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CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL TAXATION WITH ENDOGENOUS ENTRY*

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Abstract

This study considers Corporate Social Responsibility (CSR) in Cournot markets with endogenous entry and investigates the effects of CSR on environmental taxation and welfare consequences. We show that the optimal tax under free entry is higher than that under blockaded entry and also higher than marginal environmental damage. We then show that a higher taxation is socially excessive from the viewpoint of socially optimal CSR, which requires an appropriate regulatory framework for CSR promotion. Finally, we show that the environment is less damaged but social welfare deteriorates accompanied with CSR when the fixed cost is low, while pollution abatement activities will reduce the optimal tax and improves both environmental damage and social welfare.

Keywords: consumer-friendly firm, corporate social responsibility, environmental tax, free entry, blockaded entry
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I. *Introduction*

In recent decades, as the world's economy is moving towards higher levels of globalization

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and economic liberalization, the renewal of regulated markets which includes not only the abolition of entry restrictions but the creation of environmental protections has been extensively implemented. In practice, government has continuously conducted not only command-and-control environmental regulations such as best available technology standards and subsidies, but also market-based environmental regulations such as taxes and cap-and-trades.

Regarding environmental taxation, various studies have explored the effect of taxation in imperfect competition markets. In specific, in a blockaded entry market where the number of firms is fixed, the optimal tax rate is equal to the marginal environmental damage in perfect competition markets while it falls short of the marginal damage in imperfect competition markets. In a free-entry market where the number of firms is endogenously determined, however, the optimal tax might be higher (or lower) than the marginal environmental damage because the tax effect on the output can be offset by the effect on the number of entering firms.[1] Thus, under the liberalization policy the environmental tax can work for reducing excessive entry, which is caused by a business-stealing effect in an oligopolistic competition.[2]

Recently, corporate social responsibility (CSR) becomes much popular in the business economics, contrary to the traditional view of profit maximization as the sole objective of a private firm. Since the pioneering analysis of Porter and Kramer (2006), CSR has now become a mainstream global business strategy and a large number of firms in the world issue various CSR statements/activities.[3] GE's Ecomagination program, Nestle's Creating Shared Values, and Unilevel's Simple Living Plan are excellent examples. Nowadays, more and more firms are gradually adopting corporate self-disciplines that take more into account than profits, i.e., that regard ethical issues and community welfare as important business routines.

This aspect has also motivated the recent economic analysis of mixed oligopolies in which profit-oriented private firms compete with not-for profit firms. For example, regarding CSR-firm as a consumer-friendly firm, which cares for consumer surplus, Goering (2012, 2014) and Brand and Grothe (2013, 2015) examined a vertical supply chain and Matsumura and Ogawa (2014) and Kopel and Brand (2012) analysed horizontal products differentiation. Also, Wang *et al.* (2012), Chang *et al.* (2014) and Liu *et al.* (2018) explored strategic tariff policy and Liu *et al.* (2015), Leal *et al.* (2018) and Garcia *et al.* (2018) examined the environmental policy.

This paper extends their analysis of CSR-initiatives into the polluting industry with endogenous entry under environmental taxation. Our approach is different with the standard analysis of mixed oligopolies where private firms compete with a public firm in free entry markets.[4] Cato (2008) shows that nationalization policy is preferable to a privatization policy if

[1] See Katsoulacos and Xepapadeas (1995) and Lee (1999). In the subsequent research, it is proved that the optimal emission tax rate in free-entry markets depends on the curvature of market demand (Requate, 2007), the degree of product differentiation (Fujiwara, 2009), the output elasticity of emissions (Sugeta, 2017) and consumers awareness (Hsu *et al.*, 2017). However, all these analyses still support that the optimal tax can reduce excessive entry.

[2] There has been considerable interest in examining the excessive entry problem in the free entry oligopolistic markets since the pioneering studies by Mankiw and Whinston (1986) and Suzumura and Kiyono (1987). See, for example, Suzumura (2012) and Wang *et al.* (2014) reviewed the recent analysis on the excessive-entry theorem.

[3] According to KPMG (2013), nearly 92% of the 250 largest companies worldwide issued CSR reports and more than 30% (71% and 90%) of companies in the US (the UK and Japan, respectively) adopted CSR in 2013.

[4] In the literature of mixed oligopolies, various studies have examined the welfare effect of privatization in a free-entry market and showed that the presence of a public firm can serve as an alternative to direct entry regulations in precluding excessive-entry problems. See, for example, Matsumura and Kanda (2005), Brandao and Castro (2007), Ino and Matsumura (2010), Cato and Matsumura (2012, 2015), Wang (2016), Xu *et al*. (2017) and Xu and Lee (2018).

the public firm earns positive profit, which also supports the result in Matsumura and Kanda (2005). But, they assume that the external costs vary exogenously with aggregate outputs and the public firm fully internalizes the environmental externality without considering environmental policy. On the contrary, our approach takes the analysis of Pal and Saha (2015), Xu *et al*. (2016) and Lee and Xu (2018), who examine the optimal emission tax when the public firm takes abatement activities but does not fully internalize the environmental externality. But, they concentrate on the blockaded entry markets and did not consider the liberalization policy on free entry markets.

In this paper, we emphasize the role of CSR-firm in free entry markets and investigate the impact of the CSR on the optimal environmental tax. The analysis delivers a simple result that the CSR-firm facing endogenous entry are always aggressive compared to the private firms and thus it produces larger output. This result is comparable with the analysis of Lambertini and Tampiere (2015) and Leal *et al.* (2018) under Cournot duopoly, who showed that CSR-firm produces larger output, which induces rivals to reduce their output. Thus, under blockaded entry a higher taxation than the marginal environmental damage can be optimal to the society when the firm adopts CSR activities too high.

However, when entry is endogenous, a larger production of the CSR-firm leads to the small number of firms, which will reduce the excessive entry in free entry market. Further, a higher taxation can also reduce firm's output, but it can also indirectly increase firm's output by reducing the number of firms. Thus, when the excessive entry problem is significant, the optimal environmental tax can be higher than the marginal environmental damage even in the small degree of CSR.[5] In particular, if the fixed cost exceeds a certain level, the CSR-firm maybe beneficial from the perspective of not only social welfare but also environmental protection. However, if the fixed cost is low, the environment is less damaged but social welfare deteriorates accompanied with a CSR-firm while pollution abatement activities will reduce the optimal tax in free entry markets but improve environmental damage and social welfare.

We also show that a higher taxation is socially excessive from the viewpoint of socially optimal degree of CSR. This implies that an appropriate regulatory framework is necessary for promoting CSR. Thus, if the government can control the degree of CSR, the optimal degree of CSR may be positive while the environmental tax is imposed at the Pigouvian level.

Finally, we compare the result in the blockaded entry markets where the government can set entry regulations, and show that the optimal tax under free entry should be higher than that under blockaded entry. It implies that the socially excessive entry problem calls for a higher environmental taxation even with a CSR-firm, but it depends on the degree of CSR. Therefore, the active role of governmental guideline for CSR, rather than considering it on a voluntary basis, is necessary.[6]

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[5] Note that the market role of CSR-firm to increase the output aggressively can be interpreted as that of Stackelberg leadership with dominant private or public firms. Regarding the output and welfare effects of the Stackelberg leadership, see Etro (2008) and Ino and Matsumura (2010, 2012).

