Love Initially, Hurt Eventually:
Corporate Social Responsibility and Consumer Welfare

Abstract

Both government policies and CSR activities by private firm are accompanied with good intentions to improve welfare. We in this paper aim to examine the welfare effect of CSR initiative in the context of asymmetric Cournot oligopoly with strategic tax pol- icy. Although CSR activities by efficient firms are favorable to consumer welfare, we find that increases in both the number of inefficient CSR firms and the degree of CSR activities unexpectedly reduce consumer welfare. With inefficient CSR firms, the government may either tax or subsidize firms. Furthermore, more CSR firms or higher degree of CSR ac- tivities will promote taxation or reduce subsidy. We also discuss robustness of our results in an asymmetric oligopoly with environmental externality, and a Stackelberg model with both efficient and inefficient leaders in the production stage. Our main results continue to hold in these two extensions. Our findings thus yield rich implications for competition and tax policy.

Key words: undesirable CSR, asymmetric oligopoly, Cournot, environmental externality, Stackelberg

JEL Classification: H23, L13, M14

1 Introduction

There is one well-recognized Chinese adage: "Love Initially, but Hurt Eventually"(Huainanzi, Western Han Dynasty), which reveals a fact that outcomes are often contrary to our desires and wishes. It thus causes our deep thinking of a well-known business practice: Corporate Social Responsibility (henceforth CSR), which aims to benefits consumers through environmental efforts, philanthropy, ethical labor practices, and volunteering. We find that the strategic use of CSR by modern enterprises who have a larger scope than only pursuing profit maximization hurts consumers who these firms initially intend to provide additional benefits through their consumer-friendly activities.

In the real-world industry, CSR initiated by the competing firms has gained increasing attention and became a mainstream business activity for firms in today's globalized market environment.[1] Recent prominent examples include Google Green and Google Energy, GE's Ecomagination Program, Xerox's Community Involvement Program, and Nestle's Creating Shared Value, etc. In recent decades, researchers have paid an increasing attention to CSR. In the context of the basic Cournot model, it is generally believed that increasing CSR activities always benefits consumer welfare, which is also the foundation of competition policy in the European Union and many other countries. The result that CSR improves consumer welfare can be found in a substantial literature such as Chang et al. (2014), Brand and Grothe (2015), Lambertini and Tampieri (2015), Manasakis et al. (2018), etc. Furthermore, the European Union Commission's Green Paper (2001) titled "Promoting a European framework for corporate social responsibility" evidently shows the belief that CSR is welfare improving (Fanti and Buccella, 2017). When CSR started becoming widespread, it is worth exploring whether it really improves consumer welfare as is generally believed.

Both government policies and CSR activities by private firms are accompanied with good intentions to improve consumer welfare (Crifo and Forget, 2015). It thus becomes very interesting to examine the welfare effects of CSR under strategic tax policy by the government. Such a consideration, which is neglected in the literature, might generate important insights for the competition policy and tax policy, and enrich the results in the literature of CSR.

We in this paper examine the welfare effects of CSR initiative in the context of Cournot oligopolies with asymmetric productivity in the presence of strategic tax policy, in the following two cases: (i) inefficient firms launch the CSR initiative, and (ii) efficient firms launch the CSR initiative.[2] The first finding in this paper is that CSR activities by either efficient or inefficient firms would not change industry output and consumer welfare in the absence of taxation, as long as the number of participants and the degree of CSR activities are the same. This result is new in the literature. Furthermore, increases in both the number of CSR firms and the degree of CSR activities improve consumer welfare without taxation.

By contrast, in presence of strategic tax policy, we find that the conventional wisdom that CSR benefits consumers is not necessarily true. In case (i), increases in both the number of inefficient CSR firms and degree of CSR activities unexpectedly reduce consumer welfare. The government can either tax or subsidize firms in this case. Furthermore, more CSR firms and

[1] KPMG (2015) reports that CSR is now undeniably a mainstream business practice worldwidely (European Commission, 2001, 2006; Matsumura and Ogawa, 2014; Manasakis et al. 2018).

[2] We call the firms which incorporate CSR into their output decisions "CSR firms" thereafter.

higher degree of CSR activities will promote taxation or reduce subsidy. In case (ii), increases in both the number of efficient CSR firms and the degree of CSR activities improve consumer welfare. The government will always subsidize firms. Moreover, increasing CSR may lead to more government subsidies when there are fewer efficient firms and a low market demand. Our main results are robust in consideration of an asymmetric oligopoly with environmental externality, and a Stackelberg model with both efficient and inefficient leaders.

As shown in Hubbard et al. (2017), it is widely observed in United States that inefficient firms (i.e., poorly performing firms) also engage in CSR activities other than efficient firms (i.e., well-performing firms). Further examples can be found in China, England, and Italy, etc. Thus, the finding that CSR by inefficient firms hurts consumer welfare is very important and should be noticed by competition authorities. The reason for this result is as follows. For any given tax rate, an increase in the number of CSR firms or the degree of CSR activities generates an output shift effect. When inefficient firms engage in CSR activities, this effect induces inefficient firms to produce more and efficient firms to produce less, which is undesirable for market efficiency. Thus, the government will take the chance to correct market inefficiency through tax policy. Generally, it responds to raise the tax rate which therefore leads to a decrease in industry output. As a result, CSR by inefficient firms are undesirable from the view of consumer welfare.

After the literature review, this paper is organized as follows. Section 3 formulates our model and presents the main analysis. In Section 4, we extend our analysis to an asymmetric oligopoly with environmental externality, and a Stackelberg model with both efficient and inefficient leaders. Section 5 concludes this paper.

2 Literature Review

CSR which originates from the expectations of the society for appropriate business behavior and outcomes (Wood, 1991), has gained increasing attention over the past few decades. Recently, more and more theoretical literature explore the competition between CSR firms and profit maximizing firms to examine the effects of CSR on firms' strategies and welfare.[3]

Goering (2010) propose a two-period durable-goods framework and show that a firm may earn higher profits as it increases its degree of CSR. Chang et al. (2014) study the welfare implications of CSR in an import-competing market with both home and foreign firms. When only the foreign firm launches CSR initiative, the government strategically raises the import tariff to improve social welfare. By contrast, when both firms launch CSR initiative, it is optimal for the government to reduce import tariff which leads to a winwinwin equilibrium. Lambertini and Tampieri (2015) investigate the effect of CSR on firms' profits and social welfare when production generates a negative environmental externality. The main result is that, in a large market, a CSR firm has higher profits than a profit-maximizing firm, and its presence improves consumer welfare and social welfare. Manasakis et al. (2018) reexamine CSR in an international market with a home firm and a foreign firm. The authors find out that under both exports

[3]The literature has provided numerous interesting perspectives on the aspects of CSR. One strand of the literature considers CSR as the private provision of public goods and the private curtailment of public bads. In general, the obtained results are parallel with those in the literature on the private provision of public goods, (e.g., Bagnoli and Watts, 2003; Kotchen, 2006). Another strand of the literature investigates the possible motivations for CSR (e.g., Baron 2001, 2009; Porter and Kramer, 2006).

and FDI, CSR by the multinational firm improves its equilibrium output and profits as well as consumer welfare and social welfare. Wang et al. (2018) study a duopoly competition with one CSR firm under different market structures including both Cournot and Stackelberg. The authors highlight the effects of firms' position on outputs and profits under the consideration of CSR.

