Strategic Implications of Consumer and Corporate Environmental Preferences*

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Abstract

There is evidence that markets are increasingly shaped by consumers' and corporate preferences for more sustainable choices. In a model where firms can reduce emissions by choosing a more environmentally friendly production technology, we ask whether such preferences alter firms' pricing and strategy decisions. When firms have narrow preferences, in that they care only for their own emissions, or equally when consumers care only about their own consumption, environmentally sensitive preferences (weakly) dampen price competition. Instead, when firms pollute to a different degree, price competition intensifies either when firms have broad preferences, as they care about total pollution, or when consumers have social preferences, as they discount a more polluting firm's product by more when this is chosen by fewer fellow consumers. With firm broad preferences or consumer social preferences, firms' choices of more sustainable production become strategic complements. Then, a more intrinsically motivated leader can also induce a purely profit-motivated follower to choose a more environmentally friendly product or technology, as otherwise price competition would intensify. This is in line with recent evidence that documents such a (causal) relationship in firms' environmental or, more generally, CSR strategies.

Keywords: Consumer and firm's environmental preferences; Social preferences; Choice of green technology JEL codes: C72, D62, H41

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1 Introduction

There is a mounting body of evidence indicating a robust trend towards corporate sustainability, particularly over the past decade. While the term "corporate sustainability" encompasses various corporate strategies, the focus of this paper lies predominantly on its environmental dimension. Notably, significant voluntary effort has been observed, exemplified by the fact that almost all of the world's largest companies now issue sustainability reports and establish environmental targets. Moreover, more than 2,000 companies have committed to science-based carbon targets, and approximately one-third of Europe's largest public companies have pledged to achieve net zero by 2050 (Winston, 2022). Beyond mere pledges and goal-setting, recent studies have documented an increase in corporate environmental efforts. For instance, Aghion et al. (2023) analyzed patents from 8,562 automobile-sector firms across 41 countries and found that between 1998-2002 and 2008-2012, the share of "green" innovation rose by 23.4%, while that of "brown" innovations (linked to internal combustion engines) decreased by 20%.

This shift has been attributed to both government intervention, along Pigou's (1920) recommendations, and voluntary actions by environmentally-conscious consumers and firms. The economic literature extensively examines environmental regulation and its impact on green innovation and more recently there is also a growing body of research exploring the influence of "green consumers." However, little attention has been paid to the effect of voluntary firm actions. In this paper, we delve into both consumer and corporate preferences, analyzing how they "pull" and "push" green innovation depending on their particular specification.

Our theoretical framework draws inspiration from recent work by Dewatripont and Tirole (2022), which explores various approaches to modeling corporate "moral preferences." Following the definition of corporate sustainability at different levels, we differentiate between situations in which firms define their environmental responsibility narrowly, hereafter "narrow preferences", focusing solely on metrics relevant to their own actions, and when they define it broadly, hereafter "broad preferences", considering wider implications such as competitor reactions (e.g., also potential "leakage"). While similar assumptions regarding broad preferences are made by Hart and Zingales (2017) and Broccardo et al. (2022), our departure lies in positing that a firm's motivation, under both narrow and broad preferences, is primarily partisan, aligning more closely with a narrowly defined environmental objective alongside profit maximization. This nuanced perspective reflects the complexities of real-world business motivations.[1]

Nonetheless, there are crucial distinctions between broader and narrower defined firms' environmental objectives, especially in an oligopolistic environment. With regards to pricing, when firms' objectives are narrowly tied to their own emissions, this always dampens competition and pushes up prices. Conversely, when a firm's objective is broad in that it cares also about the "leakage" and when it is greener than its rival, it will price more aggressively to steal market share from its more polluting rival, provided that this does not push up aggregate output and emissions. These disparities extend to firms' technology choices. We consider a Stackelberg game scenario, where the firm acting as a leader is the more intrinsically motivated firm. Under broad environmental preferences the leader can essentially coerce its rival into also adopting low-emission technologies to mitigate competitive pressures.[2] In contrast, narrow environmental preferences lack this strategic complementarity.

Similar dynamics emerge when analyzing consumer preferences. When consumers exhibit only individualistic environmental preferences, favoring environmentally friendly products, firms' technology and product choices result in standard vertical differentiation. When firms have heterogeneous standards, such a difference dampens competition. However, when consumers exhibit social preferences, whereby the desirability of a brown product decreases as fewer consumers purchase environmentally harmful alternatives, firms' strategic interactions mirror those observed with broadly defined firm environmental preferences. When consumers have social preferences, price competition intensifies, and firms' technology choices become strategic complements once again.

With broad corporate environmental preferences or consumer social preferences, even firms lacking intrinsic motivation are inclined to embrace higher environmental standards. In both scenarios, the impetus originates from the strategic objective of

[1] In particular, this implies that, other than for profit reasons, a firm does not "care" about its consumers, which, in the extreme, would make antitrust provisions obsolete, nor does it care about the welfare of its competitors' shareholders and thus its competitors' profits. For instance, Broccardo et al. (2022) avoid such implications as they consider perfect competition.

[2] Essentially the follower fears fierce price competition in case of selecting the brown technology.

mitigating price competition. This observation aligns with empirical findings highlighting a strategic complementarity in firms' adoption of green or, more generally, corporate social responsibility (CSR) strategies (e.g., Cao et al., 2019; Li et al., 2023). These studies suggest, among other factors, the role of managerial peer pressure in prompting similar actions by competitors, all else being equal.

The theoretical literature has so far predominantly centered on the significance of cost synergies (e.g., Albuquerque and Cabral, 2023), which are also fundamental to the extensive literature on R&D coordination and joint ventures (e.g., d'Aspremont and Jacquemin, 1988; Kamien et al., 1992). Furthermore, scholars have explored product differentiation strategies, particularly among multiproduct firms (e.g., Garcia et al., 2020). Notably, our theory suggest that such strategic complementarity is stronger when firms are closer competitors and their products closer substitutes, while this may not be the case in theories based on management peer effects or cost synergies.

In terms of consumer preferences, the assumption of green consumerism aligns with a substantial body of literature, particularly in environmental economics (e.g., Ambec and Donder, 2022, for a recent example and comprehensive overview). In this paper we assume that consumer's choices depend on the products' level of emissions, that is, the consumer internalizes voluntarily part of the externality her choice creates. This assumption is based on increasing evidence that consumers are worried about the level of pollution, they feel well-informed and they believe they can play a role in protecting the environment (see for example Eurobarometer (2014) and (2017)) and has been used in the environmental literature (e.g. Constantatos et al. (2022)). Social preferences, which we also incorporate, have been examined in designing environmental policy (e.g. Nyborg et al, 2006, Dasgupta et al. 2016 and Sartzetakis et al., 2023) and have also been addressed in studies of competition policy like Inderst et al. (2021).

