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Product Sustainability and Consumer Environmental Awareness in Differentiated Markets

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Abstract Sustainable management of natural stock resources can be promoted through state intervention. This study investigates optimal regulatory strategies to mitigate the negative environmental effects of human activities within a duopolistic, differentiated linear market à la Hotelling framework. The analysis is conducted from both a business and a social perspective, aiming to elucidate the role of regulatory interventions, awareness campaigns, and sustainable production characteristics in shaping firm behavior and market outcomes. Under the business perspective, a game-theoretical approach is employed, involving the regulator and two competing firms. The equilibrium in prices and production characteristics is derived, revealing how firms respond to sustainable characteristics and awareness campaigns. In the social perspective, where the regulator has complete control, optimal strategies are determined to maximize social welfare, resulting in reduced differentiation and enhanced sustainability. This study identifies the optimal level of awareness campaign and sustainable characteristic proposed by the regulator. The findings highlight the significance of coordinated regulatory policies and awareness campaigns to induce firms toward more sustainable practices, ultimately contributing to a more ecologically balanced market. The study offers insights for policymakers and practitioners seeking effective strategies to

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address environmental concerns in differentiated markets, thereby promoting sustainable economic growth and reducing ecological impacts.

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Introduction

The foundation of sustainable development rests upon the prudent utilization and consumption of renewable natural resources (McCormick & Kautto, 2013). To propel such development, the United Nations called for a reassessment of consumption and production models in industrialized nations, aligned with the Paris Agreement and the Sustainable Development Goals (Organization for Economic Co-operation and Development, 2016). This forms the cornerstone of the bioeconomy (Georgescu-Roegen, 1977) achieved through the delicate balance between economic growth, social advancement, and environmental preservation. The bioeconomy encompasses the creation of novel products, services, and adoption of sustainable consumption and production patterns. When usage is responsible and consumption of these resources remains within limits, the possibility of natural regeneration persists.

The traditional means of environmental safeguarding (taxes or fines) encountered particular resistance in the business world due to the challenges of individually defining the resulting harm. In recent times, the promotion of consumer environmental awareness gained traction, as it plays a substantial role in the consumer decision-making processes. In this context, consumer environmental awareness held significant importance in the conduct of environmentally conscious consumers, to the extent that it was deemed as a pivotal challenge in steering individuals towards sustainability (Turaga et al., 2010). Over the medium and long term, the sustainability of consumer environmental awareness could be maintained through investments in education that incorporated environmental programs in schools, in infrastructure and services supporting renewable energies or green infrastructure, and within the industry, by championing circular processes.

However, urgent immediate action was warranted, despite environmental awareness campaigns being touted as highly successful short-term measures (He & Deng, 2020). Indeed, over the last decade, public authorities launched media campaigns to alert citizens to the detrimental impacts of poor consumption habits. Environmental awareness campaigns orchestrated by governmental bodies demonstrated their effectiveness in heightening public engagement, altering consumption preferences, and thwarting the production of ecologically harmful goods.

This study addresses the question of identifying optimal public policies to encourage suitable pro-environmental conduct among the populace, thereby replacing conventional command and control mechanisms. To illustrate such policies, an imperfect competition model of horizontal product differentiation is embraced.

The body of literature concerning environmental policies within the context of imperfect competition is extensive (for a comprehensive survey, refer to Lambertini, 2013;

Requate, 2006). Numerous studies have delved into the implications of environmental strategies within horizontally differentiated markets. To illustrate, utilizing the Hotelling model (1929), Eriksson (2004) investigated the extent to which consumer consideration of negative environmental externalities can supplant public intervention. The findings reveal that "green consumption would only have a modest influence" (Eriksson, 2004, p. 281). Conrad (2005) employed a variant of the Hotelling model in which each point along the production spectrum corresponded to a measure of environmental quality. He introduced an environmental factor into individual preferences to formalize the negative implications of not opting for the highest environmental quality product. The study demonstrated that equilibrium outcomes are not socially efficient.

Clemenz (2010) explored the impact of eco-labels on emission reduction in a market featuring horizontal product differentiation. The study revealed that the method of reduction has a discernible impact on the effectiveness and efficiency of eco-labels. Espínola-Arredondo and Zhao, (2012) undertook a linear analysis of a model city with two types of consumers, namely, green and neutral. They examined a scenario where the final products of two firms were symmetrical, except for their respective environmental impacts. In an efficiency comparison, they found that within the context of horizontal product differentiation, environmental regulation yielded greater social welfare than the absence of policies.