In addition to the above mentioned papers, the literature of CSR further investigate several important issues such as vertical interactions (Goering, 2014; Brand and Grothe, 2015; Chen et al., 2016; Chang et al., 2019), privatization (Kim et al., 2019; Xu and Lee, 2019), endogenous timing (Matsumura and Ogawa, 2014), environmental CSR (Liu et al., 2015; Lambertini et al., 2016; Leal et al., 2019; Lee and Park, 2019; Nie et al., 2019), entry deterrence (Planer-Friedrich and Sahm, 2020), and managerial delegation (Kopel and Brand, 2012; Fanti and Buccella, 2017), etc.

We are aware that Fanti and Buccella (2017) also find out that CSR by firms unexpectedly hurts consumer welfare. In their model, there are two CSR firms producing a homogeneous product at constant zero marginal cost under Cournot competition. The owner of each firm hires a manager and delegates the output decision to this manager. As shown by the authors, CSR generates two counteracting effect: the well-known output expansion effect which benefits consumer welfare, and a bonus mitigating effect which reduces managers' bonus and therefore negatively affect the production. In equilibrium, the second negative effect of CSR dominates the first positive effect and thus always leads to a reduced production.

The present paper complements the contribution by Fanti and Buccella (2017), but some distinctive differences between the two studies should be emphasized. Firstly, we present a model with asymmetric Cournot oligopoly rather than a symmetric duopoly. In our paper, an increase in CSR is reflected in two dimensions: the degree of CSR activities as in the literature, and the number of CSR firms which is absent in the literature. Secondly, we examine the welfare effect of CSR with the consideration of strategic tax policy rather than managerial delegation. Lastly but most importantly, we find out that CSR by inefficient firms hurts consumer welfare, but CSR by efficient firms improves consumer welfare. This result is remarkably different from that in Fanti and Buccella (2017). Furthermore, the mechanism in this paper is significantly different. The driving factors to our result are the endogenous output shifting owing to CSR, and the resulting tax policy by the government. As such, our results generate important insights for competition policy.

Our paper is also related to the literature on indirect taxation. Representative contributions include Delipalla and Keen (1992), Wang and Zhao (2009), Dinda and Mukherjee (2014), Wang et al. (2019a, 2019b), to name but a few. As we know, competition policy and tax policy are two important issues for governments. It is thus very interesting to examine the welfare effect of CSR under strategic tax policy to better understand how these two policies are connected.

3 The Model and the Analysis

We propose an oligopoly industry with $n \geq 1$ identical efficient firms with marginal cost d, and $m \geq 1$ symmetric inefficient firms with marginal cost c, where $0 \leq d < c$.[4] All firms compete in a Cournot fashion with homogeneous products. The inverse market demand function is $P = a - Q$, where P is market price, and $Q = \sum_{i=1}^{n} q_i + \sum_{j=1}^{m} q_j$ is industry output, where q_i denotes the output of a typical efficient firm and q_j denotes that of a typical inefficient firm. We assume that either efficient firms or inefficient firms may launch the CSR initiative.

In line with the literature, we model CSR with a broader firm objective function and assume that CSR firms also care about a share of consumer welfare in addition to profits. Thus, the objective function of each CSR firm can be rewritten as $U = \pi + \alpha CS$, where α represents the weight for consumer welfare, and $CS = Q^2/2$ denotes consumer welfare. This way of modelling CSR firms is widely adopted in the literature (see Brand and Grothe, 2015; Lambertini and Tampieri, 2015; and Fanti and Buccella, 2018; Kim et al., 2019; etc.).[5]

It is important to note that CSR activities are reflected in two dimensions in this asymmetric Cournot oligopoly: the degree of CSR activities as in the literature, and the number of CSR firms which is absent in the literature. We propose a two-stage game.

- In stage 1, the welfare-maximizing government determines a unit tax, t, to maximize social welfare, which is the sum of industry profit, consumer welfare and tax revenue.

- In stage 2, all firms compete in a Cournot fashion, taking the taxation set by the government as given.

As usual, the game is solved by backward induction. In the benchmark model, we assume all firms are active in equilibrium. We examine the following two cases: (i) inefficient firms launch the CSR initiative, and (ii) efficient firms launch the CSR initiative. In each case, we assume that a number, x, of these efficient/inefficient firms participate in CSR activities with a degree of α.

We mainly address the following question: does consumer welfare increase as commonly believed when a higher weight is given to consumer welfare (i.e., a higher α) or more firms in the market adopt CSR activities (i.e., a higher x)?

3.1 Undesirable CSR: Inefficient firms adopt CSR Strategies

Consider the case in which a number, x, of inefficient firms adopt CSR activities. The market thus consists of n efficient (non-CSR) firms, x inefficient CSR firms, and $m - x$ inefficient non-CSR firms. We start our analysis from the second stage. The profit for each efficient firm is $\pi_i = (a - Q - d - t)q_i$, for $i = 1, 2, \ldots, n$. Under Cournot competition, the first-order condition

[4] See also in Dinda and Mukherjee (2014), and Wang et al. (2019a, 2019b). Such a model enables us to capture CSR activities by both efficient and inefficient firms.

[5] Note that the weight assigned to consumer welfare in the objective function of the CSR firm is exogenously given here. The literature also discusses the endogeneity of CSR in different contexts, such as vertical markests (Goering, 2014; Brand and Grothe, 2015), environmental externality (Lambertini et al., 2016), and entry deterrence (Planer-friedrich and Sahm, 2020).

for each efficient firm is given by

$$a - Q - d - t - q_i = 0, \text{ where } i = 1, 2, \ldots, n. \tag{1}$$

The profit for each inefficient firm is $\pi_j = (a - Q - c - t)q_j$, for $j = 1, 2, \ldots, m$. For the x inefficient CSR firms, each one chooses its quantity to maximize the weighted sum of its own profit and consumer welfare, i.e., $U_j = \pi_j + \alpha Q^2/2$, where $j = 1, 2, \ldots, x$. Simple calculations yield the first-order conditions as

$$a - Q - c - t - q_j + \alpha Q = 0, \text{ where } j = 1, 2, \ldots, x. \tag{2}$$

Simultaneously, the $m - x$ inefficient non-CSR firms determine quantities to maximize profits π_j, which leads to the following first-order conditions:

$$a - Q - c - t - q_j = 0, \text{ where } j = x + 1, x + 2, \ldots, m. \tag{3}$$

By solving the above $n + m$ first-order conditions, we obtain the equilibrium quantities in the second-stage as

$$\begin{cases} q_n &= \frac{(c-d)m-(a-d-t)(x\alpha-1)}{1+m+n-x\alpha}; \\ q_x &= \frac{(a-c-t)((1-x\alpha)+m\alpha)+n((a-d-t)\alpha-c+d)}{1+m+n-x\alpha}; \\ q_{-x} &= \frac{(d-c)n-(a-c-t)(x\alpha-1)}{1+m+n-x\alpha}, \end{cases} \tag{4}$$

where q_n, q_x, and q_{-x} denote the quantities for the efficient firms, inefficient CSR firms, and inefficient non-CSR firms, respectively. The nonnegativity of individual output requires that $0 < \alpha < 1/x$, and $t < (c + cn + ax\alpha - a - dn - cx\alpha)/(x\alpha - 1)$. Substituting the equilibrium quantities in (4) back into the profit functions, we can get the equilibrium profits. Summing up the individual quantities in equilibrium yield the following results:

$$Q^d = \frac{n(a - d + (c - d)m - t + (d + t - a)x\alpha)}{1 + m + n - x\alpha}, \tag{5}$$

$$Q^c = \frac{a(m + nx\alpha) - m(c + cn - dn + t) - n(d + t)x\alpha}{1 + m + n - x\alpha}, \tag{6}$$

where Q^d and Q^c denote the total quantities of the efficient firms and that of the inefficient firms, respectively. The industry output is thus

$$Q = \frac{a(m + n) - n(d + t) - m(c + t)}{1 + m + n - x\alpha}. \tag{7}$$

Lemma 1. *The following properties of equilibrium quantities hold:*

(i). $\partial Q^d/\partial t < 0$, $\partial Q^c/\partial t < 0$, *and* $\partial Q/\partial t < 0$*;*

(ii). $\partial Q^d/\partial x < 0, \partial Q^d/\partial \alpha < 0$*;* $\partial Q^c/\partial x > 0, \partial Q^c/\partial \alpha > 0$*; and* $\partial Q/\partial x > 0, \partial Q/\partial \alpha > 0$.

