alpha^I = \kappa + \frac{a - \beta - \sqrt{(a - \beta)^2 + 4\gamma E[(a - \beta)\kappa - 2bE]}}{2\gamma E}. \quad (13)$$

Under the emission tax, given t,

$$\hat{q}^T(t) = \frac{a - \beta - \kappa t}{2b},\ \hat{x}^T(t) = \frac{t}{\gamma},\ \pi^T = \frac{2bt^2 + \gamma(a - \beta - \kappa t)^2}{4b\gamma}, \quad (14)$$

and, given $E \in [0, E^B)$,

$$t^T = \frac{\gamma[(a - \beta)\kappa - 2bE]}{2b + \gamma\kappa^2}. \quad (15)$$

Substituting (13) and (15) into (12) and (14), respectively, we obtain

$$\pi^I = \frac{(a-\beta)\left(\sqrt{(a-\beta)^2+4\gamma E[(a-\beta)\kappa-2bE]}+a-\beta+2\gamma\kappa E\right)}{8b+4\gamma\kappa^2},$$
$$\pi^T = \frac{(a-\beta)^2+2b\gamma E^2}{4b+2\gamma\kappa^2}.$$

The difference between π^I and π^T becomes

$$\pi^I-\pi^T = \frac{(a-\beta)\left\{\sqrt{(a-\beta)^2+4\gamma E[(a-\beta)\kappa-2bE]}-(a-\beta)\right\}+2\gamma E[(a-\beta)\kappa-2bE]}{8b+4\gamma\kappa^2}.$$

Note that, since $E^B=(a-\beta)\kappa/2b$, $\sqrt{(a-\beta)^2+4\gamma E[(a-\beta)\kappa-2bE]}\geq a-\beta$ and $(a-\beta)\kappa > 2bE$ for $E\in(0,E^B)$. These yield Proposition 2.

We now prove Lemma 4(i). Differentiating the profit functions, we obtain

$$\frac{d\pi^C}{dE} = \frac{\gamma[\kappa(a-\beta)-2bE]}{2b+\gamma\kappa^2}, \tag{16}$$
$$\frac{d\pi^I}{dE} = \frac{\gamma(a-\beta)}{4b+2\gamma\kappa^2}\left(\frac{\kappa(a-\beta)-4bE}{\sqrt{(a-\beta)^2+4\gamma E[(a-\beta)\kappa-2bE]}}+\kappa\right), \tag{17}$$
$$\frac{d\pi^T}{dE} = \frac{2b\gamma E}{2b+\gamma\kappa^2}.$$

Then, the difference between $d\pi^C/dE$ and $d\pi^I/dE$ is

$$\frac{d\pi^C}{dE}-\frac{d\pi^I}{dE} = \frac{\gamma(\kappa(a-\beta)-4bE)\left(\sqrt{(a-\beta)^2+4\gamma E[(a-\beta)\kappa-2bE]}-a+\beta\right)}{2\left(2b+\gamma\kappa^2\right)\sqrt{(a-\beta)^2+4\gamma E[(a-\beta)\kappa-2bE]}}.$$

Then, $d\pi^C/dE \gtreqless d\pi^I/dE$ if and only if $E \lesseqgtr (a-\beta)\kappa/4b$.

Next, the difference between $d\pi^I/dE$ and $d\pi^T/dE$ is

$$\frac{d\pi^I}{dE}-\frac{d\pi^T}{dE} = \frac{\gamma[\kappa(a-\beta)-4bE]}{4b+2\gamma\kappa^2}\left(\frac{a-\beta}{\sqrt{(a-\beta)(a-\beta+4\gamma\kappa E)-8b\gamma E^2}}+1\right).$$

Then, $d\pi^I/dE \gtreqless d\pi^T/dE$ if and only if $E \lesseqgtr (a-\beta)\kappa/4b$. Therefore, by defining $\hat{E}_1 = (a-\beta)\kappa/4b$, we obtain Lemma 4(i).