Governmental strategies have also been subject to analysis in relation to environmental awareness as an environmental policy. Van der Made and Schoonbeek (2009) undertook persuasive awareness campaigns that heighten consumer environmental concern. Sartzetakis et al. (2012) examined the role of information regarding environmental damage linked to the consumption of specific products within a dynamic framework. This information served as a policy instrument complementing environmental taxes. The model incorporated an advertising campaign that aids in reducing information asymmetry between the population and the business sector. Kaufman (2014) presented a dynamic learning model to assess the comparative effectiveness of financial incentives and informative advertising campaigns in encouraging environmentally conscious purchases. Mantovani et al. (2016) studied the strategic competition between an ecological company and a polluting competitor. Meanwhile, Mantovani and Vergari (2017) compared two policy instruments aimed at reducing carbon emissions. He and Deng (2020) applied the Hotelling model to ascertain how the social and environmental component of consumer environmental awareness affects pricing policies and differentiation strategies employed by firms.

In line with the posed question, the objective of this study is to analyze a governmental policy aimed at promoting sustainable goods production and determining the optimal solutions that facilitate its advancement. To achieve this goal, a regulated market with differentiated products and conscientious consumers within the linear city model of Hotelling (1929) was considered. The regulatory authority proposes a sustainable characteristic for production, supported by an awareness campaign. It is posited that the sustainable characteristic prompts consumers to regard the promoted attribute as a consumption benchmark and, accordingly, is integrated as an additional component within their preference structure. This assumption resembles the consumer preference framework in the research conducted by He and Deng (2020), where the reference attribute was societal. These researchers explored how price and feature competition among firms were influenced by consumer environmental awareness in the absence of public

environmental policies. With the incorporation of an environmental regulator in the current model, consumer preference structure becomes simultaneously determined by price, the degree of product differentiation, and the ecological harm perceived by consumers through consumer environmental awareness. Thus, the model's formalization expands into a multi-agent game, encompassing various agents, firms, and a planner.

The analysis is conducted from two perspectives: business and social. In both instances, the scope of consumer environmental awareness will be restricted by economic or ideological constraints, as no state possesses boundless economic resources, and not all ideologies are environmentally conscious.

The present study illustrates that, irrespective of the perspective, the regulator must execute the most comprehensive awareness campaign possible, while assigning weight to the sustainable characteristic. Nonetheless, in the context of the business standpoint, the authorities must possess a minimum capacity to carry out the necessary awareness campaign, aiming to instill in consumers an understanding of the environmental attributes of products, thus influencing their consumption choices. Employing this approach, the optimal characteristics of firms do not achieve social efficiency unless high consumer environmental awareness is present. In any scenario, state policies enable the promotion of responsible consumer behavior and sustainable production. This research demonstrates that preventive environmental policies have the potential to encourage conscientious consumption behavior and sustainable production, without incurring additional costs, thereby enhancing competition. Consequently, this is a valuable consideration in shaping environmental policies, either as a complement or a replacement for traditional mechanisms.

The Model

It is considered a duopolistic market differentiated *á la Hotelling*, in which an environmental authority proposes a sustainable production characteristic and is supported by an awareness campaign. This campaign advertises messages about the harm that can be caused by inappropriate behavior and suggests that each individual act accordingly. This concept is supported by the theory of moral motivation from Schwartz's norms (1970, 1977), revised by Turaga et al. (2010), according to which the activation of personal moral norms influenced environmental behavior. However, in this case, this activation is not interpreted as bad or good citizen conscience, but rather as a social fear perceived by the warnings of environmental damage (Conrad, 2005; Mantovani & Vergari, 2017; Mantovani et al., 2016).

The market is regulated and represented by an interval $I = [0, 1]$[1] where two firms are located, a continuum of uniformly distributed consumers and a social planner. Firms 1 and 2 are located in $x_1 \in [0, 1]$ and $x_2 \in [0, 1]$, respectively, such that $x_1 < x_2$[2]and they sell the good at price p_i and $i = 1, 2$. It is assumed that each consumer $x \in [0, 1]$ buys a single unit of the product bearing a transportation cost

[1] The interval I formalizes a range of authorized production characteristics.
[2] This order of the characteristics $x_1 < x_2$ does not mean that company 1 is less concerned about sustainability than company 2.

$T(x, x_i) = t(x - x_i)^2$, with $t > 0$ that measures consumer taste x by acquiring the good from the company x_i. Let $c \in [0, 1]$ be the sustainable characteristic of the regulator advertised and supported by an awareness campaign that warns of the damage generated by an unsustainable consumption pattern and is different from c.