Lemma 1(i) reveals the well-known *output reduction effect* of unit taxation as in Dinda and

Mukherjee (2014). Lemma 1(ii) demonstrates two important effects of CSR. Firstly, for any given tax rate, more firms in the market engaging in CSR activities or a higher weight for consumer welfare would shift production from efficient firms toward inefficient firms, which lowers the market efficiency. This is what we call the *output shift effect* of CSR. Secondly, the resulting output shifting due to CSR further increases industry output, thus making the consumers better off. We call it the *output expansion effect* of CSR.

The following result is straightforward from Lemma 1(ii).

Proposition 1. *In the absence of taxation, an increase in either the degree of CSR activities, or in the number of CSR firms, raises consumer welfare.*

Importantly, without the consideration of strategic tax policy, an increase in CSR, either in the degree of CSR activities or in the number of CSR firms, always improves consumer welfare. This result is commonly observed in the existing literature, and serves as a benchmark for future comparisons.

Now, we examine the effects of the strategic tax policy. To show this, we solve the first stage of the game, where the government determines t to maximize social welfare, which is

$$SW = \sum_{i=1}^{n} \pi_i + \sum_{j=1}^{m} \pi_j + Q^2/2 + tQ.$$

By solving the first-order condition, we get the equilibrium tax rate as

$$t^* = \frac{cm + dn + (d-c)nx^2\alpha^2 + a(m+n)(x\alpha - 1) + H_1(x,\alpha)}{(m+n)^2}, \tag{8}$$

where $H_1(x,\alpha) = \big(c(m(n-1) + n + n^2) - dn(2+m+n)\big)\, x\alpha$.

Lemma 2. *In equilibrium, t^* can be either positive or negative. Furthermore, $\partial t^*/\partial \alpha > 0$ and $\partial t^*/\partial x > 0$.*

Lemma 2 implies that the government may either tax firms or subsidize them. This result is in contrast to the finding by Dinda and Mukherjee (2014) that the government will always subsidize firms without the consideration of CSR. Furthermore, increasing CSR through either α or x will induce the government to increase t due to the output expansion effect of CSR. Incorporating the equilibrium tax rate into (7) yields that

$$Q^* = \frac{a(m+n) + (d-c)nx\alpha - dn - cm}{m+n}. \tag{9}$$

We next examine how consumer welfare changes with more CSR activities in the market. The following results follow straightforwardly from the equilibrium output.

Proposition 2. *Under strategic tax policy, an increase in either the number of inefficient CSR firms, x, or the degree of CSR activities, α, reduces consumer welfare.*

Implied by Proposition 2, increasing CSR by inefficient firms is undesirable from the perspective of consumer welfare, which is in sharp contrast to the findings in the literature. The reason for our result is as follows. We have seen that, for any given t, an increase in either x or α on one hand increases industry output which benefits consumers, but on the other hand shifts production from efficient firms toward inefficient firms which hurts the overall production efficiency. Thus, the government will strategically raise t to increase the tax revenue (or reduce the subsidy), and correct the market inefficiency as far as possible. The industry output decreases as a result. This result is very important for competition policy.

3.2 Favorable CSR: Efficient firms adopt CSR Strategies

Next, we consider the case in which a number, x, of efficient firms engage in CSR activities. The market thus consists of x efficient CSR firms, $n-x$ efficient non-CSR firms, and m inefficient (non-CSR) firms. In the second stage, the profit for each efficient firm is $\pi_i = (a-Q-d-t)q_i$, for $i = 1, 2, \ldots, n$. The $n-x$ efficient non-CSR firms choose quantities to maximize profits, π_i, which leads to the following first-order conditions

$$a - Q - q_i - d - t = 0, \text{ where } i = x+1, x+2, \ldots, n. \tag{10}$$

For the x efficient CSR firms, each one chooses its quantity to maximize the weighted sum of its own profit and consumer welfare: $U_i = \pi_i + \alpha Q^2/2$. The first-order conditions are given by

$$a - Q - q_i - d - t + \alpha Q = 0, \text{ where } i = 1, 2, \ldots, x. \tag{11}$$

Simultaneously, the m inefficient (non-CSR) firms determine quantities to maximize profits $\pi_j = (a-Q-c-t)q_j$, for $j = 1, 2, \ldots, m$. Simple calculations yield first-order conditions as

$$a - Q - q_j - c - t = 0, \text{ where } j = 1, 2, \ldots, m. \tag{12}$$

By solving these $n+m$ first-order conditions in (10)-(12), we obtain the equilibrium quantities in the second-stage:

$$\begin{cases} q_x & = \frac{(d+t-a)(x\alpha-1-n\alpha)+m(c-d+\alpha(a-c-t))}{1+m+n-x\alpha}; \\ q_{-x} & = \frac{a+(c-d)m+(d+t-a)(x\alpha-1)}{1+m+n-x\alpha}; \\ q_m & = \frac{(d-c)n+(c+t-a)(x\alpha-1)}{1+m+n-x\alpha}, \end{cases} \tag{13}$$

where q_x, q_{-x}, and q_m denote the quantities for the efficient CSR firms, efficient non-CSR firms, and inefficient firms, respectively. The nonnegativity of individual output requires that $0 < \alpha < 1/x$, and $t < (c + cn + ax\alpha - a - dn - cx\alpha)/(x\alpha - 1)$. Substituting the equilibrium quantities in (13) back into the profit functions, we can get the equilibrium profits. Summing up the individual quantities of all firms leads to that

$$Q^d = \frac{n(a-d+m(c-d)-t) + x\alpha m(a-c-t)}{1+m+n-x\alpha}, \tag{14}$$

$$Q^c = \frac{m((d-c)n - (a-c-t)(x\alpha-1))}{1+m+n-x\alpha}. \tag{15}$$

Thus, the industry output is given by

$$Q = \frac{a(m+n) - n(d+t) - m(c+t)}{1+m+n-x\alpha}. \tag{16}$$

For any given tax rate, the equilibrium industry output in the second stage calculated in (16) is exactly the same as that obtained in (7), which can be easily observed in the first-order conditions.

Proposition 3. *In the absence of taxation, the industry output remains unchanged for any given x and α, no matter which firms participate in CSR activities.*

It is commonly believed that CSR by efficient firms could be better for consumer welfare than that by inefficient firms. However, Proposition 3 reveals that, without the consideration of strategic tax policy by the government, CSR activities by either efficient or inefficient firms would not change consumer welfare, as long as the number of participants and the degree of CSR activities are the same. That the distribution of CSR firms is irrelevant to industry output and consumer surplus is counter-intuitive and new in the literature.