As previously noted, our assumption regarding firms' intrinsic motivation resonates with recent literature. Broadly speaking, the literature delineates two primary motivations for firms engaging in actions beyond pure profit maximization: "Delegated philanthropy" and "insider-initiated corporate philanthropy." According to the former perspective, firms are incentivized by advantages in the product or capital markets. This concept underpins some strands of finance literature on socially responsible investment, where active investors with social preferences influence corporate decision-making (e.g., Landier and Lovo, 2020; Pastor et al., 2021; Gollier and Pouget, 2022). The role of market pressure in prompting firms to adopt "green" practices has also been extensively explored in the management science literature (see early contributions by Bansal and Roth, 2000, or Porter and Kramer, 2006). The works by Dewatripont and Tirole (2022) and Broccardo et al. (2022), as referenced earlier, exemplify the second strand of literature. This assumption also underpins some research on activist investors, such as Oehmke and Opp (2020), to the extent that these do not compensate firms with a lower cost of capital. Furthermore, family-held businesses or those founded and led by entrepreneurs may also pursue objectives stemming from the personal motivations of their owners, even if doing so reduces profits.

The rest of the paper is organized as follows. Section 2 defines consumers' preferences and firm's payoffs and sets up the game. Section 3 defines the solution of the pricing stage of the game under both narrow and broad firm preferences, ignoring initially consumers' environmental and social preferences. Section 4 describes first the follower's and then the leader's equilibrium choices of product and emission technology. The final Section briefly summarizes the results.

2 Model

Consider a market populated by the mass one of consumers, each of which purchases (at most) a single unit. There are two firms serving the market, $i = 1$ and 2. Firms' products are horizontally differentiated, which allows them to earn a margin above costs. Production and consumption of this product generates emissions e_i, which are assumed to be linear in production, i.e., $e_i = q_i\theta_i$, where θ_i is the rate of emissions per unit of output. Firms can produce using either a highly emitting technology, hereby denoted brown (b) or a technology with substantially lower emissions per unit of output, hereby denoted green (g) technology. Decreasing the rate of emissions, that is, $\theta_g < \theta_b$, requires abatement at the source, which increases the per unit production cost, that is, $c_g > c_b$. Different technologies may also be associated with different fix costs, F_i, as discussed below. Presently, we set $F_i = 0$.

We start with a situation in which both firms use the brown technology and we examine whether any or both firms will adopt the green technology, assuming that one of them acts as a leader. Formally, we examine the following sequential game: at the first stage, firm 1, the leader, chooses whether to adopt the green technology; at the second stage firm 2 makes her technology choice and in the final stage, given their technology choices, they compete in prices.

Consumers Consumers purchase one unit of the product and receive an immediate use value, u, from the product independent of the variant they choose. We assume that consumers are environmentally aware taking into account, when they choose from which firm to purchase, the emissions generated by the product of their choice. In particular we assume that consumers have perfect information about firms' choice of technology and they integrate this information into their decision making by subtracting $\mu\theta_i$ from their utility, where $\mu \geq 0$ is a taste parameter expressing consumer's aversion to emissions. The term $\mu\theta_i$ captures thus an additional term of potential vertical differentiation, as expressed by environmental incentives that guide consumers' choice when the two firms choose different technology. We assume that all consumers within a given society and at a given point in time have the same preferences, i.e., the same value of μ. This allows us to abstract from more standard differentiation motives of why firms may want to choose different technologies, thereby serving different segments of the market.

Furthermore, we assume that consumers are socially motivated, that is, each individual consumer responds to the choice of other consumers with which she interacts in the market. We assume that the social norm favors the green technology and thus consumers choosing the brown product variant receive social pressure. We model socially motivated preferences by introducing a disutility term $\gamma\widehat{s}$, where $\widehat{s}$ denotes consumer's expectation of the green variant's market share, and $\gamma \geq 0$ is a taste parameter expressing consumer's response to the social norm. That is, the higher is the share of consumers purchasing the green product variant the higher is the social pressure to those still purchasing the brown variant. Letting u_g be the utility from consuming the green variant and u_b that from the brown variant, we define,

$$u_g = u - p_g - d\tau - \mu\theta_g, \tag{1}$$

$$u_b = u - p_b - d\tau - \mu\theta_b - \gamma\widehat{s}. \tag{2}$$

The term $d\tau$, captures horizontal preferences in a standard way, with d denoting the distance of the firm's offer to the consumer's preferred variant.

Firms We denote firm profits by $\pi_i = q_i(p_i - c_i) - F_i$. We further assume that firms also have environmental/ecological preferences, usually framed under the term corporate social responsibility (CSR); see our motivation in the Introduction. We model firms' ecological preferences as a conscious sacrifice of profits in order to improve environmental quality. Given that firms show their environmental preferences in a variety of ways not confined in efforts to reduce only their own emissions, we model firm's environmental preferences in two ways: (a) Narrow preferences (N), i.e. firms care only about their own emissions, in which case their payoff is,

$$\Pi_i^N = \pi_i - \lambda_i e_i \tag{3}$$

(b) Broad preferences (B), i.e. firms care about total emissions, in which case their payoff is,

$$\Pi_i^B = \pi_i - \lambda_i \left(e_1 + e_2\right). \tag{4}$$

Here, $\lambda_i \geq 0$ is a taste parameter expressing firm's level of ecological preferences. We assume that firms can exhibit different level of environmental preferences $\lambda_1 \neq \lambda_2$, and we examine both cases of narrow and broad environmental preferences.

Roadmap of the analysis We analyze first price competition at stage 3 of the model. There, we pay special attention of how ecological and social preferences, both of consumers and firms, affect firms' pricing strategies. Subsequently, we consider the Stackelberg game in technology choice, with firm $i = 1$ moving first. Here, our special emphasis is on how a leader with strong ecological preferences may be able to tilt the follower.

3 Price competition (3nd stage)

We start with the solution of the last stage of the game. Initially only the brown technology is available and thus neither consumers nor firms can express their environmental preferences, and there are no social motivations. In this case, firm i's equilibrium market share, s_i, and profits are given by

$$\begin{aligned} s_i &= \frac{1}{2} - \frac{c_i - c_j}{6\tau}, \\ \pi_i &= \frac{1}{2\tau}\left(\tau - \frac{c_i - c_j}{3}\right)^2. \end{aligned}$$

In symmetry, $c_i = c_j$, firms share the market equally and their profits are $\pi_i = \frac{\tau}{2}$.

Given the complexity of the solution when both consumers and firms have environmental preferences, we present first the solution assuming that consumers do not have environmental preferences. This allows us to discuss the difference between narrowly and broadly defined firms' environmental preferences. The case of interest with both consumers and firms being environmentally conscious is then presented.

