Noncooperative and Cooperative Environmental Corporate Social Responsibility

by

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We formulate several quantity and price competition models that investigate the adoption of environmental corporate social responsibility (ECSR) by firms competing in the market. First, we consider emission cap commitments. Under quantity competition, ECSR is adopted by joint-profit-maximizing industry associations because of its effect of weakening quantity competition. However, it is not adopted without industry associations. By contrast, under price competition, individual firms voluntarily adopt ECSR without the industry associations and they choose a higher level of ECSR with the industry associations. Second, we consider emission intensity commitments (commitment to per-output emissions) and find that it is less likely to restrict market competition.

Keywords: corporate social responsibility, anticompetitive effect, emission cap, emission intensity

JEL classification code: M14, Q57, L13

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1 Introduction

There are broad, longstanding arguments about how instrumental differences among environmental policies affect firms' incentives and whether they improve or worsen environmental problems. Traditionally, governments have preferred to use command-and-control regulations, taxes, and subsidies to tackle environmental issues. However, an alternative approach has emerged recently, which incentivizes voluntary actions by firms or industry associations to improve their environmental performance beyond compliance.[1] Voluntary approaches have various advantages over traditional command-and-control style regulations (Vogel, 2005; McWilliams, Siegel, and Wright, 2006; Calveras, Ganuza, and Llobet, 2007). For example, it can be more quickly and flexibly implemented because fewer conflicts exist between policymakers and firms. Although this self-regulation has been widely adopted in recent decades, its effects and mechanism are not well understood either theoretically or empirically. Specifically, voluntary emission reduction (i.e., abatement) will increase a company's own cost and thus might cause a cost disadvantage when its rivals do not participate in the voluntary emission reduction cooperatively. In addition, if all firms accept higher costs to engage in the voluntary agreement, who pays for the increased costs? Thus, it is important to investigate why the voluntary approach works in markets and how it affects the economy more broadly.

Voluntary actions taken to tackle environmental issues are generally labeled as environmental corporate social responsibility (ECSR), which has gained increasing attention from researchers (Lyon and Maxwell, 2004; Lambertini and Tampieri, 2015; Liu, Wang, and Lee, 2015; Poyago-Theotoky and Yong, 2019) due to the fact that many listed firms are highly concerned about ECSR (KPMG International, 2013). The Carbon Disclosure Project (CDP North America, 2013), for example, reported that major companies, such as ExxonMobil, Walt Disney, Walmart, and Microsoft, use an internal (implicit) carbon price as an incentive and a strategic planning tool.

There are various reasons profit-maximizing firms take voluntary actions in the market. One possible explanation is that even though ECSR is costly, it can form part of an optimal firm strategy if the society rewards social behavior.[2] More specif-

[1] Because of worldwide political pressures concerning climate change, many polluting companies are voluntarily reducing their energy use or greenhouse gas (GHG) emissions and actively participating in GHG emissions reporting programs. For example, in 2014, 26 major firms in the power generation, cement production, and steel sectors in Korea voluntarily declared they would reduce fine dust emissions. Most recently, EuroVAprint, an association of leading European printer and copier manufacturers, has established a voluntary agreement with ongoing activities to continuously improve the energy consumption of its equipment.

[2] As McWilliams and Siegel (2001) and Baron (2008) argued, this strategic behavior can be interpreted as a market-driven interaction to maximize the profits induced by the demand side or as a hedge against the risk of future regulation or activism (Kitzmueller and Shimshack, 2012). Recent works such as Goering (2014) and Brand and Grothe (2015) considered a bilateral monopoly and showed that firms voluntarily adopt

ically, ECSR is connected with advertising – or the public reputation of firms. If consumers bear at least some of the negative externalities and value ECSR, firms adopting ECSR could attract increased demand and thereby earn higher profits (see Liu, Wang, and Lee, 2015, and works cited therein). Some empirical works have suggested that the financial performance of firms believed to be highly concerned with ECSR is relatively higher.[3] A second explanation is that self-regulation can be used as a countermeasure to regulatory threats by government, allowing firms to avoid public regulation in the first place (Maxwell, Lyon, and Hackett, 2000; Antweiler, 2003). A third argument is that firms or industry associations adopt voluntary actions to avoid the pressure from activists, whose instrument for generating pressure is boycott, as considered by Baron (2001).

This study contributes to the literature by extending the knowledge on strategic ECSR: we demonstrate that adopting ECSR can be profitable for firms even if it neither raises their reputation nor acts as a countermeasure for the regulatory threat from government and activists. This is because anti-competitive effects can be the driver for ECSR. Furthermore, we highlight the importance of industry associations and the type of ECSR from that perspective.[4]

We discuss two kinds of ECSR typically adopted by firms or industry associations.[5] Firstly, emission cap commitments mean that firms commit to an upper limit

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corporate social responsibility (CSR) to increase profits. In their model, CSR implies that firms are concerned about consumer surplus.

[3] Margolis, Elfenbein, and Walsh (2007) used meta-analysis and detected a modest positive average correlation between CSR and corporate financial performance.

[4] Many industry and economic associations play leading roles in ECSR, such as the Japan Association of Corporate Executives, Japan Business Federation, Japan Iron and Steel Federation, Federation of Electric Power Companies of Japan, and the Federation of German Industries (Bundesverband der Deutschen Industrie), which is an alliance of associations, including many influential industry associations in Germany. Notably, Baron (2001) discussed the collective action in the industry against industry boycotts using anecdotal evidence (Greenpeace's campaign). In addition, the business community has formed its own organizations specializing in CSR. For example, Business for Social Responsibility (BSR) is a business association founded in 1992 to provide corporations with expertise on the subject and to provide opportunities for business executives to advance the field and learn from one another. See Carroll and Shabana (2010) for a detailed discussion on BSR practices of business associations.

[5] As mentioned above, internal carbon pricing is a typical measure used as an incentive and strategic planning tool, and has been adopted by some major companies such as ExxonMobil, Walt Disney, Walmart, and Microsoft (CDP North America, 2013). If the corresponding tax revenue is used for consumers (promoting sales or price discounting), this measure is equivalent to an emission intensity commitment (Ino and Matsumura, 2019). However, if it is obtained by players outside the market (e.g., it is used for donation), it is equivalent to an emission cap commitment (Hirose and Matsumura, 2020). Therefore, we believe that discussing emission cap and emission intensity commitments are relevant here. Moreover, we think that our basic principle shown in the analysis of emission cap commitment can apply to the cases of many other ECSR commitments that raise firms' marginal costs.

of emissions.[6] In this way, committing to reduce total emissions is the equivalent of a cap on emission levels. This concept builds on absolute emission targets. Examples include many companies in the energy and semiconductor industries in the U.S. and UK (Margolick and Russell, 2001; Lee and Kutner, 2010), among which NRG Energy, a leading energy company in the U.S., is a typical example (Cardwell, 2014). Furthermore, according to the CSR reports of the Japan Association of Corporate Executives and Japan Business Federation, many major Japanese firms have adopted such commitments.[7] The second kind of ECSR is an emission intensity commitment whereby firms commit to an emission level per unit of output.[8] For an example of an emission intensity association, firms in the electric power industry formulated Electricity Business Low Carbon Society Council, committing to an emission intensity of 0.37 kg/kWh.[9]

For each of the above two types, we formulate the following two-stage duopoly game. In the first stage, each firm or the industry association to which both firms belong chooses the level of commitment as ECSR. In the second stage, the firms compete in the market and engage in emission abatement activities subject to their emission constraints.

Emission cap commitment yields the following results. In a quantity competition model, the industry association chooses a strictly positive degree of ECSR, though individual firms do not adopt ECSR without the association. By contrast, in a price competition model individual firms voluntarily adopt a positive degree of ECSR and the industry association chooses a higher level of ECSR. These findings together suggest that industry associations have a stronger incentive to encourage firms to adopt ECSR than each individual firm alone. In addition, we show that ECSR may harm welfare, either in Bertrand competition or Cournot competition, because ECSR restricts competition and raises prices.

Antitrust legislation prevents cooperative action in prices or quantities and thus prohibits the formation of price or quantity cartels. However, it is unclear whether firms cooperate when choosing their degrees of ECSR in the face of such regulations and how the cooperative action affects social welfare.[10] Indeed, business and industry associations often play a leading role in the adoption of ECSR by member

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6 There are other terms to express this type of constraint, such as an "emission standard" as referred to by Amir, Gama, and Werner (2018).