Formally, it is assumed that consumers perceive and internalize campaign ads as a loss of environmental utility when acquiring a feature x_i other than c. This loss of utility is similar to an environmental cost whose representation is given by the following function, $\Gamma(x_i, c, \gamma) = \gamma(c - x_i)^2$, such that $\gamma \in \left[0, \overline{\gamma}\right]$ describes the intensity of the campaign level, and $\overline{\gamma}$ represents the threshold of maximum intensity, with $\overline{\gamma} \in [0, \infty[$. Taking into account the cost of transportation $T(x, x_i)$ and including the environmental cost $\Gamma(x_i, c, \gamma)$, the utility of consumer x when you buy feature x_i is given by: $u(x, x_i) = K - \left[p_i + T(x, x_i) + \Gamma(x_i, c, \gamma)\right]$, $i = 1, 2$ where K represents the income or surplus of each consumer, which is high enough to guarantee the purchase of the chosen good for all consumers.

The indifferent consumer $\hat{x}$ is obtained by equating the utility functions: $u(\hat{x}, \mathrm{x}_1) = u(\hat{x}, \mathrm{x}_2)$ and is formulated as:

$$\hat{x}\left[(p_1, p_2), (x_1, \mathrm{x}_2), (c, \gamma)\right] = \hat{x}_0 + \frac{\gamma}{2t}\left((x_2 + x_1) - 2c\right) \tag{1}$$

where $\hat{x}_0 = \frac{p_2 - p_1}{2t(x_2 - x_1)} + \frac{(x_2 + x_1)}{2}$, $t \neq 0$, is the indifferent consumer in the unregulated market ($\gamma = 0$) (D'Aspremont et al., 1979).

The indifferent consumer $\hat{x}$ depends not only on the locations and prices of the firms, but also on the environmental variables (c, γ). The demands of firms 1 and 2 are given by:

$$Q_1(p_1, p_2) = \begin{cases} 0 & if \quad \hat{x} \leq 0 \\ \hat{x} & if \quad 0 \leq \hat{x} \leq 1 \\ 1 & if \quad \hat{x} \geq 1 \end{cases}, \; Q_2(p_1, p_2) = \begin{cases} 0 & if \; \hat{x} \leq 0 \\ 1 - \hat{x} & if \; 0 \leq \hat{x} \leq 1 \\ 1 & if \; \hat{x} \geq 1 \end{cases}$$

where $0 \leq \hat{x}_C \leq 1$ is equivalent, in terms of prices, to:

$$(x_2 - x_1)[2\gamma c - (t + \gamma)(x_2 + x_1)] \leq p_2 - p_1 \leq (x_2 - x_1)[2(t + \gamma c) - (t + \gamma)\left(x_2 + x_1\right)].$$

Without loss of generality, production costs are assumed to be equal to zero such that the benefit of company i is expressed as

$$B_i = p_i Q_i. \tag{2}$$

Social welfare is equal to consumer surplus minus the total transportation cost and minus the total environmental cost. Its formulation is given by the following function:

$$W = K - (C_T + D_T) \tag{3}$$

such that the expressions of the total cost of choice C_T and the total environmental cost D_T correspond to:

$$C_T = \int_0^{\hat{x}} T(x, x_1)dx + \int_{\hat{x}}^1 T(x, x_2)dx \tag{4}$$

$$D_T = \int_0^{\hat{x}} \Gamma(c, x_1)dx + \int_{\hat{x}}^1 \Gamma(c, x_2)dx]. \tag{5}$$

The objective of the analysis of the model is to determine the optimal behavior of the regulator to activate the personal norms of consumers that induce them to engage in pro-environmental behavior and replace the traditional instruments of command and control. The objective will be addressed from two perspectives: business and social.

The solution in both cases is obtained by backward induction. Under the business approach, backward induction is formalized as a game in four stages, since there is interaction between the two firms in addition to the regulator. In the initial phase, the regulator chooses the characteristic c. In the second phase, he decides the level of awareness γ. In the third stage, the companies set their production characteristics (x_1, x_2). In the last stage, they choose the prices (p_1, p_2). From the social perspective, it is assumed that all decisions are made by the regulator. In this case, the following elements will be determined sequentially. The regulator first chooses the sustainable characteristic c, then the level of awareness γ, and finally, the production characteristics (x_1, x_2) of the firms. Proposition proofs are in the Online Supplemental Appendix.

Optimal Strategies From a Business Perspective

In the context of the business perspective, the model involves strategic interactions between three key agents: the regulator, firm 1, and firm 2. The regulator takes sequential actions by first selecting the sustainable production characteristic (c) and then determining the level of advertising (γ). Subsequently, the firms engage in decisions regarding their commercial characteristics (x_1, x_2) and then the prices (p_1, p_2).