3.1 Brown consumers: $\mu = 0$, $\gamma = 0$, and green firms: $\lambda_H > \lambda_L$

Assume that the green technology becomes available and only firms are environmentally sensitive, that is, $\mu = 0$ and $\gamma = 0$. From (1) and (2) the two product variants' market share is,

$$q_i = s_i = \frac{1}{2} - \frac{p_i - p_j}{2\tau},\ i = g, b. \tag{5}$$

3.1.1 Narrow firm preferences

We will first consider the case that firms have narrow environmental preferences. Define,

$$k_i = c_i + \lambda_i \theta_i. \tag{6}$$

This represents marginal costs augmented by the firm's care for (lower) emissions. Then, firm's objective function in (3) can be written as,

$$\Pi_i = q_i\left(p_i - k_i\right). \tag{7}$$

Note that maximization of (7) with respect to p_i, while using from (5) that $\frac{\partial q_i}{\partial q_i} = -\frac{1}{2\tau}$, yields $q_i = \left(p_i - k_i\right)/2\tau$. Substituting this into (7) allow us to express firm i's payoff as function of the price only

$$\Pi_i = \left(p_i - k_i\right)^2/2\tau.$$

Substituting q_i from (5) into (7), and maximizing with respect to p_i yields both firms' price best responses, which we solve for the equilibrium prices,

$$p_i^N = \tau + \frac{1}{3}(2k_i + k_j). \tag{8}$$

Substituting the equilibrium price difference $p_i^N - p_j^N = (k_i - k_j)/3$ into (5) yields the equilibrium market shares,

$$q_i^N = \frac{1}{2} - \frac{k_i - k_j}{6\tau} = \frac{1}{2} - \frac{(c_i - c_j) + (\lambda_i\theta_i - \lambda_j\theta_j)}{6\tau}. \tag{9}$$

Substituting $p_i^N - k_i = \tau + \frac{1}{3}(k_j - k_i)$ into $\Pi_i^N = (p_i - k_i)^2/2\tau$, yields firm i's equilibrium payoff,

$$\Pi_i^N = \frac{1}{2\tau}\left(\tau - \frac{k_i - k_j}{3}\right)^2. \tag{10}$$

We now make several immediate observations regarding the nature of the characterized price equilibrium, and how this is affected by firms' ecological preferences. Firms' environmental sensitivity unambiguously lessens competition in that it increases both firms' prices, i.e., both p_i and p_j increase as we increase λ_i for one firm. Aggregate profits are given by

$$\sum_{i=1}^{2}\pi_i^N = \sum_{i=1}^{2}\left(\Pi_i^N + \lambda_i\theta_i q_i\right) = \tau + \frac{(k_i - k_j)^2}{9\tau} + \sum_{i=1}^{2}\lambda_i\theta_i q_i > \tau.$$

Consider now the case that both firms choose the same technology, that is, $c_i = c_j$ and $\theta_i = \theta_j$, but they have different environmental sensitivity, $\lambda_i \neq \lambda_j$. In such case, the more environmentally sensitive firm will lose market share, since $\lambda_i > \lambda_j$ results in $q_i^N = \frac{1}{2} - \frac{\theta(\lambda_i - \lambda_j)}{3} < \frac{1}{2}$. The firm's profits are lower than those of its rival, but with $\pi_i^N = \frac{\tau}{2} + \frac{\theta^2(\lambda_i - \lambda_j)^2}{18\tau} + \frac{\theta}{6}(2\lambda_i + \lambda_j) > \frac{\tau}{2}$ still higher than if both firms had $\lambda_i = \lambda_j = 0$. It is also immediate that a more environmentally sensitive firm "suffers" more from own emissions, so that its payoff decreases with λ_i for two reasons: first, due to the direct effect; second, as it loses market share with respect to its rival. Specifically, this can be seen from inspecting $\Pi_i^N = \frac{1}{2\tau}\left(\tau + \frac{(\lambda_j - \lambda_i)\theta}{3}\right)^2$.

3.1.2 Broad firm preferences

To examine firms' broad environmental preferences, we first define,

$$\varkappa_i = c_i + \lambda_i(\theta_i - \theta_j). \tag{11}$$

Then, firm's objective function in (3) can be written as,

$$\Pi_i = q_i\left(p_i - \varkappa_i\right) - \lambda_i\theta_j\left(q_i + q_j\right), \tag{12}$$

which, following the same steps as above, can be expressed as function of the price only,

$$\Pi_i = \frac{1}{2\tau}\left(p_i - \varkappa_i\right)^2 - \lambda_i\theta_j.$$

Substituting q_i from (5) into (12), and maximizing with respect to p_i, yields both firms' price best responses, which we solve for the equilibrium prices,

$$p_i^B = \tau + \frac{1}{3}(2\varkappa_i + \varkappa_j). \tag{13}$$

Substituting the equilibrium price difference $p_i^B - p_i^B = \left(\varkappa_i - \varkappa_j\right)/3$ into (5) yields the equilibrium market shares,

$$q_i^B = \frac{1}{2} - \frac{\left(c_i - c_j\right) + \left(\lambda_i + \lambda_j\right)\left(\theta_i - \theta_j\right)}{6\tau}. \tag{14}$$

Substituting $p_i^B - \varkappa_i = \tau + \frac{1}{3}(\varkappa_j - \varkappa_i)$ into $\Pi_i^B = \left(p_i^B - \varkappa_i\right)^2/2\tau - \lambda_i\theta_j$, yields firm i's equilibrium payoff,

$$\Pi_i^B = \frac{1}{2\tau}\left(\tau + \frac{\varkappa_j - \varkappa_i}{3}\right)^2 - \lambda_i\theta_j. \tag{15}$$

Again, we have several comments on how environmental sensitivity affects prices, profits, and payoffs. As in the case of narrow preferences, environmental sensitivity lessens competition, increasing prices which results in increased profits, though now only when firms are heterogeneous. To see this, observe that

$$\sum_{i=1}^{2}\pi_i^B = \sum_{i=1}^{2}\left(\Pi_i^B + \lambda_i\theta_j\right) = \tau + \frac{\left(\varkappa_i - \varkappa_j\right)^2}{9\tau} > \tau,$$

When firms choose the same product variant, that is, $c_i = c_j$ and $\theta_i = \theta_j$, they price at $p_i^B = \tau + c$, they share the market equally, and their profits are $\pi_i^B = \frac{\tau}{2}$, regardless of their level of environmental sensitivity. Thus, contrary to the case of narrow preferences, under broad environmental preferences, if both firms adopt the same technology there will be no change in price and profits. The above discussion is summarized in Proposition 1.

Proposition 1 *In the case that only firms have environmental preferences and only the leader adopts the green technology, competition is lessened regardless of whether their environmental preferences are defined narrowly or broadly. If both firms choose the same technology, either keeping the brown or both adopting the green, competition is lessened only when firms environmental preferences are defined narrowly.*

3.2 Green consumers: $\mu > 0$, $\gamma > 0$ and green firms: $\lambda_H > \lambda_L$

Assume now that both firms and consumers are environmentally sensitive, as also $\mu > 0$ and $\gamma > 0$. Assume further that one of the two firms offers the green variant and that consumers' expectations about the green variant's market share are realized, $s_g = \widehat{s}$, where $s_g = q_g$, given that the total market is unity, i.e., $q_g + q_b = 1$.

From (1) and (2), we derive each of the two product variants' market share,

$$q_g = \frac{\tau + p_b - p_g + \mu(\theta_b - \theta_g)}{2\tau - \gamma}, \tag{16}$$

$$q_b = \frac{\tau + p_g - p_b - \mu(\theta_b - \theta_g) - \gamma}{2\tau - \gamma}. \tag{17}$$

Note that with asymmetric product choices, demand becomes more sensitive when consumers have social preferences, $\gamma > 0$. Since $\theta_b > \theta_g$ and $\gamma > 0$, from the above, $\frac{\partial q_g}{\partial \mu} > 0$, and $\frac{\partial q_g}{\partial \gamma} > 0$, that is, the green variant's market share is increasing in consumers' environmental sensitivity and social motivation.

