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Relative quality-related (dis)utility in a vertically differentiated oligopoly with an environmental externality

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ABSTRACT. In a vertically differentiated setting, we consider a two-stage game between a clean firm and a dirty producer with quality competition at the first stage and price competition at the second stage under the assumption that consumers have relative preferences for quality. The equilibrium configuration changes depending on the consumers' dispersion and the relative preferences: either both producers are active at equilibrium, or the green producer is the only firm active in the market, the brown competitor being out. We analyze how the equilibrium changes when preferences are country specific (developed vs. developing countries). Finally, we show that whatever the market configuration at equilibrium, there can be a pollution damage reduction compared to the standard case without relative preferences. To the best of our knowledge, we are the first to introduce in the literature of green consumerism the notion of (possibly country-specific) relative preferences.

1. Introduction

1.1. Some preliminary considerations

In the last decades, an increasing number of consumers have declared their willingness to pay a price premium for green products (EC, 2011). This phenomenon opened the door to a debate among researchers about the consequences, if any, of an environmentally friendly behavior on equilibrium market configuration and pollution. The aim of this paper is to contribute to the above debate. We develop our analysis taking for granted three facts. First, people are now aware of the problems deriving from pollution and *ceteris paribus* a brown good is considered less worthy than a green alternative. Second, consumption has, at least in part, some social/psychological drivers. For this to be evident, it suffices to leaf through newspapers. In 2007, considering the surprising success obtained

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by Toyota with its hybrid car Prius, *The New York Times* reported the top five reasons why Prius owners bought their cars. The main reason for purchasing the car was because it 'makes a statement about me', and more precisely, 'it shows the world that its owner cares' (Maynard, 2007). Rather, environmental protection was at the bottom on the list: people 'bought a symbol of preserving the environment that they could incorporate into a narrative of who they are or who they wish to be', while having 'only a basic understanding of environmental issues or the ecological benefits of HEVs (hybrid electric vehicles)' (Heffner *et al*., 2007: 409).[1] Consumers enjoy consumption of green goods not only because of the intrinsic characteristics of these goods but also because while purchasing, they get social approval (say *social rewards)*. Rather, under brown purchases, people can feel socially disapproved, thereby incurring *social punishment*.[2] To the extent that green purchases are used to obtain (and advertise) a socially worthy image, the benefit from a pro-environmental behavior is larger, the greener the goods compared to the ordinary (namely, brown) products.[3] Conversely, in the case of brown purchases, the frustration of consumers is stronger, the dirtier their good compared with the green alternative. Obviously, these social/psychological drivers work unevenly worldwide and this statement constitutes the third fact on which our model rests.

1.2. The empirical evidence

As Inglehart (1990) and Buttel (1992) argue, the responsibility to protect the environment belongs to a set of values arising among wealthy people after their basic needs have been met. Accordingly, while the threat of social disapproval can be a significant driver of green consumption in developed and wealthy countries, the same may not hold whenever food and safety standards are not guaranteed by policy makers. In contexts where only a few people can buy (possibly costly) green goods, social *stigma* cannot be attached to those individuals who cannot afford environmentally friendly products. Nevertheless, social approval can still flow from a green behavior if its pro-social content is recognized in the

[1] In a way, this consumers' attitude to environmentally friendly goods resembles that arising in the case of conspicuous consumption, taking place whenever people are willing to pay a higher price for a functionally equivalent good in order to advertise their wealth, their social status or other specific characteristics. Drawing on the theoretical frame of conspicuous consumption, one can explain for example why home owners overinvest in solar panels and underinvest in other green home improvements, like additional insulation and window caulking: while the former investment is conspicuous, the latter is not. Along the same rationale, the pro-environmental attitude is more often observed in shopping and eating, namely in cases when the behavior is directly observed.

[2] See on this, Arrow (1971), Andreoni (1990), Rege (2004), Frey and Stutzer (2006), Nyborg *et al*. (2006) and Autio *et al*. (2009).

[3] There is a large volume of literature discussing the social dimension of green consumption. See Griskevicius *et al*. (2010) on the notion of *status competition* and the effect of status seeking in green behavior.

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community. The country-specific nature of social preferences is not only consistent with Maslow's hierarchy-of-needs where the ethical role of consumption belongs to higher order needs (Maslow, 1954), but also validated by several empirical analyses. Kunze (2008), studying the social construction of bottled water consumption in New Zealand, points out that the effect of social image on socially responsible consumptions depends on the market share of socially responsible consumer (SRC) products. When few consumers opt for social responsibility, *social distinction* is still an important motive for doing it. On the other hand, when almost all consumers choose social responsibility, then there is a *stigma* attached to not doing it and peer pressure may force consumers to adopt SRC products. Along the same rationale, Carlsson *et al*. (2010) test for conformity in green consumption between males and females in Sweden and find that the proportion of consumers choosing environmentally friendly coffee over standard coffee plays a significant and positive role in women's willingness-to-pay for environmentally friendly coffee. In Alcott (2009), households receiving reports of their electricity consumption and comparisons to that of their one hundred nearest geographical neighbors, in houses of comparable size, make significant reductions in their energy consumption. Welsch and Kuhling (2009) find that, in Germany, the use of solar thermal systems, the subscription to green electricity and the purchase of organic food are all three conditioned by the consumption patterns of reference persons. Salazar *et al*. (2013) evaluate the effect of social pressure on consumption among students, lecturers and administrative personnel in a university in the Netherlands. They find that individuals provided with information about their peers' choice are three times more likely to 'buy' a sustainable product than those without this information. In low-income countries, the attitude toward green behavior is different. While consumers have some green concerns, they do not feel the personal responsibility of protecting the environment, because of their low income compared with the high price of green goods. Goswami (2008) finds that only a small segment of consumers – wealthier liberal professionals – is positively motivated to prefer eco-labeled clothing in India, supporting the idea that only a few (richer) consumers in developing countries may be ready to pay a premium for green products. Bhate (2001) states that, in developing countries, consumers are at the early stage of green consumption. While recognizing that environmental protection should be a priority among people, developing country consumers do not perceive the responsibility of protecting the environment. Tantawi *et al*. (2006) find that Egyptian consumers perform several actions that harm their environment while perceiving their environment to be highly polluted. This is mainly due to the fact that they attribute to the government the main responsibility for protecting the environment.[4] Hopkins and Mehanna

[4] According to Cleveland *et al*. (2005), even the pro-environment activists/consumers of India, in the light of the damages done by developed counterparts, question the responsibility that developing countries are often required to assume.

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(2000) state that, although Egyptian consumers would display some environmental sensitiveness, they rank first their economic concerns rather than environmental concerns. This evidence confirms that consumption choices have some social drivers. Furthermore, under poor economic conditions, it is unlikely that a green behavior can be enforced by threat of guilt. However, there can still be room for social preferences to play a role, via social approval and respect. Accordingly, we first analyze the effects of these social drivers on market equilibrium in a general setting and then discuss their role under the assumption that they are country specific.

1.3. The basic framework

Although recently increasing attention has been devoted to the impact of environmental awareness on market structure and polluting activities (Moraga-Gonzalez and Padro-Fumero, 2002; Eriksson, 2004; Conrad, 2005; Nyborg *et al.*, 2006; Rodriguez-Ibeas, 2007; García-Gallego and Georgantzís, 2009; *inter alia*), to the best of our knowledge we are the first to study the role of green consumerism while taking into account that social drivers can be country specific. We consider a market consisting of two firms providing vertically differentiated goods to a population of consumers (Lombardini-Riipinen, 2005; García-Gallego and Georgantzís, 2009). The source of differentiation is environmental quality and consumers display relative preferences for quality.[5] These relative preferences are added to the standard satisfaction derived from the intrinsic characteristics of products: their qualities and their prices. Accordingly, utility from green consumption is higher: (i) the higher the environmental quality of the variant, and (ii) the larger the quality gap between green and brown products, as this gap determines green consumers' contribution to environment protection. Conversely, when buying the brown variant, consumers' utility is decreased by these relative preferences. Indeed, consumers get frustrated by the brown environmental quality of their good compared to that of the green alternative. This way of modeling the utility function mirrors the idea that people seek a relative position among peers and buy products also because of their social value. The higher the quality of the product, namely its ranking along *the quality ladder*, the higher its social value and the corresponding position it confers to the buyer along the *social ladder*. An alternative way to model the utility function would be relating the satisfaction of an individual when consuming a variant of quality i with the average quality available in the market.[6] We are induced to privilege the

[5] Some papers deal with specific relative preferences, such as Akerlof (1997) where the satisfaction of a consumer increases with the difference between the personal status and others' status. Alexopoulos and Sapp (2006) and Riechmann (2006) analyze relative preferences from the point of view of firms. These preferences are also labeled '*other-regarding preferences*'.