7 https://www.keidanren.or.jp/english/policy/csr.html, last visited March 2, 2020. More specifically, many Japanese firms adopted SBT (Science Based Target). See https://www.mizuho-ir.co.jp/topics/2018/pdf/sbt01_02.pdf (in Japanese), last visited March 2, 2020. Tokyo Gas Co., Ltd. recently announced that it will reduce CO_2 emission by 10 million tons by 2030 and archive zero emission by 2050 (Tokyo Gas Co., Ltd., 2019).

8 For examples and discussions on emission intensity, see Helfand (1991), Farzin (2003), Lahiri and Ono (2007), and Ino and Matsumura (2019). Note that Lahiri and Ono (2007) refers to the type of commitment as a "relative emission standard," while Amir, Gama, and Werner (2018) as a "performance standard."

9 See https://www.meti.go.jp/shingikai/sankoshin/sangyo_gijutsu/chikyu_kankyo/shigen_wg/pdf/h30_001_04_01.pdf (in Japanese), last visited March 2, 2020.

10 The literature on cooperative R&D investigates the effect of cooperative action before market competition and how the spillover effect is internalized (d'Aspremont and

firms. For example, many Japanese associations – such as the Japan Association of Corporate Executives, Japan Business Federation, Japan Iron and Steel Federation, and Federation of Electric Power Companies of Japan – emphasize ECSR in their reports and on their websites, and encourage – and often force – member firms to adopt ECSR.[11] Thus, we believe that cooperation in forming ECSR is quite natural and realistic.

The implications of adapting emission intensity commitments are varied and contrasts significantly with emission caps. A joint-profit-maximizing industry association may not always choose a positive degree of ECSR when choosing the desired level of emission intensity, since the upper limit of total emissions is proportional to the level of output. Thus, the output-restriction effect of ECSR under emission intensity initiatives is weaker than that under the emission cap, meaning that the former is also less likely to restrict competition. Thus, it can be inferred that if emission intensity commitments are adopted by an association, ECSR is more likely to be formed for benevolence or improving industry image, such as for advertising, rather than for mitigating market competition.

In fact, this type of ECSR was adopted by the Federation of Electric Power Companies of Japan before the Great East Japan Earthquake. The members of this association were dominant electric companies from 10 areas in Japan, each with 90–100% market share in their respective areas. Because competition was very weak in the Japanese electric power market, the association had little incentive to induce collusion by ECSR. Therefore, we suggest that this type of ECSR was adopted for improving industry image or reducing the likelihood of external pressure.

Regarding the anti-competitive effects of industry associations, several papers have been published on this topic. Marshall and Marx (2012) have shown how third-party organizations themselves can be useful directly maintaining collusion. One of the clearest examples is AC-Treuhand AG, which presented itself as a consulting firm for industry groups, but was later found by the European Commission to have been facilitating collusion by gathering and sharing prices and quantities for different industry participants. Furthermore, Azar, Schmalz, and Tecu (2018) have shown that co-ownership of all firms in a particular market by financial firms such as BlackRock and Vanguard (through their mutual funds) can weaken competition. Nevertheless, the mechanisms in both these papers are quite different from that in this study.

The rest of this paper is organized as follows. Section 2 presents the basic model of emission cap commitments. Sections 3 and 4 investigate quantity and price competition, respectively, and present our main results. Section 5 shows that emission

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Jacquemin, 1988; Ziss, 1994). Our focus is the self-regulation which includes competitive disadvantage over rivals, not simply reduced to cost-reducing effects.

[11] See https://www.fepc.or.jp/library/links/report/index.html (in Japanese), http://www.jisf.or.jp/en/activity/climate/documents/CommitmenttoaLowCarbonSocietyFY30.pdf, and the information in footnote 7, last visited March 2, 2020.

intensity commitments yield contrasting results to that of emission cap commitments. Finally, section 6 concludes.

2 The Model with Emission Cap Commitment

This study uses a symmetric duopoly model where two identical firms – firms 1 and 2 – produce homogeneous commodities,[12] for which the inverse demand function is given by $P(Q) : \mathbb{R}_+ \mapsto \mathbb{R}_+$. We assume that $P(Q)$ is twice continuously differentiable and $P'(Q) < 0$ for all Q as long as $P > 0$. Let $C(q_i) : \mathbb{R}_+ \mapsto \mathbb{R}_+$ be the cost function of firm i, where $q_i \in \mathbb{R}_+$ is the output of firm i. We suppose C is twice continuously differentiable, increasing, and convex for all q_i.[13] We assume that the marginal revenue is decreasing (i.e., $P'(Q)+P''(Q)q_i < 0$). Under quantity competition, this guarantees that the strategies are strategic substitutes and that the second-order condition and the stability condition are satisfied.

There are emissions associated with the production, which yields a negative externality. After emissions have been generated, they can be reduced through pollution abatement. Firm i's emission level is $e_i := g(q_i)-x_i$, where $g : \mathbb{R}_+ \mapsto \mathbb{R}_+$ is emissions associated with production and x_i $(\in \mathbb{R}_+)$ is firm i's abatement level.[14] We assume that g is twice continuously differentiable, increasing, and convex for all q_i.

Firm i $(i = 1,2)$ adopts emission cap T_i that commits itself to be under an upper limit T_i. Whenever firm i exceeds the emission cap imposed on itself, it has to abate the excess emissions, given by the function $x_i = g(q_i)-T_i$, at a cost of $K(x_i)$. We suppose that K is twice continuously differentiable, increasing, and strictly convex. We further assume that $K(0) = K'(0) = 0$. This assumption guarantees that the socially optimal level of abatement is never zero and that the profit function is smooth.[15] We regard that firms adopt ECSR if and only if the emission cap constraint is binding (i.e., $g(q_i) > T_i$ in equilibrium).

Firm i's profit is

$$P(Q)q_i - C(q_i) - K(g(q_i) - T_i).$$

[12] We can show that Propositions 1 and 2 hold even if we introduce product differentiation, which is discussed later in section 4 under moderate conditions. Proposition 1 holds if the strategies are strategic substitutes and the stability condition is satisfied in the quantity-competition stage, though Proposition 2 holds even without the condition of the strategic substitute.

[13] We can relax this assumption. Our results hold if $C'' - P' > 0$ for all q_1 and q_2 as long as $P > 0$.

[14] The type of abatement is so-called "end-of-pipe abatement" and the standard setting in this literature (e.g., Montero, 2002; Lahiri and Ono, 2007; Amir, Gama, and Werner, 2018). We use the similar notation following Amir, Gama, and Werner (2018).

[15] As discussed later, the marginal cost is C' when the constraint is not binding and $C' + K'g'$ when it is binding. The assumption guarantees that the cost function is continuously differentiable. In other words, the cost curve does not jump and is not kinked at the point $g(q_i)-x_i = T_i$.

We examine the following two-stage game. In the first stage, firms noncooperatively or cooperatively commit to their emission caps. In the noncooperative case, each firm i independently chooses T_i to maximize its own profit. In the cooperative case, the industry association chooses $T_i = T_j = T$ to maximize joint profits. In the second stage, the firms compete in Cournot fashion facing their emission constraints imposed by themselves.[16]

To examine the strategic effect of the self-regulation, we assume that the upper limit of the emission is chosen by firms before the product-market competition. The first stage describes the situation in which firms set their emission goal in the long run. For instance, according to Cardwell (2014), NRG Energy has committed to reduce its emissions 50 percent by 2030 and 90 percent by 2050.

Because there is no heterogeneity among firms, we focus on the symmetric equilibrium in which all firms choose the same actions in equilibrium.

3 *Quantity Competition*

We solve the game by backward induction. First, we discuss the second stage. Given T_i and T_j, the firms choose quantities to maximize their profits subject to the emission constraint. Let $q_i^{SQ}(T_i, T_j)$ (*second*-stage game equilibrium output under *quantity* competition) be the equilibrium output of firm i $(i = 1,2,\ i \neq j)$.[17]

There are three possible cases: (i) neither firm faces the emission cap constraint due to the looser limit (i.e., $g(g_i) \leq T_i$), (ii) both firms face the emission constraints due to the stricter limit (i.e., $g(g_i) \geq T_i$), or (iii) only one firm, firm i, faces the emission constraint (i.e., $g(g_i) \geq T_i$ and $g(g_j) \leq T_j$).

First, we consider case (i). The profit of firm $i = 1,2$ for $g(q_i) \leq T_i$ is $\Pi_i(q_i, q_j) = P(Q)q_i - C(q_i)$. Let the superscript UQ denote the equilibrium outcome of this case (*unconstrained quantity* competition). The equilibrium output, q^{UQ}, is characterized by the following first-order condition:

$$\frac{\partial \Pi_i}{\partial q_i} = P'(Q)q_i + P(Q) - C'(q_i) = 0 \quad (i = 1,2,\ i \neq j).$$

The second-order condition $2P' + P'q_i - C'' < 0$ is satisfied. The equilibrium is unique, stable, and symmetric under the assumptions mentioned in the previous section.[18] Eventually, if $T_i \geq T^{UQ} := g(q^{UQ})$ $(i = 1,2)$, we regard that no firm adopts ECSR.

