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Informing the Uninformed, Sensitizing the Informed: The Two Sides of Consumer Environmental Awareness

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Abstract

How do environmental information and awareness interact to improve environmental quality by changing consumer behavior and firm strategies? This article provides theoretical insights using an original differentiation model within a general framework whose specific cases have been studied previously. On the demand side, only informed consumers differentiate brown from green product quality, while uninformed consumers consider these perfect substitutes. Moreover, all informed consumers value the green product and devalue the brown product as a result of an aversion effect but are heterogeneous in their environmental awareness. On the supply side, two firms offer different environmental qualities and compete on price. We consider two types of environmental campaigns: one that increases the number of informed consumers and one that increases the environmental awareness of informed consumers. We show that these campaigns crucially determine three market configurations: segmented; fragmented, with a brown product that appeals to both uninformed consumers and a fraction of informed consumers; and covered. Assuming that the greenest consumer behavior is abstention, we find that both campaigns do not always lead to better environmental quality; that is, a situation in which all consumers are informed and some highly environmentally aware is not necessarily the greenest situation. Depending on the aversion effect, the budget of the campaign organizer, and their relative cost-effectiveness, information and awareness-raising campaigns must be carefully combined to achieve the best possible environmental quality.

JEL-Codes: D110, D620, D830, L150, Q580.

Keywords: information campaign, NGO campaign, environmental awareness, environmental quality, vertical product differentiation.

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1 Introduction

How can consumers become aware of the environmental characteristics of products when they have little or no information about the environmental impact of their consumption? Most consumers are unfamiliar with the environmental impacts of food products and therefore are unable to identify environmentally friendly food products ([Hartmann, Lazzarini, Funk, & Siegrist, 2021](#)). Many are also unfamiliar with ecolabels, which are designed to inform them about the environmental performance of products in different areas. In Europe, for example, only 38% of consumers report having seen or heard of the European Union Ecolabel, 41% incorrectly believe it is awarded to organic food and beverage products, and 33% claim not to know whether they have bought products with an ecolabel or not. In contrast, 73% consider the environmental impact of a product important when making a purchase decision ([European Commission, 2023](#)). This study aims to gain theoretical insights into the role of consumers' knowledge and awareness of the environmental harmfulness of products in their consumption choices between green and brown products and the resultant implications for firms' strategies, market equilibrium, and environment.

The extensive socio-psychological and marketing literature¹ on pro-environmental behavior, such as the purchase of environmentally friendly products, indicates that such behavior is favored by consumers with environmental knowledge and awareness. The starting point of this literature is the observation of a gap between environmental attitudes and behavior ([Stern, 2000](#), [Vermeir & Verbeke, 2006](#)). Although measures for environmental concern are becoming more sophisticated with multiple underlying constructs ([Dunlap, 2016](#)), their relationship to sustainable consumption behavior is still complex ([Saari, Damberg, Frömbing, & Ringle, 2021](#)). Product characteristics, such as price, quality, and convenience, and socio-economic characteristics of consumers, such as age, education, and income, help explain why environmental concern does not always translate into pro-environmental behavior ([Diamantopoulos, Schlegelmilch, Sinkovics, & Bohlen, 2003](#); [Joshi & Rahman, 2015](#); [Meyer, 2015](#)). Environmental values and knowledge are significant factors in the relationship between environmental attitudes toward purchasing green products and actual green purchasing behavior. [Vermeir and Verbeke \(2006, 2008\)](#) show that young Belgians' information and knowledge about environmental issues related to food products

¹Despite the rich literature on this subject, we cite only a few articles, focusing on literature reviews and empirical studies using European survey data, especially variables related to consumers' environmental knowledge.

support the transformation of positive attitudes toward sustainable products into behavioral intentions to purchase such products, along with personal values and social norms, perceived consumer effectiveness in solving environmental problems, and perceived availability of green products. Using a large European survey dataset, [Golob and Kronegger \(2019\)](#) and [Saari et al. \(2021\)](#) also show the essential role of environmental knowledge and awareness. [Golob and Kronegger \(2019\)](#) demonstrate that Europeans’ pro-environmental behavior is strongly influenced by their sense of personal responsibility and willingness to pay (WTP) for environmentally friendly products, which in turn are strongly influenced by the perceived importance of environmental issues and only weakly influenced by their level of information about environmental issues (which is also weakly influenced by the perceived importance of environmental issues). [Saari et al. \(2021\)](#) prove that Europeans’ environmental risk perception and environmental knowledge are contingent on their environmental concerns and that all three factors promote sustainable consumption behavior. Consumers’ environmental knowledge and awareness are even more critical when purchasing ecolabeled products, as such pro-environmental behavior also requires consumer understanding and trust in ecolabels ([Taufique, Siwar, Talib, Sarah, & Chamhuri, 2014](#)). [Grunert, Hieke, and Wills \(2014\)](#) show that Europeans’ use of information on four sustainable labels is tied to both high environmental concern and a good understanding of the concept of sustainability and sustainable labels, which in turn depend on socio-economic characteristics and personal values. More recently, [Vázquez, Lanero, García, and Morano \(2023\)](#) show that, when faced with 28 sustainability labels on various common household products, nearly half of Spanish consumers have difficulty recognizing the labels, have neutral or negative attitudes toward them, and therefore are unlikely to purchase labeled products. As a result, to avoid buying environmentally harmful products, consumers must have objective information about their harmfulness and also be sufficiently aware of the environmental issues they raise. In this research, we model objective information and subjective awareness-raising as two different tools for increasing consumers’ environmental consciousness to investigate their complementary nature, their effects on consumer behavior and firm strategies, and components of welfare, including environmental quality.