[6] A priori, this would be a possibility. Typically, relative preference emerges when a consumer's satisfaction depends on the ratio between one's own consumption (the so-called selfish consumption) and the consumption by another or the average of several others (namely others' consumption).

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current formulation as it naturally stems from the mix between the literature on the *status* or *positional* effects and models of vertical product differentiation. In the former approach, people compare their social position (as it is defined by the consumption of a particular good) with that of their peers, namely their colleagues at the office, their neighbors, their relatives, so that the reference point for attributing their behavior with a social content is represented by those who are next.[7] There is also a further reason justifying our modeling choice and it lies on the ground of the models of vertical product differentiation. Typically in vertical product differentiation, firm i competes with the next higher or next lower rival. As a by-product of this, both its market power and its profit are directly related to the quality gap between the quality of its own variant and that of the next one. Our formulation enables us to keep this property unchanged, thereby allowing for a comparison between the predictions of our model and those coming from a traditional approach in vertical differentiation. In a two-stage game in which firms choose their qualities in the first step and compete in prices in the second one under partial market coverage, we analyze how market equilibrium configurations depend on the type and the intensity of relative preferences. We start the analysis under the general assumption that social rewards and social punishment can co-exist. Then, we study the properties of the model when either social rewards (i) or social punishment (ii) only take place. From a theoretical viewpoint, the first scenario represents a natural entry point for disentangling the main properties of the model. Also, this structure enables to treat scenarios (i) and (ii) as particular cases of the general one. Furthermore, as explained in the previous section, our choice is consistent with the mixed evidence on social drivers: while there are cases with only one driver taking place (either social punishment in developed countries or social rewards in developing countries), quite often both of them play a role in developed and wealthy countries.

The remainder of the paper is organized as follows. Section 2 introduces the model. Section 3 characterizes the demand functions and section 4 provides a detailed analysis of the equilibrium of the market under *social punishment* (SP) and *social reward* (SR). In section 5, we develop some welfare considerations. Then, we describe the equilibrium configuration when either SP or SR only plays a role (section 6) and later we discuss the role of some assumptions (section 7). Finally, section 8 concludes the paper. Proofs and intermediate results are relegated to an appendix wherever this improves the readability of the paper.

[7] On this point: 'Washington, D.C., imposed a five-cent tax on every disposable bag, paper or plastic, handed out at any retail outlet in the city that sells food, candy or liquor. But more important than the extra cost was something more subtle: no one got bags automatically anymore. Instead, shoppers had to ask for them – *right in front of their fellow customers*. The result? Retail outlets that typically use 68 million disposable bags per quarter handed out 11 million bags in the first quarter of this year and fewer than 13 million bags in the second quarter, according to the district's Office of Tax and Revenue' (*Wall Street Journal*, October 2010).

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2. The model

Assume that in an uncovered market there are two *firms*, say firm H and firm L, offering goods to a population of consumers. These goods can be differentiated in terms of environmental quality: we say the firm H produces a high-quality good q_H, namely an environmentally friendly good, while the rival L produces a low-quality good q_L, namely a brown good.[8] Consumers are characterized by their intensity of environmental concern θ and are uniformly distributed on $[0, \overline{\theta}]$ with density equal to $\frac{1}{\overline{\theta}}$. The parameter θ is proportional to the willingness to pay (henceforth WTP) for quality, so that $\overline{\theta}$ denotes the maximal WTP among consumers.[9] Each consumer is supposed to buy at most one unit of product from the firm that ensures to her the highest utility except if the alternative of no purchase is better. So, the utility from consumption is affected by both the variant's quality q_i and the quality gap between variants.[10] This latter component can mirror the psychological satisfaction from consuming the best variant compared with the alternative, or the frustration taking place when consuming the ordinary good.

In particular, the conditional indirect utility of a type-θ consumer when buying from the green firm, i.e., the high-quality good (q_H), is written as:

$$U_H(\theta) = \begin{cases} \theta q_H - p_H + \alpha(q_H - q_L) & \text{if she buys from firm } H, \\ 0 & \text{otherwise.} \end{cases},$$

and the conditional indirect utility of a type-θ consumer when buying the low-quality alternative q_L is:

$$U_L(\theta) = \begin{cases} \theta q_L - p_L + \beta(q_L - q_H) & \text{if she buys from firm } L, \\ 0 & \text{otherwise,} \end{cases}$$

[8] In our model, like in Rodriguez-Ibeas (2007) and Andrè *et al.* (2009), the meaning of the variables q_H and q_L accurately follows the traditional approach in vertical differentiation as in Mussa and Rosen (1978) and Gabszewicz and Thisse (1979). In other approaches, it is related to the abatement effort of firms affecting the emission intensity of goods. Typically, the lower the emission intensity per unit of production, the higher the environmental quality of the product. See, for example, Moraga-Gonzalez and Padro-Fumero (2002) and Lombardini-Riipinen (2005). Finally, different levels of social responsibility of producers can also be the source of vertical differentiation between products (see, e.g., García-Gallego and Georgantzís, 2009).

[9] Under the assumption on density, the population of consumers is always constant. See on this García-Gallego and Georgantzís (2009).

[10] Our analysis is related to that of Nyborg *et al.* (2006) where the roles of moral motivation and social norms are investigated for explaining the green consumerism. In particular, assuming that people get an improved self-image when purchasing green, they find that consumers may display herd behavior if green consumerism is motivated by internalized social norms.

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where $q_i \in [\underline{q}, \overline{q}]$, $\forall i = L, H$. $\underline{q} > 0$ is the minimal quality required, p_i being the price p_i of the variant i, $p_i \in [0, y]$, $\forall i = L, H$, where y is the consumer's income which is supposed to be the same for all the population.

While the two terms $\theta q_i - p_i$ with $i = L, H$ follow from the traditional approach in vertical differentiation, the term $\alpha(q_H - q_L)$ in $U_H(\theta)$ deriving from the relative preferences captures the additional benefit of the consumer θ when she buys a higher quality than that existing in the market.[11] We will refer to it later as social reward (SR). The parameter α determines the intensity of these relative preferences: the higher α, the larger the benefit from consuming q_H compared to q_L. Symmetrically, $\beta(q_L - q_H)$ in $U_L(\theta)$ represents the intensity of relative preferences for the low quality. It is negative as it reflects the loss for a type-θ consumer to purchase a quality which is lower than the available alternative. We will refer to it later as social punishment (SP). In order to complete the description of the model we assume that

$$\bar{\theta} \geq \alpha.$$

This assumption is necessary to identify the whole set of the *equilibria candidates*[12]: it requires the highest WTP to be strictly larger than the SR coming from green purchases. In a way, this assumption reconciles our setting with the traditional model of vertical differentiation: while giving a role to the social motivation as a driver of consumption (namely the parameter α), it attributes a key position to the standard component in the neoclassical approach, namely the highest WTP for quality $\bar{\theta}$. Also, without any loss of generality:

$$0 < \beta < \alpha$$

with $\alpha, \beta \in]0, 1]$.[13]

Since prices are more easily adjusted than qualities, it is reasonable to model price and quality competition by a two-step game in which firms choose their qualities in the first step and compete in prices in the second one.

The game is solved by backward induction. We determine first the demand for each firm as a function of p_i and q_i, for $i = L, H$. Then, we determine the price equilibrium for given qualities and finally the quality choices of firms.

[11] This formal framework of relative preferences for quality is the same as in Ghazzai (2008). Notice, however, that, in her paper, she deals with a multi-product monopoly and investigates whether relative preferences for quality may favor multi-product strategies.