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[16] Gersbach and Requate (2004) and Amir, Gama, and Werner (2018) allow firms to invest in environmental R&D which improves abatement technologies to reduce the abatement cost. In their model, firms can pre-invest in abatement technology, and then firms engage in both Cournot fashion and abatement activities. Our focus is the effect of self-regulation on the equilibrium outcomes, so we assume that there is no pre-investment stage.

[17] The notations used in this paper are summarized in appendix section A.1.

[18] See Vives (1999).

Second, we consider case (ii). As long as the emission cap constraint is binding, the profit function is $\Pi_i(q_i, q_j, T_i) = P(Q)q_i - C(q_i) - K(g(q_i) - T_i)$. The first-order condition is

$$\frac{\partial \Pi_i}{\partial q_i} = P'q_i + P - C' - K'g' = 0 \quad (i = 1,2,\ i \neq j). \tag{1}$$

The second-order condition and the stability condition are satisfied. Thus, a unique equilibrium exists and is stable.

Differentiating (1) leads to

$$\frac{dq_i^{SQ}}{dT_i} = -\frac{(\partial^2\Pi_i/\partial q_i \partial T_i)(\partial^2\Pi_j/\partial q_j^2)}{(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i)} > 0,$$
$$\frac{dq_j^{SQ}}{dT_i} = \frac{(\partial^2\Pi_i/\partial q_i \partial T_i)(\partial^2\Pi_j/\partial q_j \partial q_i)}{(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i)} < 0,$$

where we use $\partial^2\Pi_i/\partial q_i \partial T_i = K''g' > 0$, the second-order condition ($\partial^2\Pi_i/\partial q_i^2 = 2P' + P''q_i - C'' - K''(g')^2 - K'g'' < 0$), and the stability condition.[19] The second-order condition and the stability condition are satisfied under the standard assumptions we made in section 2.

An increase in T_i increases q_i because it reduces firm i's marginal cost $C' + K'g'$, which indirectly reduces q_j through the strategic interaction. Furthermore, because $|\partial^2\Pi_j/\partial q_j^2| = |2P' + P''q_j - C'' - K''(g')^2 - K'g''| > |\partial^2\Pi_j/\partial q_j \partial q_i| = |P' + P''q_j|$, we obtain $dq_i^{SQ}/dT_i + dq_j^{SQ}/dT_i > 0$ (the direct effect dominates the indirect effect through strategic interaction).

Third, we consider case (iii). In this case, the equilibrium outputs are characterized by

$$\frac{\partial \Pi_i}{\partial q_i} = P'q_i + P - C' - K'g' = 0, \tag{2}$$
$$\frac{\partial \Pi_j}{\partial q_j} = P'q_j + P - C' = 0 \quad (j \neq i). \tag{3}$$

The equilibrium outputs depend only on T_i. Differentiating (2) and (3) leads to

$$\frac{dq_i^{SQ}}{dT_i} = -\frac{(\partial^2\Pi_i/\partial q_i \partial T_i)(\partial^2\Pi_j/\partial q_j^2)}{(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i)} > 0,$$
$$\frac{dq_j^{SQ}}{dT_i} = \frac{(\partial^2\Pi_i/\partial q_i \partial T_i)(\partial^2\Pi_j/\partial q_j \partial q_i)}{(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i)} < 0.$$

Again, an increase in T_i directly increases q_i and reduces q_j through the strategic interaction. Furthermore, because $|\partial^2\Pi_j/\partial q_j^2| = |2P' + P''q_j - C''| > |\partial^2\Pi_j/\partial q_j \partial q_i| = |P' + P''q_j|$, we obtain $dq_i^{SQ}/dT_i + dq_j^{SQ}/dT_i > 0$ (the direct effect dominates the indirect effect through strategic interaction).

[19] $(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i) = (2P' + P''q_i - C'' - K''(g')^2 - K'g'')(2P' + P''q_j - C'' - K''(g')^2 - K'g'') - (P' + P''q_i)(P' + P''q_j) > 0.$

We now consider the first stage in which each firm i independently chooses T_i to maximize its own profit. Let the superscript *NQ* denote the equilibrium outcome of this game (*noncooperative* ECSR choice under *quantity* competition). We show that cases (ii) and (iii) never appear in equilibrium, and thus, the emission cap constraint is not binding in equilibrium.

As long as the constraint for firm i is binding, for any T_i,

$$\frac{\partial \Pi_i}{\partial T_i} = \frac{\partial \Pi_i}{\partial q_i}\frac{dq_i^{SQ}}{dT_i} + \frac{\partial \Pi_i}{\partial q_j}\frac{dq_j^{SQ}}{dT_i} + K' > 0 \quad (i = 1,2,\ i \neq j),$$

where we use $\partial \Pi_i/\partial q_i = 0$ (first-order condition), $\partial \Pi_i/\partial q_j = P'q_i < 0$, $dq_j^{SQ}/dT_i < 0$, and $K' > 0$. Thus, a marginal increase in T_i increases firm i's profit until the constraint is not binding. This implies that cases (ii) and (iii) never appear in equilibrium. These discussions lead to the following proposition.

PROPOSITION 1 *Under quantity competition, no firm individually adopts ECSR (i.e., $T^{NQ} \geq T^{UQ}$).*

Next, we consider the model in which the industry association chooses $T = T_1 = T_2$ to maximize the industry profit. Let the superscript *CQ* denote the equilibrium outcome of this game (*cooperative* ECSR choice under *quantity* competition).

As discussed above, when $T < T^{UQ}$, firms face severe constraints on emissions and are need to incur the abatement cost. On the other hand, firms' profits remain unchanged for $T \geq T^{UQ}$ because $(q_1,q_2) = (q^{UQ},q^{UQ})$ for all $T \geq T^{UQ}$. Thus, the industry association's objective function is given by

$$\sum_{i=1}^{2}\Pi_i = \begin{cases} 2\big(P(Q)q_i^{SQ}(T) - C\left(q_i^{SQ}(T)\right) + K\big(g\big(q_i^{SQ}(T)\big) - T\big)\big) & \text{if } T < T^{UQ}, \\ 2\big(P\left(2q^{UQ}\right)q^{UQ} - C\left(q^{UQ}\right)\big) & \text{if } T \geq T^{UQ}. \end{cases}$$

Note that the joint-profit function is continuous at T^{UQ} since $\lim_{T\to T^{UQ}} q_i^{SQ}(T) = q^{UQ}$ and $\lim_{T\to T^{UQ}} K\big(g\big(q_i^{SQ}(T)\big) - T\big) = K\big(g\big(q^{UQ}\big) - T^{UQ}\big) = K(0) = 0$. The figure shows the shape of the joint-profit function under a linear demand.

We show that $T^{CQ} < T^{UQ}$, and thus, case (ii) appears in equilibrium by showing that a marginal decrease in T from T^{UQ} increases the joint profit.

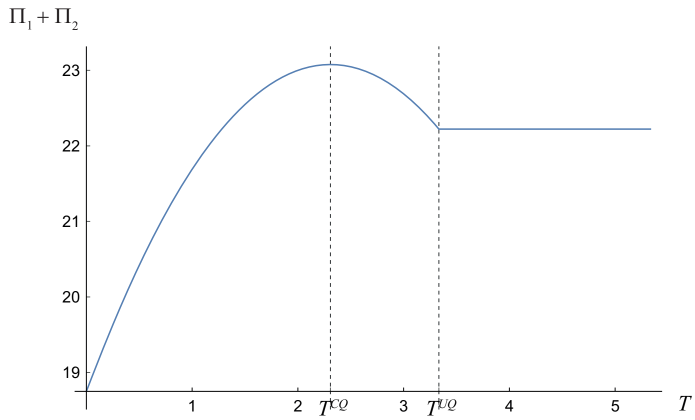
For $T \in [0,T^{UQ}]$, we obtain[20]

$$\left.\frac{\partial(\Pi_1+\Pi_2)}{\partial T}\right|_{T=T^{UQ}} = 2\left.\frac{\partial \Pi_1}{\partial T}\right|_{T=T^{UQ}} = 2\frac{\partial \Pi_1}{\partial q_2}\left(\frac{dq_2^{SQ}}{dT_1} + \frac{dq_2^{SQ}}{dT_2}\right) < 0,$$

where we use $\partial \Pi_1/\partial q_1 = 0$ (first-order condition), $\partial \Pi_1/\partial q_2 = P'q_1 < 0$, $dq_2^{SQ}/dT_1 + dq_2^{SQ}/dT_2 > 0$ (the direct effect dominates the indirect effect), and $K'(0) = 0$ (note that $T_i = g(q_i)$ when $T = T^{UQ}$). Thus, a marginal decrease in T_i from T^{UQ} increases joint profits. In other words, $T \geq T^{UQ}$ is never optimal for the industry association. These discussions lead to the following proposition.

