Corporate Social Responsibility, Profits, and Welfare in a Duopolistic Market*

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Abstract

We consider a two-stage game in a differentiated duopoly, where firms can pursue both a profit and a socially responsible objective. We assume that the maximum willingness-to-pay of consumers increases with the weights given by firms to their social objective, and that the social objective has a negative impact on the firms' output. In the first stage of the game, the firms decide on the weight of their social objective and, in the second stage, firms compete à la Cournot. We show that accounting for social concerns in the firms' objective is generally profitable, and that lower output and higher profits can be attained in equilibrium when the impact of firms' social awareness on consumers' willingness to pay is above a given threshold that depends on the products substitutability parameter. However, we find that the impact of firms' social awareness on consumers' and total welfare is ambiguous.

1 Introduction

On April 11, 2019, the French National Assembly amended the Civil Code in order to give greater consideration to social and environmental issues in companies' strategies and activities. While initially article 1833 of the Civil Code stated that "every firm must have lawful objects and be formed in the common interest of the members," it now expressly mentions that each firm must also take into consideration social and environmental issues. Thus, to comply with the law, firms must pursue multiple objectives. It remains to be seen how effective will this new law be in changing firms' behaviour (there is, after all, a difference between paying attention and actually addressing social and environmental issues). This amendment also created a new legal status, *entreprise à mission* (purpose driven company). This legal status requires a firm, not only to generate profit for its shareholders, but also to do so in a way that addresses social and environmental issues.[1] For instance, in June 2020, Danone became France's first large listed company to adopt this new legal status. Danone shareholders voted to enshrine the group's mission to bring "health through food" to consumers into its corporate by-laws.

In addition to legal requirement, social pressures also incite firms to pursue multiple objectives. For instance, some companies may wish to demonstrate leadership and responsibility by announcing their participation in the effort to reduce greenhouse gas accumulation. In many cases, Corporate Social Responsibility (CSR) has become an instrument to attract consumers, who are increasingly considering social responsibility as important attributes in their choice of products.

This paper contributes to a growing literature on oligopolistic competition in a CSR context.[2] We specifically contribute to the study of the strategic motivation for corporate social responsibility, as introduced in Baron (2001) and McWilliams & Siegel (2001). That is, we take the view that firms are

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[1] This new legal status is akin to the Benefit Corporations in the U.S. See Segrestin et al., 2020, for an overview of the new French corporate legal status and of its relationships with other corporate forms recently introduced in various countries.

[2] See Kitzmueller & Shimshack (2012) and Schmitz & Schrader (2015) for surveys of the literature on CSR.

not altruistic *per se*. Rather, firms behave in a socially responsible way when they find that doing so is profitable. In that spirit, we address two research questions:

i) Under what conditions is it profitable for firms to behave in a socially responsible way?

ii) Assuming that these conditions are met, is the adoption of CSR policies welfare improving for their customers?

To answer these questions it is useful to consider models where the firms' level of CSR is endogenous.[3] There are many ways to do that, depending on how social responsibility is defined (e.g. consumer surplus, pollution abatement) and on the market structures considered.[4]

As to market structures, some papers consider a supply chain where the products are complements (Goering 2014; Brand & Grothe 2015; Garcial et al. 2018; Fanti & Buccella 2020), while others examine CSR in a monopolistic competition setting (Giallonardo & Mulino 2016). These contributions all assume that a socially responsible firm cares for consumers' surplus. Deltas et al. (2013) consider a horizontally differentiated duopoly, where consumers care about the product's "greenness" and where firms can differ in their chosen level of greenness, and notably show that greenness is under-provided.

Some recent contributions address the issue at hand in the standard Cournot competition framework. In each case, the level of CSR is defined as the weight firms put on consumer surplus in their objective function, before deciding upon supply. Fanti & Buccella (2017) consider a simple duopoly model with differentiated products. They show that, depending on the degree of product differentiation and firms' social concern (weight of consumer welfare in the firms' objective) different equilibria arise (CSR rules can be adopted by all firms, only one, or none). Under Bertrand competition, however, they show universal profit maximization is the unique equilibrium.

In a symmetric setting, Planer-Friedrich & Sahm (2020a) show that the endogenous level of CSR is positive, for any given number of firms. However, positive CSR levels imply smaller equilibrium profits. They also find that an incumbent monopolist can use CSR as an entry deterrent (so that CSR may increase market concentration). Planer-Friedrich & Sahm (2020b) consider a Cournot duopoly where firms differ in their marginal costs of production. The authors show that the most efficient firm chooses a higher CSR level, reinforcing its dominant position. If the (fixed) cost of CSR are sufficiently high, only the more efficient firm will engage in CSR.

Lambertini & Tampieri (2015) consider a firm's CSR objective including both the welfare of consumers and environmental concerns. They contrast a setting where all the firms are profit maximising with one where only one firm is CSR. They show that, provided the market is large enough, the CSR firm obtains a higher profit and its presence improves social welfare (the positive price effect, along with an output expansion, is high enough to outweigh the negative effect associated with pollution.

Our paper contributes to the stream of literature that considers vertical differentiation, where the consumers willingness to pay (WTP) is affected by the firms' level of CSR. García-Gallego & Georgantzís (2010) assume that firms use CSR as vertical differentiation strategy and study market structures ranging from monopoly to duopoly with complete market coverage. CSR is not defined precisely, apart from the fact that it entails an additional cost for the firm. The authors find that, in most cases, (exogenous) increases in the consumers' social consciousness yield higher profits to socially responsible firms, and may lead to higher levels of social welfare, provided that the market structure is left unchanged. However, when an increase in the consumer's social consciousness changes the market structure, welfare may fall, while one of the duopolists' profits rise.

Doni & Ricchiuti (2013) also obtain mixed results regarding the welfare effect of CSR, defined as the level of polluting emissions' abatement, according to the nature of the abatement cost function. If the costs of the cleaning process are fixed, then social welfare is increasing in consumers' WTP and in firms'

[3]There exist a significant stream of literature that studies the effects of CSR by directly *assuming* that some or all of the firms are socially responsible. See for instance Conrad (2005), Rodriguez-Ibeas (2007), Yanase (2013), Wirl et al. (2013) and Lambertini et al. (2020).

[4]Other issues relate to whether the approach is dynamic, like the evolutionary approach in Königstein & Müller (2001), Planer-Friedrich & Sahm (2018) and Kopel & Lamantia (2018), or whether a certification process is involved, as in Liu et al. (2015).