Lemma 3. *The following properties of equilibrium quantities hold:*

(i). $\partial Q^d/\partial t < 0$, $\partial Q^c/\partial t < 0$, *and* $\partial Q/\partial t < 0$;

(ii). $\partial Q^d/\partial x > 0, \partial Q^d/\partial \alpha > 0$; $\partial Q^c/\partial x < 0, \partial Q^c/\partial \alpha < 0$; *and* $\partial Q/\partial x > 0, \partial Q/\partial \alpha > 0$.

Lemma 3 confirms the effects of tax and CSR on industry output. The main difference lies in that an increase in CSR now shifts production from inefficient firms toward efficient ones, which thus improves market efficiency.

In the first stage, the government decides t to maximize social welfare. After the usual straightforward calculations mirroring those in the previous section, we obtain the equilibrium tax rate by solving the first-order condition:

$$t^{**} = \frac{cm + dn - a(m+n) + cmx^2\alpha^2 + Z_1(x,\alpha)}{(m+n)^2}, \tag{17}$$

where $Z_1(x,\alpha) = x\alpha(a(m+n) - cm(2+m+n) + d(m(1+m+n-x\alpha) - n))$.

Lemma 4. *In equilibrium, t^{**} is always negative. Furthermore,*

(i). *when* $n > m$, $\partial t^{**}/\partial x > 0$ *and* $\partial t^{**}/\partial \alpha > 0$;

(ii). *when* $n < m$, $\partial t^{**}/\partial x > 0$ *and* $\partial t^{**}/\partial \alpha > 0$ *if* $a > d + m(2+m+n-2x\alpha)(c-d)/(m+n)$; *otherwise, the opposite occurs.*

Interestingly, when efficient firms engage in CSR activities, the government always subsidizes firms to stimulate production. The reason is due to the efficiency-enhancing output shift effect of CSR. Thus, the government tends to subsidize firms to encourage more production by efficient CSR firms. Generally, the more are the CSR activities, the lower is the subsidy. The reason is due to the output expansion effect of CSR, which motivates the government to reduce the subsidy to squeeze government spending. Unexpectedly, we observe in Lemma 4(ii) that the government may be inclined to increase the subsidy when the demand is relatively small and the number of efficient firms is smaller than that of the inefficient firms. In this case, the government's primary motivation is to shift the production from inefficient firms to efficient firms, expecting these efficient firms to be the main force of market supply, and therefore realize the largest possible improvement in market efficiency.

The equilibrium industry output is obtained as

$$Q^{**} = \frac{a(m+n) + (c-d)mx\alpha - dn - cm}{m+n}. \tag{18}$$

We next examine how consumer welfare changes with more CSR activities in the market.

Proposition 4. *Under strategic tax policy, an increase in either the number of efficient CSR firm, x, or the degree of CSR activities, α, improves consumer welfare.*

The results in Proposition 4 is straightforward. Such CSR activities by efficient firms improve market efficiency due to output shift effect, which is therefore encouraged by the government under strategic subsidy policy. The industry output increases as a result.

4 Two Extensions

In this section we investigate the robustness of our results to the consideration of environmental externality, and asymmetric Stackelberg oligopoly. Importantly, we show that our key result — that CSR activities by inefficient firms are undesirable — is robust to these changes.

4.1 CSR in presence of Environmental Externality

We first apply our benchmark model to examine the effects of CSR in an asymmetric oligopoly with environmental externality. Firms are identical in the marginal production cost, which is normalized to zero. However, firms differ in the amount of polluting emissions, denoted by e, in the process of production. In this section, efficient firms are those with advanced pollution-reducing technologies.

Consider a polluting industry with $n \geq 1$ identical efficient firms which generate λ, where $\lambda < 1$, unit of emission for one unit of output, and $m \geq 1$ symmetric inefficient firms which generate one unit of emission for one unit of output. That is, $e_i = \lambda q_i$ for each efficient firm i, and $e_j = q_j$ for each inefficient firm j. The damage function which captures the negative externality (pollution) of production is given by $D = d(\sum_{i=1}^{n} e_i + \sum_{j=1}^{m} e_j)$, where $d > 0$ is the coefficient of environmental damage function.[6] The government imposes an emission tax t on all firms.

As in the benchmark model, all firms compete in a Cournot fashion with homogeneous products, and the inverse market demand function is $P = a - Q$. We allow either efficient firms or inefficient firms to engage in social CSR activities, and examine the effects of CSR activities

[6] The consideration of a negative environmental externality (pollution) can also be found in Lambertini and Tampieri (2015), Lambertini et al. (2016), and Lee and Park (2019).

on consumer welfare with the presence of an emission tax. It is very important to note that we follow Lambertini and Tampieri (2015), Lambertini et al. (2016), and Nie et al. (2019) to assume that (i) the CSR firms' social concern is consumer surplus, and (ii) consumer surplus is not affected by pollution, i.e., consumers are not green consumers.

To avoid repetition, we provide the main results in this section, which are obviously tractable with the same procedures more extensively detailed above in the benchmark model and are available on request.

Case I: Inefficient firms adopt CSR Strategies

Consider the case in which a number, x, of inefficient firms adopt CSR activities. We have $\pi_i = (a - Q)q_i - te_i$, for each efficient firm, and $\pi_j = (a - Q)q_j - te_j$, for each inefficient firm. In the second stage, each non-CSR firm determine its production to maximize profit, while each inefficient CSR firm produces to maximize $U_j = (a - Q)q_j - te_j + \alpha Q^2/2$. By solving the $n + m$ first-order conditions, we obtain the equilibrium quantities in the second-stage as

$$\begin{cases} q_n & = \frac{a+t(m-(1+m)\lambda)+x\alpha(t\lambda-a)}{1+m+n-x\alpha}; \\ q_x & = \frac{a(1+n\alpha)-(n+1)t+(a-t)(m-x)\alpha+nt\lambda(1-\alpha)}{1+m+n-x\alpha}; \\ q_{-x} & = \frac{a-(1+n-n\lambda)t+(t-a)x\alpha}{1+m+n-x\alpha}, \end{cases} \tag{19}$$

which yield that

$$Q = \frac{a(m+n) - t(m+n\lambda)}{1+m+n-x\alpha}. \tag{20}$$

In the first stage, the government determines t to maximize social welfare, which is

$$SW = \sum_{i=1}^{n} \pi_i + \sum_{j=1}^{m} \pi_j + Q^2/2 + tQ - d(\sum_{i=1}^{n} e_i + \sum_{j=1}^{m} e_j).$$

By solving the first-order condition, we get the equilibrium tax rate as

$$t_E^* = \frac{a(x\alpha-1)(m+n\lambda)+d(1+m+n-x\alpha)\left(m\left(1+n(\lambda-1)^2\right)+n\lambda(x\alpha(1-\lambda)+\lambda)\right)}{(m+n\lambda)^2}. \tag{21}$$

We assume that $a > d\left(m\left(1+n(\lambda-1)^2\right)+n\lambda(\lambda+x\alpha(1-\lambda))\right)/(1+n\lambda)$ to ensure all firms are active in the market. The industry output in equilibrium can be obtained as

$$Q_E^* = \frac{(x\alpha-1-m-n)(dm(1+n)-a(m+n\lambda)+dn\lambda(x\alpha-2m+\lambda(1+m-x\alpha)))}{(1+m+n+x\alpha)(m+n\lambda)}. \tag{22}$$

Proposition 5. *In an asymmetric oligopoly with environmental externality and emission tax, an increase in either the number of inefficient CSR firms, x, or the degree of CSR activities, α, reduces consumer welfare.*

Proposition 5 indicates that our result in Proposition 2 continues to hold in an asymmetric oligopoly with environmental externality and emission tax. Straightforward calculations mirroring those in the benchmark model reveal that increasing CSR by inefficient firms also generates an output shifting effect which lowers the overall production efficiency. As a response, the government will strategically raise t to increase the tax revenue (or reduce the subsidy) and correct the market inefficiency, which therefore leads to industry output reduction.