20 The joint-profit function is continuous with respect to T but is kinked at $T = T^{UQ}$. Therefore, we restrict $T \in [0,T^{UQ}]$. Remember that the joint profit function is continuous with respect to T and $\partial(\Pi_1+\Pi_2)/\partial T = 0$ for $T > T^{UQ}$.

Figure
The Joint-Profit Function



Proposition 2 *Under quantity competition, the industry association adopts ECSR (i.e., $T^{CQ} < T^{UQ}$).*

A marginal decrease in T_1 (T_2) from T^{UQ} decreases firm 1's (firm 2's) profit by the second order (envelope theorem), whereas a marginal decrease in T_2 (T_1) from T^{UQ} increases firm 1's (firm 2's) profit by the first order. Therefore, a simultaneous decrease in T_1 and T_2 increases joint profits.

Propositions 1 and 2 indicate that the industry association plays a crucial role in adopting ECSR. Although firms have no incentive to adopt ECSR, they accept ECSR coordinated by the industry association because it serves as a collusive device that restricts their output, resulting in a higher price.

Finally, we discuss the welfare implications of ECSR. The total social surplus (firm profits plus consumer surplus minus the loss caused by the externality) is given by

$$W = \int_0^Q P(z)dz - \sum_{i=1}^{2}[C(q_i) + K(g(q_i) - T_i)] - \eta\left(\sum_{i=1}^{2} T_i\right),$$

where $\eta : \mathbb{R}_+ \mapsto \mathbb{R}_+$ is the welfare loss of emissions. We assume that η is twice continuously differentiable, increasing, and convex.

Suppose the government can choose $T = T_1 = T_2 \leq T^{UQ}$. Given the Cournot competition in the second stage, W is denoted by the following function.

$$W(T) = \int_0^Q P(z)dz - \sum_{i=1}^{2}[C(q_i^{SQ}) + K(g(q_i^{SQ}) - T)] - \eta(2T).$$

We obtain

$$\frac{\partial W}{\partial T} = 2\left(- P' q_1^{SQ} \left(\frac{dq_1^{SQ}}{dT_1} + \frac{dq_2^{SQ}}{dT_1} \right) + K' - \eta' \right), \tag{4}$$

where we use (1). The first term in (4) represents the welfare-improving effect of output expansion caused by a lesser degree of ECSR ($-P'q_1$ is equal to the price-cost margin $P - C' - K'g'$). The second term represents the abatement cost-saving effect. The third term represents the welfare loss caused by an increase in emissions.

The sign of the derivative at $T = T^{CQ}$ is negative if η' is large enough. In this case, T^{CQ} ($< T^{UQ}$) is still too large from the viewpoint of social welfare, and it implies that ECSR by industry association improves welfare as long as $W(T)$ is concave. Note that each firm chooses $T = T^{UQ}$ without the industry association. However, if η' is sufficiently small, (4) is positive and the degree of ECSR adopted by the industry association is too high for social welfare (i.e., the loss of collusive behavior dominates the emission-reducing effect), and thus ECSR may be harmful for welfare.

We now discuss this point explicitly using a numerical example. Suppose $P = \alpha - Q$, $C = 0$, $g = \theta q_i$, $K = kx_i^2/2$, and $\eta = d(e_1 + e_2)$.[21] Then, we obtain

$$W(T) = \frac{4\alpha^2 - 2\theta^2 k^2 T(T + \theta(d\theta - \alpha)) + k(4\theta T(2\alpha - 3d\theta) - 9T^2 + \alpha^2\theta^2) - 18dT}{(\theta^2 k + 3)^2}.$$

Comparing the cooperative case with the noncooperative case (no ECSR), we obtain

$$W(T^{CQ}) - W(T^{UQ}) = \frac{\alpha\theta(6d(4\theta^4k^2 + 21\theta^2k + 27) - \alpha\theta k(10\theta^2 k + 27))}{9(4\theta^2 k + 9)^2}.$$

This is positive if and only if

$$d > \tilde{d} := \frac{10\alpha\theta^3k^2 + 27\alpha\theta k}{24\theta^4k^2 + 126\theta^2 k + 162}.$$

Thus, we obtain the following proposition.

PROPOSITION 3 *Suppose $P = \alpha - Q$, $C = 0$, $g = \theta q_i$, $K = kx_i^2/2$, and $\eta = d(e_1 + e_2)$. Then, the cooperative ECSR improves social welfare if and only if $d > \tilde{d}$.*

4 Price Competition

We now consider Bertrand competition with product differentiation.[22] Assume there are two symmetric firms which produce differentiated products. The di-

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[21] $\eta = d(e_1 + e_2)^2$ may be a more natural formulation. We obtain a similar result in this formulation with messier exposition.

[22] Without product differentiation, there is no pure–strategy equilibrium in our setting.

rect demand function for product i is given by $D_i(P) : \mathbb{R}_+ \mapsto \mathbb{R}_+$ where $P := (p_1, p_2) \in \mathbb{R}^2_+$ is the price vector. We assume that D is twice continuously differentiable for all $P > 0$. The demand function is downward sloping, $\partial D_i/\partial p_i < 0$, $i = 1,2$, and $\partial D_i/\partial p_j > 0$, $j \neq i$ as long as $D > 0$. The latter condition means that these goods are substitutes. In addition, we assume that the direct effect of a price change dominates the indirect effect, $\sum_{j=1}^{2}(\partial D_i/\partial p_j) < 0$ and $\partial^2 D_i/(\partial p_i)^2 + |\partial^2 D_i/\partial p_i \partial p_j| < 0$. We further assume that the demand functions have increasing differences in (p_i, p_j), $\partial^2 D_i/\partial p_i \partial p_j \geq 0$, which implies that the price setting game is supermodular. These are standard assumptions in the literature on Bertrand competition in differentiated product markets.[23] Except for the demand system, we follow the same structure in the quantity competition analysis.

The emission abatement level x_i is the same as that in the previous section. Here, we discuss the second-stage price competition. The firms choose their prices independently, given T_1 and T_2. Let $p_i^{SP}(T_i, T_j)$ (*second*-stage game equilibrium outcome under *price* competition) be the equilibrium price of firm i ($i = 1,2, i \neq j$). Similar to the quantity competition analysis, there are three possible cases: (i) neither firm faces the emission cap constraint, (ii) both firms face the constraints, or (iii) only one firm, firm i, faces the emission constraint.

First, consider case (i). The profit of firm i for $g(D_i(P)) \leq T_i$ is $\Pi_i(p_i, p_j) = p_i D_i(P) - C(D_i(P))$. Let the superscript *UP* denote the equilibrium outcome of this case (*unconstrained price* competition). The equilibrium price, p_i^{UP}, is characterized by the following first-order condition:

$$\frac{\partial \Pi_i}{\partial p_i} = D_i(P) + p_i \frac{\partial D_i}{\partial p_i} - C' \frac{\partial D_i}{\partial p_i} = 0 \quad (i = 1,2,\ i \neq j).$$

The second-order condition $\partial D_i/\partial p_i + (1 - (\partial D_i/\partial p_i)C'')\partial D_i/\partial p_i + (p_i - C') \times \partial^2 D_i/\partial p_i^2 < 0$ is satisfied. Then, a unique, stable, and symmetric equilibrium exists. If $T_i \geq T^{UP} := g(D_i(P^{UP}))$ ($i = 1,2$), we regard that no firm adopts ECSR.

Second, we consider case (ii). As long as the emission cap constraint is binding, the profit function is $\Pi_i(p_i, p_j, T_i) = p_i D_i(P) - C(D_i(P)) - K(g(D_i(P)) - T_i)$. The first-order condition is

$$\frac{\partial \Pi_i}{\partial p_i} = D_i(P) + p_i \frac{\partial D_i}{\partial p_i} - C' \frac{\partial D_i}{\partial p_i} - K' g' \frac{\partial D_i}{\partial p_i} = 0 \quad (i = 1,2,\ i \neq j). \tag{5}$$

The second-order condition and the stability condition are satisfied.[24] Thus, a unique equilibrium exists and is stable.