CSR. On the other hand, social welfare may be reduced by an increase of consumers' WTP and/or firms' CSR when the abatement costs are variable.

Lee & Kil (2018) analyse how consumers' active behaviour changes the market and how this affects firms' CSR strategies, which are related to consumer surplus. They notably show that in a duopoly market with two CSR firms, as consumers increase their demand for the CSR firm's goods, both firms' profits decrease in equilibrium. Firms adopt CSR despite the decline in profit compared to the case when they do not adopt CSR cooperatively. Yet, in that case, CSR adoption leads to an increase in social welfare.

In this paper, CSR is related to environmental concerns. Using the motivating context of "purpose driven companies," we assume that consumers are likely to value environmentally responsible behaviour per se, even if the perceived impact of individual firms' CSR policies is likely to be small, and that their WTP increases when firms put a positive weight on social issues in their decision-making process.

Specifically, we consider a differentiated duopoly à la Dixit (1979) and Singh & Vives (1984), where an increase in the weight assigned by a given firm to a CSR objective increases the quality (vertical) differentiation of its product.[5] We model the interactions in the differentiated duopoly as a two-stage game. In the first stage, firms decide to consider or not an additional objective in their production decision, and decide on the relative importance of the weights assigned to profit vs. CSR. In the second stage of the game, competing firms decide on their production levels.

Our stylized model directly relates CSR policies to the output level. In that context, we find that, when the consumers' WTP for a commitment to responsible policies is above a given threshold that depends on the products substitutability parameter, the Nash equilibrium is Pareto improving for the firms. We also find that consumer's welfare can either increase or decrease when firm engage in (profit driven) socially responsible behaviour.

The paper is organized as follows. In Section 2, we lay out the main ingredients of our model. Section 3 solves for the equilibrium quantities when firms have already chosen their level of CSR. Section 4 solves for the equilibrium CSR strategy, examining under what conditions firms would find it profitable to choose a positive level of CSR. Section 5 addresses the impact of CSR on consumer's welfare. Section 6 briefly concludes the paper.

2 Model

We consider a differentiated Cournot duopoly, where firms may decide to pursue a double objective. We analyse a two-stage game, where, in a first stage, firms announce their CSR awareness level (which could be 0), and, in the second stage, firms compete in quantity.

Let q_i denote the production level of Firm i, $i \in \{1,2\}$ and q denote the vector (q_1, q_2). In the sequel, $j \equiv 3-i$. We assume that CSR policies have a negative impact on the output level of firms. One specific example is the case where production results in polluting emissions e_i that are proportional to the production level, $e_i = \rho_i q_i$, where ρ_i is the amount of pollutant per unit of output.[6] A socially responsible policy reducing polluting emissions can then be achieved in the short term by reducing production, and the CSR level of Firm i is characterized by the relative weight used for the two attributes (profit vs. polluting emissions) in its objective function, that is

$$\begin{aligned} O_i\left(q;\mu_i,\rho_i\right) &= \mu_i\pi_i(q) - \left(1-\mu_i\right)e_i \\ &= \mu_i\pi_i(q) - \left(1-\mu_i\right)\rho_i q_i,\ i \in \{1,2\}, \end{aligned}$$

where $\pi_i(q)$ is the profit of Firm i and $\mu_i \in (0,1]$ characterizes the relative importance of both attributes for Firm i.

Define $d_i \equiv \frac{(1-\mu_i)\rho_i}{\mu_i} \in [0,\infty)$. We consider firms that pursue the following dual objective:

$$O_i\left(q;d_i\right) = \pi_i(q) - d_i q_i,\ i \in \{1,2\}, \tag{1}$$

[5] Formally, the demand side of our model bears some similarity with the model used in Lee & Kil (2018). But in our setting CSR is related to environmental concerns as opposed to consumer surplus.

[6] Note that CSR policies based on consumers' surplus usually have the reverse impact, that is, they tend to increase the output level of firms (see for instance Lambertini & Tampieri 2015 for a discussion in a model where both types of policies are considered).

that is, profit maximization and output minimization. The parameter d_i characterizes the degree of social awareness of a firm; a firm with $d_i = 0$ maximizes pure profit, while a positive d_i indicates that the firm also minimizes its output, for instance for environmental considerations. We call parameter d_i the *social awareness parameter* of Firm i, in the specific context where CSR awareness results in an output minimization objective.

We suppose that firms are able to make their d_i known to the consumers. Note that this is a strong assumption, as this parameter is not directly observable from the product's characteristics, but has to be inferred indirectly from the firm's declarations and publications, relying on other stakeholders (e.g. shareholders, associations, certification agencies) for verification and enforcement.[7]

Following Dixit (1979) and Singh & Vives (1984), the representative consumer's[8] utility function is assumed quadratic strictly concave and is given by

$$U(q_i, q_j, y) = a_i q_i \left(1 + k d_i\right) + a_j \left(1 + k d_j\right) q_j - \frac{b_i q_i^2}{2} - \frac{b_j q_j^2}{2} - \gamma q_i q_j + y,$$

where y is a composite good, and a_i, a_j, γ, k, b_i and b_j are positive parameters (products are substitutes). The coefficient k is the consumer's *social consciousness*; it indicates that the representative consumer values the social awareness of firms, so that d_i increases the quality (vertical) differentiation of product i and the consumers' willingness to pay. This behavioural assumption differs from the case where consumers care about the product's (as in Deltas et al. 2013) or the firm's (as in Doni & Ricchiuti 2013) "greenness," or environmental impact. As in Garcí a-Gallego & Georgantzís (2009) and Lee & Kim (2018), we rather assume that consumers value products sold by firms that put a positive weight on CSR (here, committing to reduce their environmental impact).[9]

The strict concavity of the representative consumer's utility function assumption implies that

$$\gamma^2 < b_1 b_2. \tag{2}$$

Let $k_i \equiv k a_i$. To ensure that the maximum utility of the consumer is achieved in the positive quadrant, we further assume that

$$\gamma < \min_{i \in \{1,2\}} \left\{ b_i \frac{a_j + k_j d_j}{a_i + k_i d_i} \right\}. \tag{3}$$

Maximizing the representative consumer's utility under a budget constraint yields the inverse demand functions for $i \in \{1, 2\}$

$$p_i = \max\{0; a_i + k_i d_i - b_i q_i - \gamma q_j\}.$$

As usual in the economics literature, we further assume that own price effect is larger than the cross price effect,

$$\gamma < b_i,\ i \in \{1, 2\}, \tag{4}$$

which ensures that Condition (2) is satisfied.