Finally, we show Lemma 4(ii). When $E=E^B$, $x=0$. Since $c_x=0$ when $x=0$, from (9), we have $d\pi^C/dE = d\pi^I/dE = 0$ when $E=E^B$. From (17), we have $d\pi^T/dE>0$ as long as $E>0$. These imply Lemma 4(ii). ■

Proof of Proposition 3

Suppose that either $E_o \geq \hat{E}_1$ or $E_o < \hat{E}_1$ and $(d\pi^T/dE)(\hat{E}_1) > L'(\hat{E}_1 - E_o)$. In the former case, since $E_r^i > E_o$, we have $E_r^i > \hat{E}_1$. In the latter case, the strict concavity of $\pi^T(E_r) - L(\Delta E)$ and $(d\pi^T/dE)(\hat{E}_1) = (d\pi^I/dE)(\hat{E}_1) = (d\pi^C/dE)(\hat{E}_1)$ by Lemma 4 imply that $E_r^i > \hat{E}_1$ for each i. Therefore, in both cases, $E_r^i > \hat{E}_1$ for each i.

We then show that $E_r^I < E_r^T$. Suppose $E_r^T = E^B$. From Lemma 4(ii) and $L'(E^B - E_o) > 0$, we have $E_r^I < E^B$. Therefore, $E_r^I < E_r^T$ holds .

Suppose $E_r^T < E^B$. We show that $E_r^I < E_r^T$ by contradiction. If $E_r^I \geq E_r^T$, since $(d\pi^T/dE)(E_r^T) > (d\pi^I/dE)(E_r^T)$ by Lemma 4, the first-order condition implies $(d\pi^I/dE)(E_r^T) < (d\pi^T/dE)(E_r^T) = L'(E_r^T - E_o)$. Since $\pi^I(E_r) - L(\Delta E)$ is strictly concave in E_r, we must have $E_r^I < E_r^T$, which contradicts $E_r^I \geq E_r^T$. Therefore, $E_r^I < E_r^T$.

By a similar procedure, we also have $E_r^C < E_r^I$.

Suppose next that $E_o < \hat{E}_1$ and $(d\pi^T/dE)(\hat{E}_1) < L'(\hat{E}_1 - E_o)$. By applying a procedure similar to the one in the previous paragraphs, we have $E_r^i < \hat{E}_1$ for each i and, then, $E_r^C > E_r^I > E_r^T$.

Finally suppose that $E_o < \hat{E}_1$ and $(d\pi^T/dE)(\hat{E}_1) = L'(\hat{E}_1 - E_o)$. Since $(d\pi^T/dE)(\hat{E}_1) = (d\pi^I/dE)(\hat{E}_1) = (d\pi^C/dE)(\hat{E}_1)$ by Lemma 4, the strict concavity of $\pi^T(E_r) - L(\Delta E)$ implies $E_r^C = E_r^I = E_r^T$.■

Proof of Proposition 4

$d\pi^T/dE(\hat{E}_1) > (=, <) L'(\hat{E}_1 - E_o)$ holds if

$$h < (=, >) \frac{2b(a-\beta)\gamma\kappa}{[(a-\beta)\kappa - 4bE_o](2b + \gamma\kappa^2)}.$$

Therefore, Proposition 4 is directly derived from Proposition 3. ■

References

Aidt, T. S. (1998) 'Political internationalization of economic externalities and environmental policy', *Journal of Public Economics* 69, 1–16. https://doi.org/10.1016/S0047-2727(98)00006-1

Aidt, T. S. (2010) 'Green taxes: refunding rules and lobbying', *Journal of Environmental Economics and Management* 60, 31–43. https://doi.org/10.1016/j.jeem.2010.04.001

Amir, R., Gama, A., and Werner, K. (2018) 'On environmental regulation of oligopoly markets: emission versus performance standards', *Environmental and Resource Economics*, 70(1), 147–167. https://doi.org/10.1007/s10640-017-0114-y

Alesina, A. and Passarelli, F. (2014) 'Regulation versus taxation', *Journal of Public Economics* 110, 147–156.

Barnett, A. H. (1980) 'The Pigovian tax rule under monopoly', *American Economic Review* 70, 1037–1041. https://www.jstor.org/stable/1805784

Baumol, W. J. and Oates, W. E. (1988) *The Theory of Environmental Policy* (second edition), Cambridge University Press, Cambridge.

Besanko, D. (1987) 'Performance versus design standards in the regulation of pollution', *Journal of Public Economics* 34(1), 19–44. https://doi.org/10.1016/0047-2727(87)90043-0

Buchanan, J. M. (1969) 'External diseconomies, corrective taxes, and market structure', *American Economic Review* 59, 174–177. https://www.jstor.org/stable/1811104

Cai, D. and Li, J. (2020) 'Pollution for sale: firms' characteristics and lobbying outcome', *Environmental and Resource Economics* 77, 539–564 https://doi.org/10.1007/s10640-020-00507-z

Carraro, C., Katsoulacos, Y., and Xepapadeas, A. (1996) 'Environmental Policy and Market Structure', Kluwer Academic Publishers, Dordrecht, The Netherlands.