Differentiating (5) leads to

$$\frac{dp_i^{SP}}{dT_i} = -\frac{(\partial^2 \Pi_i/\partial p_i \partial T_i)(\partial^2 \Pi_j/\partial p_j^2)}{(\partial^2 \Pi_i/\partial p_i{}^2)(\partial^2 \Pi_j/\partial p_j{}^2) - (\partial^2 \Pi_i/\partial p_i \partial p_j)(\partial^2 \Pi_j/\partial p_j \partial p_i)} < 0,$$

$$\frac{dp_j^{SP}}{dT_i} = \frac{(\partial^2 \Pi_i/\partial p_i \partial T_i)(\partial^2 \Pi_j/\partial p_j \partial p_i)}{(\partial^2 \Pi_i/\partial p_i{}^2)(\partial^2 \Pi_j/\partial p_j{}^2) - (\partial^2 \Pi_i/\partial p_i \partial p_j)(\partial^2 \Pi_j/\partial p_j \partial p_i)} < 0,$$

23 See Vives (1999).

24 We show that the stability condition is satisfied in appendix section A.2.

where we use $\partial^2\Pi_i/\partial p_i\partial T_i = (\partial D_i/\partial p_i)K'g' < 0$, the second-order condition,[25] and the stability condition.[26]

An increase in T_i decreases p_i because it reduces firm i's marginal cost $C'+K'g'$, which indirectly reduces p_j through the strategic interaction.

Third, we consider case (iii). In this case, the equilibrium prices are characterized by

$$\frac{\partial \Pi_i}{\partial p_i} = D_i(P) + p_i\frac{\partial D_i}{\partial p_i} - C'\frac{\partial D_i}{\partial p_i} - K'g'\frac{\partial D_i}{\partial p_i} = 0, \tag{6}$$

$$\frac{\partial \Pi_j}{\partial p_j} = D_i(P) + p_i\frac{\partial D_i}{\partial p_i} - C'\frac{\partial D_i}{\partial p_i} = 0 \quad (j \neq i). \tag{7}$$

The equilibrium prices depend only on T_i. Differentiating (6) and (7) leads to

$$\frac{dp_i^{SP}}{dT_i} = -\frac{(\partial^2\Pi_i/\partial p_i\partial T_i)(\partial^2\Pi_j/\partial p_j^2)}{(\partial^2\Pi_i/\partial p_i{}^2)(\partial^2\Pi_j/\partial p_j{}^2) - (\partial^2\Pi_i/\partial p_i\partial p_j)(\partial^2\Pi_j/\partial p_j\partial p_i)} < 0,$$

$$\frac{dp_j^{SP}}{dT_i} = \frac{(\partial^2\Pi_i/\partial p_i\partial T_i)(\partial^2\Pi_j/\partial p_j\partial p_i)}{(\partial^2\Pi_i/\partial p_i{}^2)(\partial^2\Pi_j/\partial p_j{}^2) - (\partial^2\Pi_i/\partial p_i\partial p_j)(\partial^2\Pi_j/\partial p_j\partial p_i)} < 0.$$

Again, an increase in T_i decreases p_i and indirectly reduces p_j through the strategic interaction.

We now consider the model in which each firm i independently chooses T_i to maximize its own profit. Let the superscript NP denote the equilibrium outcome of this game (*noncooperative* ECSR choice under *price* competition). We show that cases (i) and (iii) never appear in equilibrium, and thus, the emission cap constraint is binding for both firms.

Suppose the constraint for firm i is not binding. As long as the constraint for firm i is not binding, its profit remains unchanged. Consider a marginal decrease in T_i from the point where the emission without abatement is equal to T_i. We obtain

$$\frac{\partial \Pi_i}{\partial T_i} = \frac{\partial \Pi_i}{\partial p_i}\frac{dp_i^{SP}}{dT_i} + \frac{\partial \Pi_i}{\partial p_j}\frac{dp_j^{SP}}{dT_i} + K' < 0 \quad (i = 1, 2,\ i \neq j),$$

where we use $\partial\Pi_i/\partial p_i = 0$ (first-order condition), $\partial\Pi_i/\partial p_j = (p_i - C' - K'g')\partial D_i/\partial p_j > 0$, $dp_j^{SP}/dT_i < 0$, and $K'(0) = 0$. Thus, a marginal decrease in T_i increases firm i's profit. This implies that cases (i) and (iii) never appear in equilibrium. Again, remember that firm i's profit function is continuous with respect to T_i and it does not depend on T_i as long as T_i is so large that the constraint is not binding. These discussions lead to the following proposition.

PROPOSITION 4 *Under Bertrand competition, firms noncooperatively adopt ECSR (i.e., $T^{NP} < T^{UP}$).*

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25 $\partial^2\Pi_i/\partial p_i^2 = \partial D_i/\partial p_i + (1 - (C'' + K''(g')^2 + K'g'')(\partial D_i/\partial p_i))\partial D_i/\partial p_i + (p_i - C' - K'g')\partial^2 D_i/\partial p_i^2 < 0$.

26 In section A.2, we show that $(\partial^2\Pi_i/\partial p_i{}^2)(\partial^2\Pi_j/\partial p_j{}^2) - (\partial^2\Pi_i/\partial p_i\partial p_j)(\partial^2\Pi_j/\partial p_j\partial p_i) > 0$.

In contrast to the quantity competition model, each firm voluntarily adopts ECSR, which increases its marginal costs of production.[27] An increase in the production cost of firm i raises firm i's price as well as its rival's price through strategic interaction, resulting in an increase in firm i's profit. It implies that the strategic effect (raising the equilibrium price) dominates the direct effect (increasing the cost of production). At first glance, this seems unusual. However, imposing the self-regulation increases the abatement cost, $K(x_i)$, not the production cost, $C(D_i(P))$. Thus, the direct effect is significantly smaller than the strategic effect, especially at the beginning of the self-regulation, because K' is small.

We now compare the cooperative and noncooperative cases under price competition. We consider the model in which the industry association chooses $T = T_1 = T_2$ to maximize the industry profit. If $T \geq T^{UP}$, neither firm faces the emission constraint, so the prices of both firms do not depend on T. Thus, the joint profits do not depend on T. We assume that for $T \leq T^{UP}$, joint profit is concave with respect to T.

Let the superscript *CP* denote the equilibrium outcome of this game (*cooperative* ECSR choice under *price* competition). We show that $T^{CP} < T^{NP}$ is in equilibrium by showing that a marginal decrease in T from T^{NP} increases joint profits.

We obtain

$$\begin{aligned}\left.\frac{\partial(\Pi_1+\Pi_2)}{\partial T}\right|_{T=T^{NP}} &= 2\left.\frac{\partial \Pi_1}{\partial T}\right|_{T=T^{NP}} \\ &= 2\left(\frac{\partial \Pi_1}{\partial p_2}\left(\frac{dp_2^{SP}}{dT_1}+\frac{dp_2^{SP}}{dT_2}\right)+K'\right) = 2\frac{\partial \Pi_1}{\partial p_2}\frac{dp_2^{SP}}{dT_2} < 0,\end{aligned}$$

where we use $\partial\Pi_i/\partial p_i = 0$ (first-order condition), $\partial\Pi_i/\partial p_j = (p_i - C' - K'g')\partial D_i/\partial p_j > 0$, $dp_i^{SP}/dT_i < 0$, and $(\partial\Pi_i/\partial p_j)(dp_j^{SP}/dT_i) + K' = 0$ when $T_i = T^{NP}$. Thus, the marginal decrease in T_i from T^{NP} increases the joint profit. This implies that T^{NP} is too large from the joint-profit-maximizing viewpoint. These discussions lead to the following proposition.

PROPOSITION 5 *Under price competition, the industry association adopts a higher level of ECSR (i.e., $T^{CP} < T^{NP} < T^{UP}$).*

A decrease in T_i raises the price of firm i and increases the profit of firm j. When firm i individually chooses T_i, firm i considers its own profit only and does not take into account this rival's profit-raising effect. Thus, T^{NP} is too large from the viewpoint of joint profit maximization.

Under price competition, we obtain welfare implications similar to those discussed in section 3. When the degree of negative externality of emissions is large, even T^{CP} is too large for social welfare. However, when the degree of negative ex-

[27] The strategic ECSR depends on whether firms compete on quantities or prices. The result is similar to those in the literature on strategic choice of managerial incentives and endogenous ownership structure (Fershtman and Judd, 1987; Purroy and Salas, 2000; Lee and Park, 2019).

ternality of emissions is small, even $T^{NP}(> T^{CP})$ is too small for social welfare. In short, ECSR can be either beneficial or harmful for social welfare.