[6] The promotion of CSR has become a top priority in the policy agenda for sustainable development in many countries and international organization. Further encouragement of CSR became a central policy objective in the United States and European Union. In the UK government website (http://www.csr.gov.uk/policy.shtml), it is stated that: "The Government can provide a policy and institutional framework that stimulates [socially responsible] companies to raise their performance [voluntarily] beyond minimum legal standards. Our approach is to encourage and incentivize the

The remainder of this paper is organized as follows. In Section 2, we introduce the basic model. In Section 3, we examine the optimal environmental tax in free entry markets. In Section 4, we compare and discuss the effects of CSR-firm on the optimal tax under entry regulation and pollution abatement activities, respectively. Section 5 concludes the analysis.

II. *The Model*

We consider a mixed market with a CSR-firm and n private firms ($n>0$) producing homogeneous goods. Contrary to profit-maximizing private firms, a CSR-firm, denoted by firm 0, cares for not only its profits but also consumer surplus. The inverse demand function is linear, given by $P=A-Q$, where P is the market price, $Q=q_0+\sum_{i=1}^{n}q_i$ is the market output, and the amount of the good produced by firm i is q_i, $i=1,2,...,n$. Without loss of generality, each firm has the same quadratic cost function,[7] $C(q_j)=\frac{1}{2}q_j^2+F$, where F is the fixed entry cost, $j=0,1,...,n$.

We assume that the production process causes environmental pollution and each unit of the good produced by firms creates one unit of pollutant (i.e., $e_j=q_j$).[8] The government imposes an environmental tax t per unit of pollutant emitted. Then, the profit function of firm j is

$$\pi_j=Pq_j-\frac{1}{2}q_j^2-F-tq_j. \tag{1}$$

We use a linear environmental damage function, for the sake of analytic simplicity, $ED=dQ$, where d denotes marginal environmental damage. The government's tax revenue is defined as $T=tQ$. Then, if the environmental tax is equal to the marginal damage, i.e., $t=d$, the tax revenue is equal to the environmental damage. The social welfare is defined as the sum of consumer surplus, total profits of firms, and tax revenue, minus environmental damage:

$$W=CS+\pi_0+\sum_{i=1}^{n}\pi_i+T-ED, \tag{2}$$

where $CS=\frac{1}{2}Q^2$. We assume that a private firm seeks profit maximization, whereas a CSR-firm considers not only its own profits but also consumer surplus. That is, we assume that CSR initiative includes both profitability and consumer surplus, as a proxy of its own concern on consumers, and thus the objective of the CSR-firm is a combination of consumers surplus and its own profit:[9]

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adoption of CSR, through best practice guidance, and, where appropriate, intelligent [soft-law] regulation and fiscal incentives." See also Steurer (2010).

[7] Since the pioneering study of De Fraja and Delbono (1989) in a mixed market, many researchers have assumed the same production efficiency between the firms. Matsumura and Kanda (2005) present some useful arguments on the increasing cost function.

[8] In Section 4.4, we consider the case that polluting firms can choose pollution abatement technology and examine how pollution abatement activities affect our results in a mixed market.

[9] This objective function shows that the firm takes its profit-maximizing decision under consumer-oriented consideration in which consumer surplus in the market does not fall below a fixed level. The result of this type of price

$$G = \pi_0 + \alpha\, CS, \tag{3}$$

where $\alpha \in [0,1]$ indicates the weight assigned to consumer. Note that in a long-run equilibrium where private firms can enter a market without entry regulation, the number of the private firms is determined at the point where the profit of the private firms is zero ($\pi_i = 0$) in a free-entry equilibrium. Then, if the environmental tax is equal to the marginal damage (i.e., $t = d$), the social welfare in (2) equals the objective of the CSR-firm in (3) at the free entry equilibrium under the full consideration of consumer surplus (i.e., $\alpha = 1$). Finally, we assume that $0 < F < F_{nF} \equiv \dfrac{3(2-\alpha)^2(A-d)^2}{2(6-3\alpha+\alpha^2)^2}$ in order to have interior solutions in the following analysis.

The game runs as follows. In the first stage, the government sets the environmental tax before firms move. In the second stage, given t, each private firm decides whether to enter the market (the entry cost is sunk if a private firm enters the market), where the number of private firms is endogenously determined by a free-entry market condition (zero-profit condition). In the third stage, the firms compete in quantities in a Cournot fashion. We solve the game by backward induction to obtain a subgame perfect Nash equilibrium.

III. *The Analysis of Free Entry Equilibrium*

In the third stage, firm 0 chooses its output level q_o to maximize its objective function in (3), and private firms choose their output levels q_i to maximize their own profits in (1). The first-order conditions are as follows:

$$\frac{\partial G}{\partial q_o} = A - t - 2q_o - (1-\alpha)\left(q_o + \sum\nolimits_{i=1}^{n} q_i\right) = 0, \tag{4}$$

$$\frac{\partial \pi_i}{\partial q_i} = A - t - q_o - \sum\nolimits_{i=1}^{n} q_i - 2q_i = 0. \tag{5}$$

Combining (4) and (5), the equilibrium outputs are

$$q_o = \frac{(2+n\alpha)(A-t)}{2(3+n-\alpha)} \text{ and } q_i = \frac{(2-\alpha)(A-t)}{2(3+n-\alpha)}. \tag{6}$$

Note that firm 0 produces more outputs than those of private firms, i.e., $q_o > q_i$. Thus, as firm 0 cares for consumer surplus more, it behaves more aggressively and the concern on consumer surplus expands the production. A higher emission tax will reduce the output of firm 0 while the effect of tax on the output of the private firm depends on the indirect effect on the number of firms. That is, a larger number of firms reduces the output of the private firm because of the business-stealing effect, but it will not affect the output of firm 0.

regulation is equivalent to that of the rate-of-return regulation for the public firm, in which the government obtains the market outcomes that maximize consumer surplus subject to permitting the firm to earn some fixed profit. On this point, see Lee (1998). Note also that this formulation of the objective function is comparable with the mixed market where a public firm no longer internalizes environmental externalities in its objective function. For more discussion, see Barcena-Ruiz and Garzon (2006), Beladi and Chao (2006) and Xu *et al.* (2016).

The equilibrium profits of the firms are

$$\pi_0=\frac{(2+n\alpha)(6-\alpha(4+n))(A-t)^2}{8(3+n-\alpha)^2}-F,\ \pi_i=\frac{3(2-\alpha)^2(A-t)^2}{8(3+n-\alpha)^2}-F. \tag{7}$$

In the second stage, each private firm earns zero profit in the equilibrium. Under free-entry conditions where the profit of private firms in (7) is zero, we can obtain the equilibrium number of private firms:

$$n=\frac{(2-\alpha)(A-t)}{4}\sqrt{\frac{6}{F}}+\alpha-3. \tag{8}$$

Note that private firms exist in a free-entry market only when the tax or/and fixed entry cost is small, i.e., $n>0$ only if $0<F<\frac{3(2-\alpha)^2(A-t)^2}{8(3-\alpha)^2}$. Then, we have that the number of private firms decreases with higher tax (or/and fixed cost) and higher degree of CSR, i.e., $\frac{\partial n}{\partial t}<0$, $\frac{\partial n}{\partial F}<0$ and $\frac{\partial n}{\partial \alpha}<0$.