[12] In particular, under $\bar{\theta} \geq \alpha$ we will show that the game can lead a priori to two market configurations at equilibrium. If $\bar{\theta} < \alpha$, one of the two configuration is immediately ruled out. However, as will be clarified later, whenever $\bar{\theta} \geq \alpha$, it can still be that one market configuration never arises at equilibrium. See, on this point, the technical details provided in appendix 4 and the discussions in section 4.1.

[13] Notice that the assumption on the relative magnitude of α and β does not alter our main findings. Indeed, one could also assume the reverse, namely $\beta > \alpha$, without changing the qualitative properties of the model.

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3. Demand characterization

Let us denote $\hat{\theta}$ the marginal consumer who is indifferent[14] between buying product L or product H, with:

$$\hat{\theta} = \frac{p_H - p_L}{q_H - q_L} - (\alpha + \beta).$$

Also, let θ_L be the consumer who is indifferent between buying product L and not buying at all. She is defined as the solution to $U_L(\theta_L, p_L) = 0$, which implies that:

$$\theta_L = \frac{p_L + \beta(q_H - q_L)}{q_L} > 0.$$

In the same way, we define θ_H, the consumer indifferent between buying product H and not buying at all, as:

$$\theta_H = \frac{p_H - \alpha(q_H - q_L)}{q_H} > 0 \text{ if } p_H > \alpha(q_H - q_L).$$

Accordingly, we provide in Lemma 1 the demand functions faced by Firm L and Firm H.

Lemma 1. *The demand function of Firm L is written as follows:*

$$D_L = \begin{cases} \overline{\theta} - \theta_L & if \quad \theta_L < \overline{\theta} < \hat{\theta} \\ \hat{\theta} - \theta_L & if \quad \theta_L \leq \hat{\theta} \leq \overline{\theta} \\ 0 & if \quad \hat{\theta} < \theta_H < \overline{\theta} \end{cases}$$

while that of Firm H is given by:

$$D_H = \begin{cases} \bar{\theta} - \theta_H & if \quad \hat{\theta} < \theta_H < \overline{\theta} \\ \overline{\theta} - \hat{\theta} & if \quad \theta_L \leq \hat{\theta} \leq \overline{\theta} \\ 0 & if \quad \theta_L < \overline{\theta} < \hat{\theta} \end{cases}$$

Proof : The proof is provided in appendix 1. □

Notice that, in the case $\theta_L < \overline{\theta} < \hat{\theta}$, the demand function for firm L turns out to be $\overline{\theta} - \theta_L > 0$, while that for firm H is nil. Thus, it is straightforward to conclude that in this range of θ-parameters, firm L monopolizes the market, while firm H is inactive. By the same reasoning, firm H monopolizes the market whenever $\hat{\theta} < \theta_H < \overline{\theta}$, firm L being inactive in this range of θ-parameters. Finally, in the case when $\theta_L \leq \hat{\theta} \leq \overline{\theta}$, firm H and firm L share the market.[15]

[14] We easily deduce the expression of the indifferent consumer from: $U_H(\theta) = U_L(\theta)$.
[15] See appendix 2 for details on this.

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4. The game

As usual, we start solving the second stage of the game under the assumption that variants' quality has been defined at the first stage. Then, we move to the quality competition subgame.

4.1. Price subgame

Let Π_i be the profit function of Firm i,

$$\Pi_i(q_i, p_i, q_j, p_j) = p_i D_i(p_i, p_j).$$

As usual, in order to identify the equilibrium prices, we first define the best reply functions[16] of Firm L and Firm H. Solving the systems of best replies allows us to determine the price equilibrium. Let $H_1 = \frac{(\bar{\theta}-\alpha+\beta)}{2\beta}$ and $H_2 = \frac{\bar{\theta}-\alpha+2\beta+\sqrt{\bar{\theta}^2+\alpha^2+4\beta^2-2\bar{\theta}\alpha+4\bar{\theta}\beta+4\alpha\beta}}{4\beta}$. In appendix 4 we prove that, when $\frac{q_H}{q_L} \leq H_1$, both firms are active in the market and equilibrium prices $p_H^*(q_H, q_L)$ and $p_L^*(q_H, q_L)$ are given by:

$$\begin{cases} p_H^* = (q_H - q_L)\dfrac{\left(2\bar{\theta}+2\alpha+\beta\right)q_H - \alpha q_L}{4q_H - q_L} \geq 0 \\ p_L^* = (q_H - q_L)\dfrac{-2\beta q_H + \left(\bar{\theta}-\alpha+\beta\right)q_L}{4q_H - q_L} \geq 0 \end{cases}$$

thereby getting equilibrium profits equal to

$$\Pi_H^*(p_H^*) = \frac{\left(\left(2\bar{\theta}+2\alpha+\beta\right)q_H - \alpha q_L\right)^2 (q_H - q_L)}{(4q_H - q_L)^2}$$

$$\Pi_L^*(p_L^*) = \frac{q_H\left(2\beta q_H - \left(\bar{\theta}-\alpha+\beta\right)q_L\right)^2 (q_H - q_L)}{q_L\,(4q_H - q_L)^2}.$$

Notice that the condition $\frac{q_H}{q_L} \leq H_1$ cannot be met without the inequality $H_1 > 1$ being satisfied, which implies $\bar{\theta} > \alpha + \beta \geq \alpha$. Accordingly, a necessary condition for both firms being active in the market is that the highest WTP for quality is far higher than the parameters capturing the social component of consumption. Of course, whenever this condition is not met, the low-quality producer is so strongly penalized by the social dimension of consumption that there is no room for him/her in the market. Notice that the above rationale holds a fortiori when considering that $\bar{\theta} \geq \alpha$. Indeed, if this condition is not satisfied, then the SR coming from green consumption is so strong as to prevent brown purchases, whatever the quality of the brown good. That is to say that, under $\bar{\theta} < \alpha$, it is as if the brown producer would cease to play a role in competition.

[16] We provide details on these functions in appendix 3.

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On the contrary, in the case when $\frac{q_H}{q_L} > H_1$, the green firm evicts the brown firm from the market and the equilibrium price of the high-quality firm turns out to be[17]:

$$\begin{cases} p_H^+(q_H, q_L) = \dfrac{(q_H - q_L)(\beta q_H + \alpha q_L)}{q_L} \\ p_L^+(q_H, q_L) = 0 \end{cases} \quad \text{if} \quad \frac{q_H}{q_L} \leq H_2$$

$$\begin{cases} p_H^\circ(q_H, q_L) = \dfrac{1}{2}\left(\bar{\theta} q_H + \alpha (q_H - q_L)\right) \\ p_L^\circ(q_H, q_L) = [0, y] \end{cases} \quad \text{if} \quad \frac{q_H}{q_L} > H_2,$$

while the corresponding profits at price equilibrium are written as

$$\Pi_H^\circ(p_H^\circ) = \frac{\left(\bar{\theta} q_H + \alpha (q_H - q_L)\right)^2}{4 q_H} \text{ and}$$

$$\Pi_H^+(p_H^+) = \frac{\left(\bar{\theta} q_L - \beta (q_H - q_L)\right)(q_H - q_L)(\beta q_H + \alpha q_L)}{q_L^2}.$$

It is worth remarking that the assumption $\bar{\theta} \geq \alpha$ plays a role even in this configuration. Indeed, the range of parameters such that condition $\frac{q_H}{q_L} > H_2$ is met is larger, the higher is α.[18] At $\frac{q_H}{q_L} > H_2$, the price p_H° is only related to the SR, as β does not affect this price. So, once more, for α sufficiently large, it is as if there would be no room for the brown player in the competition game.

Notice also that in the case with the low-quality firm being out of the market, the equilibrium price p_H changes depending on the quality gap between variants. It is p_H^+ in the case when the green quality is not significantly different from the brown quality or p_H° otherwise, namely when the high quality is substantially far from the low alternative. From direct comparison between $p_H^+(q_H, q_L)$ and $p_H^\circ(q_H, q_L)$, it emerges that $p_H^+(q_H, q_L) > p_H^\circ(q_H, q_L)$ for q_H sufficiently large, namely $q_H > H_2 q_L$, and $p_H^\circ(q_H, q_L) > p_H^+(q_H, q_L)$ otherwise, namely whenever $q_H \leq H_2 q_L$. That is to say that at equilibrium, firm H quotes a price $p_H = \min[p_H^\circ(q_H, q_L), p_H^+(q_H, q_L)]$ as the market share of H decreases with p_H.[19] We can summarize the above findings as follows.