Case II: Efficient firms adopt CSR Strategies

Next, we consider the case in which a number, x, of efficient firms engage in CSR activities. The equilibrium outcomes in the last stage can be obtained as

$$\begin{cases} q_x &= \frac{a((m+n-x)\alpha+1)-t((\lambda(n-x)\alpha+1)+m(\alpha+\lambda-1))}{1+m+n-x\alpha}; \\ q_{-x} &= \frac{a(1-x\alpha)+t(m-(1+m-x\alpha)\lambda)}{1+m+n-x\alpha}; \\ q_m &= \frac{a-(1+n)t+(t-a)x\alpha+nt\lambda}{1+m+n-x\alpha}, \end{cases} \tag{23}$$

which yield that

$$Q = \frac{a(m+n)-t(m+n\lambda)}{1+m+n-x\alpha}. \tag{24}$$

In the first stage, the government determines t to maximize social welfare, which leads to the equilibrium tax rate as

$$t_E^{**} = \frac{a(x\alpha-1)(m+n\lambda)+d(1+m+n-x\alpha)\left(m\left(1+x\alpha(\lambda-1)+n(\lambda-1)^2\right)+n\lambda^2\right)}{(m+n\lambda)^2}. \tag{25}$$

We assume that $a > d\left(m\left(1+x\alpha(\lambda-1)+n(\lambda-1)^2\right)+n\lambda^2\right)/(m+n\lambda)$ such that all firms are active in equilibrium. Incorporating the equilibrium tax rate into (24) yields that

$$Q_E^{**} = \frac{a(m+n\lambda)-d\left(m\left(1+x\alpha(\lambda-1)+n(\lambda-1)^2\right)+n\lambda^2\right)}{m+n\lambda}. \tag{26}$$

Proposition 6. *In an asymmetric oligopoly with environmental externality and emission tax, an increase in either the number of efficient CSR firms, x, or the degree of CSR activities, α, improves consumer welfare.*

As in Proposition 4, increasing CSR by efficient firms are favorable for consumer welfare. The main reason is due to the efficiency-enhancing output shift effect of CSR in this case. As a result, the same argument provided in Section 3.2 applies.

4.2 CSR in Asymmetric Stackelberg Oligopoly

In this section, we discuss the robustness of our results in the benchmark Cournot model by allowing firms to move sequentially in production.[7] Consider a Stackelberg oligopoly with $n \geq 1$ identical leaders and $m \geq 1$ symmetric followers, which produce a homogeneous product. We

[7] Stackelberg model is a very important model in the literature concerning imperfect competition in addition to Cournot model, which may yield different welfare implications (Wang et al., 2018, and Wang et al., 2019b).

allow both efficient and inefficient firms to be leaders in two separate cases.[8] In each case, there are a number, x, of efficient (or inefficient) firms participating in CSR activities with a degree of α. All other settings are the same as that in the benchmark model.

We propose a three-stage game with the following timing. In the first stage, the government determines a unit tax rate to maximize social welfare. In the second stage, all leaders independently and simultaneously decide about their individual supply, taking the taxation set by the government as given. In the last stage, all followers decide upon their outputs independently and simultaneously after observing the total output supplied by leaders.

Case I: Efficient leaders

In this case, efficient firms act as Stackelberg leaders. As before, we analyze two scenarios with either CSR by inefficient firms or CSR by efficient firms.

Inefficient followers adopt CSR strategies

In the last stage, the profit function for each non-CSR follower can be written as $\pi_{-x} = (a - Q - t - c)\, q_{-x}$, where $Q = \sum_{j=1}^{x} q_x + \sum_{j=x+1}^{m} q_{-x} + \sum_{i=1}^{n} q_i$. Similarly, the objective function for each CSR follower can be written as $U_x = (a - Q - t - c)q_x + \alpha Q^2/2$. All inefficient followers simultaneously choose quantities to maximize their own objective functions. By solving the first-order conditions, the equilibrium output of a typical CSR follower, and that of a typical non-CSR follower can be found as

$$q_x = \frac{(a-c-t)(1+m\alpha-x\alpha)+(\alpha-1)\sum_{i=1}^{n} q_i}{1+m-x\alpha}, q_{-x} = \frac{(a-c-t)(1-x\alpha)-\sum_{i=1}^{n} q_i}{1+m-x\alpha}.$$

In the following analysis, we assume that the market demand (represented by a) is sufficiently large such that all followers are active in production. In the second stage, each leader determines its output to maximize $\pi_i = (a - Q - t - d)\, q_i$. By solving the first-order conditions, the equilibrium output of a typical leader, denoted by q_l, can be found as

$$q_l = \frac{a + cm - d(1+m) - t + (d+t-a)x\alpha}{1+n}.$$

Incorporating the expression of q_l into q_{-x} and q_x leads to the quantities by inefficient firms in the last stage. Furthermore, the industry output can be obtained as

$$Q = \frac{(a-t)(m+n+mn) + (d+t-a)nx\alpha - cm - dn(1+m)}{(1+n)(1+m-x\alpha)}. \tag{27}$$

[8] The assumption of efficient leaders is commonly observed in the literature, such as Ono (1978), and Mukherjee and Wang (2013). However, the opposite may happen as shown by Matsumura (1997) and Hirata and Matsumura (2011). Our analysis in the benchmark model is thus extended to two different cases with either efficient leaders or inefficient leaders.

In the first stage, the government decides t to maximize social welfare $SW = \sum_{j=1}^{x} \pi_x + \sum_{j=x+1}^{m} \pi_{-x} + \sum_{i=1}^{n} \pi_i + Q^2/2 + tQ$. Simple calculations yield the equilibrium tax rate as

$$t^* = \frac{a(x\alpha - 1)(m + n + mn - nx\alpha) - H_2(x, \alpha) + H_3(x, \alpha)}{(m + n + mn - nx\alpha)^2}, \tag{28}$$

where $H_2(x, \alpha) = dn(1 + m - x\alpha)(x\alpha(2 + m + n + mn - (1 + n)x\alpha) - 1)$, and $H_3(x, \alpha) = c\left(m^2 n(1 + n)x\alpha + n(1 + n)x\alpha(x\alpha - 1)^2 - m(x\alpha - 1)(1 + 2n(1 + n)x\alpha)\right)$. By (27) and (28), we obtain the equilibrium industry output as

$$Q^* = \frac{(a - c)m + (a - d)(mn + n) + nx\alpha((c - d)(x\alpha - m - 1) - a + d)}{m + n + mn - nx\alpha}.$$