3.2.1 Narrow firm preferences

Substituting q_i from (16) and (17) into (7), and maximizing with respect to p_i yields both firms' price best response functions, which we solve for equilibrium prices,

$$p_g^N = \tau + \frac{1}{3}(2k_g + k_b + \mu(\theta_b - \theta_g) - \gamma), \tag{18}$$

$$p_b^N = \tau + \frac{1}{3}(2k_b + k_g - \mu(\theta_b - \theta_g) - 2\gamma). \tag{19}$$

Substituting the equilibrium price difference

$$p_b^N - p_g^N = (k_b - k_g - 2\mu(\theta_b - \theta_g) - \gamma)/3$$

into (16) and (17) yields the equilibrium market shares,

$$q_g^N = \frac{3\tau - \Delta c + \mu\Delta\theta + \rho - \gamma}{3(2\tau - \gamma)} = \frac{1}{3} + \frac{\tau + \rho - w}{3(2\tau - \gamma)}, \quad (20)$$

$$q_b^N = \frac{3\tau + \Delta c - \mu\Delta\theta - \rho - 2\gamma}{3(2\tau - \gamma)} = \frac{1}{3} + \frac{\tau - \rho + w - \gamma}{3(2\tau - \gamma)}, \quad (21)$$

where $\Delta c = c_g - c_b > 0$, $\Delta\theta = \theta_b - \theta_g > 0$, $w = \Delta c - \mu\Delta\theta$, and $\rho = \theta_b\lambda_b - \theta_g\lambda_g$.

Note that $\rho > 0$ if $\frac{\lambda_g}{\lambda_b} < \frac{\theta_b}{\theta_g}$, that is, if the ratio of environmental preferences of the green to brown firm does not exceed that ratio of the improvement in the emissions rate resulting from the adoption of the green technology.

To focus on the most interesting cases, we assume that the consumers' environmental preferences alone cannot offset the cost burden of adopting the green technology, which we hereafter call net cost burden of green technology w, which we assume to be positive:

$$w = \Delta c - \mu\Delta\theta > 0. \quad (22)$$

From (20) we can conclude that if only the leader adopts the green technology, her market share decreases with the cost difference Δc,it increases with consumers' environmental awareness μ and the improvement in the rate of emissions, $\Delta\theta$. It increases also if $\rho > 0$, and finally it increases in γ if $\tau + \rho > w$.

Substituting

$$p_i^N - k_i = \tau + \frac{1}{3}(k_j - k_i + \mu(\theta_j - \theta_i) - \gamma)$$

into $\Pi_i = (p_i - k_i)^2 / (2\tau - \gamma)$, yields both firms' equilibrium payoff,

$$\Pi_g^N = \frac{1}{2\tau - \gamma}\left(\tau + \frac{k_b - k_g + \mu\Delta\theta - \gamma}{3}\right)^2, \quad (23)$$

$$\Pi_b^N = \frac{1}{2\tau - \gamma}\left(\tau - \frac{k_b - k_g + \mu\Delta\theta + 2\gamma}{3}\right)^2, \quad (24)$$

with $k_b - k_g + \mu\Delta\theta = -\Delta c + \rho + \mu\Delta\theta = \rho - w$. The difference between the two firms' payoff is,

$$\Delta\Pi^N = \Pi_g^N - \Pi_b^N = \frac{2}{3}\left[\frac{\gamma}{2} + \rho - w\right], \quad (25)$$

which for $\lambda_g = \lambda_b$ becomes

$$\Delta\Pi^N = \frac{2}{3}\left[\frac{\gamma}{2} + \lambda\Delta\theta - w\right].$$

Therefore, the green firm's payoff exceeds that of the brown if $\frac{\gamma}{2} + \rho > w$.

Firms' profits at the equilibrium are,

$$\pi_g^N = \frac{(3\tau - \gamma + \rho - w)(3\tau - \gamma + \rho - w + 3\lambda_g \theta_g)}{9(2\tau - \gamma)}, \tag{26}$$

$$\pi_b^N = \frac{(3\tau - 2\gamma + w - \rho)(3\tau - 2\gamma + w - \rho + 3\lambda_b \theta_b)}{9(2\tau - \gamma)}. \tag{27}$$

The difference between the two firms' profit is,

$$\Delta\pi^N = \frac{1}{3}\left[\gamma + \frac{\rho}{2} - 2w + \frac{(\lambda_b \theta_b + \lambda_g \theta_g)\left(\frac{\gamma}{2} + \rho - w\right)}{(2\tau - \gamma)}\right]. \tag{28}$$

3.2.2 Broad firm preferences

Substituting q_i from (16) and (17) into (12), and maximizing with respect to p_i yields both firms' price best response functions, which we solve for the equilibrium prices,

$$p_g^B = \tau + \frac{1}{3}(2\varkappa_g + \varkappa_b + \mu(\theta_b - \theta_g) - \gamma), \tag{29}$$

$$p_b^B = \tau + \frac{1}{3}(2\varkappa_b + \varkappa_g - \mu(\theta_b - \theta_g) - 2\gamma). \tag{30}$$

Substituting the equilibrium price difference $p_b^B - p_g^B = (\varkappa_b - \varkappa_g - 2\mu(\theta_b - \theta_g) - \gamma)/3$ into (16) and (17) yields, with $\sigma = \rho + (\theta_b \lambda_g - \theta_g \lambda_b)$, the equilibrium market shares,

$$q_g^B = \frac{3\tau - \Delta c + \mu\Delta\theta + (\lambda_g + \lambda_b)\Delta\theta - \gamma}{3(2\tau - \gamma)} = \frac{1}{3} + \frac{\tau + \sigma - w}{3(2\tau - \gamma)}, \tag{31}$$

$$q_b^B = \frac{3\tau + \Delta c - \mu\Delta\theta - (\lambda_g + \lambda_b)\Delta\theta - 2\gamma}{3(2\tau - \gamma)} = \frac{1}{3} + \frac{\tau - \sigma + w - \gamma}{3(2\tau - \gamma)}, \tag{32}$$

where, $\sigma = (\lambda_g + \lambda_b)\Delta\theta$. If only one firm offers the green product variant, its market share decreases with the cost difference, since $c_H > c_L$, increases with consumers ' environmental sensitivity μ, and the improvement in the rate of emissions $\Delta\theta$, and finally it is increasing in γ if $\tau + \sigma > w$.

Assuming that the firm that moves first choosing the green technology has the higher environmental preferences, i.e. $\lambda_g > \lambda_b$, then $\sigma > \rho$. From (31) and (20) we observe that if $\sigma > \rho$ then $q_g^B > q_g^N$.