The equilibrium outputs of the firms and total market are as follows:

$$q_o=\frac{A-t}{2}\alpha+\frac{\sqrt{6F}}{3}(1-\alpha),\ q_i=\frac{\sqrt{6F}}{3},\ \ Q=A-t-\frac{2\sqrt{6F}}{3}. \tag{9}$$

Note that the equilibrium output of the private firm is not affected by taxation. It implies that the direct effect of taxation to increase the output of the private firm in (6) will be cancelled out by the indirect effect of taxation imposed to decrease the number of firms in (8), which will indirectly reduce the output of the private firm in (6).

Finally, the profit of firm 0 is as follows:

$$\pi_0=\frac{\sqrt{6F}\,\alpha(1+\alpha)(A-t)}{6}-\frac{(A-t)^2\alpha^2}{8}-\frac{\alpha(2+\alpha)}{3}F. \tag{10}$$

Note that firm 0 can survive in free entry markets, i.e., $\pi_0\geq 0$, only when $F_M\equiv\frac{3\alpha^2(A-t)^2}{8(2+\alpha)^2}\leq F<\frac{3(2-\alpha)^2(A-t)^2}{8(3-\alpha)^2}$. Otherwise, it will earn negative profits and thus exit (or becomes profit-maximizing private firm) in the long-run, i.e., $\pi_0<0$ when $0<F<F_M$. Note that $\frac{\partial F_M}{\partial \alpha}>0$. Thus, a higher degree of CSR will reduce the survival range for the CSR-firm in free entry markets. Then, we have two market configurations, private market where firm 0 does not exist and mixed market where firm 0 exists, depending on the size of fixed cost.

1. Private Market

When the fixed cost is small ($0<F<F_M$), the CSR-frim does not exist in the long-run

equilibrium. In a private oligopoly under free entry, we assume that $n+1$ private firms compete in polluting market.[10] Using the first-order condition in (5), we have the equilibrium outputs and profits of private firms:

$$q_i=\frac{A-t}{3+n},\ Q=\frac{(1+n)(A-t)}{3+n},\ \pi_i=\frac{3(A-t)^2}{2(3+n)^2}-F. \tag{11}$$

Then, under free-entry conditions, where the profit of private firms in (11) is zero, we can obtain the equilibrium number of private firms

$$n=\frac{A-t}{2}\sqrt{\frac{6}{F}}-3. \tag{12}$$

The number of private firms is positive and it decreases as the tax or/and fixed (entry) cost increases.

Substituting the equilibrium number of private firms into (11), we derive the following equilibrium outputs:

$$q_i=\frac{\sqrt{6F}}{3},\ \mathrm{Q}=A-t-\frac{2\sqrt{6F}}{3}. \tag{13}$$

Note that each private firm's output is also independent of the level of the tax at equilibrium in a private oligopoly, i.e., $\frac{\partial q_i}{\partial t}=0$. This is because the equilibrium output of the private firm is determined at the zero-profit condition, in which the equilibrium output is exactly the difference between the average cost and the marginal cost.[11] However, the environmental tax affects not only the number of firms but also the total market outputs.

The resulting consumer surplus, environmental damage, and social welfare are

$$CS=\frac{1}{2}\left(A-t-\frac{2\sqrt{6F}}{3}\right)^2,\ ED=d\left(A-t-\frac{2\sqrt{6F}}{3}\right),$$
$$W=\frac{1}{2}\left(A-t-\frac{2\sqrt{6F}}{3}\right)\left(A+t-2d-\frac{2\sqrt{6F}}{3}\right). \tag{14}$$

In the first stage, the government chooses the environmental tax to maximize its social welfare in (14). The optimal environmental tax is

$$t^P=d, \tag{15}$$

where superscript "P" denotes the equilibrium outcome of this free-entry private market. From equation (15), we obtain the following lemma.

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[10] For the comparable results with Section 3.2 where a CSR-firm operates and the total number of firms in the market is $n+1$, we set the number of firms in a private oligopoly as $n+1$, instead of n.

[11] Due to the profit-maximization condition of the firm and the zero-profit condition at free-entry equilibrium, each firm's equilibrium output is the difference between average cost and marginal cost. That is, we have $AC_i=MC_i+q_i$, which yields $q_i=\sqrt{6F}/3$ in (13). However, the minimum efficient scale occurs at AC=MC, which yields $q_{mes}=\sqrt{2F}>q_i$. Thus, each firm produces less than the social optimum where the average cost equals the marginal cost. This is the so-called business-stealing effect, which causes excessive entry into the market.

Lemma 1. *The optimal environmental tax is exactly determined at the level of marginal environmental damage in free entry private market where a CSR-firm does not exist.*

Lemma 1 represents that an environmental tax can be used not only to internalize environmental damage, but also to control the number of private firms. A higher taxation directly lowers the firm's output, it can also indirectly increase the firm's output by reducing the number of firms. And the direct effect of taxation on output and the indirect effect on output offset each other. This result is consistent with the previous result in Katsoulacos and Xepapadeas (1995) and Lee (1999) who showed that in a private market under free entry, the optimal environmental tax should be equal to marginal environmental damage.

Substituting the optimal environmental tax into (12), we can obtain the equilibrium number of private firms

$$n^P = \frac{A-d}{2}\sqrt{\frac{6}{F}} - 3. \tag{16}$$

Note that we have $n^P > 0$ in the regions of private market[12] where $0 < F < F_M$.

This yields the optimal output levels of each private firm and market:

$$q_i^P = \frac{\sqrt{6F}}{3},\ Q^P = A-d-\frac{2\sqrt{6F}}{3}. \tag{17}$$

Finally, the consumer surplus, environmental damage, and social welfare in a private market are as follows:

$$CS^P = \frac{1}{2}\left(A-d-\frac{2\sqrt{6F}}{3}\right)^2,\ ED^P = d\left(A-d-\frac{2\sqrt{6F}}{3}\right),\ W^P = \frac{1}{2}\left(A-d-\frac{2\sqrt{6F}}{3}\right)^2. \tag{18}$$

It is noteworthy that the social welfare is identical to the consumer surplus in (18) in a free entry private oligopoly, i.e., $CS^P = W^P$.

2. Mixed Market

When the fixed cost is large $\left(F_M \leq F < \frac{3(2-\alpha)^2(A-t)^2}{8(3-\alpha)^2}\right)$, the CSR-frim exists in the long-run equilibrium. Using the results in (9), we have consumer surplus, environmental damage, and social welfare as follows:

$$CS = \frac{1}{2}\left(A-t-\frac{2\sqrt{6F}}{3}\right)^2,\ ED = d\left(A-t-\frac{2\sqrt{6F}}{3}\right),$$

$$W = \frac{4-2\alpha-\alpha^2}{3}F - \frac{(4A-A\alpha-A\alpha^2-4d+t\alpha+t\alpha^2)}{6}\sqrt{6F} + \frac{(A-t)(4A-A\alpha^2-8d+4t+t\alpha^2)}{8}. \tag{19}$$

In the first stage, the government chooses the environmental tax to maximize its social

[12] Note that $F_M < \frac{(A-d)^2}{6}$.

welfare in (19). The optimal environmental tax is

$$t^F = \frac{1}{4+\alpha^2}\left(A\alpha^2 + 4d - \frac{2\alpha(1+\alpha)\sqrt{6F}}{3}\right), \tag{20}$$

where superscript "F" denotes the equilibrium outcome of this free-entry mixed market. Then, from (20), we can derive that $t^F > d$ when[13] $0 < F < F_{nF}$. Then we obtain the following lemma.