Proposition 1. *At the subgame price equilibrium, whenever the green firm is not significantly less polluting than the brown competitor, namely* $\frac{q_H}{q_L} \leq H_1$, *then*

[17] As 'a product may be "inactive" in the sense that it may be proposed to consumers in a catalogue without having a positive demand' (Bonnisseau and Lahmandi-Ayed, 2007), even in this scenario the relative gap between variants plays a role in determining social benefits or punishment.

[18] See appendix 4.

[19] The demand function of the high-quality firm in case of market monopolization is defined by: $D_H = \bar{\theta} - \frac{p_H - \alpha(q_H - q_L)}{q_H}$.

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both firms (H and L) are active in the market at positive equilibrium prices. On the contrary, in the case when the green producer is by far less polluting than the brown firm, that is, $\frac{q_H}{q_L} > H_1$*, then only the former can be active in the market, the latter being out. At this equilibrium, the price of the green variant depends on the quality gap between goods.*

4.2. Quality subgame

Let us consider now the quality choice at the first stage of the game. To this aim, it is worth recalling that at the second stage, we find that the low-quality firm can either compete against the rival, or be inactive depending on the quality gap between variants.

The quality best reply (denoted BR) functions of firms in the above evoked scenarios are provided in Proposition 2.

Proposition 2. *The profit function of the high-quality firm always increases in* q_H*, regardless of the quality gap between variants. Thus, its quality's best reply function is always obtained as:*

$$\varphi_H(q_L) = \bar{q}.$$

Regarding the low-quality firm, when it can be active in the market (i.e., $\bar{\theta} \geq \beta + \alpha$*), its quality's best reply function is obtained as:*

$$\varphi_L(q_H) = \gamma q_H,$$

where $\gamma = \frac{\left(2\bar{\theta}-2\alpha-\beta+\sqrt{(2\bar{\theta}-2\alpha+\beta)(2\bar{\theta}-2\alpha+25\beta)}\right)}{7\bar{\theta}-7\alpha+3\beta}$.

Notice that our finding on the top-quality choice is in line with those emerging in the traditional literature on vertical differentiation with no production costs: as recalled by Gabszewicz and Thisse (1979), if there is no cost for quality improvement, then the high-quality firm always selects the top quality as the profit function is always increasing in the top quality. On the contrary, we find that the BR function of the low-quality firm departs from that typically observed. For this to be evident, take as a reference point the model by Choi and Shin (1992). They study a three-stage game with vertical differentiation. At the first stage, Firm 1 defines its quality q_1, where $q_1 \in [0, \bar{q}]$; then at the second stage, Firm 2 defines q_2 from the interval $[0, q_1]$, having observed q_1; finally, at the third stage, firms compete in price. Quality choice is costless, as in our model. In Choi and Shin, both firms are active at equilibrium. Further, if tastes are sufficiently diverse so that some consumers do not buy from either firm, then the market is not covered. In this case, the BR function of the low-quality firm is $\varphi_L(q_H) = \frac{4}{7}q_H$. As at equilibrium, $q_H = \bar{q}$, it follows that $q_L = \frac{4}{7}\bar{q}$. So, while we confirm that $\varphi_H(q_L) = \bar{q}$, the social preferences in our model raise the equilibrium quality of the brown variant with reference to the traditional setting above described.[20]

[20] We check by a simple calculation that $\gamma > \frac{4}{7}$.

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To summarize:

Proposition 3. *Whenever the intensity of relative preferences prevails over the dispersion of consumers (namely $\bar{\theta} < \beta + \alpha$), then at the SPNE the brown firm cannot be active in the market which is accordingly monopolized by the green producer. In the case when the reverse holds (namely $\bar{\theta} \geq \beta + \alpha$), there is room in the market for the brown competitor whenever the quality gap between variants is sufficiently small.*

5. Welfare analysis

In this section we identify the role, if any, of relative preferences in welfare. To this aim, we first describe the welfare properties of the model when these preferences do not take place, with this setting representing a *baseline*. We borrow details on the baseline from Choi and Shin (1992). Although the model has been partially described at the end of section 4.2, we add here some further details for ease of exposition. In particular, we recall that the equilibrium price of the low-quality producer is $\frac{2}{7}$ of the price of the high-quality firm. Further, at this equilibrium, the market share of the high-quality firm is given by $\frac{7}{12}\bar{\theta}$, while that of the low-quality is $\frac{7}{24}\bar{\theta}$. Then, we compare the welfare under relative preferences with the baseline. As the social welfare W is the sum of environmental damage deriving from global emissions, consumers surplus, and firms' profits, we consider each of the above evoked components in order to draw some insights. We develop the analysis taking into account that two market configurations can be observed at equilibrium: either both firms are active at positive equilibrium prices or only the green firm is active, the dirty competitor being inactive.

5.1. Duopoly structure at equilibrium

5.1.1. Pollution damage

For this analysis, we focus on the so-called *pollution damage* and, starting from the existing literature, assume that this damage depends both on the amount of production and the quality of goods, the green variant being less polluting than the brown alternative.

Let us remark that the relative preferences change both (i) the optimal quality of the brown firm and (ii) firms' market shares.

One can show that[21]

Lemma 2. *Compared to the baseline, under relative preferences, the optimal quality of the brown variant increases while its market share shrinks.*

Accordingly, when the green variant is not polluting at all, the aggregate emissions decrease under social drivers compared to the baseline. Still, the role of these drivers in reducing aggregate emissions is a priori ambiguous when the green good entails some pollution: indeed, as a result of this market share effect, under social preferences, emissions coming from the

[21] The proof of Lemma 2 is available upon request from the authors.

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brown variant decrease but those determined by the green production can raise with reference to the baseline. In appendix 5, we prove that, under this circumstance, relative preferences reduce aggregate emissions iff the green variant is sufficiently green. If this is not the case, aggregate emissions increase under social preferences compared to the baseline. In other words, because of the market share effect (namely the rise in the market share obtained by the green producer due to the existence of the social drivers), the green variant has to be by far less polluting than the dirty alternative in order to entail a reduction in global emissions.

5.1.2. Consumer surplus

From standard computations,[22] we find that consumers' surplus obtained by consumers buying the low-quality variant under social preferences CS_L is higher than the corresponding consumers' surplus observed in Choi and Shin $CS_L^{c,s}$, namely $CS_L > CS_L^{c,s}$. Accordingly, consumers buying the low-quality variant always benefit from the existence of social drivers in consumption. At first sight, this result could be counterintuitive: while being frustrated by the SP effect (captured by the term $-\beta(q_H - q_L)$), consumers enjoy a higher surplus under SP than that emerging in a setting without this social effect. This is due to the fact that the existence of this SP forces the low-quality producer to quote a lower price than in the alternative framework without the relative preferences, with a strong benefit for the buyers of the low-quality variant. Furthermore, this positive price effect overcompensates the negative one (namely the social frustration) coming from the social dimension of consumption.

When considering the consumers' surplus under green (namely high-quality) purchases, we find that consumers' surplus obtained by consumers buying the green variant under relative preferences CS_H is higher than the corresponding consumers' surplus observed in Choi and Shin, namely $CS_H > CS_H^{c,s}$ for $\beta > \frac{\alpha}{11}$. Rather interestingly, even when the social benefit enables the high-quality producer to quote a higher price than the corresponding one in Choi and Shin, the *social premium* in the utility function for the consumers buying the high-quality variant is so huge as to compensate the negative *price effect*.

5.1.3. Firms' profits

As far as firms' profits go, let us consider first profits accruing to Firm L. We prove[23] that equilibrium profits for Firm L are lower in our setting than those arising in Choi and Shin's model; while profits accruing to Firm H can be larger or smaller in our setting than in Choi and Shin's. Notice that as the market share of the high-quality firm under social preferences is always larger than the corresponding share in Choi and Shin, the condition on whether $\Pi_H \gtrless \pi_H^{c,s}$ is only concerned with the equilibrium prices under

[22] All the computations are available upon request from the authors.