The production cost of a quantity q_i by Firm i is equal to $c_i q_i$. As a consequence, the profit of Firm i is given by

$$\begin{aligned} \pi_i(q; d) &= \max\left\{0; q_i \left(p_i - c_i\right)\right\} \\ &= \max\left\{0; q_i \left(m_i + k_i d_i - b_i q_i - \gamma q_j\right)\right\}, \end{aligned}$$

[7] One example is Total, which states its vision as "to be the company of responsible energies" (https://www.sustainable-performance.total.com/en) and is presently facing trial from concerned associations because its actions do not fit its declared pro-environmental objectives. Another is Danone, where shareholders voted to alter the corporation's by-laws to reflect the company's objective to promote health.

[8] We could easily assume that there are two kinds of consumers, those who value CSR and those who don't. This would not change our results qualitatively, but would make the exposition cumbersome.

[9] Some firms do invest in publicity to inform their customers of measures to reduce their production, or to incite them to reduce their consumption. Examples can be found in the energy sector (both in electricity and oil production, see for instance Engie and Total), in the food sector, where actions are taken to reduce waste, and in some cases in the manufacturing sector (recycling).

where $m_i \equiv a_i - c_i > 0$. We further assume that

$$\gamma < \frac{b_j m_i}{m_j} \text{ for } i \in \{1,2\}, \tag{5}$$

which ensures that, when firms put no weight on a CSR objective ($d_1 = d_2 = 0$), the Cournot equilibrium of the differentiated duopoly is interior.

Condition 3 requires that the impact of firm's social awareness on consumers' willingness to pay be bounded. Specifically, we will analyse the impact of the following assumptions on the value of parameter k:

$$k_i = ka_i < 1 \text{ for } i \in \{1,2\} \tag{6}$$

$$L_i \equiv 4b_1 b_2 k_i - \gamma^2 > 0 \text{ for } i \in \{1,2\}. \tag{7}$$

3 Second-stage equilibrium

For a given social awareness vector $d = (d_i, d_j)$, given that firms pursue a double objective as indicated in Equation (1), the reaction function of Firm i to a production level q_j by the rival firm is

$$q_i(q_j; d) = \max\left\{0; \frac{m_i - \gamma q_j - d_i(1-k_i)}{2b_i}\right\}.$$

Condition (6) ensures that the production of Firm i is decreasing in its awareness level d_i; in the sequel, we assume that Condition (6) is satisfied.

Assuming an interior solution, the corresponding equilibrium solution for $i \in \{1,2\}$ is

$$q_i(d) = r_{1i} d_i + r_{2i} d_j + r_{3i}, \tag{8}$$

with

$$\begin{aligned}
r_{1i} &\equiv \frac{-2b_j(1-k_i)}{K} < 0 \\
r_{2i} &\equiv \frac{\gamma(1-k_j)}{K} > 0 \\
r_{3i} &\equiv \frac{2b_j m_i - \gamma m_j}{K} > 0 \\
K &\equiv 4b_i b_j - \gamma^2 > 0,\ i \in \{1,2\},
\end{aligned}$$

indicating that an increase in the social awareness of Firm i will lead to a reduction of its production in equilibrium, but to an increase in the production of the competing firm. Note however that, under Assumption (4), an increase in the social awareness of Firm i will lead to a net reduction in the total production:

$$r_{1i} + r_{2j} = -(1-k_i)\frac{2b_j - \gamma}{K} < 0.$$

Corresponding equilibrium prices are given by

$$p_i(d) = f_{1i} d_i + f_{2i} d_j + f_{3i},$$

with

$$\begin{aligned}
f_{1i} &= \frac{2b_i b_j (k_i + 1) - \gamma^2}{K} > 0, \\
f_{2i} &= \gamma b_i \frac{1-k_j}{K} > 0, \\
f_{3i} &= c_i + b_i \frac{2b_j m_i - \gamma m_j}{K} > 0,
\end{aligned}$$

indicating that an increase in the social awareness of Firm i will lead to an increase of the price of both products in equilibrium.

4 First-stage equilibrium

In the first stage of the game, firms select their social awareness parameter by maximizing their profit, accounting for the fact that announcing a reduction of output objective will have a positive impact on the consumers' demand. The profit of Firm i corresponding to weights $d = (d_i, d_j)$ is then

$$\pi_i(d) = q_i(d)\left(m_i + k_i d_i - b_i q_i(d) - \gamma q_j(d)\right),$$

where the quantities $q_i(d)$ are the equilibrium solutions of the duopoly game, obtained in Equation (8). Since the equilibrium strategies are linear in d_i and d_j, the resulting objective functions of firms are quadratic:

$$\pi_i = s_{1i} d_i^2 + s_{2i} d_j^2 + s_{3i} d_i d_j + s_{4i} d_i + s_{5i} d_j + s_{6i},$$

where

$$\begin{aligned}
s_{1i} &= r_{1i}\left(k_i - b_i r_{1i} - \gamma r_{2j}\right) \\
&= -2b_j\left(1 - k_i\right)\frac{2b_i b_j - \gamma^2 + 2b_i b_j k_i}{K^2} < 0 && (9)\\
s_{2i} &= -r_{2i}\left(b_i r_{2i} + \gamma r_{1j}\right) = \gamma^2 b_i \frac{\left(1-k_j\right)^2}{K^2} > 0 && (10)\\
s_{3i} &= \left(r_{2i}\left(k_i - 2b_i r_{1i}\right) - \gamma\left(r_{1i} r_{1j} + r_{2i} r_{2j}\right)\right) \\
&= \frac{L_i \gamma\left(1 - k_j\right)}{K^2} && (11)\\
s_{4i} &= \left(k_i r_{3i} + r_i\left(m_i - 2b_i r_{3i}\right) - \gamma\left(r_i r_{3j} + r_{3i} r_{2j}\right)\right) \\
&= \frac{L_i\left(2b_j m_i - \gamma m_j\right)}{K^2} && (12)\\
s_{5i} &= \left(r_{2i}\left(m_i - 2b_i r_{3i}\right) - \gamma\left(r_{1j} r_{3i} + r_{2i} r_{3j}\right)\right) \\
&= 2\gamma\left(1 - k_j\right) b_i \frac{2b_j m_i - \gamma m_j}{K^2} > 0 && (13)\\
s_{6i} &= r_{3i}\left(m_i - b_i r_{3i} - \gamma r_{3j}\right) = b_i \frac{\left(2b_j m_i - \gamma m_j\right)^2}{K_2^2} > 0. && (14)
\end{aligned}$$

Notice that s_{3i} and s_{4i} are positive when Conditions (6) and (7) are satisfied.