Lemma 2. *The optimal environmental tax is higher than marginal environmental damage in free entry mixed market where a CSR-firm exists.*

Lemma 2 represents that a higher environmental tax than marginal environmental damage can be used to control the number of private firms when the number is small (due to a higher fixed entry cost). This is in contrast to the result in Lemma 1 where a CSR-firm does not exist. The CSR-frim is aggressive in producing output, given the number of entering firms, which might increase total outputs and environmental damage as well. Thus, a higher taxation that decreases total market outputs is required in a mixed market under free entry equilibrium.

Substituting the optimal environmental tax in (20) into (8), we can obtain the equilibrium number of private firms:

$$n^F = \frac{(2-\alpha)(A-d)}{4+\alpha^2}\sqrt{\frac{6}{F}} - \frac{2(6-3\alpha+\alpha^2)}{4+\alpha^2}. \tag{21}$$

Note that $n^F > 0$ if $0 < F < F_{nF}$. Then, we have the equilibrium outputs as follows:

$$q_0^F = \frac{2(3\alpha(A-d) + \sqrt{6F}(2-2\alpha+\alpha^2))}{3(4+\alpha^2)},\ q_i^F = \frac{\sqrt{6F}}{3},\ Q^F = \frac{2(6(A-d) - \sqrt{6F}(4-\alpha))}{3(4+\alpha^2)}. \tag{22}$$

Substituting also these outputs, we can obtain the profit of firm 0 as follows:

$$\pi_0^F = \frac{8\sqrt{6F}\alpha(A-d+A\alpha-d\alpha)}{3(4+\alpha^2)^2} - \frac{2(A-d)^2\alpha^2}{(4+\alpha^2)^2} - \frac{\alpha(32+8\alpha-\alpha^3)}{3(4+\alpha^2)^2}F. \tag{23}$$

Hence, the CSR-firm can earn a non-negative profit at free entry equilibrium only when $F_0 \equiv \frac{6\alpha^2(A-d)^2}{(8+4\alpha+\alpha^2)^2} \leq F \leq F_{0max} \equiv \frac{6(A-d)^2}{(4-\alpha)^2}$.

Finally, the consumer surplus, environmental damage, and social welfare in a mixed market are as follows:

$$CS^F = \frac{2(6(A-d) - \sqrt{6F}(4-\alpha))^2}{9(4+\alpha^2)^2},\ ED^F = \frac{2d(6(A-d) - \sqrt{6F}(4-\alpha))}{3(4+\alpha^2)},\ W^F = \frac{2}{4+\alpha^2}\left(A-d-\frac{4-\alpha}{6}\sqrt{6F}\right)^2. \tag{24}$$

The social welfare increases as the fixed cost becomes smaller, in which case more private firms enter the market and thus in return the optimal tax becomes higher.

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[13] Note that $F_{nF} < \frac{3(2-\alpha)^2(A-t)^2}{8(3-\alpha)^2}$.

IV. *Policy Discussions*

In the previous analysis, we show that (I) in the absence of CSR-firm, a private market equilibrium is sustainable where $n+1$ symmetric firms exist when $F<F_0$, and (II) in the presence of CSR-firm, a mixed market equilibrium is sustainable where n private firms exist when $F_0 \leq F \leq F_{nF}$ while the market will be monopoly by the CSR-firm when $F_{nF}<F<F_{0max}$. In the below, we will compare the welfare consequences between private and mixed markets, and discuss on the policy considerations in the context of a mixed market configuration where one CSR-firm can coexist with n private firms when $F_0 \leq F \leq F_{nF}$.

1. The Welfare Effect of a CSR-firm

Lemma 3. *Comparisons the outcomes between private and mixed markets yield the followings:*[14]

1. $n^P > n^F$ *and* $t^P < t^F$,
2. $Q^P > Q^F$ *and* $ED^P > ED^F$,
3. $W^P \gtrless W^F$ *when* $F \lessgtr F_w \equiv \dfrac{3(8+8\alpha+5\alpha^2-4(1+\alpha)\sqrt{4+\alpha^2})(A-d)^2}{2(8+3\alpha)^2}$.

The first part of Lemma 3 states that a higher environmental tax in a mixed market yields a smaller number of private firms. It represents that the CSR-firm is beneficial to reduce the excessive entry problem at free entry market. The second part of Lemma 3 states that total market outputs in a private market are greater than those in a mixed market. It also implies that the CSR-firm is also beneficial to the environment. The third part of Lemma 3 shows that a CSR-firm is beneficial to both social welfare and environmental quality when fixed cost is large, i.e., $F_w<F<F_{nF}$. Fig. 1 shows the welfare and profit of the CSR-firm in mixed and private markets. Then we obtain the following Proposition.

Proposition 1. *The CSR-firm is beneficial from the perspective of not only environmental protection but also social welfare when the entry cost is high enough.*

We can provide economic interpretation. A CSR-firm is aggressive and thus it produces outputs at a higher cost (also called the production cost-increasing effect), but as it produces more outputs than private firms, it can reduce the number of private firms (this is the cost-decreasing effect of the duplication of fixed costs). Therefore, the welfare consequences depends on how the two opposite effects work. In the case that the fixed cost is lower than a certain level and thus a large number of private firms enters the free entry mixed market, the CSR-firm's production cost-increasing effect is less significant than the cost-decreasing effect of the duplication of fixed costs. Therefore, when the fixed cost is large, the CSR-firm is beneficial to the society than a private oligopoly.

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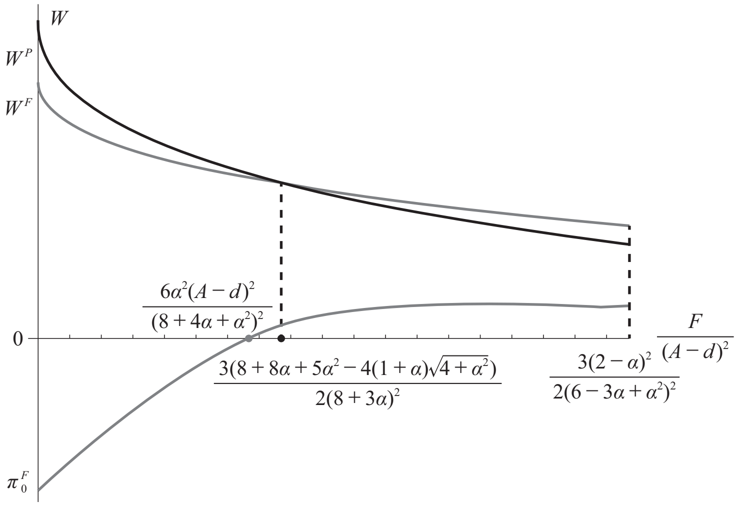
[14] *Proof:* $W^P - W^F = \dfrac{\alpha(3\alpha(A-d)^2 - 4\sqrt{6F}(A-d)(1+\alpha)+2F(8+3\alpha))}{6(4+\alpha^2)} \gtrless 0$ *iff* $F \lessgtr F_w \equiv \dfrac{3(8+8\alpha+5\alpha^2-4(1+\alpha)\sqrt{4+\alpha^2})(A-d)^2}{2(8+3\alpha)^2}$ *when* $0<F<F_{nF}$.