Substituting $p_i^B - \varkappa_i = \tau + \frac{1}{3}(\varkappa_j - \varkappa_i + \mu(\theta_j - \theta_i) - \gamma)$ into $\Pi_i = (p_i - \varkappa_i)^2 / (2\tau - \gamma) - \lambda_i \theta_j$, yields both firms' equilibrium payoff,

$$\Pi_g^B = \frac{1}{2\tau - \gamma}\left(\tau + \frac{\varkappa_b - \varkappa_g + \mu\Delta\theta - \gamma}{3}\right)^2 - \lambda_g \theta_b, \quad (33)$$

$$\Pi_b^B = \frac{1}{2\tau - \gamma}\left(\tau - \frac{\varkappa_b - \varkappa_g + \mu\Delta\theta + 2\gamma}{3}\right)^2 - \lambda_b \theta_g. \quad (34)$$

with $\varkappa_b - \varkappa_g + \mu\Delta\theta = -\Delta c + \mu\Delta\theta + \sigma = \sigma - w$. The difference between the two firms' payoff is,

$$\Delta\Pi^B = \Pi_g^B - \Pi_b^B = \frac{2}{3}\left[\frac{\gamma}{2} + \sigma - w - \frac{3}{2}(\lambda_g \theta_b - \lambda_b \theta_g)\right],$$

which for $\lambda_g = \lambda_b$ becomes, $\Delta\Pi^B = \frac{2}{3}\left[\frac{\gamma}{2} - w + \frac{\lambda}{2}\Delta\theta\right]$. Therefore, the green firm's payoff exceeds that of the brown if $\frac{\gamma}{2} + \sigma > w + \frac{3}{2}(\lambda_g \theta_b - \lambda_b \theta_g)$.

Substituting $\sigma = \rho + (\theta_b \lambda_g - \theta_g \lambda_b)$, in the above we can rewrite

$$\Delta\Pi^B = \frac{2}{3}[\frac{\gamma}{2} + \rho - w - \frac{1}{2}(\lambda_g \theta_b - \lambda_b \theta_g)].$$

This allows direct comparison with the payoff difference under narrowly defined preference: $\Delta\Pi^N > \Delta\Pi^B$ if $\lambda_g \theta_b > \lambda_b \theta_g$. Therefore if the leader adopting the green strategy is more environmentally sensitive, its payoff advantage over the follower is larger under narrow preferences.

The following Proposition summarizes the comparison between narrow and broad preferences.

Proposition 2 *If only the leader adopts the green technology and assuming $\lambda_g > \lambda_b$, it charges a higher price relative to the follower. The price difference is smaller under broad difference and thus, its market share is higher under broad relative to narrow preferences, but the difference between its own and the follower's payoff is higher under narrow preferences.*

Finally, firms' profits at the pricing equilibrium are,

$$\pi_g^B = \frac{(3\tau - w - \gamma + \sigma)(3\tau - w - \gamma + \sigma - 3\lambda_g \Delta\theta)}{9(2\tau - \gamma)}, \quad (35)$$

$$\pi_b^B = \frac{(3\tau + w - 2\gamma - \sigma)(3\tau + w - 2\gamma - \sigma - 3\lambda_b \Delta\theta)}{9(2\tau - \gamma)}. \quad (36)$$

4 Firms' equilibrium choices of product and emission technology

In this section, we examine firms' sequential choice of product variant and thereby emission technology, given the solution at the last stage of the game. We assume that the leader, firm 1, is more environmentally sensitive, that is, $\lambda_1 > \lambda_2$.

We use the following notation: The first subscript denotes the firm while the first superscript the type of firm preferences (N for narrow, B for broad), the second subscript denotes follower's choice of technology (g for green, b for brown) while the second superscript the leader's choice of technology. For example, $\Pi_2^N\big|_b^g$ denotes follower's profits under narrowly defined firms' environmental preferences, when the leader chooses the green and the follower the brown technology.

4.1 Narrow firm preferences with $\mu > 0$ & $\gamma > 0$

4.1.1 2nd stage: follower's choice

We start by examining the choice of the follower at the second stage, assuming first that in the first stage the leader adopts the green technology, i.e. $1 = g$. If also firm 2 adopts the green technology, both firms will have the same cost and emissions' rate, i.e., $c_1 = c_2 = c_g$, and $\theta_1 = \theta_2 = \theta_g$. In the symmetric choice case, social pressure does not exists, i.e. $\gamma = 0$, and only price difference can affect firms' market share and payoffs. Thus, from (10) the follower's payoff when choosing also the green variant is,

$$\Pi_2^N\big|_g^g = \frac{1}{2\tau}\left(\tau + \frac{(\lambda_1 - \lambda_2)\,\theta_g}{3}\right)^2,$$

while if she keeps the brown technology, from (24), her payoff is,

$$\Pi_2^N\big|_b^g = \frac{1}{2\tau - \gamma}\left(\tau - \frac{k_b - k_g + \mu\Delta\theta + 2\gamma}{3}\right)^2,$$

with $1 = g$ and $2 = b$. Therefore, firm 2 will follow the leader in adopting the green technology if,

$$\Pi_2^N\big|_g^g - \Pi_2^N\big|_b^g > 0 \Longrightarrow \lambda_2\Delta\theta + \left[2\gamma - \left(1 - \sqrt{\frac{2\tau - \gamma}{2\tau}}\right)(3\tau + (\lambda_1 - \lambda_2)\,\theta_g)\right] > w. \tag{37}$$

Note first that in the absence of social pressure on consumers choosing the brown variant, i.e. $\gamma = 0$, the above condition simplifies to,

$$\left[\Pi_2^N \Big|_g^g - \Pi_2^N \Big|_b^g \right]_{\gamma=0} > \text{ if } \lambda_2 \Delta\theta > w.$$

Thus, if $\gamma = 0$, the follower will choose to follow the leader in adopting the green technology only if its environmental sensitivity is high enough to outweigh w.

When consumers have social preferences, i.e. $\gamma > 0$, the follower's incentives to choose the green variant increase. Recall from (20), that $\frac{\partial q_g^N}{\partial \gamma} > 0$ for $\frac{\lambda_g}{\lambda_b} < \frac{\theta_b}{\theta_g}$ and $\tau + \rho > w$. This suggests that the second term in the left hand side of (37) is positive, which can be proven as follows: Consider the case that both firms have the same environmental sensitivity, i.e., $\lambda_1 = \lambda_2$. Then, the second term in the left hand side of (37) is positive, $2\gamma - \left(1 - \sqrt{\frac{2\tau-\gamma}{2\tau}}\right) 3\tau > 0$, which is true for any values of τ and γ for which $2\tau - \gamma > 0$. Assuming the leader to be more environmentally sensitive, i.e. $\lambda_1 > \lambda_2$, for the second term in the left hand side of (37) to be positive we require $(\lambda_1 - \lambda_2)\,\theta_g < \frac{2\gamma}{\left(1-\sqrt{\frac{2\tau-\gamma}{2\tau}}\right)} - 3\tau > 0$, which is always true. The second term in the left hand side of (37) is positive and increasing in a decreasing rate with γ, for all admissible values of γ.