We now compute the equilibrium profits and production corresponding to three possible scenarios, where firms can decide to include or not a reduction of their output in their objective function.

4.1 No social awareness weight

The first scenario is the benchmark case where none of the firms considers an output reducing objective, so that $d_i = d_j = 0$. The equilibrium solution of the duopoly game and corresponding equilibrium profit are then, for $i \in \{1, 2\}$

$$\begin{aligned}
q_i^B &= r_{3i} > 0 \\
p_i^B &= f_{3i} > 0 \\
\pi_i^B &= s_{6i} > 0.
\end{aligned}$$

4.2 One socially aware firm

In the second scenario, only Firm i chooses to announce an output reducing policy, so that $d_j = 0$. The optimization problem of Firm i is concave since $s_{1i} < 0$. The optimal level of social awareness for Firm i is then given by

$$\begin{aligned}
d_i^i &= \max\left\{0, -\frac{s_{4i}}{2s_{1i}}\right\} \\
&= \frac{2b_j m_i - \gamma m_j}{4b_j\left(1 - k_i\right)\left(2b_i b_j - \gamma^2 + 2b_i b_j k_i\right)} \max\left\{0, L_i\right\}.
\end{aligned}$$

Note that $d_i^i > 0$ under Assumption (7) while $d_i^i = 0$ if $L_i \leq 0$. The equilibrium solution of the duopoly game under Assumption (7) is

$$\begin{aligned} q_i^i &= r_{1i} d_i^i + r_{3i} \\ &= \frac{1}{2} \frac{2b_j m_i - \gamma m_j}{2b_i b_j (k_i + 1) - \gamma^2} > 0, \\ q_j^i &= r_{2j} d_i^i + r_{3j} > 0. \end{aligned}$$

Proposition 1 *Under Assumption (7), when only Firm i has an output reduction objective, it produces less than in the benchmark case, while its rival increases its production. Total production is lower and both firms' prices and profits are higher than in the benchmark case.*

Proof. See Appendix 6.1 ■

4.3 Two socially aware firms

In the third scenario, we assume that both firms choose their social awareness parameters independently. Since $s_{1i} < 0$, the optimization problem of each firm is concave. For a given d_j, the impact of d_i on Firm i's profit is given by

$$\begin{aligned} \frac{d\pi_i}{dd_i} &= 2s_{1i} d_i + s_{3i} d_j + s_{4i} \\ &= 2s_{1i} d_i + L_i \frac{\gamma (1 - k_j)}{K^2} d_j + L_i \frac{(2b_j m_i - \gamma m_j)}{K^2}. \end{aligned} \tag{15}$$

Note that when $L_i \leq 0$, Firm i's profit is decreasing in d_i for any $d_j \geq 0$. The equilibrium value for the social awareness parameter of Firm i is then $d_i = 0$ and the solution reduces to the scenario analyzed the preceding paragraph. Otherwise, the best response of Firm i satisfies

$$d_i = -\frac{s_{3i} d_j + s_{4i}}{2s_{1i},} > 0.$$

Under Conditions (6) and (7), $s_{3i} > 0$ and $s_{1i} < 0$, which indicates that the firms' social awareness parameters are strategic complements, resulting in an emulation aspect: an increase in the weight assigned to the CSR objective by one firm has a positive impact on the social awareness level of the other firm.

Accordingly, under Assumption (7), the equilibrium solution is

$$d_i^N = \frac{s_{3i} s_{4j} - 2s_{1j} s_{4i}}{4s_{1i} s_{1j} - s_{3i} s_{3j}} > 0, \tag{16}$$

with $q_i^N > 0$ for $i \in \{1, 2\}$ (see Appendix 6.2).

Proposition 2 *Under Assumption (7), when both firms decide on their social awareness parameter independently, the impact with respect to the benchmark case is a decrease of the total production and polluting emissions, and an increase in the profit of both firms.*

Proof. See Appendix 6.3 ■

4.4 Equilibrium

Using the above results, the first stage of the duopoly game corresponds to the following matrix game

	$d_2 = 0$	$d_2 > 0$
$d_1 = 0$	$\left(\pi_1^B, \pi_2^B\right)$	$\left(\pi_1^2, \pi_2^2\right)$
$d_1 > 0$	$\left(\pi_1^1, \pi_2^1\right)$	$\left(\pi_1^N, \pi_2^N\right),$

where the entries correspond to the equilibrium profits of the three possible scenarios. We will consider three cases according to the sign of L_i, $i \in \{1, 2\}$.

4.4.1 Sufficiently high impact for both products

The following proposition shows that when Assumption (7) is satisfied for $i \in \{1, 2\}$, that is, when the consumer's social consciousness (parameter k) is such that the impact of social awareness is sufficiently high for both products, the Nash equilibrium where both firms choose to announce an output reduction policy using a positive social awareness weight is Pareto improving and corresponds to the best outcome for both firms. Moreover, in equilibrium, the output of both firms is reduced with respect to the benchmark case, resulting in a reduction of total pollution.

Proposition 3 *Under Assumption (7), the Nash equilibrium of the two-stage game corresponds to the pair* $\left(d_1^N, d_2^N\right)$*, which results in a lower production level and a higher profit for both firms with respect to the benchmark case and to the case where only one firm is socially aware.*

Proof. See Appendix 6.4. ■

4.4.2 Low impact for both products

When consumers do not value social awareness, or when the value of k is relatively low, that is,

$$k \leq \min_i \left\{ \frac{\gamma^2}{4b_1 b_2 a_i} \right\},$$

neither firms finds it profitable to adhere to output reduction policy, and the equilibrium in the first stage of the game is $d_1 = d_2 = 0$, which corresponds to the classical equilibrium in a differentiated duopoly.