5 *Emission Intensity Commitment*

In this section, we consider ECSR by the emission intensity commitment. For simplicity, we assume that without abatement activity, the emission level is proportional to the output level, that is $g(q_i) = \theta q_i$. We normalize $\theta = 1$. Note that this specification satisfies the assumptions in the previous sections. Firm i ($i = 1,2$) chooses the emission intensity $t_i \in [0,1]$ and commits to $e_i/q_i \leq t_i$. Thus, we regard firm i as adopting ECSR if $t_i < 1$.

First, we consider quantity competition. In the second stage, each firm i chooses its output and abatement level to maximize its profit subject to the emission constraint. If $t_i = 1$, because there is no binding constraint on firm i, q_i^{UQ} is the equilibrium output.

If $t_i < 1$, firm i has to abate emissions, given by the function $x_i = (1-t_i)q_i$. Thus, the profit of firm $i = 1,2$ can be rewritten as $\Pi_i(q_i, q_j, t_i) = P(Q)q_i - C(q_i) - K((1-t_i)q_i)$. Let $q_i^{SQ}(t_i, t_j)$ be the equilibrium output of firm i ($i = 1,2,\ i \neq j$) in this subgame. The equilibrium output, q_i^{SQ}, is characterized by the following first-order condition:

$$\text{(8)} \qquad \frac{\partial \Pi_i}{\partial q_i} = P'(Q)q_i + P(Q) - C'(q_i) - (1-t_i)K' = 0 \quad (i = 1,2,\ i \neq j).$$

The second-order condition and the stability condition are satisfied under the assumptions discussed in section 3. Thus, a unique equilibrium exists and is stable.

Differentiating (8) leads to

$$\frac{dq_i^{SQ}}{dt_i} = -\frac{(\partial^2\Pi_i/\partial q_i \partial t_i)(\partial^2\Pi_j/\partial q_j^2)}{(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i)} > 0,$$
$$\frac{dq_j^{SQ}}{dt_i} = \frac{(\partial^2\Pi_i/\partial q_i \partial t_i)(\partial^2\Pi_j/\partial q_j \partial q_i)}{(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i)} < 0,$$

where we use $\partial^2\Pi_i/\partial q_i \partial t_i = K' + (1-t_i)K''q_i > 0$, the second-order condition ($\partial^2\Pi_i/\partial q_i{}^2 = 2P' + P''q_i - C'' - (1-t_i)^2K'' < 0$), and the stability condition.[28] Furthermore, because

$$\left|\frac{\partial^2\Pi_j}{\partial q_j^2}\right| = |2P' + P''q_j - C'' - (1-t_j)^2K''| > \left|\frac{\partial^2\Pi_j}{\partial q_j \partial q_i}\right| = |P' + P''q_j|,$$

we obtain $dq_i^{SQ}/dt_i + dq_j^{SQ}/dt_i \geq 0$ (the direct effect dominates the indirect effect through strategic interaction).

[28] $(\partial^2\Pi_i/\partial q_i{}^2)(\partial^2\Pi_j/\partial q_j{}^2) - (\partial^2\Pi_i/\partial q_i \partial q_j)(\partial^2\Pi_j/\partial q_j \partial q_i) = (P''q_i + 2P' - C'' - (1-t_i)^2K'')(P''q_j + 2P' - C'' - (1-t_j)^2K'') - (P''q_i + P')(P''q_j + P') > 0.$

We now highlight one important property. Because $K'(0) = 0$ when $t_i = 1$, $\partial^2 \Pi_i / \partial q_i \partial t_i = K' + (1-t_i)K'' q_i = 0$ when $t_i = 1$. Thus, we obtain $dq_i^{SQ}/dt_i = dq_j^{SQ}/dt_i = 0$ when $t_i = 1$.

We now discuss the first-stage action. First, we consider the model in which each firm i individually chooses t_i to maximize its own profit.

For any $t_i \in [0,1)$, we obtain

$$\frac{\partial \Pi_i}{\partial t_i} = \frac{\partial \Pi_i}{\partial q_i}\frac{dq_i^{SQ}}{dt_i} + \frac{\partial \Pi_i}{\partial q_j}\frac{dq_j^{SQ}}{dt_i} + K' q_i^{SQ} > 0, \quad (i = 1,2,\ i \neq j),$$

where we use $\partial \Pi_i / \partial q_i = 0$, $\partial \Pi_i / \partial q_j = P' q_i < 0$, $dq_j^{SQ}/dt_i < 0$, and $K' q_i^{SQ} > 0$. Therefore, each firm chooses $t_i = 1$. These discussions lead to the following proposition.

Proposition 6 *Under quantity competition with emission intensity commitment, no firm individually adopts ECSR (i.e., $t_i^{NQ} = 1$).*

Next, we consider the model in which the industry association chooses $t = t_i = t_j$ to maximize the joint profit. We assume that the joint profit is concave in t_i. We obtain

$$\left.\frac{\partial (\Pi_i + \Pi_j)}{\partial t}\right|_{t=1} = 2\frac{\partial \Pi_i}{\partial t} = 2\left(\frac{\partial \Pi_i}{\partial q_j}\left(\frac{dq_j^{SQ}}{dt_i} + \frac{dq_j^{SQ}}{dt_j}\right) + K' q_i^{SQ}\right) = 0,$$

where we use $dq_i^{SQ}/dt_i = dq_j^{SQ}/dt_i = 0$, and $K'(0) = 0$ when $t = 1$. This implies that $t = 1$ is optimal. This leads to the following proposition.

Proposition 7 *Suppose the joint profit is concave in t. Under quantity competition with emission intensity commitment, even the industry association does not adopt ECSR (i.e., $t^{CQ} = 1$).*

It is possible that the assumption that the joint profit is concave in t is restrictive. We show that

$$\left.\frac{\partial (\Pi_i + \Pi_j)}{\partial t}\right|_{t=1} = 0,$$

but it might imply that $t = 1$ yields locally minimized joint profits rather than maximized ones if the abovementioned assumption is not satisfied. However, it is quite difficult to derive a clear condition guaranteeing this assumption. We now present an example satisfying this assumption.

Suppose demand is linear ($P = \alpha - Q$), marginal cost is constant and normalized to zero, and the abatement cost function is quadratic ($K = kx_i^2/2$). We also assume the cost of abatement is not too large ($k < (2+\sqrt{13})/3$). Then, we obtain[29]

$$\frac{\partial (\Pi_i + \Pi_j)}{\partial t} = \frac{2\alpha^2 k(1-t)(1+k(1-t)^2)}{(3+k(1-t)^2)^3}. \tag{9}$$

[29] The detailed derivation of (9) is relegated to appendix section A.3.

This is positive for $t \in [0,1)$ and zero when $t = 1$. Thus, $t = 1$ (no ECSR) maximizes the joint profits.

Proposition 7 is in sharp contrast to Proposition 2. Even the industry association that maximizes joint profit does not adopt ECSR. Under the emission intensity commitment, it can emit $t_i q_i$, whereas under the emission cap commitment, the firm can emit e_i independently of q_i. Thus, each firm has a stronger incentive to expand its output under the emission intensity commitment. Therefore, the output-restricting effect of ECSR is weaker under the emission intensity commitment.

We now consider price competition. Suppose the demand is given by $p_i = \alpha - \beta q_i - \beta\delta q_j$ $(i = 1,2,\ i \neq j)$, the marginal cost is constant and normalized to zero, and the abatement cost function is quadratic $K = kx_i^2/2$. Again, we assume the cost of abatement is not too large $(k < \beta(2+\sqrt{13})/4)$. Then, the profit function of firm i is

$$\Pi_i(t_i,t_j) = \frac{\alpha^2(2\beta(1-\delta^2)+k(1-t_i)^2)(\beta(-\delta^2-\delta+2)+k(1-t_j)^2)^2}{H}.$$

where $H = 2(\beta^2(\delta^4-5\delta^2+4)+k^2(1-t_i)^2(1-t_j)^2-\beta(\delta^2-2)k((t_i-2)t_i+(t_j-2)t_j+2))^2$.

As in the emission cap commitment case, firms have a stronger incentive for adopting ECSR under price competition than under quantity competition. Thus, we rationally infer that firms may adopt ECSR under price competition even in the emission intensity commitment case. This is true only when the degree of product differentiation is small.

First, we consider the noncooperative case in which each firm i individually chooses t_i to maximize its own profit. Taking the first derivative of the profit function with respect to t_i and evaluating it given $t_j = 1$, we obtain

$$\left.\frac{\partial \Pi_i}{\partial t_i}\right|_{t_j=1} > 0$$

for any $t_i \in [0,1)$ and zero when $t_i = 1$. This implies that no ECSR equilibrium exists regardless of δ. Moreover, if $\delta < \sqrt{2/3}$, this is the unique equilibrium. However, if the degree of product differentiation is sufficiently small, there is another symmetric equilibrium in which each firm i chooses $t_i < 1$. When the degree of product differentiation is sufficiently small, competition is tough without ECSR, and firms have strong incentives to soften the market competition by adopting ECSR.