Efficient leaders adopt CSR Strategies

In the last stage, each inefficient follower produces to maximize its profit, which is given by $\pi_j = (a - Q - t - c)\, q_j$, where $Q = \sum_{i=1}^{x} q_x + \sum_{i=x}^{n} q_{-x} + \sum_{j=1}^{m} q_j$. The equilibrium quantity of a typical follower, denoted by q_f, is obtained as

$$q_f = \frac{a - \sum_{i=1}^{x} q_x - \sum_{i=x}^{n} q_{-x} - t - c}{m + 1}.$$

In the second stage, a number, x, of these efficient firms choose quantities to maximize $U_x = (a - Q - t - d)\, q_x + \alpha Q^2/2$. The rest efficient firms maximize profits given by $\pi_{-x} = (a - Q - t - d)\, q_{-x}$. The equilibrium output of a typical CSR leader, and that of a typical non-CSR leader can be obtained by solving the first-order conditions, i.e.,

$$q_x = \frac{(m+1)((a-d)(\alpha(n-x)+1)+t(x\alpha-1)+(c - d)m)+(a - c)m\alpha-(m + n + mn)t\alpha}{1 + m + n + mn - x\alpha},$$

$$q_{-x} = \frac{(1 + m)(m(c - d) - (d + t - a)(x\alpha - 1))}{1 + m + n + mn - x\alpha}.$$

Incorporating the expressions of q_{-x} and q_x into q_f leads to the quantities by inefficient firms. Furthermore, the industry output can be obtained as

$$Q = \frac{(a - t - c)m + (a - t - d)(mn + n)}{1 + m + n + mn - x\alpha}. \tag{29}$$

In the first stage, the government decides t to maximize social welfare, which yields that

$$t^{**} = \frac{a(m + n + mn)(x\alpha - 1) + cm(1 - x\alpha(2 + m + n + mn - x\alpha)) + Z_2(x, \alpha)}{(m + n + mn)^2}, \tag{30}$$

where $Z_2(x, \alpha) = d\left(mx\alpha(1 + m - x\alpha) + n\left(1 + m + \left(m^2 - 1\right) x\alpha\right)\right)$. By (29) and (30), we obtain the equilibrium output as

$$Q^{**} = \frac{(a - c)m + (a - d)(mn + n) + (c - d)mx\alpha}{m + n + mn}.$$

We next examine how consumer welfare changes with an increasing CSR, and summarize the results in the following proposition.

Proposition 7. *In a Stackelberg oligopoly with efficient leaders, we find that (i) when inefficient followers adopt CSR, an increase in either the number of inefficient CSR firm, x, or the degree of CSR activities, α, reduces consumer welfare; but (ii) when efficient leaders adopt CSR, an increase in either the number of efficient CSR firm, x, or the degree of CSR activities, α, improves consumer welfare.*

Proposition 7 confirms the results of undesirable CSR (Proposition 2) and favorable CSR (Proposition 4) in an asymmetric Cournot oligopoly with efficient leaders, which implies that the moves (simultaneously or sequentially) of efficient and inefficient firms do not change this result. The main reasons are due to the above-mentioned output shift effect of CSR, which hurts/improves market efficiency when inefficient/efficient firms engage in CSR activities.

Case II: Inefficient leaders

In this case, inefficient firms act as Stackelberg leaders. As usual, the game is solved by backward induction.

Inefficient leaders adopt CSR Strategies

In the production stage, inefficient firms move before efficient firms. The objective functions can be easily obtained following the above analysis. Furthermore, the calculations for the equilibrium outcomes are standard following backward induction.

After the standard calculations mirroring those in the previous section, we obtain the equilibrium industry output as (see calculations in Appendix)

$$Q = \frac{(a-d-t)n + (a-c-t)(mn+m)}{1+m+n+mn-x\alpha}. \tag{31}$$

In the first stage, the government decides t to maximize social welfare. Simple calculations yield the equilibrium tax rate as

$$t^* = \frac{a(m+n+mn)(x\alpha-1) - (c-d)nx^2\alpha^2 + H_4(x,\alpha)}{(m+n+mn)^2}, \tag{32}$$

where $H_4(x,\alpha) = dn + cm(1+n) + (c(1+n)(m(n-1)+n) - dn(2+m+n+mn))x\alpha$. By (31) and (32), we obtain the equilibrium output as

$$Q^* = \frac{(a-d)n + (a-c)(mn+m) + (d-c)nx\alpha}{m+n+mn}.$$

Efficient firms adopt CSR Strategies

Next, we switch to the situation in which efficient followers in the last stage involve in CSR activities. After the standard calculations under Stackelberg competition, we obtain the equilibrium industry output as (see calculations in Appendix)

$$Q = \frac{(a-t)(n+m+mn) + (t+c-a)mx\alpha - dn - cm(1+n)}{(1+m)(1+n-x\alpha)}. \tag{33}$$

In the first stage, the government decides t to maximize social welfare. Thus, we have

$$t^{**} = \frac{a(x\alpha-1)(n+m(1+n-x\alpha)) + dx\alpha\left(m(1+m)(1+n-x\alpha)^2 - n\right) + Z_3(x,\alpha)}{(n+m(1+n-x\alpha))^2}, \tag{34}$$

where $Z_3(x,\alpha) = dn - cm(1+n-x\alpha)(x\alpha(2+m+n+mn-(1+m)x\alpha)-1)$. By (33) and (34), we obtain the equilibrium industry output as

$$Q^{**} = \frac{(a-c)(m+mn) + (a-d)n + mx\alpha(2c-a-d) + m(d-c)x\alpha(x\alpha-n)}{n+m(1+n-x\alpha)}.$$

With inefficient leaders, we find that our results in the benchmark model continue to hold.

Proposition 8. *In a Stackelberg oligopoly with inefficient leaders, we find that (i) when inefficient leaders adopt CSR, an increase in either the number of inefficient CSR firm, x, or the degree of CSR activities, α, reduces consumer welfare; but (ii) when efficient followers adopt CSR, an increase in either the number of efficient CSR firm, x, or the degree of CSR activities, α, improves consumer welfare.*

Proposition 8 implies that our results in the benchmark model are robust to the consideration of inefficient leaders in a Stackelberg model, which further implies that our result of undesirable CSR by inefficient firms is irrespective of leadership in Stackelberg oligopolies.

5 Concluding Remarks

Corporate social responsibility refers to strategies that firms employ to be socially responsible and in-line with public expectations. Examples of CSR include environmental efforts, philanthropy, ethical labor practices, and volunteering. In recent decades, researchers have paid an increasing attention to CSR. In the context of the basic Cournot model, it is generally believed that increasing CSR activities always benefits consumer welfare, which is also the foundation of competition policy in the European Union and many other countries.

In this paper, we incorporate strategic tax/subsidy policy in an asymmetric Cournot oligopoly to study the effects of CSR on consumer welfare. Our results are summarized as follows.

Firstly, in the absence of taxation, increases in both the number of CSR firms and the degree of CSR activities improve consumer welfare (Proposition 1). This result is consistent with the finding in the related literature. However, it is worth noting that CSR activities by either efficient or inefficient firms, i.e., the distribution of CSR firms, would not change industry output and consumer welfare, as long as the number of participants and the degree of CSR activities are the same (Proposition 3).

Secondly, with the introduction of strategic tax policy, we find that increases in both the number of inefficient CSR firms and the degree of CSR activities unexpectedly reduce consumer welfare (Proposition 2). The government may either tax or subsidize firms. Furthermore, more CSR firms or higher degree of CSR activities will promote taxation or reduce subsidy (Lemma 2). By contrast, increases in the number of efficient CSR firms and the degree of CSR activities raise consumer welfare (Proposition 4). The government will always subsidize firms to encourage the efficiency-enhancing output shifting. Interestingly, increasing CSR may lead to more government subsidies when there are fewer efficient firms and a low market demand (Lemma 4).