FIGURE 1. WELFARE AND PROFIT COMPARISONS UNDER FREE ENTRY



Proposition 1 shows that the welfare effects of the CSR-firm depend on the degree of CSR and fixed cost. It also implies that an appropriate regulatory framework might be necessary for promoting an appropriate degree of CSR. Thus, the active role of governmental guideline for promoting CSR, rather than considering it on a voluntary basis, might be useful.[15]

2. Optimal Promotion for CSR

We examine the optimal promotion of CSR from the viewpoint of welfare, rather than voluntarily given degree of CSR in the market selection. Then, the government determines not only the optimal environmental tax rate but the optimal degree of CSR. In the first stage, the government chooses the degree of CSR promotion and environmental tax to maximize its social welfare in (19). Then, the optimality condition of environmental tax in (20) yields the following optimal degrees of CSR promotion and environmental tax rate:

$$t^*=d \text{ and } \alpha^*=\frac{4\sqrt{F}}{\sqrt{6}(A-d)-4\sqrt{F}}. \tag{25}$$

where superscript "*" denotes the optimal solutions.

Lemma 4. *The optimal environmental tax is exactly determined at the level of marginal environmental damage in free entry market when the optimal degree of CSR is promoted.*

A few remarks are in order. First, accompanied with the optimal promotion of CSR, the

[15] The promotion of CSR has become a priority in the policy agenda for sustainable development in recent years. In particular, the encouragement of CSR became a central policy objective in the developed countries such as United States and European Union. See, Liu *et al*. (2018)

optimal environmental tax is the same with marginal environmental damage, i.e., $t^{*}=t^{P}=d<t^{F}$. Thus, the optimal promotion of CSR will reduce the optimal tax rate to the Pigouvian level, which will maximize the welfare than a higher taxation. Second, we have $0\leq\alpha^{*}\leq 1$ only when $\frac{3(A-d)^2}{32}\leq F\leq\frac{3(A-d)^2}{8}$. Thus, the optimal promotion of CSR can be positive or negative depending on the entry cost. In particular, it should be larger than one if the entry cost is sufficiently small. It implies that when the excessive entry problem is significantly serious, the role of CSR-firm should be highly over-emphasized. Finally, we have $\frac{\partial\alpha^{*}}{\partial A}<0$, $\frac{\partial\alpha^{*}}{\partial d}>0$ and $\frac{\partial\alpha^{*}}{\partial F}>0$. This states that the optimal degree of CSR should be more promoted as (i) market size decreases, (ii) marginal environmental damage increases and (iii) entry cost increases.

Substituting the optimal degrees of CSR promotion and environmental tax into (8), we can obtain the equilibrium number of private firms:

$$n^{*}=\frac{A-d}{2}\sqrt{\frac{6}{F}}-4. \tag{26}$$

The equilibrium number of private firms in (26) is smaller than that in the private market in (16), i.e., $n^{P}>n^{*}$. Thus, the optimal promotion of CSR is effective to reduce excessive entry problem.

Then, we have the equilibrium outputs as follows:

$$q_0^{*}=\frac{2\sqrt{6F}}{3},\ q_i^{*}=\frac{\sqrt{6F}}{3},\ Q^{*}=A-d-\frac{2\sqrt{6F}}{3}. \tag{27}$$

Note also that the equilibrium output of each private firm and the total market are the same as those in the private market in (17). Thus, the optimal promotion of CSR provides the same level of consumer surplus, but reduces the entering number of firms and total entry costs of the society.

Substituting also these outputs, we can obtain the profit of firm 0 as follows:

$$\pi_0^{*}=\frac{F}{3}. \tag{28}$$

Thus, the CSR-firm under the optimal promotion of CSR can earn a positive profit and survive in free entry market. In sum, the emergence of CSR-firm can be beneficial to the society when an appropriate regulatory framework for the promotion of CSR is constructed. Therefore, the active role of governmental guideline for promoting CSR, rather than considering it on a voluntary basis, is imperative.

Finally, we obtain the consumer surplus, environmental damage and social welfare under the optimal promotion of CSR:

$$CS^{*}=\frac{1}{2}\left(A-d-\frac{2\sqrt{6F}}{3}\right)^2,\ ED^{*}=d\left(A-d-\frac{2\sqrt{6F}}{3}\right),\ W^{*}=\frac{1}{2}\left(A-d-\frac{2\sqrt{6F}}{3}\right)^2+\frac{F}{3}. \tag{29}$$

These results show that consumer surplus and environmental damage are the same with the results in private market, but the social welfare can be enhanced. Then we obtain the following proposition.

Proposition 2. *The social welfare can be enhanced under the optimal promotion of CSR irrespective of the fixed cost.*

3. Comparisons with Blockaded Entry

We compare with the blockaded entry case where the government can control the number of entering private firms in a mixed market.[16] When a CSR-firm exists and the number of private firms is exogenously given, from (6) and (7), the social welfare becomes

$$W = \frac{(1+n)(A-t)(A(2-\alpha)(8+2n+n\alpha)+t(8+4n+n\alpha^2)-8d(3+n-\alpha))}{8(3+n-\alpha)^2} - (1+n)F. \quad (30)$$

The differentiation of W yields the following optimal environmental tax under blockaded entry:

$$t^B = d + \frac{(4\alpha-4+n\alpha^2)(A-d)}{8+4n+n\alpha^2}, \quad (31)$$

where superscript "B" denotes the equilibrium outcome of the blockaded-entry mixed market. From (31), we have $t^B \lessgtr d$ when $\alpha \lessgtr \frac{2(\sqrt{1+n}-1)}{n}$. In special, $t^B < d$ when $\alpha = 0$ while $t^B > d$ when $\alpha = 1$. Then we obtain the following lemma.

Lemma 5. *The optimal environmental tax is lower (higher) than marginal environmental damage when the degree of CSR is lower (higher) under blockaded entry.*

This result is comparable with the analysis of Lambertini and Tampiere (2015) and Leal *et al.* (2018) who considered Cournot duopoly and showed that CSR-firm produces larger output, which induces rivals to reduce their output. It states that when the firm adopts CSR activities too high under blockaded entry, a higher taxation than the marginal environmental damage can be optimal to the society. When the degree of CSR is lower, it is consistent with the result in a private oligopoly under blocked entry, where the optimal environmental tax should be lower than the marginal environmental damage.[17] Thus, under-production of the private firms can be outweighed by over-production by the consumer-friendly firm if the degree of CSR is too high. Then, a higher environmental tax will reduce production that is in excess of welfare maximization. In addition, the optimal tax increases as the number of private firms increases.