Next, we consider the cooperative case. The industry association chooses $t = t_i = t_j$ to maximize the joint profit given by

$$\Pi_i + \Pi_j = \frac{\alpha^2(2\beta(1-\delta)+k(1-t)^2)}{(\beta(2+\delta-\delta^2)+k(1-t)^2)^2}.$$

We obtain

$$\frac{\partial(\Pi_i+\Pi_j)}{\partial t} = \frac{2\alpha^2 k(\beta(2-\delta-3\delta^2)+k(1-t)^2)(1-t)}{(\beta(2+\delta-\delta^2)+k(1-t)^2)^3}. \tag{10}$$

Assuming that the degree of product differentiation is not small ($\delta < 2/3$), this is always positive for $t \in [0,1)$ and zero when $t = 1$. That is, the industry association also chooses no ECSR. However, if $\delta > 2/3$, the industry association chooses ECSR (i.e., chooses $t < 1$).

As mentioned in the Introduction, emission intensity commitment is adopted in some industries, such as the Japanese electric power industry. One possibility is that firms in the industry face price competition and the degree of product differentiation is small. Another possibility is that firms adopt ECSR for benevolence or improvement of industry image, such as advertising, and not for enhancing collusion. Alternatively, firms may adopt ECSR to prevent government from imposing stricter formal regulations in future. In any case, our results suggest that emission intensity commitments may have a weaker effect for softening competition than emission cap commitments.

6 *Concluding Remarks*

In this paper, we demonstrate that profit-maximizing industry associations have a strong incentive to adopt ECSR even when it induces member firms to engage in unprofitable emission abatement activities. The result is robust to the type of product market (Cournot and differentiated Bertrand competition). This cost increase raises prices or reduces quantities, resulting in an increase in industry profits. Therefore, collusion in an ECSR can mitigate market competition and reduce welfare, even though it reduces total emissions.

In addition, we show that whether the effect of restricting competition is significant depends on the type of ECSR. Specifically, we show that the emission cap commitment has this effect, but the emission intensity commitment may not. Based on the type of ECSR which firms or industry associations adopt, we identify the risk of the output distortion from ECSR.

A limitation of this study is that we overlook other environmental policies such as emission taxes and tradable permits. ECSR may reduce environmental taxes or relax other environmental regulations, which would increase industry profits further. Introducing the government as an active player that implements environmental policies and investigating the relationship between these policies and ECSR are avenues left for future research.

Appendix

A.1 Notation

Table
Notation in this Paper

Superscript		
	under *Quantity* Competition	
SQ	*Second*-stage equilibrium output under constraints	$\{q_i^{SQ}\}$
UQ	*Unconstrained* quantity competition	$\{q_i^{UQ}, T_i^{UQ}\}$
NQ	*Noncooperative* ECSR choice	$\{T_i^{NQ}\}$
CQ	*Cooperative* ECSR choice	$\{T^{CQ}\}$
	under *Price* Competition	
SP	*Second*-stage equilibrium output under constraints	$\{p_i^{SP}\}$
UP	*Unconstrained* price competition	$\{p_i^{UP}, T_i^{UP}\}$
NP	*Noncooperative* ECSR choice	$\{T_i^{NP}\}$
CP	*Cooperative* ECSR choice	$\{T^{CP}\}$

A.2 Stability Condition under Price Competition

$$
\begin{aligned}
&\frac{\partial^2 \Pi_i}{\partial {p_i}^2}\frac{\partial^2 \Pi_j}{\partial {p_j}^2} - \frac{\partial^2 \Pi_i}{\partial p_i \partial p_j}\frac{\partial^2 \Pi_j}{\partial p_i \partial p_j}\\
&= \left(\frac{\partial D_i}{\partial p_i} + \left(1-(C''+K''(g')^2+K'g'')\frac{\partial D_i}{\partial p_i}\right)\frac{\partial D_i}{\partial p_i} + (p_i - C' - K'g')\frac{\partial^2 D_i}{\partial p_i^2}\right)\\
&\quad \times \left(\frac{\partial D_j}{\partial p_j} + \left(1-(C''+K''(g')^2+K'g'')\frac{\partial D_j}{\partial p_j}\right)\frac{\partial D_j}{\partial p_j} + (p_j - C' - K'g')\frac{\partial^2 D_j}{\partial p_j^2}\right)\\
&\quad - \left(\left(1-(C''+K''(g')^2+K'g'')\frac{\partial D_i}{\partial p_i}\right)\frac{\partial D_i}{\partial p_j} + (p_i - C' - K'g')\frac{\partial^2 D_i}{\partial p_i \partial p_j}\right)\\
&\quad \times \left(\left(1-(C''+K''(g')^2+K'g'')\frac{\partial D_j}{\partial p_j}\right)\frac{\partial D_j}{\partial p_i} + (p_i - C' - K'g')\frac{\partial^2 D_j}{\partial p_i \partial p_j}\right) > 0.
\end{aligned}
$$

A.3 Derivation of (9)

Suppose there are two identical firms, firms 1 and 2, produce homogeneous products for which the inverse demand function is given by $P = \alpha - Q$, where Q is total quantity. We assume the common marginal production cost is constant and this is normalized to zero, and the abatement cost function is quadratic ($K(x_i) = kx_i^2/2$).

For simplicity, we assume that without abatement activity, the emission level is proportional to the output level. That is $g(q_i) = eq_i$. We normalize $e = 1$.

Firm i ($i = 1,2$) adopts the emission intensity $t_i \in [0,1]$ and commits to $(q_i - x_i)/q_i \leq t_i$. We regard firm i as adopting ECSR if $t_i < 1$. Firm i's profit, π_i, is

$$Pq_i - \frac{kx_i^2}{2},$$

where the second term represents the abatement cost and k is a positive constant.

To obtain (9), we solve the game by backward induction. The firms choose their quantities independently, given t_i and t_j. For $t_i < 1$, firm i's profit, Π_i, is

$$Pq_i - \frac{k((1-t_i)q_i)^2}{2}.$$

The first-order condition is

$$\frac{\partial \Pi_i}{\partial q_i} = \alpha - 2q_i - q_j - k(1-t_i)q_i = 0 \quad (i = 1,2,\ i \neq j).$$

We obtain the equilibrium outputs:

$$q_i^{SQ} = \frac{\alpha(k(1-t_j)^2+1)}{k^2(1-t_i)^2(1-t_j)^2 + 2k(t_i^2 - 2t_i + t_j^2 - 2t_j + 2) + 3}.$$

Substituting these equilibrium quantities into the profit function, we have the following resulting profit:

$$\Pi_i(t_i,t_j) = \frac{\alpha^2(2+k(1-t_i))(k(1-t_j)^2+1)^2}{2(k^2(1-t_i)^2(1-t_j)^2 + 2k(t_i^2 - 2t_i + t_j^2 - 2t_j + 2) + 3)^2}.$$

We now discuss the first-stage action. We consider the model in which the industry association chooses $t = t_i = t_j$ to maximize the joint profit. We obtain

$$\frac{\partial(\Pi_i + \Pi_j)}{\partial t} = \frac{\alpha^2 k(1-t)(1+k(1-t)^2)}{(3+k(1-t)^2)^3}.$$

The second-order condition

$$\frac{\alpha^2 k(3k^2(1-t)^4 - 4k(1-t)^2 - 3)}{(3+k(1-t)^2)^4} < 0$$

is satisfied if $k < (2+\sqrt{13})/3$.