[23] The comparisons of firms' profits between our setting and that of Choi and Shin's model are available upon request from the authors.

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the two scenarios.[24] Then, in order to conclude on the impact of social preferences on welfare, one may wonder whether, at the condition such that $CS_H > CS_H^{c,s}$ (namely $\beta > \hat{\beta} = \frac{\alpha}{11}$), profits accruing to firm H under social preferences are higher than the corresponding values in Choi and Shin. We show also that the difference in prices $\left(p_H - p_H^{c,s}\right)$ is positive (respectively, negative) at $\beta = 0$ and $\beta = \frac{\alpha}{11}$ (respectively, $\beta = \alpha$) and decreasing in β, so that for $\beta < \beta^*$, with $\beta^* \in]\frac{\alpha}{11}, \alpha[$, one finds that $\left(p_H - p_H^{c,s}\right) > 0$, while the reverse is true (namely $\left(p_H - p_H^{c,s}\right) \leq 0$) for $\beta \geq \beta^*$.

Accordingly, one can conclude the following:

Proposition 4. *There exists an admissible range of parameters such that the social dimension of consumption increases consumers' surplus and high-quality firm profits, while reducing the aggregate emissions compared to Choi and Shin's setting. In this range, only the low-quality firm is penalized.*

5.2. Monopoly structure at equilibrium

Let us now consider the alternative scenario with only the green firm active in the market. From algebraic computation, the market share of the green firm under social preferences *at the monopoly equilibrium is lower than the corresponding one observed in the duopoly structure*. Accordingly, as under monopoly the brown variant is no longer on sale, we can conclude for a positive role of social drivers in reducing emissions with reference to the traditional setting with the brown producer active in the market. As far as consumers go, there are three components affecting the consumers' surplus. First, consumers are damaged by the lower number of varieties in the market. Second, it can be shown that the price equilibrium of the green variant under monopoly turns out to be higher than the corresponding price observed under duopoly. Third, the market share of the green firm under monopoly is lower than that observed under duopoly. So, it is straightforward to conclude consumers' surplus decreases under monopoly with reference to the duopoly structure.

Finally, profit accruing to the high-quality firm Π_H° is higher than the one observed in the duopoly of the Choi and Shin setting (namely $\Pi_H^{\circ} > \pi_H^{c,s}$). Further, we prove[25] that:

$$\Pi_H^{\circ} > \left(\pi_H^{c,s} + \pi_L^{c,s}\right).$$

So, when the green firm monopolizes the market, in our setting the producer surplus is larger and the pollution is lower than the corresponding ones in Choi and Shin with the two firms active at equilibrium.

[24] Thus, notice that whenever equilibrium profits in Choi and Shin $\pi_H^{c,s}$ are higher than Π_H in our setting, it can only be due to a significantly lower price under social preferences.

[25] The proof is available upon request from the authors.

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6. Two natural specifications: when drivers are country specific

We apply now the general analysis to the specific cases when either SP and SR takes place separately. To this aim, we first consider the scenario with SP, thus putting $\alpha = 0$ and $\beta > 0$. Then, we move to the case with SR, thereby assuming $\alpha > 0$ and $\beta = 0$.

6.1. Social punishment ($\alpha = 0$ and $\beta > 0$)

In the case when only SP takes place, it is easy to show that the main properties of the general model still hold. In particular, when replicating the above analysis with $\alpha = 0$, one can show that, at the price subgame:

- In the case when $q_H > \frac{(\bar{\theta}+\beta)}{2\beta} q_L$, namely the green variant is by far less polluting than the dirty alternative, the green firm evicts the brown firm from the market and the equilibrium price of the high-quality firm turns out to be:

$$\begin{cases} p_H^+(q_H, q_L) = \dfrac{(q_H - q_L)\,\beta q_H}{q_L} \\ p_L^+(q_H, q_L) = 0 \end{cases} \quad \text{if} \quad \frac{q_H}{q_L} \leq \frac{(\bar{\theta}+2\beta)}{2\beta}$$

$$\begin{cases} p_H^\circ(q_H, q_L) = \dfrac{1}{2}\left(\bar{\theta} q_H\right) \\ p_L^\circ(q_H, q_L) = [0, y] \end{cases} \quad \text{if} \quad \frac{q_H}{q_L} > \frac{(\bar{\theta}+2\beta)}{2\beta}$$

- On the contrary, whenever $q_H \leq \frac{(\bar{\theta}+\beta)}{2\beta} q_L$, namely the green quality, is not significantly less polluting than the brown variant, both the green and the brown firms are active in the market.[26] In this case, with the two firms sharing the market, equilibrium prices p_i^* are equal to

$$\begin{cases} p_H^* = (q_H - q_L)\,\dfrac{\left(2\bar{\theta} + \beta\right) q_H}{4q_H - q_L} \\ p_L^* = (q_H - q_L)\,\dfrac{\left(\bar{\theta} + \beta\right) q_L - 2\beta q_H}{4q_H - q_L} \end{cases}$$

We summarize the above findings as follows.

Proposition 5. *Under social punishment, at the subgame price equilibrium, two market configurations can be observed depending on the quality gap between variants: either both firms are active at positive equilibrium prices (as the green firm is not significantly less polluting than the brown competitor), or only the former can stay active in the market, the latter being evicted.*

At the quality subgame, it is easy to see that the profit function of the high-quality firm is still monotonically increasing in q_H, regardless of the market structure at equilibrium. Further, the quality's best reply function

[26] Of course, for this condition to be meaningful, one needs to verify that $\frac{(\bar{\theta}+\beta)}{2\beta} \geq 1$ i.e., $\bar{\theta} \geq \beta$.

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of the brown firm is obtained as: $\varphi_L(q_H) = \begin{cases} 0 & \text{if } \bar{\theta} < \beta \\ \gamma^{SP} q_H & \text{if } \bar{\theta} \geq \beta \end{cases}$ where $\gamma^{SP} = \frac{\left(2\bar{\theta}-\beta+\sqrt{(2\bar{\theta}+\beta)(2\bar{\theta}+25\beta)}\right)}{7\bar{\theta}+3\beta}$.

So, we can conclude that:

Proposition 6. *Under social punishment, the high-quality firm chooses the highest quality* $q_H^* = \bar{q}$*, while the equilibrium quality of the low-quality firm is obtained as* $q_L^* = \gamma^{SP}\bar{q}$ *when it is active in the market.*

To summarize, if $\bar{\theta} \leq \beta$, only the high-quality firm is active in the market with

$$q_H^* = \bar{q} \text{ and } p_H^{\circ}(q_H, q_L) = \frac{1}{2}\bar{q}\bar{\theta}.$$

Rather, if $\bar{\theta} > \beta$, both firms can be active in the market with

$$\begin{cases} q_L^* = \gamma^{SP}\bar{q} \text{ and } p_L^* = \dfrac{\left((\bar{\theta}-7\beta)\left(2\bar{\theta}+\beta\right)+(\bar{\theta}+\beta)\sqrt{\rho}\right)\left(\sqrt{\rho}-4\beta-5\bar{\theta}\right)}{\left(\sqrt{\rho}-13\beta-26\bar{\theta}\right)\left(7\bar{\theta}+3\beta\right)}\bar{q} \\ q_H^* = \bar{q} \text{ and } p_H^* = \dfrac{\left(\sqrt{\rho}-4\beta-5\bar{\theta}\right)\left(2\bar{\theta}+\beta\right)}{\left(\sqrt{\rho}-13\beta-26\bar{\theta}\right)}\bar{q} \end{cases}$$

where $\rho = \left(2\bar{\theta}+\beta\right)\left(2\bar{\theta}+25\beta\right)$.[27]

6.2. Social rewards ($\alpha > 0$ *and* $\beta = 0$)

Let us move now to the alternative scenario with SR. In the case of SR, it emerges that there exists a unique candidate subgame price equilibrium such that both firms are active in the market at positive equilibrium prices.[28] From standard computations, we find that the candidate equilibrium prices are given by:

$$p_H^{**} = (q_H - q_L)\frac{2\bar{\theta}q_H + 2\alpha q_H - \alpha q_L}{4q_H - q_L}$$

$$p_L^{**} = q_L(q_H - q_L)\frac{\bar{\theta}-\alpha}{4q_H - q_L}.$$

To guarantee that the above price equilibria candidates are indeed an equilibrium, we assume that:[29]

$$\bar{\theta} \geq \alpha.$$

[27] The profit functions as well as the market shares of both firms are deduced from the equilibrium prices and qualities. For the readability of the paper, we omitted their analytical expressions, but they are available upon request from the authors.