4.4.3 Sufficient impact for one product

When there is a significant quality differentiation between the two products and when the value of k is large enough, that is, if

$$\frac{\gamma^2}{4b_1 b_2 a_i} < k \leq \frac{\gamma^2}{4b_1 b_2 a_j},$$

then the firm with the highest choke price a_i finds it profitable to announce that it will reduce its output. The equilibrium in the first stage is then $(d_i > 0, d_j = 0)$ which results in a lower total production and a higher profit for both firms than the classical differentiated duopoly equilibrium, as shown in Proposition 1.

4.5 Is it profitable for firms to behave in a socially responsible way?

We have shown in Propositions 1 and 3 that when $L_i > 0$, Firm i will find it profitable to reduce its output (and its polluting emissions), which will result in a higher profit for both firms and in a lower global production level. This result is driven by two considerations; the first one is that it is generally globally profitable to reduce total output in an oligopoly; indeed, the collusive solution always implies a reduction in total output (see Appendix 6.5). In addition, consumers' response to a firm's environmentally responsible behavior results in a price increase for a given output level. The consequence of these two complementary effects is positive, provided that the impact in the consumers' willingness to pay, represented by the parameter k, is sufficiently high. The threshold value for k is increasing in the substitutability parameter γ: a higher k is required when products are highly substitutable.[10]

In an environmental context, the equilibrium solution differs from green-washing. Firms do behave in a socially responsible way, including an environmental objective in their profit function, and do reduce their polluting emissions. In a game theoretic context, this solution also differs from a collusive outcome. Actually, since the equilibrium production levels in the second stage are linear in d, it is straightforward to show that there exist a unique pair $\left(d_1^C, d_2^C\right)$ that results in the collusive outcome of the standard Cournot game (see Appendix 6.5). However, this pair of weights is not an equilibrium; moreover, the collusive

[10] Note that when products are independent ($\gamma = 0$), L_i is strictly positive for any feasible k.

outcome in the standard game is no longer the first best when $k > 0$, because of the impact of $\left(d_1^C, d_2^C\right)$ on the market prices. Finally, it is not necessarily the case that the equilibrium solution at $\left(d_1^N, d_2^N\right)$ be closer to the collusive than the competitive outcome in the benchmark case, or even moving in the same direction since the collusive outcome does not necessarily result in a decrease in output from both firms.

Figures 1 and 2 are graphical representations of the output levels under collusion and competition in the benchmark case ($k = 0$) and for contrasting values of the consumers' social consciousness parameter k. In Figure 1, the collusive equilibrium results in a reduction of both q_1 and q_2, while in Figure 2, it results in an increase in q_1 and a decrease in q_2. Figures 1 and 2 show the impact of k on the competitive solution at the equilibrium d.

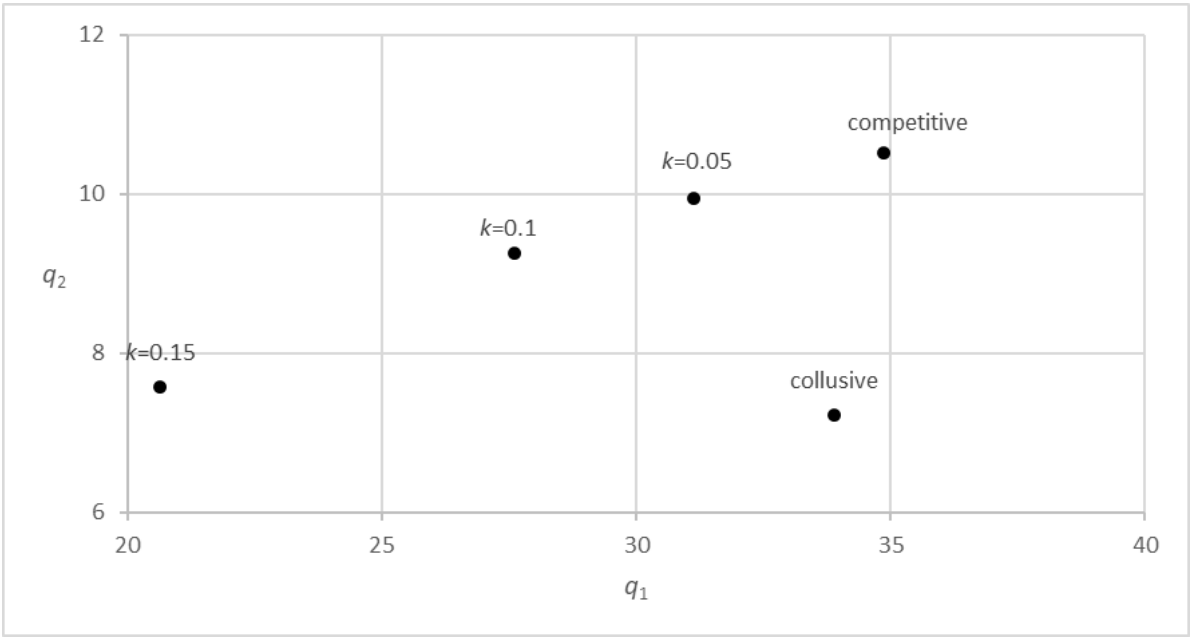

Figure 1: Equilibrium quantities (q_1, q_2) corresponding to the collusive solution and to the Nash equilibrium for $k = 0$ (benchmark), $k = 0.05$, 0.10 and 0.25. Parameter values are $a_1 = 3$, $a_2 = 2.4$, $c_1 = 1.5$, $c_2 = 1$, $\gamma = 0.01$, $b_1 = 0.02$ and $b_2 = 0.05$.

Finally, note that the combination of the reduction in polluting emissions and the increase in the consumers' willingness to pay results in a price increase for both products, which may lead to a decrease in consumers' welfare, even if consumers value social awareness of firms. This issue is investigated in the following section.