Lastly, we also extend our model to discuss the effects of CSR on consumer welfare with the introduction of (a) environmental externality and (b) a Stackelberg model. Our main result that CSR activities by inefficient/efficient firms hurt/raise consumer welfare continue to hold in these two extensions. We believe our results generate important policy implications.

A number of areas are worthwhile directions for future research based on the present model. Firstly, we examine homogeneous products under both Cournot and Stackelberg competition. It is very interesting to extend the model to asymmetric and differentiated oligopolies under both Cournot and Bertrand competition. We believe that the analysis of asymmetric and differentiated oligopolies would greatly enrich the literature on CSR. Another direction is to examine the effects of CSR on consumer welfare under a strategic ad valorem tax. As commonly recognized in the literature, unit taxation and ad valorem taxation may lead to different outcomes (Delipalla and Keen, 1992; Wang and Zhao, 2009; and Wang et al., 2019b). The consideration of ad valorem taxation could yield some interesting results and thus generate important policy implications. Still a third avenue is to consider foreign investors in our model. Empirical evidence reveals that foreign investors are influential buyers of private firms in certain industries. Such a model may enable us to study how the presence of foreign investors change our results under strategic taxation.

Appendix: Proofs

Proof of Lemma 1:

Consider first part (i): Following (5)-(7), simple calculations lead to that

$$\frac{\partial Q^d}{\partial t} = \frac{n(x\alpha - 1)}{1 + m + n - x\alpha} < 0,$$

$$\frac{\partial Q^c}{\partial t} = -\frac{m + nx\alpha}{1 + m + n - x\alpha} < 0, \quad \text{and} \quad \frac{\partial Q}{\partial t} = \frac{-m - n}{1 + m + n - x\alpha} < 0.$$

The first inequality holds with the assumption $\alpha < 1/x$.

Consider next part (ii): Simple calculations yield that

$$\frac{\partial Q^d}{\partial x} = \frac{n(cm + dn - (a - t)(m + n))\alpha}{(1 + m + n - x\alpha)^2} < 0,$$

$$\frac{\partial Q^c}{\partial x} = \frac{(1 + n)((a - t)(m + n) - cm - dn)\alpha}{(1 + m + n - x\alpha)^2} > 0,$$

$$\text{and} \quad \frac{\partial Q}{\partial x} = \frac{((a - t)(m + n) - cm - dn)\alpha}{(1 + m + n - x\alpha)^2} > 0.$$

Due to the symmetry, we have that

$$\frac{\partial Q^d}{\partial \alpha} < 0, \quad \frac{\partial Q^c}{\partial \alpha} > 0, \quad \frac{\partial Q}{\partial \alpha} > 0.$$

Proof of Lemma 2:

It is obvious that $t^* < 0$ when $x\alpha = 0$, and $t^* > 0$ when $x\alpha = 1$. We next show that t^* increases with x and α. By (8), we obtain that

$$\frac{\partial t^*}{\partial \alpha} = \frac{x(a(m + n) - dn(2 + m + n - 2x\alpha) + c(m(n - 1) + n(1 + n - 2x\alpha)))}{(m + n)^2}.$$

Recall that $a(m+n) > n(d+t) + m(c+t)$ by (7) and $c > d$ by assumption. We thus have that

$$\begin{aligned}
&a(m + n) + c\,(m(n - 1) + n(1 + n - 2x\alpha)) \\
=&a(m + n) + cmn - cm + cn(1 + n - 2x\alpha)) \\
>&n(d + t) + m(c + t) + dmn - cm + dn(1 + n - 2x\alpha)) \\
=&(m + n)t + dn(2 + m + n - 2x\alpha) \\
>&dn(2 + m + n - 2x\alpha).
\end{aligned}$$

It follows immediately that $\partial t^*/\partial \alpha => 0$. Similarly, we obtain that

$$\frac{\partial t^*}{\partial x} = \frac{\alpha(a(m+n) - dn(2+m+n-2x\alpha) + c(m(-1+n) + n(1+n-2x\alpha)))}{(m+n)^2} > 0.$$

Proof of Lemma 3:

For part (i), simple calculations based on (14) and (15) lead to that

$$\frac{\partial Q^d}{\partial t} = -\frac{n+mx\alpha}{1+m+n-x\alpha} < 0, \quad \text{and} \quad \frac{\partial Q^c}{\partial t} = \frac{m(x\alpha-1)}{1+m+n-x\alpha} < 0.$$

Consider next part (ii): Simple calculations yield that

$$\frac{\partial Q^d}{\partial x} = \frac{(1+m)((a-t)(m+n) - cm - dn)\alpha}{(1+m+n-x\alpha)^2} > 0,$$

$$\frac{\partial Q^c}{\partial x} = \frac{m(cm+dn-(a-t)(m+n))\alpha}{(1+m+n-x\alpha)^2} < 0,$$

$$\text{and} \quad \frac{\partial Q}{\partial x} = \frac{((a-t)(m+n) - cm - dn)\alpha}{(1+m+n-x\alpha)^2} > 0.$$

Due to symmetry, we have that

$$\frac{\partial Q^d}{\partial \alpha} > 0, \quad \frac{\partial Q^c}{\partial \alpha} < 0, \quad \frac{\partial Q}{\partial \alpha} > 0.$$

Proof of Lemma 4:

We first prove that the numerator of (17) is always negative. To this end, we rewrite the numerator as $t_{num} = (cm-dm)x^2\alpha^2 + \big(dm + dm^2 - dn + dmn + a(m+n) - cm(2+m+n)\big)\, x\alpha + cm + dn - a(m+n)$, which is a standard quadratic equation. Notice that $0 < x\alpha < 1$ and $cm - dm > 0$. As a result, $t_{num} \mid_{x\alpha=0} = cm + dn - a(m+n) < 0$ and $t_{num} \mid_{x\alpha=1} = -(c-d)m(m+n) < 0$ leads to that $t_{num} < 0$. We further obtain that

$$\frac{\partial t^{**}}{\partial \alpha} = \frac{x\left(a(m+n) - cm(2+m+n-2x\alpha) + d\left(m+m^2-n+mn-2mx\alpha\right)\right)}{(m+n)^2}.$$

Denote by $T(y) = a(m+n) - cm(2+m+n-2y) + d\left(m+m^2-n+mn-2my\right)$, where $y = x\alpha$. Next, we calculate to see whether $T(y)$ is positive or negative. In equilibrium, the two assumptions on positive quantities for all firms reduce to that $a > \frac{c+cn-dn-cy}{1-y}$ and $0 < y < 1$. It is easy to obtain that $\partial T(y)/\partial y = 2cm - 2dm > 0$. That is, $T(y)$ increases with y. At $y = 1$, it is obvious that $T(1) > 0$. At $y = 0$, we obtain that

$$\begin{aligned}T(0) &= a(m+n) - cm(2+m+n-2y) + d\left(m + m^2 - n + mn - 2my\right)\\ &> (c + cn - dn)(m+n) - cm(2+m+n) + d(-n + m(1+m+n))\\ &= (c-d)(n-m)(1+m+n).\end{aligned}$$

As a result, $T(0) > 0$ if $n > m$, which implies that $T(y)$ is always positive. In other words, $\partial t^{**}/\partial\alpha = \partial t^{**}/\partial x > 0$.