[28] Technical details on this point are available upon request.

[29] If this condition were not satisfied, the price equilibrium candidate p_L^{**} would be negative, thereby contradicting its existence as an equilibrium.

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The corresponding equilibrium profits Π_L^{**} and Π_H^{**} write as:

$$\Pi_L^{**}(q_L, q_H) = \frac{q_L (q_H - q_L) \left(\bar{\theta} - \alpha\right)^2 q_H}{(4q_H - q_L)^2}$$

$$\Pi_H^{**}(q_L, q_H) = \frac{(q_H - q_L) \left(2\bar{\theta} q_H + 2\alpha q_H - \alpha q_L\right)^2}{(4q_H - q_L)^2}.$$

Given this, we can state:

Proposition 7. *Under social rewards, at the subgame price equilibrium there exists a unique equilibrium such that both firms are active in the market at positive equilibrium prices.*

Under SR, at the subgame price equilibrium, the brown firm is never evicted from the market, regardless of the quality distance between variants. In a way, the role of relative preferences in case of SR is less significant than that observed under SP. In other words, when buying green is considered as an extraordinary behavior, there is always room in the market for the dirty producer. At the quality subgame, as $\Pi_H^{**}(q_L, q_H)$ is always increasing in q_H, it is straightforward to conclude that the green firm chooses the highest quality for the green variant. To identify the quality choice of the brown firm, it suffices to consider the best reply function $\varphi_L(q_H)$, given that $q_H^{**} = \bar{q}$.

From easy computations, we get that:

Proposition 8. *Under social rewards, the high-quality firm chooses the highest quality* $q_H^{**} = \bar{q}$, *while the equilibrium quality of the low-quality firm is obtained as* $q_L^{**} = \frac{4}{7}\bar{q}$.

So, differently from the above scenarios with SP and SR taking place simultaneously, or SP being the only driver, under SR there exists a unique SPNE with both firms always active in the market and characterized as follows:

$$\begin{cases} q_L^* = \dfrac{4}{7}\bar{q} \text{ and } p_H^{**} = \dfrac{1}{4}\left(\bar{\theta} + \frac{5}{7}\alpha\right)\bar{q} \\ q_H^{**} = \bar{q} \text{ and } p_L^{**} = \dfrac{1}{14}\left(\bar{\theta} - \alpha\right)\bar{q}. \end{cases}$$

Incidentally, in this framework, we obtain exactly the same quality result as the traditional model of vertical differentiation with partial coverage of the market (Choi and Shin, 1992).

7. A brief discussion of assumptions

Before concluding, let us briefly remark that in our analysis we assume that producing the green good does not require a higher cost than the brown alternative. This enables us to write that $C_H = C_L = 0$, where C_i represents the cost of producing the variant of quality i. The justification for this

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assumption lies on a theoretical ground. Indeed, it enables us to identify the role of the social dimension of consumption in shaping the equilibrium configuration while narrowing down its effect to the demand side of the problem: absent costs, the only component affecting the competition mode and the welfare properties of the model with reference to Choi and Shin is the new approach to consumers' preferences. Still, this omission is questionable, as in reality *costs for quality improvements* are not always negligible. As shown by Gabszewicz and Wauthy (2002), if there is no cost for quality improvement, then the high-quality firm always selects the top quality. So while assuming nil costs represents a natural entry point for the analysis, one may wonder how the game would change when removing this restriction. Typically, quality-specific costs in vertical differentiation models can be either variable (Mussa and Rosen, 1978) or fixed (Shaked and Sutton, 1983) in quantity. The more appropriate choice between these two costs depends of the type of product under consideration. When the quality is mainly related to investments in new technologies or in R&D, then the assumption of fixed quality-specific costs is more reasonable. On the contrary, when the quality can be enhanced by skilled labor, then variable costs in quantity should be preferred. In this setting, we assume that there exists a fixed cost of quality improvement so that $C_H > C_L$. In particular, we assume that this cost C_i is convex in quality, while being unrelated to the scale of production.[30] We do this to stress the role of environmentally friendly technologies in production. As such, this cost does not affect the price stage of the game: when competing in price, this cost has already been sunk and accordingly it is neglected when computing the best reply functions of Firms H and L. Nevertheless, it changes decision at the quality stage: indeed, when quality development is costless, the derivative of the high-quality firm's profit function with reference to q_H is always positive and this requires to define an upper bound to the quality choice, $\bar{q}$. This no longer holds under quality-specific costs, so that $q_H^{COST} < \bar{q}$, where q_H^{COST} represents the optimal quality choice in the new setting with costs. As immediate consequence, both the quality of the brown good and the corresponding prices of the two variants decrease, thereby changing at equilibrium the market share of producers. We can summarize these findings, saying that the existence of this quality-specific cost determines a *quality effect* and a *price effect*, both the quality of the variants and their corresponding price affecting the market share of the producers at equilibrium. In the case of the high-quality firm the two effects vary in the same direction: D_H^* is larger, the lower the quality of the variant H and the lower its price p_H. So, a decrease in quality and price at the same time raises the market share of firm H. In the case of the dirty firm, there exists typically a tradeoff between two effects on the demand function at equilibrium D_L^*: while the price effect expands the market share D_L^*, the quality

[30] The traditional assumption for such a type of cost in models of vertical differentiation is that $C_i = \frac{1}{2}q_i^2$, so that the profit function is written as: $\Pi_i = p_i D_i - C_i$. Assuming quadratic cost ensures firms' profits maximization, as the second-order conditions are satisfied.

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effect decreases it. Whenever the price effect dominates the negative quality one, one observes a raise in D_L^*.[31] As far as consumers' surplus, one needs to consider that, on one hand, consumers are worse off due to the lower quality of products. On the other hand, equilibrium prices are lower as well, so that the net effect on consumers' surplus depends on the relative weight of each change. Moreover, it is worth noting that our analysis has been developed under the assumptions that both (i) the distribution of consumers θ and (ii) the highest WTP $\bar{\theta}$ coincide in the two alternative settings with only one social driver, either SP or SR. Let us briefly discuss how the model would change when removing one of them. As far as assumption (i), although it is often stated in the vertical differentiation models that consumers are uniformly distributed in the market, recent works in the field of industrial organization have shown that different consumers' distributions can alter the equilibrium analysis.[32] Indeed, when the distribution is no longer uniform, it may happen that some of the consumers with the lowest WTP, who were not willing to buy at all (respectively, willing to buy) under uniform distribution, now purchase (respectively, stop purchasing); further, some consumers whose WTP is now higher (respectively, lower) are willing to buy a high-quality variant rather than the low-quality alternative (respectively, the low-quality variant rather than high-quality).[33] In other words, both the incentives for consumers to buy, and if so, to choose a particular variant and the equilibrium profits change with the distribution. Let us consider for example the setting where consumers are more concentrated toward $\bar{\theta}$. Typically, this scenario can be observed in high-income countries under the assumption that consumers are ranked in the market according to their income, starting from the lowest income level up to the highest one.[34] As an immediate by-product of this new distribution, profits for the high-quality firm would increase. Still, the low-quality

[31] To give an example, we can assume that $C_H = \frac{1}{2}q_H^2$. For the sake of simplicity, let us also assume that $\alpha = \beta$ and $C_L = 0$. After some cumbersome manipulations, it emerges that at equilibrium the optimal quality q_H^{COST} chosen by the green producer when facing some quality-specific cost is written as:

$$q_H^{COST} = \frac{\left(2\bar{\theta} + 3\beta - \beta\gamma\right)\left(8\bar{\theta} + 12\beta - 6\bar{\theta}\gamma - 5\beta\gamma + 4\bar{\theta}\gamma^2 - \beta\gamma^2\right)}{(4-\gamma)^3},$$

with $q_H^{COST} < \bar{q}$. As, $D_L = q_H \frac{-2\beta q_H + \bar{\theta} q_L - \alpha q_L + \beta q_L}{q_L(4q_H - q_L)}$ at the price subgame, it follows that in this case the market share can increase.