Price Equilibrium

At this stage of the game, firms compete on prices. Each one maximizes its profit with respect *to* its price given the sustainable characteristic (c), the level of advertising (γ) of the regulator, the commercial characteristics x_1, x_2 and assuming the rival's price is fixed. Substituting $\hat{x}$ in expression (1) of Q_i and using expression (2), the profit function of each company is obtained:

$$B_1(p_1,p_2)=\begin{cases}0 & if \quad p_2-p_1\in I_1\\ p_1\left[\dfrac{p_2-p_1}{2tr}+\dfrac{(t+\gamma)(x_2+x_1)}{2t}-\dfrac{\gamma c}{t}\right] & if \quad p_2-p_1\in I_2,\\ p_1 & if \quad p_2-p_1\in I_3.\end{cases}$$

$$B_2(p_1,p_2)=\begin{cases}p_2 & if \quad p_2-p_1\in I_1,\\ p_2\left[\dfrac{p_1-p_2}{2t\ r}-\dfrac{(t+\gamma)(x_2+x_1)}{2t}+(1-\dfrac{\gamma c}{t})\right] & if \quad p_2-p_1\in I_2,\\ 0 & if \quad p_2-p_1\in I_3.\end{cases}$$

where the intervals I_1 and I_2 I_3 correspond to the variation (p_2-p_1) such that:

$I_1=\left[-\infty,(x_2-x_1)\left([2\gamma c-(t+\gamma)(x_2+x_1)\right)\right]$
$I_2=\left[(x_2-x_1)\left(2\gamma c-(t+\gamma)\left(x_2+x_1\right)\right),(x_2-x_1)\left(2(t+\gamma c)-(t+\gamma)\left(x_2+x_1\right)\right)\right]$
$I_3=\left[(x_2-x_1)\left(2(t+\gamma c)-(t+\gamma)\left(x_2+x_1\right)\right),+\infty\right]$.

Proposition 1 *For* $t>0,\gamma\in(0,\overline{\gamma}]c\in[0,1]$ *and* $x_1\in[0,1]$, $x_2\in[0,1]$ *there is an equilibrium in prices* (p_1^*,p_2^*), *if and only if* $\frac{2(\gamma c-t)}{(t+\gamma)}\le x_2+x_1\le\frac{2(2t+\gamma c)}{(t+\gamma)}$ *given by the expressions*:

$$\begin{aligned}p_1^E&=\frac{\left(x_2-x_1\right)}{3}\left[2(t-\gamma\ c)+(t+\gamma)\left(x_2+x_1\right)\right]\\ p_2^E&=\frac{\left(x_2-x_1\right)}{3}\left[2(2t+\gamma\ c)-(t+\gamma)\left(x_2+x_1\right)\right].\end{aligned}\tag{6}$$

Observations The Nash equilibrium in prices (p_1^E,p_1^E) does not exist for any value of (x_1,x_2), as shown in expression (6). Expressions of the demands D_1^E, are given by

$$D_1^E=\frac{1}{6t}\left[2(-\gamma c)+(t+\gamma)\left(x_2+x_1\right)\right],D_2^E=\frac{1}{6t}\left[2(2t+\gamma c)-(t+\gamma)\left(x_2+x_1\right)\right].$$

In the case in which $x_2+x_1=\frac{(t+2\gamma c)}{(t+\gamma)}$, both prices, as well as demands and bene. fits, are equal ($p_2^E=p_1^E$, $D_2^E=D_1^E$ and $B_2^E=B_1^E$). In the opposite case, a company will have an advantage over its rival depending on the value of c with respect to $(1/2)$. Next, the optimal characteristics of each company are determined.

Equilibrium in Business Characteristics

Taking into account equilibrium prices (p_1^E,p_1^E), the Nash equilibrium in business characteristics is examined. That is, the following problem will be solved:

$$(\mathcal{P}_1)\underset{x_1\in R}{Max}\ B_1^E\left(x_1,x_2\right)\underset{x_2\in\Re}{Max}\ B_2^E\left(x_1,x_2\right).$$

Lemma 1 *The solution of* $(\mathcal{P}_1)$ *is given by.*[3]

$$x_1^* = \frac{4\gamma c - t}{4(t+\gamma)}, \tag{7}$$

$$x_2^* = \frac{4\gamma c + 5t}{4(t+\gamma)}. \tag{8}$$

Observation The $(\mathcal{P}_1)$ is resolved assuming that x_1^* and x_2^* can be any real number. However, the equilibrium values (x_1^E, x_2^E) must be defined in $[0, 1]$, which requires some restrictions on t, c and γ. The only possibility of having a feasible equilibrium is given for the case in which:

$$Max\left\{\frac{t}{4(1-c)}, \frac{t}{4c}\right\} \leq \gamma. \tag{9}$$

The result is summarised as follows.