Advertising literature makes a clear distinction between information and awareness. [Bagwell \(2007\)](#) distinguishes between informative advertising, which aims to educate consumers, and per-

suasive advertising, which aims to change consumers' tastes. While the purpose of persuasive advertising is usually to "*create spurious product differentiation and brand loyalty*" (Bagwell, 2007), which would reflect "greenwashing" when applied to the environmental characteristics of products (Delmas & Burbano, 2011; Lyon & Maxwell, 2011; Lyon & Montgomery, 2015), environmental non-governmental organizations (NGOs) can also use such advertising to raise consumer awareness of environmental issues (Heijnen & Schoonbeek, 2008; Van der Made & Schoonbeek, 2009). Because environmental characteristics of products are credence attributes, informative advertising also helps signal them to consumers (Feddersen & Gilligan, 2001; Heijnen, 2013). Thus, the informational and persuasive effects of environmental campaigns are difficult to distinguish because consumers' environmental information and environmental preferences are so closely linked. However, according to Glaeser (2014), when environmental campaigns aim only to provide information, "*given the modest levels of altruism [observed] elsewhere in human life, these campaigns would [likely] have only a modest impact on behavior*, while when they aim to alter preferences by increasing altruism, "*they would also probably do little good*." In other words, environmental information and awareness-raising campaigns should be complementary and their effectiveness in greening consumption mutually reinforcing.

These two modes of action on consumer behavior have so far been considered separately in the literature. By demonstrating the role of an activist's information about the quality of credence goods in enabling the best quality to be marketed, Feddersen and Gilligan (2001) paved the way for a first series of works examining the effect of information about the quality of the products offered on the market. In a dynamic setting in which uninformed consumers coexist with an increasing proportion of identical consumers informed about the respective health damage caused by products differentiated by their level of environmental quality, Sartzetakis, Xepapadeas, and Petrakis (2012) show that information provision can green the market and improve welfare up to a steady state. Counterintuitively, when consumers are heterogeneous in their WTP for the environmental quality of products offered by a duopoly, consumer information is not systematically beneficial to overall environmental quality and social welfare, though it does promote differentiation and the creation of a market for green products. Heijnen (2013) finds, for example, that the threat of informative advertising by an environmental group only about the most harmful product in a set increases firm profit and consumer surplus, but with ambiguous wel-

fare effects. In a similar setting, but with information acquisition costly for consumers, [Heyes, Kapur, Kennedy, Martin, and Maxwell \(2020\)](#) show that constraining information availability can sometimes benefit market outcomes but also damage the environmental outcome. [Brécard and Chiroleu-Assouline \(2024\)](#) find that increasing the proportion of informed heterogeneous consumers who devalue a brown product and value a green product as a result of an aversion effect does not always lead to environmental improvement, nor does the introduction of a product of intermediate environmental quality guarantee it. [Buehler and Schuett \(2014\)](#) consider experience, rather than credence, goods differentiated by quality level, for which consumers have heterogeneous WTP. They assume that only a fixed proportion of consumers are informed about product quality and show that firms are willing to meet high-quality standards only when the informed fraction is small.

The equally ambiguous effects of persuasive advertising, which aims to shape the preferences of consumers who are assumed to be fully informed, are the subject of another strand of literature. For example, [Heijnen and Schoonbeek \(2008\)](#) show that the threat of an environmental group launching a campaign to increase consumers' environmental awareness and WTP for the environmental quality of a product leads a monopolist to adopt cleaner production techniques, but only enough to deter activists from taking action. [Van der Made and Schoonbeek \(2009\)](#) consider a campaign that increases awareness of the difference in environmental quality between two products. While the campaign helped a greener company enter the market and attract consumers to the greener product, it did not improve the environmental quality of the market. [García-Gallego and Georgantzís \(2010\)](#) show that in a covered duopoly market, increasing consumer heterogeneity in terms of WTP for greener products benefits firms, but private interests and the environment are only aligned when consumers are initially highly heterogeneous. This reflects a special case of the model [García-Gallego and Georgantzís \(2009\)](#) developed, which starts from a monopoly market and then transforms to a duopoly by the entry of a more environmentally friendly competitor, due to the increased average environmental sensitivity of consumers. In this case, reducing or maintaining heterogeneity improves both environmental and social welfare, but increasing heterogeneity is welfare reducing.