5 Welfare impacts

5.1 Impact on consumers' utility

Recall the utility of a representative consumer who values the social awareness of firms competing in quantity and offering substitutable products:

$$U(q_i, q_j) = a_i q_i \left(1 + k d_i\right) + a_j \left(1 + k d_j\right) q_j - \frac{b_i q_i^2}{2} - \frac{b_j q_j^2}{2} - \gamma q_i q_j.$$

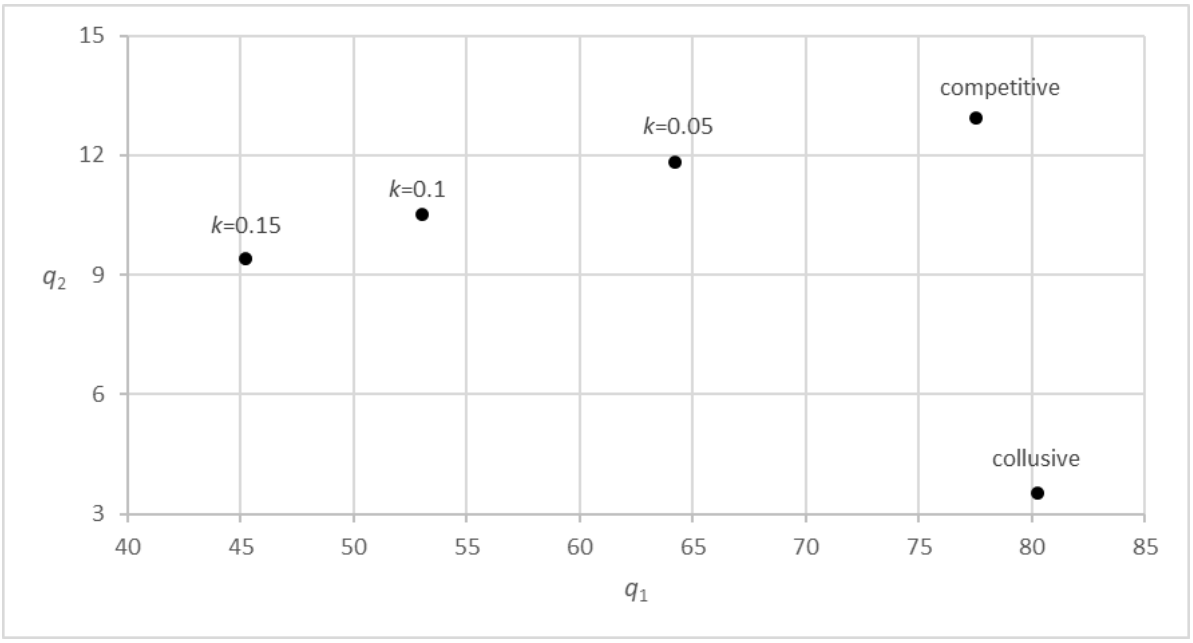

Figure 2: Equilibrium quantities (q_1, q_2) corresponding to the collusive solution and to the Nash equilibrium for $k = 0$ (benchmark), $k = 0.05$, 0.10 and 0.15. Parameter values are $a_1 = 5.34$, $a_2 = 5.45$, $c_1 = 0.5$, $c_2 = 0.37$, $\gamma = 0.0265$, $b_1 = 0.029$ and $b_2 = 0.117$.

Using Equation (8), the utility of consumers can be expressed as a quadratic function of the social awareness parameters (d_i, d_j). It can be shown that the second partial derivatives of $U(d_i, d_j)$ with respect to d_i and d_j are both negative, but U is not necessarily concave. Moreover, U is not necessarily increasing in d_i or d_j at $(0, 0)$.

Assuming Condition (7) is satisfied, it is possible to find sets of parameters yielding, in equilibrium, an increase or a decrease in the consumers' welfare with respect to the benchmark case, as illustrated in Table 1.

	Benchmark		Equilibrium					
			$k = 0.05$		$k = 0.10$		$k = 0.25$	
U	48.44		46.34		46.21		76.33	
$\pi_1 + \pi_2$	29.83		31.09		34.09		69.06	
$U + \pi_1 + \pi_2$	78.26		77.43		80.30		145.39	
	Firm 1	Firm 2	Firm 1	Firm 2	Firm 1	Firm 2	Firm 1	Firm 2
d_i	0	0	0.183	0.107	0.434	0.262	2.394	1.089
q_i	34.87	10.51	31.12	9.94	27.60	9.25	20.64	7.578
p_i	0.697	0.526	0.806	0.604	0.986	0.743	2.807	1.468
π_i	24.32	5.53	25.07	6.01	27.20	6.70	57.94	11.13

Table 1: Illustration of the impact of CSR on consumers', producers', and total welfare. Parameter values are: $a_1 = 3$, $a_2 = 2.4$, $c_1 = 1.5$, $c_2 = 1$, $\gamma = 0.01$, $b_1 = 0.02$ and $b_2 = 0.05$. The equilibrium solution is computed for $k = 0.05, 0.10$ and 0.25.

In this specific example, Product 1 has a higher choke price, marginal production cost and unit margin than Product 2, while the demand is more sensitive to the price of Product 1 than to that of Product 2. In the benchmark Cournot equilibrium, both the supply and price of Product 1 are higher than that of Product 2. When consumers value social awareness moderately ($k = 0.10$), both firms find it profitable to reduce their supply and increase their prices, which results in a decrease of the consumers' utility. When the consumers put a higher value on social awareness ($k = 0.25$), firms put a higher weight on the output reduction objective, reducing their supply and increasing their prices further, which results in an increase of the consumers' utility. Note that the utility of consumers in equilibrium is not monotone in k in general: at $k = 0.05$, the utility of consumers lower than in the benchmark case, but higher than for $k = 0.10$.

5.2 Impact on total welfare

As shown in Section 4.5, when Conditions (6)-(7) are satisfied, both firms will benefit from putting a positive weight on environmental concerns in equilibrium, with respect to the benchmark case. However, the increase in firms' welfare is not necessarily enough to offset the eventual loss in consumers' utility, as shown by the illustrative example in Table 1, where, for $k = 0.05$, the total welfare is lower than in the benchmark case.

One could argue that the social welfare should include a term accounting for the benefits of a reduction in polluting emissions, for instance by defining the social welfare by the sum

$$\begin{aligned} SC &= \pi_i + \pi_j + U - \lambda (e_i + e_j) \\ &= \pi_i + \pi_j + U - \lambda \left(\rho_i q_i + \rho_j q_j\right) \end{aligned}$$

where λ is the unit damage cost from polluting emissions (see for instance Fukuda et al. 2020). Under Condition (7), since total output and, therefore, total emissions, decrease when firms include a CSR component in their objective, one could always find a value of λ high enough to make social welfare higher in equilibrium than in the benchmark case, but this result is not guaranteed for an arbitrary damage cost.