Proposition 2 *For* $t > 0$, $0 < c < 1$ *and* $Max\left\{\frac{t}{4c}, \frac{t}{4(1-c)}\right\} \leq \gamma \leq \overline{\gamma}$, *the Nash equilibrium in characteristics is given by* $(x_1^E = x_1^*,\ x_2^E = x_2^*)$, *where* x_1^* *and* x_2^* *are defined by* (7) *and* (8).

Observations The analysis verifies that the firms are located each on one side of the regulator $(x_1^E < c < x_2^E)$. A greater intensity of the level of the awareness campaign corresponding to $\gamma > \frac{t}{4c}$ if $0 < c \leq \frac{1}{2}$, or $\gamma > \frac{t}{4(1-c)}$ if $\frac{1}{2} < c \leq 1$, completely alters the equilibrium of the traditional market (without regulation) since $(x_1^E,\ x_2^E)$ is different from $(0,\ 1)$. The equilibrium locations (x_1^E, x_2^E) depend on γ and c. However, the differentiation between both firms $\left(x_2^E - x_1^E = (3t/2(t+\gamma))\right)$ depends only on the level of awareness γ and is decreasing so that the similarity between the two increases as γ increases. Here, the demands of the firms are equal and independent of γ and c, the prices are the same but depend only on γ. As γ increases, both prices and business profit decrease: $p_1^E = p_2^E = \frac{3t^2}{2(t+\gamma)}$ and $Q_1^E = Q_2^E = \frac{1}{2}$..

It can be seen that the equilibrium depends crucially on the ratio between the sustainable characteristic and the maximum sensitisation capacity exercised by the regulator, as well as on the parameter t, which is related to the consumer's cost of choice. Starting from the condition (9), it follows that the maximum sensitisation capacity must be greater than 1/2: $(\overline{\gamma} \geq \frac{t}{2})$.

[3] For $\gamma = 0$ y/o $c = 0$ (market without regulator), $x_1^* = \frac{-1}{4}$, $x_2^* = \frac{5}{4}$ is obtained. This solution is equal to the result obtained by Lambertini (1994); Tabuchi and Thisse (1995), when firms can locate themselves over the range $(-\infty, +\infty)$.

Optimal Level of the Awareness Campaign

For environmental policies based on increasing the consumer environmental awareness to have an effect, the authorities must have a minimum capacity to raise awareness. Therefore, it is essential to ascertain the optimal level. In this case, only the equilibrium is given by (x_1^E, x_2^E), assuming that $\overline{\gamma} \geq \frac{t}{2}$.

At this stage, the optimal level of sensitization $\gamma \in \left[\frac{t}{2}, \overline{\gamma}\right]$ will be determined. The social welfare function is computed W given by expression (3), calculating the total cost of transportation C_T and the total environmental damage D_T using expressions (4) and (5). The following is obtained:

$$W = K - \left\{ t(x_2 - x_1)(\widehat{x}) \left[-\left(x_2 - x_1\right)(t+\gamma) + 2\gamma c + t\widehat{x} \right] - tx_2(1-x_2) + \gamma(x_2 - c)^2 + \frac{t}{3} \right\}.$$

Substituting (x_1^E, x_2^E) by expressions (7) and (8) and the indifferent consumer $\widehat{x}$ for the value (1/2), the following expression of the social welfare function is obtained:

$$W(\gamma, c) = K + \frac{t}{16(t+\gamma)} \left[16\gamma\ c(1-c) + t\right] + \frac{t}{3}. \tag{10}$$

Using the necessary condition for the maximization of $W(\gamma, c)$ with respect to γ, it is found that the welfare function $W(\gamma, c)$ is increasing. The solution is presented in Proposition 5.

Proposition 3 *For any* $t > 0$, $0 < c < 1$, $\gamma \in \left[\frac{t}{2}, \overline{\gamma}\right]$ *and* $\overline{\gamma} \geq \frac{t}{2}$, *the optimal awareness campaign is reached for* $\gamma_E^O = \overline{\gamma}$.