Using an encompassing differentiation model, we investigate the respective roles of environmental information and awareness in diverting consumers from a brown product and thereby im-

proving environmental quality. Our model incorporates the classic vertical differentiation model in which, on the supply side, two firms offering a product differentiated by its environmental quality compete on price. On the demand side, in line with [Brécard and Chiroleu-Assouline \(2024\)](#), we distinguish between informed and uninformed consumers and assume that only informed consumers are more or less environmentally aware. More specifically, we assume that only informed consumers differentiate between the brown and green quality of the product while uninformed consumers view them as perfect substitutes. Moreover, all informed consumers devalue the brown product and value the green product as a result of an aversion effect but are heterogeneous in their environmental awareness. Our model is unique in that it considers two types of environmental campaigns: one that increases the number of informed consumers and one that increases the environmental awareness of informed consumers. We examine how these campaigns affect environmental quality, assuming that the greenest consumer behavior is abstention.

With this original framework, we provide three new insights into the interaction between environmental information and awareness to guide consumers toward greener consumption behaviors. First, information and awareness-raising campaigns crucially determine the market configuration: it is either segmented between the segment of uninformed consumers who buy the brown product and the segment of informed consumers who buy the green product or nothing; or fragmented with a brown product that appeals to both uninformed and a fraction of informed consumers and the green product which is purchased by the most informed and environmentally aware consumers; or covered, with all consumers buying the brown or the green product. Second, in some market configurations, the campaigns have opposite effects on consumption of the brown product: one dissuades consumers from the brown product, while the other makes the brown product more attractive. Third, both campaigns do not always work in favor of higher environmental quality, so a situation in which all consumers are informed and highly environmentally aware is not necessarily the greenest situation. Thus, depending on the aversion effect, the relative cost-effectiveness of the campaigns, and the budget of the environmental NGO, information and awareness-raising campaigns must be carefully combined to achieve the highest possible environmental quality.

The remainder of the paper proceeds as follows. [Section 2](#) presents the model. [Section 3](#)

analyzes the Nash equilibrium in different situations of market configurations. Section 4 details how the share of informed consumers and the level of their environmental awareness affect their behavior and firm strategies. Section 5 reports on the optimal information and awareness-raising campaigns for environmental quality. Section 6 examines welfare implications of information and awareness-raising campaigns. Section 7 contextualizes the existing literature in the framework of our model, and Section 8 concludes.

2 The model

We propose a game consisting of three stages. In the first stage, two firms offer two environmental qualities of a good: a “brown” product with a harmful effect on environmental quality and a “green” product with a reduced or even zero effect on environmental quality. Such vertical differentiation allows firms to avoid price wars and earn profits. Only a small fraction of consumers are informed about the different environmental impacts of the two products; however, they are heterogeneous in their environmental awareness. The remaining consumers are uninformed and therefore unaware of the environmental qualities, so they consider the two products perfectly substitutable. In the second stage, an environmental NGO issues both an information campaign, which increases the fraction of informed consumers, and an awareness-raising campaign, which increases the environmental consciousness of these consumers. In the third stage, firms compete on price, and consumers decide to buy one unit of the brown product, one unit of the green product, or neither. The game thus involves three players: consumers, firms, and the campaign organizer.

2.1 Consumers

The first central assumption of the model is that only a fraction $\alpha(x)$ of consumers are informed about the different harmfulness of products i , while $1 - \alpha(x)$ of consumers are uninformed about the environmental impact of their consumption; an information campaign can increase the fraction of informed consumers through an information disclosure effort $x \geq 0$, with $\alpha(0) > 0$, $\alpha'(x) > 0$, $\alpha''(x) < 0$, and $\alpha(x) \in]0, 1]$ (see Section 2.3). The uninformed consumers do not care about the environmental quality of the product, which is therefore qualified as “neutral” and denoted $q_0 \geq 0$. Informed consumers care more or less about the environmental qualities, that

is, q_B for the brown product and q_G for the green product, where $q_B < q_0 < q_G$. Not consuming provides zero utility. To simplify the notation, we identify the increment of the environmental quality as $e_i \equiv q_i - q_0$, with $e_B < 0$ and $e_G > 0$. In other words, the informed consumers devalue the brown product, as a result of an aversion effect, and value the green product. These informed consumers are characterized as in the standard vertical differentiation model of [Mussa and Rosen \(1978\)](#) who define WTP for environmental quality as θq_i , where θ is initially assumed to be uniformly distributed over $[0, \bar{\theta}]$, with a distribution density of $1/\bar{\theta}$. The assumption that the lowest WTP for environmental quality is zero provides continuity between uninformed and informed consumers. Furthermore, all consumers, informed or not, buy one unit or none of the good.

The second central assumption of the model is that an awareness-raising campaign can further increase informed consumers' WTP for environmental quality. Their WTP is then defined by the increasing function $\theta(a)$, where $a \geq 0$ is the awareness effort of the environmental NGO (see Section 2.3). The campaign is therefore a form of persuasive advertising ([Bagwell, 2007](#); [Van der Made & Schoonbeek, 2009](#)). For the sake of simplicity, we assume that $\theta(a) = \theta \gamma(a)$, where $\gamma(0) = 1$, $\gamma'(a) > 0$, $\gamma''(a) \leq 0$, and $\gamma(a) \in [1, \bar{\gamma}]$. The awareness-raising campaign leads to a non-uniform increase in WTP: the more sensitive consumers are to the environmental characteristics of a product, the more responsive they are to the awareness-raising campaign. We extend the range of consumers' WTP for environmental quality to $[0, \bar{\theta} \gamma(a)]$,² so that the density of the distribution of consumers' WTP, equal to $1/(\bar{\theta} \gamma(a))$, decreases with a .