Cohen, A., and Keiser, D. A., (2017) 'The effectiveness of incomplete and overlapping pollution regulation: Evidence from bans on phosphate in automatic dishwasher detergent', *Journal of Public Economics* 150, 53–74. https://doi.org/10.1016/j.jpubeco.2017.03.005

Engel, K. H. (1997) 'State environmental standard-setting: Is there a "race" and is it "to the bottom"?', Hastings Law Journal 48, 271–398.

Grossman G. M. and Helpman, E. (1994) ‘Protection for sale’, *American Economic Review* 84, 833–850.

Helfand, G. (1991) ‘Standards versus standards: The effect of different pollution restrictions’, *American Economic Review* 81(3), 622–634.
https://www.jstor.org/stable/2006524

Hirose, K. and Matsumura, T. (2020) ‘A Comparison between emission intensity and emission cap regulations’, *Energy Policy* 137, 111115.
https://doi.org/10.1016/j.enpol.2019.111115

Holland, S. P. (2009) ‘Taxes and Trading versus Intensity Standards: Second-Best Environmental Policies with Incomplete Regulation (Leakage) or Market Power.’ Working Paper 15262. Working Paper Series. National Bureau of Economic Research.
https://doi.org/10.3386/w15262

Holland, S. P. (2012) ‘Emissions taxes versus intensity standards: Second-best environmental policies with incomplete regulation’ *Journal of Environmental Economics and Management* 63(3), 375–387.
https://doi.org/10.1016/j.jeem.2011.12.002

Holland, S. P., Hughes, J. E. and Knittel, C. R. (2009) ‘Greenhouse gas reductions under low carbon fuel standards?’ *American Economic Journal: Economic Policy* 1(1), 106–146.
https://doi.org/10.1257/pol.1.1.106

Ino, H. and Matsumura, T. (2019) ‘The equivalence of emission tax with tax-revenue refund and emission intensity regulation’, *Economics Letters* 182, 126–128.
https://doi.org/10.1016/j.econlet.2019.06.017

Ino, H. and Matsumura, T. (2021a) ‘Promoting green or restricting gray? An analysis of green portfolio standards’, *Economics Letters* 198, 109650.
https://doi.org/10.1016/j.econlet.2020.109650

Ino, H. and Matsumura, T. (2021b) ‘Optimality of emission pricing policies based on emission intensity targets under imperfect competition’, *Energy Economics* 98, 105238.
https://doi.org/10.1016/j.eneco.2021.105238

Katsoulacos, Y. and Xepapadeas, A. (1996) ‘Emission taxes and market structure’, in: Carraro, C., Katsoulacos, Y., Xepapadeas, A. (eds) *Environmental Policy and Market Structure*, Springer, Dordrecht, Nederland.

Kiyono, K. and Ishikawa, J. (2013) ‘Environmental management policy under international carbon leakage’, *International Economic Review* 54, 1057–1083.
https://doi.org/10.1111/iere.12028

Lahiri, S. and Ono, Y. (2007) ‘Relative emission standard versus tax under oligopoly: The role of free entry’, *Journal of Economics* 91(2), 107–128.
https://doi.org/10.1007/s00712-006-0243-1

Lee, S.-H. (1999) 'Optimal taxation for polluting oligopolists with endogenous market structure', *Journal of Regulatory Economics* 15, 293–308.
https://doi.org/10.1023/A:1008034415251

Li, Z. and Shi, S. (2015) 'Emission taxes and standards in a general equilibrium with productivity dispersion and abatement', SSRN Electronic Journal.
https://doi.org/10.2139/ssrn.2641295

Lowry, W. R. 1992. *The Dimensions of Federalism: State Governments and Pollution Control Policies.* Durham, NC: Duke University Press.

Matsumura, T. and Yamagishi, A. (2017) 'Long-run welfare effect of energy conservation regulation', *Economics Letters* 154, 64–68.
https://doi.org/10.1016/j.econlet.2017.02.030

Montero, J. P. (2002) 'Permits, standards, and technology innovation', *Journal of Environmental Economic and Management* 44(1), 23–44.
https://doi.org/10.1006/jeem.2001.1194

Pigou, A. C. (1932) *The Economics of Welfare* (fourth edition), MacMillan, London.