Observations Regardless of the value of the characteristic c that is chosen, the regulator will choose to use all its capacity to raise awareness. In this way, firms are motivated to approach the sustainable characteristic c. The optimal production characteristic of firm 1 x_1^E is less than c and increasing, $\left(0 \leq x_1^E < c, \frac{\partial x_1^E}{\partial \gamma} > 0\right)$, although for firm 2, this optimal characteristic x_2^E is greater than c $\left(0 \leq x_2^E < c, \ \frac{\partial x_2^E}{\partial \gamma} < 0\right)$. The expression of both is $x_1^{E3} = \frac{4\overline{\gamma}c - t}{4(t+\overline{\gamma})}$, $x_2^E = \frac{4\overline{\gamma}c + 5t}{4(t+\overline{\gamma})}$. Therefore, firms can theoretically be forced to have an optimal sustainable production when the awareness campaign $\overline{\gamma}$ is very high with respect to the cost of transport of consumer t, since. $\underset{\overline{\gamma}\to\infty}{Lim}\ x_1^E = \underset{\overline{\gamma}\to\infty}{Lim}\ x_2^E = c$.

Optimal Sustainability Characteristic Proposed by the Regulator

Considering the previous results, the regulator identifies the optimal sustainable production. Thus, substituting γ by $\overline{\gamma}$ in expression (10), the social welfare function is formulated:

$$W(c) = K + \frac{t}{16\left(t+\overline{\gamma}\right)}\left[16\overline{\gamma}\ c(1-c) + t\right] + \frac{t}{3}.$$

Using the first-order condition, the result of Proposition 4 is obtained.

Proposition 4 *For any* $t > 0$, $\overline{\gamma} > \frac{t}{2}$, *the optimal characteristic of the regulator is given by* $c_E^O = \frac{1}{2}$.

Observations Given the optimal sustainability characteristic $c_E^O = (1/2)$ and the optimal level of sensitization $\gamma_E^O = \overline{\gamma}$, the optimal strategies of the firms are given by the following expressions: $x_2^E = \frac{2\overline{\gamma} - t}{4(t+\overline{\gamma})}$, $x_2^E = \frac{2\overline{\gamma} + 5t}{4(t+\overline{\gamma})}$, $p_1^E = p_2^E = \frac{3t^2}{2(t+\overline{\gamma})}$. The companies are located symmetrically with respect to the extremes, as well as to $c_E^O = (1/2)$. Demand and benefits are equal for both firms $D_1^E = D_2^E = \frac{1}{2}$, $B_1^E = B_2^E = \frac{3t^2}{2(t+\overline{\gamma})}$.

The optimal sustainable characteristic c_E^O is located in a midpoint of the market, which is what is usually proposed in a real market. Despite choosing a certain characteristic of optimal sustainability, what truly drives a change in the attitude of the firms is the awareness capacity that the authorities want to offer. Recall that if the regulator chooses a minimum level of $\overline{\gamma} = \frac{t}{2}$, the policy will have no effect in terms of sustainability since the strategies followed by firms will be similar to those of a market without regulation ($x_1^E = 0,\ x_2^E = 1$) and $p_1^E = p_2^E = t$. The level of campaign carried out has to do with the financial capacity of the authorities and their political priorities regarding the improvement of sustainability. In any case, these actions will have a positive collateral effect for consumers: as $\overline{\gamma}$ increases, prices decrease (p_1^E, p_2^E) and the differentiation between products is $(x_2^E - x_1^E)$.

Optimal Strategies from a Social Perspective

Previously, it has been seen, from a business perspective, how the production characteristic differs from the characteristic c chosen by the regulator. Therefore, it is necessary to address this problem from a social perspective assuming a total intervention of the authority. Assuming that firms offer their products at the same price, the regulator sequentially chooses the optimal sustainable characteristic c, the optimal awareness campaign γ and, finally, the optimal characteristics of the companies (x_1^S, x_2^S).

Optimal Characteristics of the Firms

Assuming that the prices are the same for both firms $p_1 = p_2$, market shares are defined by the same indifferent consumer given by (1) adapted to the current context, the expression is.
$\widehat{x}^S = \frac{(t+\gamma)\ (x_2+x_1)}{2t} - \frac{\gamma c}{t}$. Thus, the condition $0 \leq \widehat{x}^S \leq 1$ corresponds to $\frac{2\gamma c}{(t+\gamma)} \leq (x_2 + x_1) \leq \frac{2\gamma c + 2t}{(t+\gamma)}$.

The objective function of the regulator is the welfare function given by expression (3). The following proposition describes the optimal choice of business characteristics.