Therefore, consumer preferences are represented by the following utility functions:

$$u_i(\theta) = \begin{cases} r - p_i & \text{for uninformed consumers} \\ r + \theta \gamma(a) e_i - p_i & \text{for informed consumers} \end{cases} \quad i = B, G, \quad (1)$$

where p_i is the price of the product i , and r is the gross WTP for the good, which includes the WTP for the "neutral" environmental quality q_0 . Not consuming provides zero utility. All uninformed consumers buy the same product i providing the highest utility (i.e., the cheapest). The segment of informed consumers can be uncovered or fully covered. We denote

²This assumption corresponds to that of "heterogeneity-enhancing" in [García-Gallego and Georgantzís \(2009\)](#). This differs from [Van der Made and Schoonbeek \(2009\)](#), who assume that the interval $[0, \bar{\theta}]$ is uniformly shifted upwards, with the WTP of all consumers within the interval increasing by the same amount.

$\Theta_i \equiv -(r - p_i)/e_i > 0$ as the marginal WTP of the informed consumer indifferent between product i at price p_i and no consumption and $\Theta_{BG} \equiv (p_G - p_B)/(e_G - e_B)$ as the marginal WTP of the informed consumer indifferent between the brown product at price p_B and the green product at price p_G .³ In the case of an uncovered segment, informed consumers' demand for the brown product is $\alpha(x)\Theta_B/(\bar{\theta}\gamma(a))$ if $\Theta_B > 0$ and 0 otherwise, and their demand for the green product is $\alpha(x)(\bar{\theta}\gamma(a) - \Theta_G)/(\bar{\theta}\gamma(a))$; consumers with marginal WTP $\theta\gamma(a)$ between Θ_B and Θ_G abstain. In the case of a covered market, informed consumers' demand for the brown product is $\alpha(x)\Theta_{BG}/(\bar{\theta}\gamma(a))$, and their demand for the green product is $\alpha(x)(\bar{\theta}\gamma(a) - \Theta_{BG})/(\bar{\theta}\gamma(a))$.

2.2 Firms

In the first stage of the game, the firms decide which environmental quality to supply. The levels of the environmental quality q_B and q_G are exogenous; they depend on a technically achievable or legally required minimum quality for q_B and on an eco-label that is well known by informed consumers for q_G . Because quality is costly, a firm chooses either the worst quality, q_B (which leads to a quality increment of e_B), or the minimum quality, q_G (which leads to a quality increment of e_G), required to add the ecolabel to its product.

In the third stage of the game, after the information and the awareness-raising campaigns in the second stage, the firms compete on price. They earn profits $\pi_i = (p_i - c_i)d_i$, where c_i are unit costs and d_i is consumer demand, with $i = B, G$. We assume that the firm that produces the brown product B bears zero cost (i.e., $c_B = 0$), while the production of the green product induces positive costs (i.e., $c_G \equiv c > 0$). We restrict our analysis to the case in which the unit production cost of the green product is too high for uninformed consumers to buy it at its competitive price but low enough for the most environmentally conscious consumer to buy it before the awareness-raising campaign:

Assumption 1 $r < c < r + \bar{\theta}e_G$

To allow different market configurations to emerge, we also assume that the unit cost satisfies Assumption 2 (see Sections 3.2 and 3.3).⁴

³Although we keep the notation of the parameters Θ_i and Θ_{BG} as simple as possible, they actually correspond to the marginal WTP for environmental quality of the indifferent consumers *after* the awareness-raising campaign, that is, $\theta\gamma(a)$.

⁴Note that $r + \bar{\theta}e_G > \frac{r(e_G - e_B)}{-e_B}$ if $r + \bar{\theta}e_B < 0$

Assumption 2 $c < \frac{r(e_G - e_B)}{-e_B}$

2.3 Environmental NGO

Information and awareness-raising campaigns are carried out by an environmental NGO to improve environmental quality, defined as

$$E = e_B d_B + e_G d_G + \bar{e}(1 - d_B - d_G). \quad (2)$$

A key assumption is that abstention is better for the environment than consumption. This means that consumers who abstain from purchasing brown and green products (representing the share $1 - d_B - d_G$ of total demand) make the best contribution to environmental quality, so we set their environmental increment to such quality to $\bar{e} \geq e_G > 0 > e_B$. Although reducing consumption of the brown product helps improve environmental quality, increasing consumption of the green product does not necessarily improve environmental quality unless it comes at the expense of the brown product.

The environmental campaigns are costly. We assume positive unit costs w_x and w_a for the information and awareness-raising campaigns. The objective of the environmental NGO is therefore to maximize E under its budget constraint $w_x x + w_a a \leq R$, where R is its campaign budget.