The equilibrium outputs of the firms and market under blockaded entry are as follows:

[16] In reality, the government might not be able to control the number of private firms perfectly, on account of political and institutional interactions and/or the historical background of the regulated industry. For example, if private investors have already invested high fixed and sunk costs before an entry regulation is imposed, the government should consider the number of existing private firms as a fixed number. See Spiller (2013).

[17] It is well-known that the optimal tax on private oligopoly under blockaded entry should be less than the marginal social damage, depending upon the relative effects of distortions such as market power and externality. See, for example, Lee (1999) and Lee and Park (2011).

$$q_0^B=\frac{2(2+n\alpha)(A-d)}{8+4n+n\alpha^2},\ q_i^B=\frac{2(2-\alpha)(A-d)}{8+4n+n\alpha^2},\ Q^B=\frac{4(1+n)(A-d)}{8+4n+n\alpha^2}. \tag{32}$$

Note again that the output of CSR-firm is larger than that of the private firm under blockaded entry, i.e., $q_0^B>q_i^B$. Substituting these outputs, we can obtain the profits of the firms:

$$\pi_0^B=\frac{2(2+n\alpha)(6-4\alpha-n\alpha)(A-d)^2}{(8+4n+n\alpha^2)^2}-F,\ \pi_i^B=\frac{6(2-\alpha)^2(A-d)^2}{(8+4n+n\alpha^2)^2}-F. \tag{33}$$

Note that CSR-firm can earn non-negative profits at the blockaded-entry equilibrium only when $0<F<\frac{2(2+n\alpha)(6-4\alpha-n\alpha)(A-d)^2}{(8+4n+n\alpha^2)^2}$ under the optimal tax rate in (31).

Finally, the consumer surplus, environmental damage, and social welfare are as follows:

$$CS^B=\frac{8(1+n)^2(A-d)^2}{(8+4n+n\alpha^2)^2},\ ED^B=\frac{4d(1+n)(A-d)}{8+4n+n\alpha^2},\ W^B=\frac{2(A-d)^2(1+n)}{8+4n+n\alpha^2}-(n+1)F. \tag{34}$$

Suppose that $0<F<\frac{6(2-\alpha)^2(A-d)^2}{(8+4n+n\alpha^2)^2}$, where the private firm under both free entry and blockaded entry earns non-negative profit at equilibrium.

Let the optimal number of firms in blockaded entry under the optimal tax rate in (31) be n^B. Then, the differentiation of social welfare in (34) with respect to n yields the following:

$$n^B=\frac{A-d}{4+\alpha^2}\sqrt{\frac{2(4-\alpha^2)}{F}}-\frac{8}{4+\alpha^2}. \tag{35}$$

Then, comparison between blockaded entry and free entry provides the following proposition.

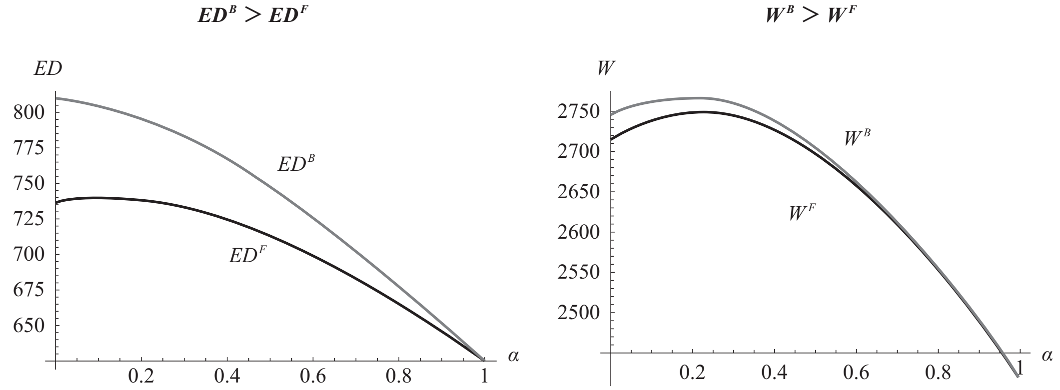
Proposition 3. *The excessive entry problem can be lessened under blockaded entry and the optimal tax under blockaded entry is lower than that under free entry.*

Proof: Comparing the number of firms between free entry and blockaded entry, we have $n^F-n^B=\frac{\sqrt{6F}(A-d)(2-\alpha)-2F(2-\alpha)(1-\alpha)-(A-d)\sqrt{2F(4-\alpha^2)}}{F(4+\alpha^2)}>0$ when $0<F<F_{nF}$ while we have $n^P>n^F>n^B$ when $F_0\leq F\leq F_{nF}$. Then, substituting (35) into (31), we have $t^B=\frac{4d+A\alpha^2}{4+\alpha^2}-\frac{2-\alpha+\alpha^2}{4+\alpha^2}\sqrt{\frac{8F(2-\alpha)}{2+\alpha}}$. Comparing this value with (20) yields $t^F-t^B=\frac{2\sqrt{2F}(3(2-\alpha+\alpha^2)\sqrt{4-\alpha^2}-\sqrt{3}\alpha(1+\alpha)(2+\alpha))}{3(2+\alpha)(4+\alpha^2)}>0$ when $0<F<F_{nF}$.

It states that a free-entry policy calls for a higher environmental tax even in the presence of CSR-firm. This is because there exists an excessive entry under free entry equilibrium and thus, compared to the blockaded entry, a higher taxation under free entry can reduce the number of firms.

Proposition 4. *Both environmental damage and social welfare under blockaded entry are*

FIGURE 2. THE EFFECTS OF ENTRY REGULATION



higher than those under free entry.

Proof: Substituting (35) into (34) and then comparing the values yields the followings: $ED^F - ED^B = -\frac{2d\sqrt{6F}(4-\alpha) - 6d\sqrt{2F(4-\alpha^2)}}{3(4+\alpha^2)} < 0$ and $W^F - W^B = -\frac{2\sqrt{6F}(A-d)(4-\alpha) - 4F(1-\alpha)^2 - 6(A-d)\sqrt{2F(4-\alpha^2)}}{3(4+\alpha^2)} < 0$ when $0 < F < F_{nF}$.

Fig. 2 shows the simulation results of environmental damage and social welfare when $A = F = 100$ and $d = 10$ in both blockaded entry and free entry markets with the same number of firms in the free entry market. It shows that the distorting effect under free entry can be reduced as the degree of CSR increases. It implies that the excessive entry problems call for a higher environmental taxation, but it depends on the degree of CSR. Therefore, the active role of governmental guideline for CSR, rather than considering it on a voluntary basis, is necessary.

4. Pollution Abatement Activities

It is reasonable to expect that free entry may lead to some improvement in eco-technology because pollution production might be abated—with related processes becoming "greener"—in the long run. We consider the case that polluting firms can choose pollution abatement technology and examine how pollution abatement activities affect our results in a mixed market with a CSR-firm.