Proposition 5 *For any* $t > 0$, $\gamma \in [0, \overline{\gamma}]$ *and* $0 < c < 1$, *there are unique optimal characteristics* $x_1^S \in [0, 1]$ *and* $x_2^S \in [0, 1]$, *whose expressions are given by*.

$$x_1^S = \frac{4\gamma c + t}{4(t + \gamma)}, \tag{11}$$

$$x_2^S = \frac{4\gamma c + 3t}{4(t + \gamma)}. \tag{12}$$

Observations The market is equally distributed $Q_1^S = Q_2^S = (1/2)$. Comparing the optimal characteristics with those of the business approach, it is verified that they are closer to $c(x_1^E \leq x_1^S)$ and $(x_2^S \leq x_2^E)$.[4] Differentiation is reduced $(x_2^S - x_1^S) = t/2(t + \gamma)$, increasing the sustainability of the system with respect to the private approach. Optimal characteristics are unique. The impact on sustainability is independent of the maximum awareness campaign $\overline{\gamma}$ and has no restrictions on γ. In this case, the ideological bias of the regulator, the will and priority given to environmental policies, are what will influence and define the actions of firms.

Substituting (x_1^S, x_2^S) by its expressions (11) and (12) and the indifferent consumer is given by $\widehat{x}^S = (1/2)$, social welfare is:

$$W(\gamma, c) = K + \frac{t}{16(t + \gamma)}[16\ \gamma\, c(1 - c) + 5t] + \frac{t}{3}. \tag{13}$$

Optimal Level of Sensitization

Knowing the preferences of the commercial characteristics (x_1^S, x_2^S) of the regulator, the optimal level of sensitization will be determined. Using the necessary condition for the maximization of $W(\gamma, c)$ given by (13) with respect to γ, it is found that the welfare function $W(\gamma, c)$ is increasing as in the private approach, so the solution is similar.

Proposition 6 *Given the optimal characteristics* (x_1^S, x_2^S) *and for any* $t > 0$, $\gamma \in [0, \overline{\gamma}]$ *and* $0 < c < 1$, *the optimal level of awareness is given by* $\gamma_S^O = \overline{\gamma}$.

Observations As in Proposition 3, the regulator must use all its capacity to raise awareness, since the optimum is reached at the upper limit of the campaign

[4] $x_1^S - x_1^E = \frac{2t}{4(t+\overline{\gamma})} > 0, x_2^S - x_2^E = \frac{-2t}{4(t+\overline{\gamma})} < 0$

regardless of the sustainable characteristic$c$. As mentioned above, a minimum level is not required for the upper limit of the level of awareness $\overline{\gamma}$. The optimal characteristics are formulated as $x_1^S = \frac{4\overline{\gamma}c+t}{4(t+\overline{\gamma})}$ and $x_2^S = \frac{4\overline{\gamma}c+3t}{4(t+\overline{\gamma})}$. As in the private approach, for very large $\overline{\gamma}$ with respect to t, the firms would produce sustainable characteristics since $\underset{\overline{\gamma}\to\infty}{Lim}\, x_1^S = \underset{\overline{\gamma}\to\infty}{Lim}\, x_2^S = c$.

Optimal Characteristics

Once the optimal strategies are known in terms of commercial characteristics, such as the level of advertising set by the regulator, the optimal sustainable production will be determined. Substituting γ by $\overline{\gamma}$ in expression (13), the social welfare function is formulated as $W(c) = K + \frac{t}{16(t+\overline{\gamma})}\left[16\overline{\gamma}c(1-c) + 5t\right] + \frac{t}{3}$. The result is determined in Proposition 7.

Proposition 7 *Given the optimal characteristics* (x_1^S, x_2^S), $\gamma_S^O = \overline{\gamma}$ *and for any* $t > 0$, *the optimal sustainable characteristic of the regulator is given by* $c_S^O = \frac{1}{2}$.

Observations Substituting c_S^O in the previous results, market equilibrium is characterized by:

$$c_S^O = \left(\frac{1}{2}\right), \gamma_S^O = \overline{\gamma}, x_1^S = \frac{2\overline{\gamma}+t}{4(t+\overline{\gamma})}, \text{and } x_2^S = \frac{2\overline{\gamma}+t}{4(t+\overline{\gamma})}$$

Similar to the private perspective, here, the regulator opts for an optimal sustainable characteristic equilibrium in the sense chosen by the midpoint of the market. It follows that, for very large $\overline{\gamma}$ with respect to t, firms will be able to produce sustainable characteristics since $\underset{\overline{\gamma}\to\infty}{Lim}\, x_1^S = \underset{\overline{\gamma}\to\infty}{Lim}\, x_2^S = \frac{1}{2}$.

As an example, assuming $t = \overline{\gamma} = 1$, that is, when the maximum parameter of sensitization $\overline{\gamma}$ equals the parameter t of intensity of taste of the characteristics, the results according to the different approaches will be:

- Private focus $\Rightarrow c_E^O = (1/2), \gamma_E^o = 1, x_1^E = \frac{1}{8}, x_2^E = \frac{7}{8}$, and
- Social focus $\Rightarrow c_S^O = (1/2), \gamma_S^o = 1, x_1^S = \frac{3}{8}, x_2^S = \frac{5}{8}$.