In addition, environmental quality contributes to social welfare, defined as the sum of consumer surplus, firm profits, and the social benefit of environmental quality:

$$W = (1 - \alpha(x))CS_U + \alpha(x)CS_I + \pi_B + \pi_G + \delta E, \quad (3)$$

where CS_U and CS_I are the surplus of uninformed and informed consumers such that

$$CS_U = r - p_i \text{ with } i = B, G. \quad (4)$$

$$CS_I = \begin{cases} \int_{\Theta_G}^{\bar{\theta}\gamma(a)} (r + ze_G - p_G) dz & \text{if } \Theta_B < 0 < \Theta_G < \bar{\theta}\gamma(a) \\ \int_0^{\Theta_B} (r + ze_B - p_B) dz + \int_{\Theta_G}^{\bar{\theta}\gamma(a)} (r + ze_G - p_G) dz & \text{if } 0 < \Theta_B \leq \Theta_G < \bar{\theta}\gamma(a) \\ \int_0^{\Theta_{BG}} (r + ze_B - p_B) dz + \int_{\Theta_{BG}}^{\bar{\theta}\gamma(a)} (r + ze_G - p_G) dz & \text{if } \Theta_G \leq \Theta_{BG} \leq \Theta_B < \bar{\theta}\gamma(a), \end{cases} \quad (5)$$

and δ is the usual marginal environmental benefit, or the monetary valuation of a marginal improvement of environmental quality E .

3 Nash equilibrium

Depending on the fraction of informed consumers, $\alpha(x)$, and the level of environmental awareness, $\bar{\theta}\gamma(a)$, three different market configurations can emerge in the Nash equilibrium (see [Appendix A](#)): *segmentation*, in which the green and the brown markets are completely independent, with the brown market serving only the uninformed consumers and the green market serving some of the informed consumers; *fragmentation*, in which the brown market serves all the uninformed consumers and some informed consumers; and *full coverage*, in which all consumers are served. Figure 1 illustrates the market configurations, with $e_B = -0.5$, $e_G = 1$, $r = 3$, and $c = 4$.⁵

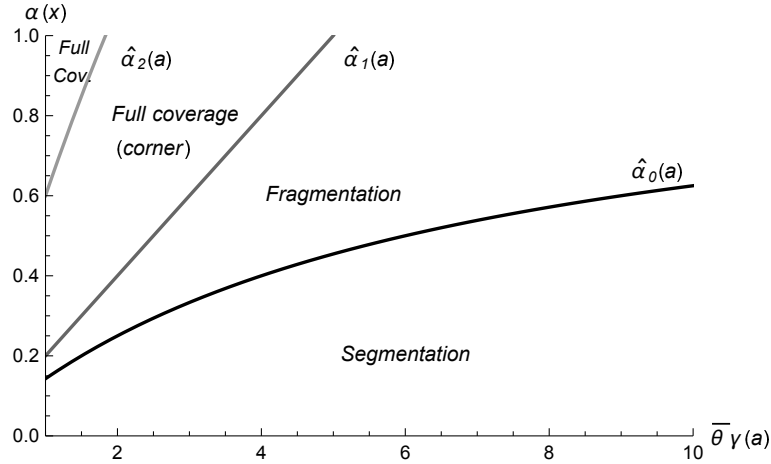


Figure 1: Market configurations

3.1 Segmentation

The market is segmented when the informed and uninformed consumers act in two independent markets: the brown market, in which all uninformed consumers consume the brown product, and the green market, in which informed consumers are either those with the highest WTP for environmental quality, who consume the green product, or those with the lowest WTP for environmental quality, who consume neither. Segmentation occurs when the fraction of informed

⁵We chose these parameters to represent all market configurations in Figure 1.

consumers is lower than $\hat{\alpha}_0(a)$, defined as

$$\hat{\alpha}_0(a) \equiv \frac{-\bar{\theta}\gamma(a)e_B}{r - \bar{\theta}\gamma(a)e_B}, \quad (6)$$

where $\hat{\alpha}_0(a)$ is an increasing and concave function of a . Furthermore, the higher the maximum WTP $\bar{\theta}$ and the lower the gross utility r and the brown quality e_B , the higher is $\hat{\alpha}_0(a)$. Regardless of the awareness-raising campaign effort, we have $0 \leq \hat{\alpha}_0(a) < 1$, which means that other market configurations may emerge for $\alpha(x) > \hat{\alpha}_0(a)$.

The firms then behave like two monopolies in their market segments. The firm supplying the brown product (hereinafter called Firm B) sets a price p_B^m equal to the maximum WTP for the brown product of uninformed consumers, $p_B^m \equiv r$. The demand for the brown product is $d_B^m \equiv 1 - \alpha(x)$ and the profit of Firm B is $\pi_B^m = (1 - \alpha(x))r$.