Thus, when $\gamma > 0$ we are interested in calculating the minimum value of consumers' social preferences above which the follower is induced to adopt the green technology when the leader does so, even though in the absence of social preferences it would have chosen the brown technology, that is, when $\lambda_2 \Delta\theta < w$. To find this value of γ we solve (37) as an equality for γ, assuming $\lambda_2 \Delta\theta < w$. This yields two positive roots, the lower of which, denoted by $\widetilde{\gamma}$ is the lower bound above which the follower will follow the leader and adopt the green technology even in the case that its own environmental sensitivity is not high enough to outweigh the cost burden, i.e. when $\lambda_2 \Delta\theta < w$.

The derivation of this critical value of γ is illustrated in Figure 1. The Figure is drawn for the following set of parameter values: $\tau = 2.6$, $\gamma = \{0, 5\}$, $\Delta c = 5$, $\mu = 3$, $\theta_b = 2$, $\theta_g = 1$, $\Delta\theta = 1$, $\lambda_1 = 2$, $\lambda_2 = 1.5$, $\Delta\lambda = 0.5$. The green solid curve illustrates the left hand side of (37) as a function of γ, i.e. follower's benefit from adopting the green technology when consumers have social preferences. It increases in a decreasing rate as γ increases, reaching the value $\gamma < 2\tau - \frac{1}{2}(\tau + \rho - w) < 2\tau$, denoted by the vertical dotted line, which is a constraint on γ from (20), since above this value the leader's share of the market exceeds one. The dashed red line illustrates the right hand side of (37), i.e. the follower's net cost burden of adopting the green technology. Note that for $\gamma = 0$, the red line is above the green curve, $\lambda_2 \Delta\theta < w$, i.e. we assume that the follower will not adopt the green technology in the absence of social preferences. Their intersection defines the minimum value of γ above which the follower will choose the green technology for $w > 0$.

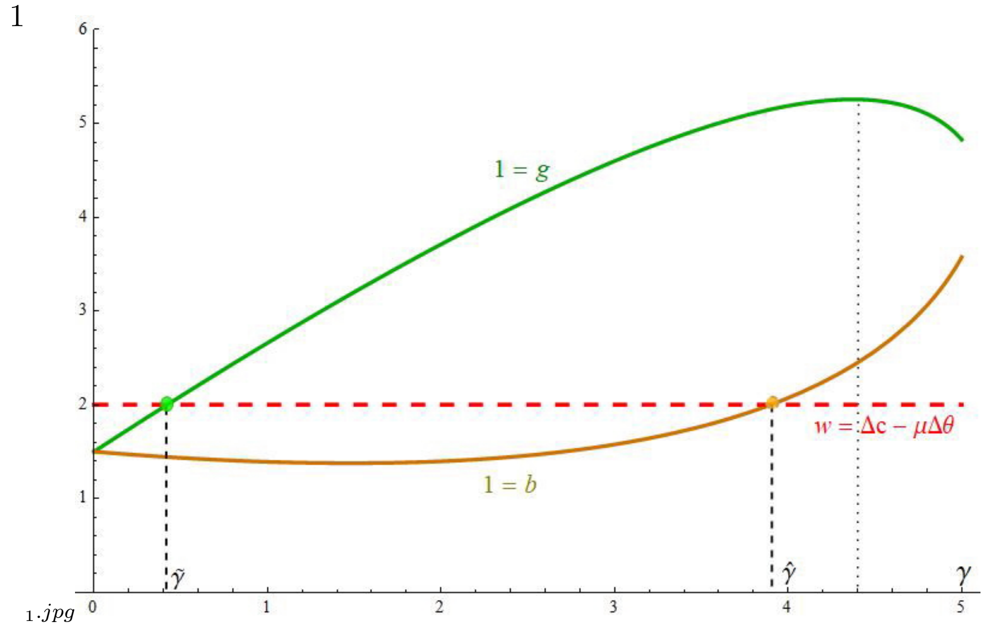

Figure 1: Follower's best responce to the leader's choice of technology as a function of consumers 'social preferences

It is clear that there is a range of γ values $2\tau - \frac{1}{2}(\tau + \rho - w) > \gamma > \widetilde{\gamma}$ for which the follower will follow the leader in adopting the green technology, while it will never adopt the new technology for lower social preferences. Therefore, there is a range of parameter values, technological c and θ, and behavioral μ and λ, for which the follower will not follow the leader in adopting the green technology if $\gamma = 0$, but it will do so if $\gamma > \widetilde{\gamma}$.

Assume now that the leader chooses the brown technology, i.e. $1 = b$, and we examine the choice of the follower. If firm 2 adopts also the brown technology, both firms will have the same cost and emissions rate, i.e., $c_1 = c_2 = c_b$, and $\theta_1 = \theta_2 = \theta_b$. If both firms choose the same product variant, as in the previous case, the follower's payoff is derived from (10),

$$\Pi_2^N\Big|_b^b = \frac{1}{2\tau}\left(\tau + \frac{(\lambda_1 - \lambda_2)\,\theta_b}{3}\right)^2,$$

while if it adopts the green technology, from (23), its payoff is,

$$\Pi_2^N\Big|_g^b = \frac{1}{(2\tau - \gamma)}\left(\tau + \frac{k_b - k_g + \mu\Delta\theta - \gamma}{3}\right)^2,$$

with $1 = b$ and $2 = g$. Therefore, firm 2 will choose the green variant if,

$$\Pi_2^N\Big|_g^b - \Pi_2^N\Big|_b^b > 0 \Longrightarrow \lambda_2\Delta\theta + \left[\left(1 - \sqrt{\frac{2\tau - \gamma}{2\tau}}\right)(3\tau + (\lambda_1 - \lambda_2)\,\theta_b) - \gamma\right] > w. \quad (38)$$

As in the case that the leader adopts the green technology, if there is no social pressure on consumers choosing the brown variant, i.e. $\gamma = 0$, the above condition simplifies to,

$$\left[\Pi_2^N\Big|_g^b - \Pi_2^N\Big|_b^b\right]_{\gamma=0} > 0 \Longrightarrow \lambda_2\Delta\theta > w.$$

For $\gamma > 0$, the second term in the left hand side of (38) is negative for low values of γ but for higher values of γ is positive and increasing in γ. The left hand side of (38) is illustrated by the brown curve in Figure 1. There is a value $\widehat{\gamma}$ above which the follower will adopt the green technology even if the leader chooses the brown technology. Thus, if the leader chooses the brown technology and $\lambda_2\Delta\theta > w$, the follower will choose the brown technology for $\gamma < \widehat{\gamma}$.

Summarizing the above discussion, the following Proposition defines follower's choice of technology under narrow preferences.

Proposition 3 ***Follower's choice under narrow preferences:***
(i) If $\lambda_2\Delta\theta > w$, the follower chooses the green technology regardless of the leader's choice and the level of consumers' social preferences.
(ii) If $\lambda_2\Delta\theta < w$, for $0 < \widetilde{\gamma} < \gamma < 2\tau - \frac{1}{2}(\tau + \rho - w)$, where $\widetilde{\gamma}$ is defined by (37), the follower will adopt the green technology when the leader also adopts the green technology. If the leader adopts the brown technology, the follower will also adopt the brown technology except for a small range of very high values of γ, $2\tau - \frac{1}{2}(\tau + \rho - w) > \gamma > \widetilde{\gamma}$.