Suppose that firm j chooses the pollution abatement level a_j. The emission level of each firm and market are given by $e_j = q_j - a_j$, and $E = e_0 + \sum_{i=1}^{n} e_i$, where firm j can reduce its emission a_j by investing the amount $\frac{1}{2}a_j^2$ in pollution abatement activities.[18] In the second stage,

[18] For simplicity of tractability, in line with the literature (Wang and Wang 2009, Lee and Park 2011, Kim et al 2018), we focus on end-of-pipe abatement, which is additively separable. According to all empirical reports, end-of-pipe abatement goods and services account for more than 70% of the pollution treatment sector. See David *et al.* (2011).

the CSR-firm and private firm simultaneously choose their levels of output and pollution abatement to maximized their objective functions. The equilibrium output and pollution abatement levels of the CSR-firm and private firm are

$$q_0=\frac{(A-t)(2+n\alpha)}{2(3+n-\alpha)}>q_i=\frac{(A-t)(2-\alpha)}{2(3+n-\alpha)},\ a_0=a_i=t. \tag{36}$$

Note that environmental tax will not only reduce the output level but also the emission level, by inducing higher abatement activities. Thus, direct taxation effect has both the output-decreasing effect and the emission-decreasing effect.

The output and price of the market are

$$Q=\frac{(1+n)(A-t)}{3+n-\alpha},\ P=\frac{A(2-\alpha)+t(1+n)}{3+n-\alpha}. \tag{37}$$

Then, the profits of the firms are as follows:[19]

$$\pi_0=\frac{(2+n\alpha)(6-4\alpha-n\alpha)(A-t)^2}{8(3+n-\alpha)^2}+\frac{t^2}{2}-F,\ \pi_i=\frac{3(2-\alpha)^2(A-t)^2}{8(3+n-\alpha)^2}+\frac{t^2}{2}-F. \tag{38}$$

Using the zero-profit conditions of the private firms under free entry, we can obtain the equilibrium number of private firms under free-entry conditions:

$$n=\frac{(2-\alpha)(A-t)}{2}\sqrt{\frac{3}{2F-t^2}}+\alpha-3. \tag{39}$$

For a positive number of private firms, we assume that $0<F<\frac{3(2-\alpha)^2(A-t)^2}{8(3-\alpha)^2}+\frac{t^2}{2}$. Note that the environmental tax will decrease (increase) the number of firms under free entry when the tax is low (high), that is, $\frac{\partial n}{\partial t}\gtrless 0$ when $t\lessgtr\frac{2F}{A}$. This is in sharp contrast to the case without abatement activities. This is because the private firm has the option to reduce its emission level without lowering its output. Therefore, depending on the market size, fixed cost and tax rate, the indirect taxation effects to reduce the outputs of private firms will cancel out or exaggerate the direct taxation effects. Again, a higher degree of CSR will decrease the number of private firms with pollution abatement activities, that is, $\frac{\partial n}{\partial \alpha}<0$ when $0<F<\frac{3(A-t)^2(2-\alpha)^2}{8(3-\alpha)^2}+\frac{t^2}{2}$

Substituting the number of private firms, we can obtain the equilibrium output and emission levels of the firms:

$$q_0=\frac{3\alpha(A-t)+2(1-\alpha)\sqrt{6F-3t^2}}{6}>q_i=\sqrt{\frac{2F-t^2}{3}},$$

$$e_0=\frac{3A\alpha-3t(2+\alpha)+2(1-\alpha)\sqrt{6F-3t^2}}{6}>e_i=\sqrt{\frac{2F-t^2}{3}}-t,$$

[19] In the following analysis, we will assume that $\pi_0\geq 0$ for the time being and then we will check the feasibility in the simulation.

$$Q = A - t - 2\sqrt{\frac{2F - t^2}{3}},\ E = A + t(1-\alpha) - \frac{8F + t(3A(2-\alpha) - t(10-3\alpha))}{2\sqrt{6F - 3t^2}}. \tag{40}$$

For a non-negative emission levels, we assume that $F \geq 2t^2$. Notice that the environmental tax will decrease the market outputs with pollution abatement activities that is, $\frac{\partial Q}{\partial t} < 0$ when $F \geq 2t^2$.

The resulting CSR-firm's profit, consumer surplus, tax revenue, environmental damage, and social welfare are as follows:[20]

$$\pi_0 = \frac{\alpha(1+\alpha)(A-t)}{2}\sqrt{\frac{2F-t^2}{3}} + \frac{\alpha(8t^2 - 3A^2\alpha + 6At\alpha + t^2\alpha)}{24} - \frac{8\alpha(2+\alpha)}{24}F,$$

$$CS = \frac{1}{2}\left(A - t - 2\sqrt{\frac{2F-t^2}{3}}\right)^2,$$

$$T = t\left(A + t(1-\alpha) - \frac{8F + t(3A(2-\alpha) + t(10-3\alpha))}{2\sqrt{6F-3t^2}}\right),$$

$$ED = d\left(A + t(1-\alpha) - \frac{8F + t(3A(2-\alpha) + t(10-3\alpha))}{2\sqrt{6F-3t^2}}\right),$$

$$\begin{aligned} W &= CS + \pi_0 + T - ED \\ &= \frac{4-2\alpha-\alpha^2}{3}F + \frac{3A^2(4-\alpha^2) - 6A(4d - t\alpha^2) - 24td(1-\alpha) + t^2(20 - 16\alpha + \alpha^2)}{24} - \frac{\gamma}{6}\sqrt{\frac{3}{2F-t^2}}, \end{aligned} \tag{41}$$

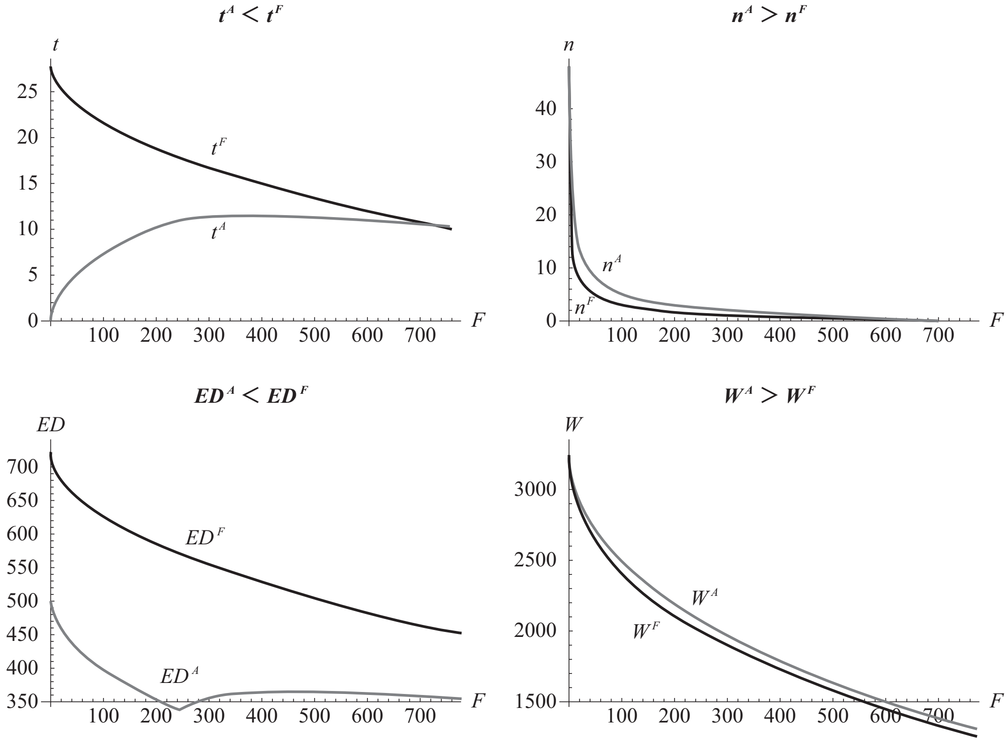
where $\gamma = 8(A-d)F - 6Adt + 2(A+5d)t^2 - 6t^3 - \alpha(2F - 3dt + 2t^2)(A-t) - \alpha^2(2F - t^2)(A-t)$.