The firm that supplies the green product (hereinafter called Firm G) sells its product to informed consumers whose WTP for the green product $\theta\gamma(a)$ is greater than Θ_G . Therefore, maximizing its monopoly profit leads Firm G to set a price p_G^m defined as⁶

$$p_G^m \equiv \frac{c + r + \bar{\theta}\gamma(a)e_G}{2}, \quad (7)$$

where $p_G^m > r$ under the assumption that $c > r$. The demand from informed consumers is

$$d_G^m \equiv \alpha(x) \frac{r - c + \bar{\theta}\gamma(a)e_G}{2\bar{\theta}\gamma(a)e_G}. \quad (8)$$

The demand for the green product is positive under Assumption 1. The profit of Firm G is then equal to $\pi_G^m = \bar{\theta}\gamma(a)e_G d_G^m / \alpha(x)$.

3.2 Fragmentation

When the fraction of informed consumers is higher than $\hat{\alpha}_0(a)$, the smaller segment of uninformed consumers still consumes the brown product, while the larger segment of informed consumers is fragmented: the informed consumers with the highest WTP for environmental quality consume the green product, those with the lowest WTP consume the brown product, and those with

⁶To simplify the notation, we omit the variables x and a in the price, demand, and profit functions.

intermediate WTP consume neither.

Market fragmentation occurs when the fraction of informed consumers is such that $\hat{\alpha}_0(a) < \alpha(x) \leq \hat{\alpha}_1(a)$, where

$$\hat{\alpha}_1(a) \equiv \frac{-\bar{\theta}\gamma(a)e_B e_G}{re_G + (c-r)e_B}. \quad (9)$$

Assumption 2 ensures that $\hat{\alpha}_1(a)$ is positive, increasing, and concave in a , but also that $\hat{\alpha}_1(a) > \hat{\alpha}_0(a)$. In addition, $\hat{\alpha}_1(a)$ increases with $\bar{\theta}$ and c and decreases with e_B , e_G , and r . Moreover, $\hat{\alpha}_1(a) < 1$ if the awareness effort a remains below a threshold implicitly defined by the following inequality:

$$\gamma(a) < \frac{r(e_G - e_B) + ce_B}{-\bar{\theta}e_B e_G} \equiv \hat{\gamma}_1. \quad (10)$$

Logically, the higher the value of $\bar{\theta}$, the lower the maximum threshold $\hat{\gamma}_1$ will be, as the awareness-raising campaign must be more restrained because consumers were already sensitive to environmental quality before the campaign. The aversion effect $|e_B|$ has a positive impact on $\hat{\gamma}_1$.

In this case, Firm G still acts as a monopolist, setting price p_G^m , facing demand d_G^m , and earning profit π_G^m . Compared to the segmentation case, Firm B is interested in lowering its price to attract the (larger fraction of) informed consumers with a WTP for environmental quality $\theta\gamma(a)$ lower than Θ_B . We can then define the demand for the brown product as $d_B = 1 - \alpha(x) + \alpha(x) (\Theta_B / (\bar{\theta}\gamma(a)))$. Maximizing its monopoly profit leads Firm B to set a price p_B^f defined as

$$p_B^f = \frac{\alpha(x)r - (1 - \alpha(x))\bar{\theta}\gamma(a)e_B}{2\alpha(x)}, \quad (11)$$

where $p_B^f < r$ when $\alpha(x) > \hat{\alpha}_0(a)$. The demand is then

$$d_B^f = \frac{1}{2} \left(1 - \alpha(x) - \frac{\alpha(x)r}{\bar{\theta}\gamma(a)e_B} \right), \quad (12)$$

and the profit is $\pi_B^f = -\bar{\theta}\gamma(a)e_B d_B^f{}^2 / \alpha(x)$.

3.3 Full coverage

When the fraction of informed consumers is greater than $\hat{\alpha}_1(a)$, the market is fully covered. Uninformed consumers still consume the brown product, while informed consumers consume either the brown or the green product.

In the segment of informed consumers, depending on the value of Θ_{BG} in relation to Θ_B and Θ_G , we consider two sub-cases (see also Wauthy, 1996; Liao, 2008). In the first case, the market is covered with an interior solution because $\Theta_G < \Theta_{BG} < \Theta_B$, which implies that all consumers who prefer the green to the brown product are willing to pay price p_G (i.e., $\theta \gamma(a) \geq \Theta_{BG} > \Theta_G$) and all consumers who prefer the brown to the green product are willing to pay price p_B (i.e., $\theta \gamma(a) < \Theta_{BG} < \Theta_B$). We show that this requires a sufficiently large segment of informed consumers, such that $\alpha(x) \geq \hat{\alpha}_2(a)$ (as defined subsequently). In the second case, because the segment of informed consumers is smaller, such that $\hat{\alpha}_1(a) < \alpha(x) \leq \hat{\alpha}_2(a)$, a corner solution sets prices to satisfy the equality $\Theta_B = \Theta_{BG} = \Theta_G$. The Nash equilibrium then corresponds to a price of the brown product equal to the limit of price p_B^f in the fragmented market when $\alpha(x)$ is at its upper bound of $\hat{\alpha}_1$, while the price of the green product is p_G^m (independent of $\alpha(x)$). In both cases, we define the demand for the green product as $d_G = \alpha(x)(\bar{\theta} \gamma(a) - \Theta_{BG}) / (\bar{\theta} \gamma(a))$ and the demand for the brown product as $d_B = 1 - d_G$.