[32] For example, Acharyya (1998) considers the effect of discrete consumers' distributions on the quality menu choice by a monopolist. More recently, Bonnisseau and Lahmandi-Ayed (2007) show that there exist particular non-uniform consumers' distributions such that the equilibrium does not exist.

[33] Benassi *et al*. (2006) clearly disentangle these mechanisms in the case of 'purely distributive' shocks to the distribution of the consumers' characteristics, namely shocks that do not modify the mean and the support of the distribution itself.

[34] Otherwise, one could imagine that the environmental concern (affecting the WTP) is positively related to the culture or the habit in a country so that developed regions might display higher WTP with reference to less developed areas.

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firm would suffer a reduction in profits to the extent that consumers willing to buy the low-quality variant under uniform distribution are now moving to purchase the high-quality alternative. A further possibility is that consumers are uniformly distributed on $[\theta_{\min}, \bar{\theta}]$ with density equal to $\frac{1}{\bar{\theta}-\theta_{\min}}$ in the country where only SP takes place (developed country), while being distributed on $[0, \theta_{\max}]$ with density equal to $\frac{1}{\theta_{\max}}$ in the country with only SR (developing country). As the intuition is that developing countries are by far less rich than their developed counterparts, it is reasonable to assume that the corresponding highest WTP ($\theta_{\max}$) in the latter group of countries is dominated by the former ($\bar{\theta}$), so $\theta_{\max} < \bar{\theta}$. It is worth remarking that, under our assumption of an uncovered market, the higher these parameters $\theta_{\max}$ and $\bar{\theta}$, the higher *ceteris paribus* the variants' price at equilibrium. Further, as the parameter $\bar{\theta}$ contributes to determine the equilibrium configuration with either both producers or only the green firm active,[35] the higher $\bar{\theta}$ the larger the set of β*-values* under which a duopoly market structure can be observed at equilibrium.

8. Conclusions

In this paper, we have considered a two-stage game between a clean firm and a dirty producer with quality competition at the first stage and price competition at the second stage of the game. We have shown that the equilibrium configuration changes depending on the consumers' dispersion and the relative preferences: either both producers are active at equilibrium, or the green producer is the only firm active in the market, the brown competitor being out. This latter case emerges whenever the relative preferences are so strong as to neutralize the dispersion force. Furthermore, we have proved that, whatever the market configuration at equilibrium, under relative preferences there can be a pollution damage reduction compared to the standard case without relative preferences, as in Choi and Shin (1992). On the contrary, the effect of these preferences on the welfare as a whole changes with the market configuration at equilibrium. Under duopoly, there exist an admissible range of parameters such that the social dimension of consumption increases consumers' surplus and high-quality firm profits with reference to the benchmark. So in this range, the low-quality firm is only penalized. Under monopoly, while profits of the high-quality firm increase, consumers' surplus can be lower. Our model displays a further interesting property. Indeed, in the case when the more pollutant firm is out from the home market, relocating production in a country with a less stringent environmental policy does not allow her to serve *via* export her own country. On the contrary, this relocation can be observed under the end-of-pipe approach. The existing literature in this field shows that in several circumstances firms can transfer polluting production abroad as a reaction to unilateral environmental measures: relocation would allow

[35] Under SR, we have proved that there exists only one equilibrium with both firms active in the market.

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these firms to neutralize a more stringent and country-specific policy and serve the home market via export, while determining an ambiguous impact on the overall pollution as a consequence of a carbon leakage effect.[36]

We escape from the above evoked carbon leakage effect because of the particular attitude of consumers to environmental concerns: brown producers can be active in their home market only in the case when their production process is sufficiently environmentally friendly compared to the green competitor. Otherwise, *transferring polluting production abroad never allows brown firms to serve their home market.*

Appendix 1: Proof of Lemma 1

Result 1 is a technical result needed to characterize the demand functions of both firms.

Result 1.

$$\begin{array}{lll} \theta_L \geq \theta_H & \Leftrightarrow & \hat{\theta} \leq \theta_i \quad for\ i = L, H \\ \theta_L \leq \theta_H & \Leftrightarrow & \hat{\theta} \geq \theta_i \quad for\ i = L, H \end{array} \tag{1}$$

Proof : Just notice that:

$$\theta_H - \theta_L = \frac{p_H q_L - q_H p_L - (q_H - q_L)\beta q_H}{q_H q_L}$$

$$\hat{\theta} - \theta_L = \frac{p_H q_L - q_H p_L - (q_H - q_L)\beta q_H}{q_L(q_H - q_L)} = \frac{\theta_H - \theta_L}{q_L}$$

$$\hat{\theta} - \theta_H = \frac{p_H q_L - q_H p_L - (q_H - q_L)\beta q_H}{q_H(q_H - q_L)} = \frac{\theta_H - \theta_L}{q_H}.$$

Thus, $(\hat{\theta} - \theta_L)$ and $(\hat{\theta} - \theta_H)$ have the same sign as $(\theta_H - \theta_L)$. Q.E.D □

Appendix 2: Demand characterization

Let us denote by $A_1 = \overline{\theta} q_L - \beta(q_H - q_L)$, $A_2 = p_H - (\overline{\theta} + (\alpha + \beta))(q_H - q_L)$, and $A_3 = \frac{q_L}{q_H} p_H - (q_H - q_L)\frac{\beta q_H + \alpha q_L}{q_H}$. Also, we denote $B_1 = \overline{\theta} q_H + \alpha(q_H - q_L)$, $B_2 = \frac{q_H}{q_L} p_L + (q_H - q_L)\frac{\beta q_H + \alpha q_L}{q_L}$, $B_3 = (\overline{\theta} + (\alpha + \beta))(q_H - q_L) + p_L$. Then, from Lemma 1, the demand functions of both firms

[36] Carbon leakage occurs when there is an increase in pollution in one country as a result of emissions reduction by a second country with a strict climate policy. It is worth noting that this *pollution haven* phenomenon would have rather negligible implications if the environmental policy were evenly settled. The current debate among politicians and economists has not yet assessed whether the fear of these adverse effects deriving from unilateral policy are overrated. See Sanna-Randaccio and Sestini (2012).

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obtain as:

$$D_L = \begin{cases} \overline{\theta} - \dfrac{p_L + \beta\,(q_H - q_L)}{q_L} & \text{if} \quad p_L \leq \min\{A_1, A_2\} \\ \dfrac{p_H - p_L}{q_H - q_L} - (\alpha + \beta) - \dfrac{p_L + \beta\,(q_H - q_L)}{q_L} & \text{if} \quad A_2 \leq p_L \leq A_3 \\ 0 & \text{if} \quad p_L \geq A_3 \end{cases}$$

$$D_H = \begin{cases} \bar{\theta} - \dfrac{p_H - \alpha\,(q_H - q_L)}{q_H} & \text{if} \quad p_H \leq \min\{B_1, B_2\} \\ \overline{\theta} - \left(\dfrac{p_H - p_L}{q_H - q_L} - (\alpha + \beta)\right) & \text{if} \quad B_2 \leq p_H \leq B_3 \\ 0 & \text{if} \quad p_H \geq B_3 \end{cases}$$

Appendix 3

The profit functions are defined as follows:

$$\Pi_i = p_i D_i \text{ with } i = L, H$$

Maximizing the profit functions with reference to p_i we obtain the following best reply functions:[37]

Best reply functions of firm L in the price game:

- If $\overline{\theta} q_L - \beta\,(q_H - q_L) < 0$,

$$\varphi_L\,(p_H) = [0, y], \forall p_H$$

- If $\overline{\theta} q_L - \beta\,(q_H - q_L) \geq 0$,

$$\varphi_L\,(p_H) = \begin{cases} \tilde{p}_L & \text{if } p_H > \dfrac{1}{2}(\overline{\theta}(2q_H - q_L) \\ & \quad +(q_H - q_L)(2\alpha + \beta)) \\ p_H - (\overline{\theta} + (\alpha + \beta)) & \text{if } \dfrac{(q_H - q_L)(2\overline{\theta} q_H + 2\alpha q_H + \beta q_H - \alpha q_L)}{(2q_H - q_L)} \\ \quad < (q_H - q_L) & \quad p_H < \dfrac{1}{2}(\overline{\theta}(2q_H - q_L) + (q_H - q_L)(2\alpha + \beta)) \\ \hat{p}_1 & \text{if } \dfrac{(q_H - q_L)(\beta q_H + \alpha q_L)}{q_L} < \\ & \quad p_H < \dfrac{(q_H - q_L)(2\overline{\theta} q_H + 2\alpha q_H + \beta q_H - \alpha q_L)}{(2q_H - q_L)} \\ [0, y] & \text{if } p_H < \dfrac{(q_H - q_L)(\beta q_H + \alpha q_L)}{q_L} \end{cases}$$

[37] Details of calculations of best reply functions are available upon request from the authors.