In both cases, the environmental situation improves significantly compared to an unregulated market ($c = \gamma = 0, x_1{}^{NR} = 0, x_2^{NR} = 1$) in which firms are at the extremes of differentiation, that is, there will be one company that does not adhere to sustainable resource management criteria while the other will show the utmost diligence in this regard. In the regulated market with a private focus, leaving the choice of sustainable characteristics to the companies, there is less evidence of their involvement. If one wants to maximize the sustainable management of natural stock resources, a

social approach is necessary since the sustainability of production improves substantially in addition to the firms approaching their positions of commercial action.

Conclusions

Reducing the adverse environmental impacts of human activities increasingly necessitates government intervention. In this context, awareness campaigns significantly enhance, thereby influencing both their consumption behavior and that of companies. Purchasing decisions wield significant influence over what is produced, consequently shaping market shares and outcomes for firms. This research seeks to elucidate this matter by formulating a regulated market of diverse products within a linear framework, where consumers are attuned to the environmental attributes of goods.

The analysis is approached from two standpoints: the business perspective and the social perspective. In the former scenario, the regulatory body initially establishes the sustainable characteristic and subsequently determines the level of accompanying awareness. Subsequently, companies vie based on features and pricing. Conversely, in the latter approach, decision-making rests solely with the regulator, who sequentially selects the sustainable characteristic, followed by the awareness level, and subsequently the production and pricing attributes of companies. The objective is to discern optimal regulatory policies and their impact on the sustainability of product traits and, where applicable, on price competition. In both instances, it is demonstrated that preemptive regulatory measures can steer companies towards adopting the production guidelines stipulated by the environmental authority.

In terms of sustainability, the outcomes prove more efficacious when corporate management is public. In contrast, under private corporate governance, the regulator's optimal decision rests on determining a sustainable production characteristic, coupled with policies to amplify consumer environmental awareness via campaigns that attain widespread awareness. This compels private companies to reduce differentiation attributes, drawing them closer to regulatory indications. The well-known outcome of maximum business differentiation is disrupted, resulting in a beneficial outcome for consumers by reducing prices. However, this outcome hinges on the authority having a minimum capacity to sensitize the populace. Without this, advancing sustainability would remain unattainable. Herein, prioritizing the authority's role becomes imperative, as achieving free-market environmental regulation sans a clear pro-environment politically will proves challenging.

From a social perspective, wherein the regulator determines production, sustainability and awareness results are similar to those of the initial approach. However, disparities arise in determining optimal product characteristics. Unlike the analysis from a free-market standpoint, executing environmental policies does not necessitate the regulator possessing a minimum capacity to disseminate awareness campaigns. Decisions are contingent solely upon the political will of state authorities, although the extent of sustainability improvement hinges on the maximum attainable awareness threshold.

Considering the results, entrusting production decisions to state authorities seems more prudent, introducing an extra dimension to the longstanding debate regarding permissive (private production decision) versus restrictive (state production decision) policies. Beyond economic considerations, the policy tools scrutinized (sustainable characteristics and awareness campaigns to enhance consumer environmental awareness) are complementary. Should the authority promote awareness to inform consumers about the perils of unsustainable product acquisition, suggesting or imposing sustainable production traits would yield no tangible effects, and vice versa.

Throughout this study, ideal conditions were assumed: Production costs for companies are uniform and negligible, consumers possess a specific consumer environmental awareness and are accountable for their actions, and the authority refrains from imposing fines. An expansion of the model to elucidate regulator behavior could entail contemplating diverse production costs for companies. Furthermore, other intervention mechanisms like fines or subsidies could be introduced, given that taxes or subsidies incentivize the reduction of pollution in the production of green and non-green goods.

Considering the growing recognition among environmental authorities of the necessity for coordinated efforts to establish a sustainable production system, integrating awareness campaigns with taxes or subsidies within the same model is advisable. This would enable quantifying the degree of complementarity between both instruments. Another intriguing avenue of exploration would involve assessing the impact of awareness campaigns on only a subset of consumers, given that achieving awareness among all consumers is a complex task with unpredictable outcomes. Additionally, the model's purpose, along with the proposed extensions, could be analyzed within markets characterized by vertical differentiation, in contexts featuring price discrimination, or within settings of quantity-based competition. This article contributes to the field of environmental economics and industrial management by furnishing a framework for investigating the required levels of awareness campaigns to be conducted by regulators and their role in shaping the spatial distribution of companies.

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