We define the threshold $\hat{\alpha}_2(a)$, which sets the boundary between a corner and an interior solution in a covered market, as

$$\hat{\alpha}_2(a) \equiv \frac{\bar{\theta} \gamma(a)(e_G - e_B)(2e_G - e_B)}{\bar{\theta} \gamma(a)(e_G - e_B)(e_G + e_B) + 3r(e_G - e_B) - c(e_G - 2e_B)}. \quad (13)$$

A sufficient condition for $\hat{\alpha}_2(a)$ to be positive and increasing in a is $c < 3r(e_G - e_B)/(e_G - 2e_B)$. Such a condition is less restrictive than Assumption 2 when the aversion effect is high ($e_B < -e_G$) but more restrictive otherwise.⁷ In addition, because $\hat{\alpha}_2(a)$ increases with $\bar{\theta}$ and c , a covered market with an interior solution is less likely to occur if the informed consumers are already aware of the environmental quality before the awareness-raising campaign and the production cost of the green product is high. Conversely, $\hat{\alpha}_2(a)$ decreases with e_B and r , while it can increase or decrease with e_G , depending on specific conditions on other parameters. Moreover, $\hat{\alpha}_2(a) < 1$ requires the awareness effort a to be constrained to

$$\gamma(a) < \frac{3r(e_G - e_B) - c(e_G - 2e_B)}{\bar{\theta}(e_G - e_B)(e_G - 2e_B)} \equiv \hat{\gamma}_2. \quad (14)$$

⁷If $e_B < -e_G$, Assumption 2 implies that $c < \frac{r(e_G - e_B)}{-e_B} < \frac{3r(e_G - e_B)}{e_G - 2e_B}$. But if $-e_G < e_B < 0$, we have $c < \frac{3r(e_G - e_B)}{e_G - 2e_B} < \frac{r(e_G - e_B)}{-e_B}$.

Because the maximum threshold $\hat{\gamma}_2$ decreases with $\bar{\theta}$ and increases with e_B ,⁸ a covered market with an interior solution is less likely to occur if informed consumers are already sensitive to environmental quality before the awareness-raising campaign and averse to the brown product.

When the market is covered with a corner solution (with $\hat{\alpha}_1(a) < \alpha(x) \leq \hat{\alpha}_2(a)$), the Nash equilibrium then corresponds to price p_B^f of the fragmented market when $\alpha(x)$ is at its upper bound of $\hat{\alpha}_1(a)$:

$$p_B^{cc} = r + \frac{(c - r + \bar{\theta} \gamma(a) e_G) e_B}{2e_G}, \quad (15)$$

and p_G^m . The demand for the brown product is then equal to

$$d_B^{cc} = \frac{2 - \alpha(x)}{2} + \frac{\alpha(x)(c - r)}{2\bar{\theta} \gamma(a) e_G}, \quad (16)$$

and $d_G^{cc} = d_G^m = 1 - d_B^{cc}$.

When the market is covered with an interior solution (with $\hat{\alpha}_2(a) < \alpha(x) \leq 1$), the equilibrium prices are

$$p_B^c = \frac{c}{3} + \frac{(2 - \alpha(x))\bar{\theta} \gamma(a)(e_G - e_B)}{3\alpha(x)}, \quad (17)$$

$$p_G^c = \frac{2c}{3} + \frac{(1 + \alpha(x))\bar{\theta} \gamma(a)(e_G - e_B)}{3\alpha(x)}. \quad (18)$$

We can then define the demand for the brown product as

$$d_B^c = \frac{1}{3} \left(2 - \alpha(x) + \frac{\alpha(x)c}{\bar{\theta} \gamma(a)(e_G - e_B)} \right), \quad (19)$$

and the demand for the green product as $d_G^c = 1 - d_B^c$.

4 Impact of information and awareness-raising campaigns

We assume that in the absence of information and awareness-raising campaigns, the fraction of informed consumers is low (i.e., $\alpha(0) \leq \hat{\alpha}_0(0)$), and we analyze the effects of both campaign types on consumer behavior and firm strategies. [Appendix B](#) shows the marginal effects of x and a on prices and demands and their cross-marginal effects in all possible Nash equilibrium

⁸The derivative $\partial \hat{\gamma}_2 / \partial e_B$ is positive only under the condition for $\hat{\alpha}_2(a) > 0$.

situations.

In the initial segmented market, the firm with the brown product captures all the surplus of uninformed consumers by selling the product at price r . The information and awareness-raising campaigns have no direct effect on the behavior of uninformed consumers and the strategies of Firm B . However, the information campaign reduces the fraction of uninformed consumers and then indirectly reduces total demand for the brown product and Firm B 's profit. In contrast, both the information and awareness-raising campaigns benefit Firm G by increasing the price of the green product and the demand of informed consumers for that product, thereby increasing its profit. At the same time, the two campaigns reinforce each other's effects: informed consumers not only increase but also become more sensitive to environmental quality. The awareness-raising campaign also increases the threshold $\hat{\alpha}_0(a)$ and then enlarges the interval of the information campaign that leads to segmentation, such that $\alpha(x) \leq \hat{\alpha}_0(a)$. This leads to Proposition 1.