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Best reply function of firm H in the price game:

$$\varphi_H(p_L) = \begin{cases} \tilde{p}_H & \text{if } p_L > \dfrac{1}{2q_H}(\theta q_H q_L - (q_H - q_L)(2\beta q_H + \alpha q_L)) \\ \dfrac{q_H}{q_L} p_L + (q_H - q_L) & \text{if } \dfrac{(\theta q_L - \alpha q_L - 2\beta q_H + \beta q_L)(q_H - q_L)}{(2q_H - q_L)} \\ \quad \leq \dfrac{\beta q_H + \alpha q_L}{q_L} & \quad p_L \leq \dfrac{1}{2q_H}(\theta q_H q_L - (q_H - q_L)(2\beta q_H + \alpha q_L)) \\ \hat{p}_H & \text{if } p_L < \dfrac{(\theta q_L - 2\beta q_H - \alpha q_L + \beta q_L)(q_H - q_L)}{(2q_H - q_L)} \end{cases}$$

Appendix 4

Three cases have to be distinguished for the best reply function of Firm H according to the sign of the thresholds of its definition domain, namely the sign of $\upsilon = \frac{(\bar{\theta} q_H q_L - (q_H - q_L)(2\beta q_H + \alpha q_L))}{2q_H}$ and $\mu = \frac{(\bar{\theta} q_L - 2\beta q_H - \alpha q_L + \beta q_L)(q_H - q_L)}{(2q_H - q_L)}$.

(1) $\mu > 0 \Leftrightarrow q_H < \frac{(\bar{\theta} - \alpha + \beta)}{2\beta} q_L$, then

$$\varphi_H(p_L) = \begin{cases} \tilde{p}_H & \text{if} \quad p_L > \upsilon \\ \frac{q_H}{q_L} p_L + \frac{(q_H - q_L)(\beta q_H + \alpha q_L)}{q_L} & \text{if} \quad \mu \leq p_L \leq \upsilon \\ \hat{p}_H & \text{if} \quad p_L < \mu. \end{cases}$$

Notice that if one would admit $\bar{\theta} < \alpha$, this scenario would never hold.

(2) If $\mu \leq 0$ and

$$\upsilon > 0 \Leftrightarrow \frac{(\bar{\theta} - \alpha + \beta)}{2\beta} q_L \leq q_H < q_L \frac{\bar{\theta} - \alpha + 2\beta + \sqrt{\bar{\theta}^2 + \alpha^2 + 4\beta^2 - 2\bar{\theta}\alpha + 4\bar{\theta}\beta + 4\alpha\beta}}{4\beta}$$

then,

$$\varphi_H(p_L) = \begin{cases} \tilde{p}_H & \text{if} \quad p_L > \upsilon \\ \frac{q_H}{q_L} p_L + (q_H - q_L) \frac{\beta q_H + \alpha q_L}{q_L} & \text{if} \quad p_L \leq \upsilon \end{cases}.$$

Notice that even in this case, the assumption that $\bar{\theta} \geq \alpha$ guarantees that $\upsilon > 0$.

(3) If $\upsilon \leq 0$, i.e., $q_H \geq q_L \frac{\bar{\theta} - \alpha + 2\beta + \sqrt{\bar{\theta}^2 + \alpha^2 + 4\beta^2 - 2\bar{\theta}\alpha + 4\theta\beta + 4\alpha\beta}}{4\beta}$ then,

$$\varphi_H(p_L) = \tilde{p}_H, \forall p_L \geq 0$$

Interestingly, as $\frac{\partial \upsilon}{\partial \alpha} < 0$, the larger α (so that the condition $\bar{\theta} < \alpha$ holds), the larger the set of parameters such that $\upsilon \leq 0$.

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Recall that the best reply of Firm L is defined for $q_H > \frac{(\bar{\theta}+\beta)}{\beta} q_L$ or $q_H \leq \frac{(\bar{\theta}+\beta)}{\beta} q_L$.

We easily check that: $\frac{(\bar{\theta}-\alpha+\beta)}{2\beta} q_L < q_L \frac{\bar{\theta}-\alpha+2\beta+\sqrt{\bar{\theta}^2+\alpha^2+4\beta^2-2\bar{\theta}\alpha+4\bar{\theta}\beta+4\alpha\beta}}{4\beta} < \frac{(\bar{\theta}+\beta)}{\beta} q_L$.

This implies that there are four cases of intersection between the best reply functions of both firms:

- Case 1: $q_H < \frac{(\bar{\theta}-\alpha+\beta)}{2\beta} q_L$;
- Case 2: $\frac{(\bar{\theta}-\alpha+\beta)}{2\beta} q_L \leq q_H < q_L \frac{\bar{\theta}-\alpha+2\beta+\sqrt{\bar{\theta}^2+\alpha^2+4\beta^2-2\bar{\theta}\alpha+4\bar{\theta}\beta+4\alpha\beta}}{4\beta}$;
- Case 3: $q_L \frac{\bar{\theta}-\alpha+2\beta+\sqrt{\bar{\theta}^2+\alpha^2+4\beta^2-2\bar{\theta}\alpha+4\bar{\theta}\beta+4\alpha\beta}}{4\beta} \leq q_H \leq \frac{(\bar{\theta}+\beta)}{\beta} q_L$;
- Case 4: $q_H > \frac{(\bar{\theta}+\beta)}{\beta} q_L$.

These four cases are depicted in figure 1.[38] Notice that cases 3 and 4 can be combined because they lead to the same set of price equilibria.

Appendix 5

The emissions of the green product $E_H = (q_{\max} - \bar{q}) D_H^*$ (respectively, brown good, $E_L = (q_{\max} - \gamma\bar{q}) D_L^*$) under social drivers is given by:

$$E_H = \frac{\left(2\bar{\theta} + 2\alpha + \beta - \alpha\gamma\right)(q_{\max} - \bar{q})}{(4-\gamma)} =$$

$$\text{resp } (E_L = \frac{\left(\bar{\theta}\gamma - 2\beta - \alpha\gamma + \beta\gamma\right)(q_{\max} - \gamma\bar{q})}{(4-\gamma)\gamma})$$

where $q_{\max}$ is the quality level such that the resulting pollution is nil. Instead, in Choi and Shin's framework they are written as: $E_H^{c,s} = (q_{\max} - \bar{q}) \frac{7}{12}\bar{\theta}$ (respectively, $E_H^{c,s} = (q_{\max} - \frac{4}{7}\bar{q}) \frac{7}{24}\bar{\theta}$).

When considering the difference in the emissions in the two alternative scenarios, namely $E(= E_H + E_L) - E^{c,s}(= E_H^{c,s} + E_L^{c,s})$, from standard computations, we find that: $E - E^{c,s} < 0$ iff $\bar{q} > \tilde{q}$ where $\tilde{q} = \frac{(16\beta+4\bar{\theta}\gamma-8\alpha\gamma-16\beta\gamma-7\bar{\theta}\gamma^2+8\alpha\gamma^2)q_{\max}}{2(4\bar{\theta}-8\alpha+4\beta-7\bar{\theta}\gamma+8\alpha\gamma-4\beta\gamma)\gamma}$. Q.E.D.

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[38] Figure 1 is available upon request from the authors.

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