When the follower's environmental sensitivity is high enough to outweigh the net cost burden, it will adopt the green technology regardless of the leader's choice in the first stage of the game. In the opposite case, the follower will always choose the brown technology, except if consumers' social preferences are significant enough to incentivize the follower to choose the green technology when the leader does so as well.

4.1.2 1st stage: leader's choice

If the leader anticipates that the follower will adopt the green technology (either if $\lambda_2\Delta\theta > w,$ or if $\lambda_2\Delta\theta < w,$ and $\gamma > \widetilde{\gamma}$), it will compare its payoff from the symmetric equilibrium, that is from (10),

$$\Pi_1^N\Big|_g^g = \frac{1}{2\tau}\left(\tau - \frac{(\lambda_1 - \lambda_2)\,\theta_g}{3}\right)^2,$$

to its payoff from the asymmetric equilibrium, that is from (24),

$$\Pi_1^N\Big|_g^b = \frac{1}{2\tau - \gamma}\left(\tau - \frac{k_b - k_g + \mu\Delta\theta + 2\gamma}{3}\right)^2,$$

with $1 = b$ and $2 = g$. Therefore, the leader, anticipating the follower's choice of the green variant, it will also choose the green variant if,

$$\Pi_1^N\Big|_g^g - \Pi_1^N\Big|_g^b > 0 \Longrightarrow \lambda_1\Delta\theta + \left[2\gamma - \left(1 - \sqrt{\frac{2\tau - \gamma}{2\tau}}\right)(3\tau - (\lambda_1 - \lambda_2)\,\theta_g)\right] > w. \tag{39}$$

Since $\lambda_1 > \lambda_2$, given that we assumed $\lambda_2\Delta\theta > w$, then $\lambda_1\Delta\theta > w$ and the leader will also choose the green technology.

Assume now that $\lambda_2\Delta\theta < w$, and the parameter values are such that (37) holds, which means that the follower will follow the leader if the leader adopts the green technology. The leader knowing this will adopt the green technology, in the first stage of the game, if (39) holds. However, if (37) holds then (39) also holds since $\lambda_1 > \lambda_2$ and the term $(\lambda_1 - \lambda_2)\,\theta_g$ enters the RHS of (39) with a negative sign. Therefore, if the leader anticipates that the follower will follow in adopting the green technology will always choose the green technology in the first stage.

Finally, assume that $\lambda_2\Delta\theta < w$, and the parameter values are such that (37) does not hold, which means that the follower will choose the brown technology regardless of the leader's choice in the first stage of the game. In such case, the leader will adopt the green technology if,

$$\Pi_1^N\big|_b^g - \Pi_1^N\big|_b^b > 0 \Longrightarrow \lambda_1\Delta\theta + \left[\left(1-\sqrt{\frac{2\tau-\gamma}{2\tau}}\right)(3\tau - (\lambda_1-\lambda_2)\,\theta_b) - \gamma\right] > w. \quad (40)$$

Since $\lambda_1 > \lambda_2$, there is a range of λ_1 values for which $\lambda_1\Delta\theta > w$ even when $\lambda_2\Delta\theta < w$. For such differences in λs the leader will definitely adopt the green technology knowing that the follower will keep the brown technology. For lower values of λ_1 for which $\lambda_1\Delta\theta < w$ the leader will also choose the brown technology since the right hand side of (44) is positive.

Figure 2 illustrates the two constraints in (39) and (44). The solid green curve depicts the left hand side of (39), the solid brown line the left hand side of (44) and the solid red line the right hand side of both. The dashed green and brown curves depict the left hand sides of the conditions of the follower's choice as illustrated in Figure 1. In drawing Figure 2, we use the same parameter values as in Figure 1. In any case that the follower will choose the green technology the leader will also choose the green technology. In the example illustrated in Figure 2, the leader will adopt the green technology for any $\gamma > \widetilde{\gamma}$ that anticipates that the follower will choose the green technology. For $\gamma < \widetilde{\gamma}$ the leader anticipating that the follower will not follow in adopting the green technology, it will choose the brown technology.

The following Proposition summarizes the above discussion and presents the equilibrium under narrow preferences.

Proposition 4 ***Equilibrium choices under narrow preferences:*** *Assuming that consumers' environmental preferences do not cover the net cost burden of adopting the green technology, that is,* $w > 0$*, then,*
(i) if neither firm is environmentally sensitive, $\lambda_1 = \lambda_2 = 0$*, and consumers do not have social preferences,* $\gamma = 0$*, then neither firm will adopt the green technology,*
(ii) if $\lambda_1 > \lambda_2 > 0$*, that is, we assume that the leader, firm* 1*, is more environmentally sensitive than the follower, then,*
(ii.a) if the leader anticipates that the follower will follow in adopting the green technology, it will adopt the green technology and thus, both firms will adopt the green technology at the equilibrium,
(ii.b) if the leader anticipates that the follower will not adopt the green technology, it

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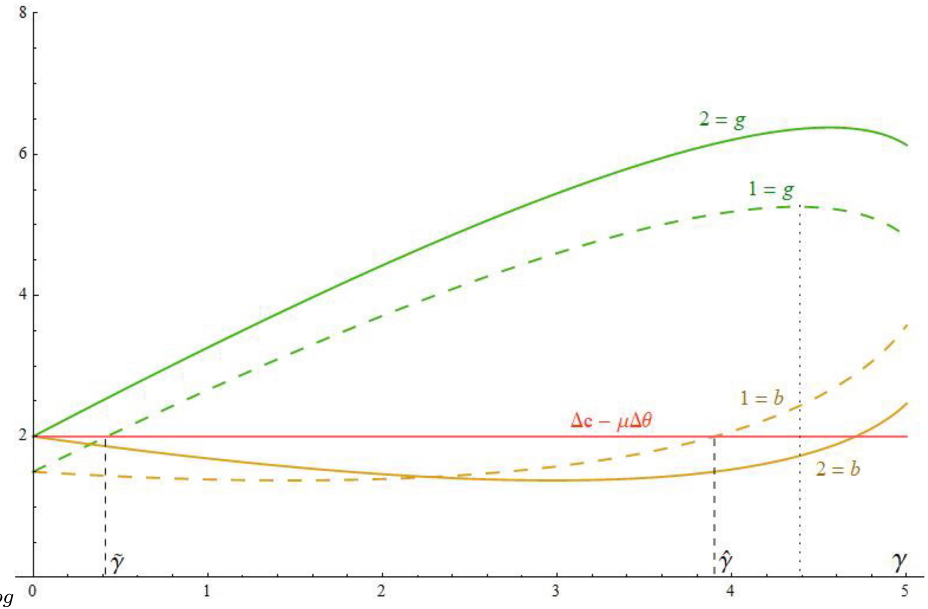

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Figure 2: Leader's choice of technology as a function of consumers' social preferences

will adopt the brown technology and the equilibrium will be with both firms adopting the brown technology.