If $n < m$, $T(y) > 0$ requires that

$$\begin{aligned}&a(m+n) - cm(2+m+n-2y) + d\left(m + m^2 - n + mn - 2my\right) > 0\\ \Rightarrow a &> \frac{cm(2+m+n-2y) - d(m+m^2-n+mn-2my)}{(m+n)}\\ \Rightarrow a &> \frac{cm(2+m+n-2y) - d(2m+m^2+mn-2my) + dm + dn}{(m+n)}\\ \Rightarrow a &> \frac{(c-d)m(2+m+n-2y) + d(m+n)}{(m+n)}.\end{aligned}$$

Otherwise, we have $T(y) < 0$, which implies that $\partial t^{**}/\partial\alpha =< 0$. Similarly, $\partial t^{**}/\partial x < 0$.

Proof of Proposition 5:

Simple calculations lead to that

$$\frac{\partial Q_E^*}{\partial\alpha} = \frac{\Phi_1 - \Phi_2}{(1+m+n+x\alpha)^2(m+n\lambda)}, \quad \text{where}$$

$$\begin{aligned}\Phi_1 = d\big(n\lambda\big(&-1 + n^2(-1+\lambda) - 2x\alpha(-1+\lambda) - x^2\alpha^2(-1+\lambda) + 3\lambda\\ &+n(-2 - 2x\alpha(-1+\lambda) + 4\lambda)\big) + m^2\left(2 + n\left(2 - 5\lambda + 3\lambda^2\right)\right)\\ &+2m\left(1 + n^2\left(1 - 3\lambda + 2\lambda^2\right) + n(2 + (x\alpha - 3)\lambda + (3 - x\alpha)\lambda^2)\right)\big),\end{aligned}$$

and $\Phi_2 = 2a(1+m+n)(m+n\lambda)$. Recall that

$$a > d\left(m\left(1 + n(\lambda-1)^2\right) + n\lambda(\lambda + x\alpha(1-\lambda))\right)/(1+n\lambda),$$

which ensures positive outputs for all firms. We therefore have

$$\Phi_2 > 2d(1+m+n)\left(m\left(1+n(\lambda-1)^2\right) + n\lambda(\lambda + x(\alpha - \alpha\lambda))\right) \equiv \Phi_3.$$

Straightforward calculations lead to that

$$\Phi_1 - \Phi_3 = dn\left((1+m+n)^2 - x^2\alpha^2\right)(\lambda-1)\lambda < 0,$$

which yields $\Phi_1 < \Phi_3 < \Phi_2$. Therefore, $\partial Q_E^*/\partial\alpha < 0$. Similarly, we have that $\partial Q_E^*/\partial x < 0$.

Proof of Proposition 6:

It follows straightforwardly that

$$\frac{\partial Q_E^{**}}{\partial x} = \frac{dm\alpha(1-\lambda)}{m+n\lambda} > 0, \quad \frac{\partial Q_E^{**}}{\partial \alpha} = \frac{dmx(1-\lambda)}{m+n\lambda} > 0.$$

Proof of Proposition 7:

Simple calculations yield that

$$\frac{\partial Q^*}{\partial x} = \frac{(d-c)n\alpha\left(m^2(1+n) - 2m(1+n)(x\alpha-1) + n(x\alpha-1)^2\right)}{(mn+m+n-nx\alpha)^2} < 0,$$

$$\frac{\partial Q^{**}}{\partial x} = \frac{(c-d)m\alpha}{m+n+mn} > 0.$$

Similarly,

$$\frac{\partial Q^*}{\partial \alpha} < 0, \quad \frac{\partial Q^{**}}{\partial \alpha} > 0.$$

Calculations for (31):

In the last stage, each efficient follower produces to maximize its profit, which is given by $\pi_i = \left(a - \sum_{j=1}^{x} q_x - \sum_{j=x}^{m} q_{-x} - \sum_{i=1}^{n} q_i - t - d\right) q_i$. The equilibrium quantity of a typical follower, denoted by q_f, is obtained as $q_f = \frac{a-t-d-\sum_{j=1}^{x} q_x - \sum_{j=x}^{m} q_{-x}}{1+n}$.

In the second stage, a number, x, of these inefficient firms choose quantities to maximize $U_x = \left(a - \sum_{j=1}^{x} q_x - \sum_{j=x}^{m} q_{-x} - \sum_{i=1}^{n} q_i - t - c\right) q_x + \alpha \frac{\left(\sum_{j=1}^{x} q_x + \sum_{j=x}^{m} q_{-x} + \sum_{i=1}^{n} q_i\right)^2}{2}$. The rest maximize $\pi_{-x} = \left(a - \sum_{j=1}^{x} q_x - \sum_{j=x}^{m} q_{-x} - \sum_{i=1}^{n} q_i - t - c\right) q_{-x}$. The equilibrium output of a typical non-CSR leader, denoted by q_{-x}, and that of a typical CSR leader, denoted by q_x, can be obtained by solving the first-order conditions. Incorporating the expressions of q_{-x} and q_x into q_f leads to the quantities by efficient followers. Furthermore, the industry output can be obtained as

$$Q = \frac{(a-d-t)n + (a-c-t)(mn+m)}{1+m+n+mn-x\alpha}.$$

Calculations for (33):

In the last stage, the profit function for each non-CSR follower can be written as $\pi_{-x} = \left(a - \sum_{i=1}^{x} q_x - \sum_{i=x}^{n} q_{-x} - \sum_{j=1}^{m} q_j - t - d\right) q_{-x}$. Similarly, the objective function for each CSR follower can be written as $U_x = \left(a - \sum_{i=1}^{x} q_x - \sum_{i=x}^{n} q_{-x} - \sum_{j=1}^{m} q_j - t - d\right) q_x + \alpha * \frac{\left(\sum_{i=1}^{x} q_x + \sum_{i=x}^{n} q_{-x} + \sum_{j=1}^{m} q_j\right)^2}{2}$. By solving the first-order conditions, the equilibrium output of a typical non-CSR follower, denoted by q_{-x}, and that of a typical CSR follower, denoted by q_x, can be found as $q_{-x} = \frac{(a-d-t)(1+n\alpha-x\alpha)+(\alpha-1)\sum_{j=1}^{m} q_j}{1+n-x\alpha}$, and $q_{-x} = \frac{(a-d-t)(1-x\alpha)-\sum_{j=1}^{m} q_j}{1+n-x\alpha}$.

In the second stage, each inefficient leader determines its output to maximize its profit, which is $\pi_j = \left(a - \sum_{i=1}^{x} q_x - \sum_{i=x}^{n} q_{-x} - \sum_{j=1}^{m} q_j - t - c\right) q_j$. By solving the first-order conditions, the equilibrium output of a typical leader, denoted by q_l, can be found as $q_l = \frac{(1-x\alpha)(a-c-t)+(d-c)n}{1+m}$. Incorporating the expression of q_l into q_{-x} and q_x leads to the quantities by inefficient firms. Furthermore, the industry output can be obtained as

$$Q = \frac{(a-t)(n+m+mn) + (t+c-a)mx\alpha - dn - cm(1+n)}{(1+m)(1+n-x\alpha)}.$$

Proof of Proposition 8:

Straightforward calculations lead to that

$$\frac{\partial Q^*}{\partial x} = \frac{(-c+d)n\alpha}{m+n+mn} < 0,$$

$$\frac{\partial Q^{**}}{\partial x} = \frac{(c-d)m\alpha\left(n(2+n-2x\alpha) + m(1+n-x\alpha)^2\right)}{(n+m(1+n-x\alpha))^2} > 0.$$

Due to symmetry, we have that

$$\frac{\partial Q^*}{\partial \alpha} < 0, \quad \frac{\partial Q^{**}}{\partial \alpha} > 0.$$

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