6 Conclusion

We have shown that, when consumers value CSR, and when CSR policies negatively impact production levels, it is possible for firms to attain higher profits by reducing their production in equilibrium, provided that the consumer social consciousness parameter k be above a given threshold that depends on the degree of product substitutability. The condition allowing for at least one firm adhering to an output reduction policy is

$$k > \frac{\gamma^2}{4b_1 b_2 a_i},$$

where the threshold is increasing in γ and decreasing in a_i. We also have shown that, in equilibrium, such a reduction in supply can increase or decrease consumers' utility, depending on the parameter values.

The analysis herein may be extended further by considering pollution abatement from other means than a reduction in production. In this perspective, it would be interesting to contrast the resulting impact on pollution and on profits, since these two policies are unlikely to be considered as similar by consumers and since they imply different abatement costs. Another issue that would be worthwhile studying is the relaxation of the assumption that consumers have perfect information on firms' commitment to CSR and production decisions.

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Appendix

6.1 Proof of Proposition 1

Proof.

1. Impact on quantities:

$$\begin{aligned} q_i^i - q_i^B &= r_{1i} d_i^i < 0 \\ q_j^i - q_j^B &= r_{2j} d_i^i > 0 \\ Q_i^i - Q_i^B &= d_i^i \left(r_{1i} + r_{2j}\right) \\ &= -d_i^i \left(\left(1 - k_i\right) \frac{2b_j - \gamma}{K} \right) < 0. \end{aligned}$$

2. Impact on prices:

$$\begin{aligned} p_i^i - p_i^B &= f_{1i} d_i^i > 0 \\ p_j^i - p_j^B &= f_{2j} d_i^i > 0. \end{aligned}$$

3. Impact on profit:

$$\begin{aligned} \pi_i^i - \pi_i^B &= d_i^i \left(s_{4i} + d_i^i s_{1i}\right) \\ &= -\frac{1}{4} \frac{s_{4i}^2}{s_{1i}} > 0 \\ \pi_j^i - \pi_j^B &= d_i^i \left(d_i^i s_{2j} + s_{5j}\right) > 0. \end{aligned}$$

■

6.2 Equilibrium weights

We show that when $L_1 > 0$ and $L_2 > 0$, $d_i^N > 0$ and $q_i^N > 0$ for $i \in \{1, 2\}$.

1. $d_i^N > 0$

$$d_i^N = \frac{s_{3i} s_{4j} - 2 s_{1j} s_{4i}}{\left(4 s_{1i} s_{1j} - s_{3i} s_{3j}\right)}$$

where $s_{3i} > 0$, $s_{4i} > 0$, $s_{1i} < 0$ for $i \in \{1, 2\}$ and

$$\begin{aligned} 4 s_{1i} s_{1j} - s_{3i} s_{3j} &= \left(k_i - 1\right)\left(k_j - 1\right) \frac{\gamma^4 + 4 b_i b_j \left(4 b_i b_j \left(k_j + 1\right)\left(k_i + 1\right) - \gamma^2 \left(k_i + k_j + 3\right)\right)}{K^3} \\ &> \left(k_i - 1\right)\left(k_j - 1\right) \frac{\gamma^4 + 4 b_i b_j \left(\gamma^2 \left(3 \left(k_i + k_j\right) + 4 k_i k_j + 1\right)\right)}{K^3} > 0 \end{aligned}$$

2. $q_i^N > 0$

$$\begin{aligned} q_i^N &= \frac{-2 b_j \left(1 - k_i\right)}{K} d_i^N + \frac{\gamma \left(1 - k_j\right)}{K} d_j^N + \frac{2 b_j m_i - \gamma m_j}{K} \\ &= \frac{-2 b_j \left(1 - k_i\right)}{K} d_i^N + \frac{\gamma \left(1 - k_j\right)}{K} d_j^N + K \frac{s_{4i}}{L_i} \\ &= s_{4i} \left(\frac{K}{L_i} + \frac{\left(1 - k_i\right)\left(1 - k_j\right)}{K^2 \left(4 s_i s_j - s_{3i} s_{3j}\right)} \left(\gamma^2 - 4 b_i b_j - 4 b_i b_j k_j\right) \right) \\ &\quad + 2 \gamma b_j \frac{s_{4j} \left(1 - k_i\right)\left(1 - k_j\right)}{K^2 \left(4 s_i s_j - s_{3i} s_{3j}\right)} \end{aligned}$$

where

$$\begin{aligned} & \frac{K}{L_i} + \frac{(1-k_i)(1-k_j)}{K^2(4s_is_j - s_{3i}s_{3j})}\left(\gamma^2 - 4b_ib_j - 4b_ib_jk_j\right) \\ = & \frac{8Kb_ib_j}{L_i}\frac{2b_ib_j(k_j+1) - \gamma^2}{(\gamma^4 + 4b_ib_j(4b_ib_j(k_j+1)(k_i+1) - \gamma^2(k_i+k_j+3)))} \\ > & 0. \end{aligned}$$

6.3 Proof of Proposition 2

Proof.

1. Impact on production:

$$\begin{aligned} Q^N - Q^B &= d_i^N(r_{2j} + r_{1i}) + d_j^N(r_{2i} + r_{1j}) \\ &= -d_i^N\frac{(1-k_i)(2b_j - \gamma)}{K} - d_j^N\frac{(1-k_j)(2b_i - \gamma)}{K} \\ &< 0. \end{aligned}$$

2. Impact on prices:

$$p_i^N - p_i^B = f_{1i}d_i^N + f_{2i}^N d_j > 0.$$

3. Impact on profit:

$$\begin{aligned} \pi_i^N - \pi_i^B &= s_{1i}\left(d_i^N\right)^2 + s_{2i}\left(d_j^N\right)^2 + s_{3i}d_i^Nd_j^N + s_{4i}d_i^N + s_{5i}d_j^N \\ &= s_{1i}\left(d_i^N\right)^2 + s_{2i}\left(d_j^N\right)^2 + s_{3i}d_i^Nd_j^N + \left(-2s_{1i}d_i^N - s_{3i}d_j^N\right)d_i^N + s_{5i}d_j^N \\ &= -s_{1i}\left(d_i^N\right)^2 + s_{2i}\left(d_j^N\right)^2 + s_{5i}d_j^N > 0. \end{aligned}$$

■

6.4 Proof of Proposition 3

Proof. We already showed that $\left(d_1^N, d_2^N\right)$ is the Nash equilibrium when Assumption (7) is satisfied (Equation 16). We now show that $\left(d_1^N, d_2^N\right)$ results in a lower production level and is Pareto improving.