A.4 Derivation of (10)

To obtain (10), we solve the game by backward induction. Here, we begin by discussing the second-stage price competition. The firms choose their price independently, given t_i and t_j. For $t_i < 1$, firm i's profit, Π_i, is

$$p_i q_i - \frac{k((1-t_i)q_i)^2}{2}.$$

The first-order condition is

$$\frac{\partial \Pi_i}{\partial p_i} = \frac{2(\alpha(3\beta + 4k(1-t_i)^2) - 3\beta(4p_i - p_j) - 4k(1-t_i)^2(2p_i - p_j))}{9\beta^2} = 0.$$

We obtain the equilibrium prices:

$$p_i^{SP} = \frac{\alpha(3\beta + 4k(1-t_i)^2)(5\beta + 4k(1-t_j)^2)}{45\beta^2 + 16k^2(1-t_i)^2(1-t_j)^2 + 28\beta k(2-(2-t_i)t_i - (2-t_j)t_j)}.$$

Substituting these equilibrium prices into the profit function, we have the following resulting profit:

$$\Pi_i(t_i, t_j) = \frac{4\alpha^2(3\beta + 2k(1-t_i)^2)(5\beta + 4k(1-t_j)^2)^2}{(45\beta^2 + 16k^2(1-t_i)^2(1-t_j)^2 + 28\beta k(2-(2-t_i)t_i - (2-t_j)t_j))^2}.$$

We now discuss the first-stage action. We consider the model in which the industry association chooses $t = t_i = t_j$ to maximize the joint profit. We obtain

$$\frac{\partial(\Pi_i + \Pi_j)}{\partial t} = \frac{32\alpha^2 k(3\beta + 4k(1-t)^2)(1-t)}{(9\beta + 4k(1-t)^2)^3}.$$

The second-order condition

$$\frac{96\alpha^2 k(-9\beta^2 - 16\beta k(1-t)^2 + 16k^2(1-t)^4)}{(9\beta + 4k(1-t)^2)^4} < 0$$

is satisfied if $k < \beta(2+\sqrt{13})/4$.

References

Amir, Rabah, Adriana Gama, and Katarzyna Werner (2018), "On Environmental Regulation of Oligopoly Markets: Emission versus Performance Standards," *Environmental & Resource Economics*, 70(1), 147–167.

Antweiler, Werner (2003), "How Effective Is Green Regulatory Threat?" *The American Economic Review*, Papers and Proceedings, 93(2), 436–441.

Azar, José, Martin C. Schmalz, and Isabel Tecu (2018), "Anticompetitive Effects of Common Ownership," *The Journal of Finance*, 73(4), 1513–1565.

Baron, David P. (2001), "Private Politics, Corporate Social Responsibility, and Integrated Strategy," *Journal of Economics & Management Strategy*, 10(1), 7–45.

— (2008), "Managerial Contracting and Corporate Social Responsibility," *Journal of Public Economics*, 92(1–2), 268–288.

Brand, Björn, and Michael Grothe (2015), "Social Responsibility in a Bilateral Monopoly," *Journal of Economics*, 115(3), 275–289.

Calveras, Aleix, Juan-José Ganuza, and Gerard Llobet (2007), "Regulation, Corporate Social Responsibility and Activism," *Journal of Economics & Management Strategy*, 16(3), 719–740.

Cardwell, Diane (2014), "NRG Seeks to Cut 90% of its Carbon Emissions," *The New York Times*, November 20, https://www.nytimes.com/2014/11/21/business/energy-environment/nrg-sets-goals-to-cut-carbon-emissions.html, accessed March 19, 2020.

Carroll, Archie B., and Kareem M. Shabana (2010), "The Business Case for Corporate Social Responsibility: A Review of Concepts, Research and Practice," *International Journal of Management Reviews*, 12(1), 85–105.

CDP North America (2013), "Use of Internal Carbon Price by Companies as Incentive and Strategic Planning Tool: A Review of Findings from CDP 2013 Disclosure," White Paper, https://www.actuaries.org.uk/system/files/documents/pdf/cdp-carbon-pricingdec13.pdf, accessed July 29, 2016.

d'Aspremont, Claude, and Alexis Jacquemin (1988), "Cooperative and Noncooperative *R&D* in Duopoly with Spillovers," *The American Economic Review*, 78(5), 1133–1137.

Farzin, Y. H. (2003), "The Effects of Emissions Standards on Industry," *Journal of Regulatory Economics*, 24(3), 315–327.

Fershtman, Chaim, and Kenneth L. Judd (1987), "Equilibrium Incentives in Oligopoly," *The American Economic Review*, 77(5), 927–940.

Gersbach, Hans, and Till Requate (2004), "Emission Taxes and Optimal Refunding Schemes," *Journal of Public Economics*, 88(3–4), 713–725.

Goering, Gregory E. (2014), "The Profit-Maximizing Case for Corporate Social Responsibility in a Bilateral Monopoly," *Managerial and Decision Economics*, 35(7), 493–499.

Helfand, Gloria E. (1991), "Standards versus Standards: The Effect of Different Pollution Restrictions," *The American Economic Review*, 81(3), 622–634.

Hirose, Kosuke, and Toshihiro Matsumura (2020), "A Comparison between Emission Intensity and Emission Cap Regulations," *Energy Policy*, 137, Article 111115.

Ino, Hiroaki, and Toshihiro Matsumura (2019), "The Equivalence of Emission Tax with Tax-Revenue Refund and Emission Intensity Regulation," *Economics Letters*, 182, 126–128.

Kitzmueller, Markus, and Jay Shimshack (2012), "Economic Perspectives on Corporate Social Responsibility," *Journal of Economic Literature*, 50(1), 51–84.

KPMG International (2013), "The KPMG Survey of Corporate Responsibility Reporting 2013," Doc. 131018, KPMG International Cooperative, The Netherlands.

Lahiri, Sajal, and Yoshiyasu Ono (2007), "Relative Emission Standard versus Tax under Oligopoly: The Role of Free Entry," *Journal of Economics*, 91(2), 107–128.

Lambertini, Luca, and Alessandro Tampieri (2015), "Incentives, Performance and Desirability of Socially Responsible Firms in a Cournot Oligopoly," *Economic Modelling*, 50, 40–48.

Lee, Joanna, and Maia Kutner (2010), "FTSE 100 Carbon Chasm," Report, Carbon Disclosure Project (CDP), London, https://www.cdproject.net/CDPResults/FTSE_100_Carbon_Chasm.pdf, accessed July 29, 2016.

Lee, Sang-Ho, and Chul-Hi Park (2019), "Eco-Firms and the Sequential Adoption of Environmental Corporate Social Responsibility in the Managerial Delegation," *The B.E. Journal of Theoretical Economics*, 19(1), 1–9.

Liu, Chih-Chen, Leonard F. S. Wang, and Sang-Ho Lee (2015), "Strategic Environmental Corporate Social Responsibility in a Differentiated Duopoly Market," *Economics Letters*, 129, 108–111.

Lyon, Thomas P., and John W. Maxwell (2004), *Corporate Environmentalism and Public Policy*, Cambridge University Press, Cambridge.

Margolick, Michael and Doug Russell (2001), "Corporate Greenhouse Gas Reduction Targets," Technical Report, Pew Center on Global Climate Change, Arlington (VA).

Margolis, Joshua D., Hillary Anger Elfenbein, and James P. Walsh (2007), "Does it Pay to Be Good? A Meta-Analysis and Redirection of Research on the Relationship between Corporate Social and Financial Performance," unpublished Working Paper, Ross School of Business, University of Michigan, Ann Arbor (MI).

Marshall, Robert C., and Leslie M. Marx (2012), *The Economics of Collusion: Cartels and Bidding Rings*, The MIT Press, Cambridge (MA) and London.

Maxwell, John W., Thomas P. Lyon, and Steven C. Hackett (2000), “Self-Regulation and Social Welfare: The Political Economy of Corporate Environmentalism,” *The Journal of Law & Economics*, 43(2), 583–617.

McWilliams, Abagail, and Donald Siegel (2001), “Corporate Social Responsibility: A Theory of the Firm Perspective,” *The Academy of Management Review*, 26(1), 117–127.

—, Donald S. Siegel, and Patrick M. Wright (2006), “Corporate Social Responsibility: Strategic Implications,” *Journal of Management Studies*, 43(1), 1–18.

Montero, Juan-Pablo (2002), “Permits, Standards, and Technology Innovation,” *Journal of Environmental Economic and Management*, 44(1), 23–44.

Poyago-Theotoky, Joanna, and Soo Keong Yong (2019), “Managerial Delegation Contracts, ‘Green’ R&D and Emissions Taxation,” *The B.E. Journal of Theoretical Economics*, 19(2), 1–10.

Purroy, Pedro, and Vicente Salas (2000), “Strategic Competition in Retail Banking under Expense Preference Behavior,” *Journal of Banking & Finance*, 24(5), 809–824.

Tokyo Gas Co., Ltd. (2019), “Tokyo Gas Group Management Vision Compass2030: Providing Energy and Solutions to the Future of our Life, Society and the Earth,” Report, Tokyo Gas Group, Tokyo.

Vives, Xavier (1999), *Oligopoly Pricing: Old Idea and New Tools*, The MIT Press, Cambridge (MA) and London.

Vogel, David (2005), *The Market for Virtue: The Potential and Limits of Corporate Social Responsibility*, Brookings Institution Press, Washington (DC).

Ziss, Steffen (1994), “Strategic R&D with Spillovers, Collusion and Welfare,” *The Journal of Industrial Economics*, 42(4), 375–393.

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