Assuming that neither consumers' environmental preferences nor firms' environmental sensitivity can outweigh the cost burden of adopting the green technology, strong consumers' social preferences can induce strategic complementarity. The leader anticipating that the follower will choose the green technology if it adopts the green technology in order to avoid aggressive asymmetric network competition, it will adopt the green technology in the first stage

4.2 Broad firm preferences with $\mu > 0$ & $\gamma > 0$

4.2.1 2nd stage: follower's choice

Assume first that, in the first stage, the leader adopts the green technology, i.e. $1 = g$. If the follower adopts also the green technology, $c_1 = c_2 = c_g$, and $\theta_1 = \theta_2 = \theta_g$ and $\gamma = 0$. In this case, from (11), $\varkappa_1 - \varkappa_2 = 0$, and thus, from (15), the follower's payoff is,

$$\Pi_2^B\big|_g^g = \frac{\tau}{2} - \lambda_2\theta_g.$$

If the follower chooses the brown technology, from (34), its payoff is,

$$\Pi_2^B\Big|_b^g = \frac{1}{2\tau - \gamma}\left(\tau - \frac{\varkappa_b - \varkappa_g + \mu\Delta\theta + 2\gamma}{3}\right)^2 - \lambda_b\theta_g,$$

with $1 = g$ and $2 = b$. Therefore, firm 2 will choose the green product variant if,

$$\Pi_2^B\Big|_g^g > \Pi_2^B\Big|_b^g \Longrightarrow (\lambda_2 + \lambda_1)\,\Delta\theta + \left[2\gamma - 3\tau\left(1 - \sqrt{\frac{2\tau - \gamma}{2\tau}}\right)\right] > w. \tag{41}$$

For $\gamma = 0$, the right hand side of (41) becomes zero and thus,

$$\left[\Pi_2^B\Big|_g^g > \Pi_2^B\Big|_b^g\right]_{\gamma=0} \text{ if } (\lambda_2 + \lambda_1)\,\Delta\theta > w.$$

In the case of broad preferences both firms' environmental sensitivity contributes in offsetting the net cost burden of adopting the green technology. Thus, the adoption of the green technology is more likely under broad, relative to narrow preferences.

For $\gamma > 0$, the second term in the left hand side of (41) is positive for all admissible values of $\gamma < 2\tau$, and is increasing in γ. Furthermore, the second term in the left hand side of (41) is always higher than the same term in (37) since $\left(1 - \sqrt{\frac{2\tau-\gamma}{2\tau}}\right)(\lambda_1 - \lambda_2)\theta_g > 0$. Therefore, the follower will follow the leader in adopting the green technology for a larger range of values of γ relative to the case of narrow preferences.

If the leader chooses the brown variant, i.e. $1 = b$, and the follower also chooses the brown variant, the follower's payoff, derived from (15), is,

$$\Pi_2^B\Big|_b^b = \frac{\tau}{2} - \lambda_2\theta_b.$$

If the follower chooses the green variant, from (33), its payoff is,

$$\Pi_2^B\Big|_g^b = \frac{1}{2\tau - \gamma}\left(\tau + \frac{\varkappa_b - \varkappa_g + \mu\Delta\theta - \gamma}{3}\right)^2 - \lambda_g\theta_b,$$

with $1 = b$ and $2 = g$. Therefore, firm 2 will choose the green variant if,

$$\Pi_2^B\Big|_g^b - \Pi_2^B\Big|_b^b > 0 \Longrightarrow (\lambda_2 + \lambda_1)\,\Delta\theta + \left[3\tau\left(1 - \sqrt{\frac{2\tau - \gamma}{2\tau}}\right) - \gamma\right] > w. \tag{42}$$

For $\gamma = 0$, $\left[\Pi_2^B\big|_g^b - \Pi_2^B\big|_b^b\right]_{\gamma=0} > 0$ if $(\lambda_2 + \lambda_1)\Delta\theta > w$. For $\gamma > 0$, the second term of the left hand side of (42) is negative for low values of γ and then it becomes positive. Overall, the left hand side of (41) is always higher than the left hand side of (37). Thus, for the same parameter values, the follower will choose the green technology for a wider range of γ values relative to the narrow preferences.

Proposition 5 ***Follower's choice under broad firms' preferences:*** *In the second stage of the game, the follower's reaction to the leader's choice is to choose the green variant when the leader does so for a wider range of γ values relative to the narrow preferences, and when the leader chooses the brown technology to choose the green again for a wider range of γ values relative to the narrow preferences.*

4.2.2 1st stage: leader's choice

If the leader anticipates that the follower will adopt the green technology, it will compare its payoff from the symmetric equilibrium, that is from (15),

$$\Pi_1^B\big|_g^g = \frac{\tau}{2} - \lambda_1\theta_g,$$

to its payoff from the asymmetric equilibrium, that is from (34),

$$\Pi_1^B\big|_g^b = \frac{1}{2\tau - \gamma}\left(\tau - \frac{\varkappa_b - \varkappa_g + \mu\Delta\theta + 2\gamma}{3}\right)^2 - \lambda_b\theta_g,$$

with $1 = g$ and $2 = b$. From the above we derive the condition under which the leader, anticipating the follower's choice of the green technology, it chooses the green technology as well,

$$\Pi_1^B\big|_g^g - \Pi_1^B\big|_g^b > 0. \tag{43}$$

In a similar manner we obtain the condition under which the leader, anticipating the follower's choice of the brown technology, it chooses the green technology,

$$\Pi_1^B\big|_b^g - \Pi_1^B\big|_b^b > 0. \tag{44}$$

It can be shown mathematically and illustrated graphically that the leader adopts the green technology for any γ when it anticipates that the follower will choose the green technology. Given that the follower chooses the green technology for a wider range of γ values relative to the narrowly defined preferences, the following Proposition presents the equilibrium under broad preferences.

Proposition 6 ***Equilibrium choices under broad preferences:*** *Assuming that consumers' environmental preferences do not cover the net cost burden of adopting the green technology, that is, $w > 0$, then,*
(i) if neither firm is environmentally sensitive, $\lambda_1 = \lambda_2 = 0$, and consumers do not have social preferences, $\gamma = 0$, then neither firm will adopt the green technology,
(ii) if $\lambda_1 > \lambda_2 > 0$, that is, we assume that the leader, firm 1, is more environmentally sensitive than the follower, then,
(ii.a) if the leader anticipates that the follower will follow in adopting the green technology, it will adopt the green technology and thus, both firms will adopt the green technology at the equilibrium,
(ii.b) if the leader anticipates that the follower will not adopt the green technology, it will adopt the brown technology and the equilibrium will be with both firms adopting the brown technology.

5 Epilogue

This paper incorporates in a Hottelling model environmental preferences for both consumers and firms as well as consumer social preferences. We distinguish between broadly and narrowly defined firms' environmental objectives. Narrowly defined objectives tend to stifle competition and raise prices, whereas broader objectives, which consider factors like "leakage" and relative environmental performance, may lead to aggressive pricing strategies to gain market share. This dynamic extends to firms' technology choices, where leaders with broader environmental preferences can influence rivals to adopt low-emission technologies in a Stackelberg game scenario.

Similarly, consumer preferences play a crucial role, with social preferences intensifying price competition and driving firms to adopt environmentally friendly practices. Our results highlight empirical evidence suggesting a strategic complementarity in firms' adoption of green or CSR strategies, influenced by factors like managerial peer pressure.

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