1. $d_i^N > d_i^i$:

$$\begin{aligned} d_i^N - d_i^i &= \frac{s_{3i}s_{4j} - 2s_{1j}s_{4i}}{4s_{1i}s_{1j} - s_{3i}s_{3j}} + \frac{s_{4i}}{2s_{1i}} \\ &= -\frac{1}{2}s_{3i}\frac{s_{4i}s_{3j} - 2s_{4j}s_{1i}}{s_{1i}(4s_{1i}s_{1j} - s_{3i}s_{3j})} \\ &= -\frac{1}{2}s_{3i}\frac{d_j^N}{s_{1i}} > 0. \end{aligned}$$

2. $Q^N < Q^i$:

$$\begin{aligned} Q^N - Q^i &= \left(d_i^N - d_i^i\right)(r_{2j} + r_{1i}) + d_j^N(r_{2i} + r_{1j}) \\ &= -\left(d_i^N - d_i^i\right)\left((1-k_i)\frac{2b_j - \gamma}{K}\right) - d_j^N\left((1-k_j)\frac{2b_i - \gamma}{K}\right) \\ &< 0. \end{aligned}$$

3. $\pi_i^N > \pi_i^i > \pi_i^B$:

$$\begin{aligned}
\pi_i^N - \pi_i^i &= s_{1i}\left(d_i^N\right)^2 + s_{2i}\left(d_j^N\right)^2 + s_{3i}d_i^N d_j^N + s_{4i}d_i^N + s_{5i}d_j^N - \left(s_{1i}\left(d_i^i\right)^2 + s_{4i}d_i^i\right) \\
&= \left(d_i^N - d_i^i\right)\left(s_{1i}\left(d_i^N + d_i^i\right)\right) + s_{3i}d_i^N d_j^N + d_j^N\left(s_{2i}d_j^N + s_{5i}\right) + s_{4i}\left(d_i^N - d_i^i\right) \\
&= \left(-\frac{1}{2}s_{3i}\frac{d_j^N}{s_{1i}}\right)\left(s_{1i}\left(d_i^N + d_i^i\right)\right) + s_{4i}\left(d_i^N - d_i^i\right) + s_{3i}d_i^N d_j^N + d_j^N\left(s_{2i}d_j^N + s_{5i}\right) \\
&= \frac{1}{2}\left(2s_{4i} + d_j^N s_{3i}\right)\left(d_i^N - d_i^i\right) + d_j^N\left(s_{2i}d_j^N + s_{5i}\right) > 0.
\end{aligned}$$

■

6.5 Monopoly / collusive output

For $k = 0$, assuming positive prices, the traditional monopoly solves

$$\max_{q_i, q_j} \; q_i\left(m_i - b_i q_i - \gamma q_j\right) + q_j\left(m_j - b_j q_j - \gamma q_i\right).$$

First order conditions yield

$$q_i^C = \frac{b_j m_i - \gamma m_j}{2\left(b_i b_j - \gamma^2\right)}, \; i \in \{1, 2\}.$$

6.5.1 Total quantity

The difference between the total monopoly quantity and the total competitive quantity in the benchmark case is given by

$$\begin{aligned}
&\frac{m_i\left(b_j - \gamma\right) + m_j\left(b_i - \gamma\right)}{2\left(b_i b_j - \gamma^2\right)} - \frac{m_i\left(2b_j - \gamma\right) + m_j\left(2b_i - \gamma\right)}{4b_i b_j - \gamma^2} \\
= \; & \gamma\frac{\left(\gamma^2 + 2b_i b_j\right)\left(m_i + m_j\right) - 3\gamma\left(b_i m_j + b_j m_i\right)}{2\left(b_i b_j - \gamma^2\right)\left(4b_i b_j - \gamma^2\right)} \\
= \; & \gamma\frac{\Delta}{2\left(b_i b_j - \gamma^2\right)\left(4b_i b_j - \gamma^2\right)}
\end{aligned}$$

where, under assumptions (4)-(5),

$$\gamma < \min\left\{b_i, b_j, \frac{b_j m_i}{m_j}, \frac{b_i m_j}{m_i}\right\}.$$

Note that Δ is decreasing in γ. Assume w.l.g. that $m_i \geq m_j$, this implies that $b_j \leq \frac{b_j m_i}{m_j}$ and $\frac{b_i m_j}{m_i} \leq b_i$.

1. If $b_j \leq \frac{b_i m_j}{m_i} \leq b_i$, at $\gamma = b_j$
$$\Delta = b_j\left(2m_i - m_j\right)\left(b_i - b_j\right) \geq 0.$$

2. If $\frac{b_i m_j}{m_i} \leq b_j$, at $\gamma = \frac{b_i m_j}{m_i}$

$$\begin{aligned}
\Delta &= b_i\left(2m_i - m_j\right)\left(b_j - \frac{b_i m_j}{m_i}\frac{m_j}{m_i}\right) \geq b_i\left(2m_i - m_j\right)\left(b_j - b_j\frac{m_j}{m_i}\right) \\
&= b_i\left(2m_i - m_j\right) b_j\frac{m_i - m_j}{m_i} \geq 0.
\end{aligned}$$

As a consequence, the total quantity is higher in a monopoly than in the competitive equilibrium.

6.5.2 Weights

Given that in the second stage equilibrium

$$q_i(d) = r_{1i}d_i + r_{2i}d_j + r_{3i},$$

then if $r_{1i}r_{1j} \neq r_{2i}r_{2j}$, there exists a weight vector d such that $q_i(d) = q_i^C$, where

$$d_i = \frac{r_{1j}\left(q_i^C - r_{3i}\right) - r_{2i}\left(q_j^C - r_{3j}\right)}{r_{1i}r_{2j} - r_{2i}r_{2j}},\ i \in \{1,2\}.$$

Replacing q_i^C, r_{1i}, r_{2i} and r_{3i} for $i \in \{1,2\}$ yields

$$d_i^C = \frac{1}{2}\gamma\frac{b_i m_j - \gamma m_i}{(1-k_i)\left(b_i b_j - \gamma^2\right)} > 0.$$