Finally, we will evaluate the optimal tax rate under the consideration of abatement activities. On the one hand, if we evaluate the welfare in (41) with the tax rate at the marginal environmental damage, we have that $\left.\frac{\partial W}{\partial t}\right|_{t=d} \gtrless 0$, depending on the parameters such as F, A, d and α. It implies that the optimal tax with abatement activities can be lower or higher than the marginal environmental damage. This contrasts sharply to the case without abatement activities in Lemma 2. On the other hand, if we evaluate the welfare in (41) at the optimal tax level without abatement activities in (20), we also have that $\left.\frac{\partial W}{\partial t}\right|_{t=t^F} \gtrless 0$, depending on those parameters. It also implies that the optimal tax with abatement activities can be lower or higher than that without abatement technology. These findings emphasize the importance of abatement technology in determining the optimal environmental tax under free entry equilibrium.

Because of its analytic complexity, we employ a simple simulation and examine the comparative effects of abatement activities on the optimal tax and social welfare. Fig. 3 shows

[20] Note that the CSR-firm can earn a non-negative profit with pollution abatement activities when $2t^2 \leq F < \frac{3(A-t)^2(2-\alpha)^2}{8(3-\alpha)^2} + \frac{t^2}{2}$.

FIGURE 3. THE EFFECTS OF ABATEMENT ACTIVITIES



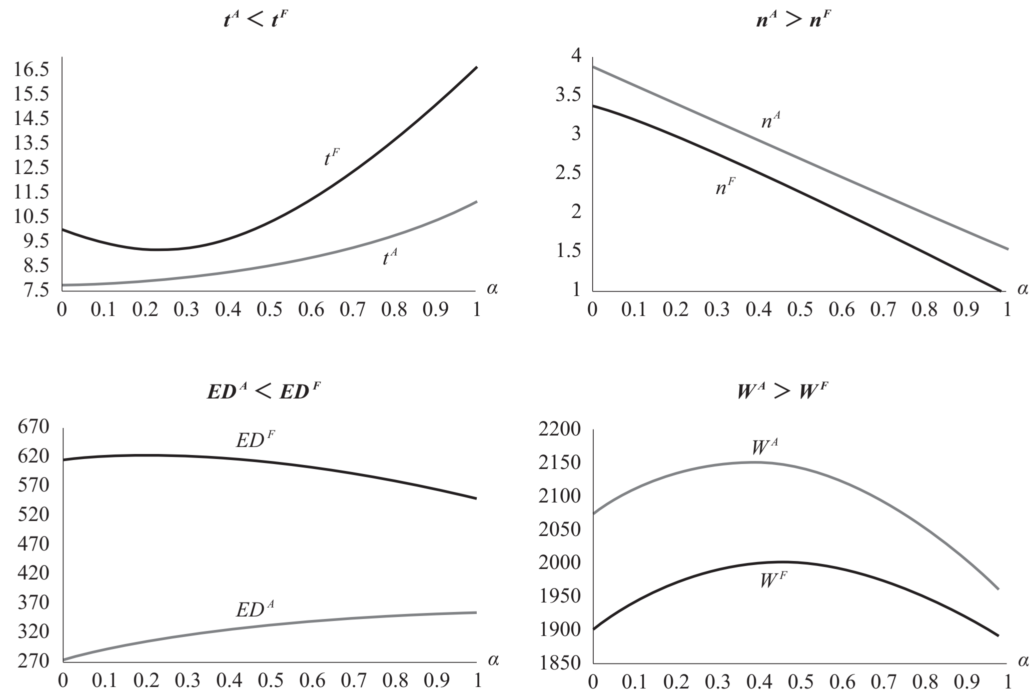
the simulation result with $A=100$, $d=10$ and $\alpha=1$.

In Fig. 3, we can see that $t^A<t^F$, $n^A>n^F$, $ED^F>ED^A$ and $W^A>W^F$ where superscript "A" denotes the equilibrium outcome when the polluting firms can choose pollution abatement technology. Thus, the eco-technology will reduce the optimal tax and increase the number of private firms in the presence of CSR. This will lead to an increase in the market output, while the total emission level decreases substantially on account of the existence of pollution abatement activities. Further, the abatement activities will increase not only consumer surplus but also social welfare. Thus, in the presence of CSR firm, providing an efficient abatement technology in a free entry market is important to improve not only environment but also social welfare in the long run. Then we obtain the following proposition.

Proposition 5. *Pollution abatement activities might reduce the optimal tax rate and increase the number of entering firms, but improve the environmental quality and social welfare in the presence of CSR-firm.*

In order to show the effect of CSR in the presence of abatement technology, we will provide simulation results with $A=100$, $F=300$, and $d=10$. Fig. 4 shows that as the degree of CSR increases, t^A increases, and n^A decreases while ED^A increases and W^A first increases and then decreases. Thus, a higher degree of CSR might not be beneficial to the society in the

FIGURE 4. THE EFFECTS OF CSR IN THE PRESENCE OF ABATEMENT TECHNOLOGY



presence of pollution abatement activities. This also implies that the active role of governmental guideline for the appropriate CSR is more necessary in the long-run where polluting firms can choose pollution abatement technology.

V. *Conclusions*

We have considered a consumer-friendly firm with CSR-initiatives in Cournot markets with endogenous entry and examined the effects of CSR on environmental tax and welfare consequences. We showed that the optimal tax under free entry is higher than that under blockaded entry and also higher than marginal environmental damage. However, we showed that a higher taxation is socially excessive from the viewpoint of socially optimal degree of CSR. Thus, the active role of governmental guideline for promoting CSR, rather than considering it on a voluntary basis, is necessary. This also implies that an appropriate regulatory framework for CSR promotion should be constructed. We further showed that the environment is less damaged but social welfare deteriorates accompanied with a CSR-firm when the fixed cost is low. However, we also showed that pollution abatement activities will reduce the optimal tax in free entry markets, but improves both environmental quality and social welfare.

Our analysis should be extended to incorporate the general formulations of demand and cost functions.[21] For example, it will be interesting to investigate the case that the consumer-friendly firm considers environmental damages in its objective function.[22] Finally, we examined quantity competition, but price competition can be an alternative in oligopolistic competition. These challenging issues are promising future research.

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[21] Lee (1999) shows that the optimal tax in a free-entry private market depends on the curvature of the market demand function, while Amir and Lambson (2000) point out the importance of the cost function in determining the output of an oligopoly. In a free-entry mixed market, Cato (2008) also shows that the optimality of privatization depends on the abatement cost function.

[22] See, for example, Kamijo and Tomaru (2014), Liu *et al.* (2015) and Lee and Xu (2018).

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