Proposition 1 *In a segmented market, the awareness-raising campaign complements the information campaign to promote green consumption, enhancing the cost-effectiveness of the green product, through $\gamma(a) > (c - r)/(\bar{\theta}e_G)$, and the mutual reinforcement of the positive effects of the campaigns.*

Whenever the information campaign is important enough to raise $\alpha(x)$ above $\hat{\alpha}_0(a)$, the market becomes fragmented. The information and awareness-raising campaigns have an indirect effect on uninformed consumers' behavior, through the price of the brown product. They also affect the behavior of informed consumers, some of whom now buy the brown product. The higher $\alpha(x)$, the greater is the demand for the brown product by informed consumers, who also become more numerous, even though the number and, thus, the demand of uninformed consumers decrease. As a result, total demand for the brown product may increase or decrease depending on the magnitude of these two contradictory effects. This leads to Proposition 2.

Proposition 2 *In a fragmented market, the information campaign increases the demand for the brown product, while the awareness-raising campaign decreases it, thus mitigating the positive effect of the information campaign, as long as $\gamma(a) < -r/(\bar{\theta}e_B)$.*

Proposition 2 stems from Appendix B, which shows that d_B^f is an increasing function of x when $\gamma(a) < -r/(\bar{\theta}e_B)$. Because $-r/(\bar{\theta}e_B) > \hat{\gamma}_1$, it follows that when the awareness-raising

campaign leads to $\hat{\alpha}_1(a) < 1$, the information campaign has the unexpected effect of increasing the demand for the brown product. This is due to the campaign's price-reducing effect on the brown product, which increases the demand of the (larger fraction of) informed consumers. However, raising awareness among informed consumers tends to turn them away from the brown product, with some of these consumers preferring to abstain rather than consume the product. As a result, the awareness-raising campaign reduces the effect of the information campaign on the demand for the brown product.

In contrast, the information and awareness-raising campaigns push Firm B to lower its price to attract informed consumers. This action tends to reduce its profit, even when the demand for the brown product increases. For the green product, the effects of the information and awareness-raising campaigns remain the same as in the case of segmentation: both campaigns unambiguously benefit the green product and Firm G . Finally, if the awareness-raising campaign is sufficiently effective in raising $\hat{\alpha}_1(a)$ above 1 and $\gamma(a)$ above $-r/(\bar{\theta}e_B)$, the information campaign reduces the total demand for the brown product. The market then remains fragmented for all x .

If the information campaign is even more effective in raising $\alpha(x)$ above $\hat{\alpha}_1(a)$, the market will be covered with a corner solution if $\alpha(x) \leq \hat{\alpha}_2(a)$ or with an interior solution if $\alpha(x) > \hat{\alpha}_2(a)$. The occurrence of full coverage requires that informed consumers' environmental awareness is not too high, which in turn requires that the awareness-raising campaign is not too effective (i.e., $\gamma(a) < \hat{\gamma}_1$). However, the information campaign has the expected effect of reducing the demand for the brown product in favor of the green product only if informed consumers' environmental awareness is sufficiently high. Conversely, the awareness-raising campaign always produces the expected effects on demand. This leads to Proposition 3.

Proposition 3 *In a covered market, the information campaign complements the awareness-raising campaign to promote green consumption as long as it keeps the fraction of informed consumers below $\hat{\alpha}_2(a)$, while a more intensive information campaign, leading to $\alpha(x) > \hat{\alpha}_2(a)$, may work in the opposite direction to that of the awareness-raising campaign.*

Proposition 3 results from the condition in which x has a positive effect on the demand for the green product. In the case of a corner solution, demand is always increasing; in the case of an interior solution, the condition is $c/(\bar{\theta}(e_G - e_B)) < \gamma(a) < \hat{\gamma}_2$, which can only be satisfied

under specific conditions on the parameters. In all cases, the information campaign intensifies the price competition between the two firms, which lower prices of both products. However, the effects of the awareness-raising campaign are clearly in favor of the green product, whose demand increases, though both prices increase as a result of the increased WTP of informed consumers.

5 Optimal information and awareness-raising campaigns

How do the information and awareness-raising campaigns affect the quality of the environment? Analysis of their influence on the demand for the brown and the green products suggests that it depends on the market configuration. In line with the Nash equilibrium, the resulting environmental quality defined in Equation 2 is characterized as⁹

$$\begin{aligned}
E^s &= \frac{1}{2} \left(2(1 - \alpha(x))e_B + \alpha(x)(\bar{e} + e_G) + \alpha(x) \frac{(c - r)(\bar{e} - e_G)}{\bar{\theta}\gamma(a)e_G} \right) & \text{if } \alpha(x) \leq \hat{\alpha}_0(a), \\
E^f &= \frac{1}{2} \left(\bar{e} + (1 - \alpha(x))e_B + \alpha(x)e_G + \alpha(x) \frac{r\bar{e}(e_G - e_B) + ce_B(\bar{e} - e_G)}{2\bar{\theta}\gamma(a)e_Be_G} \right) & \text{if } \hat{\alpha}_0(a) < \alpha(x) \leq \hat{\alpha}_1(a), \\
E^{cc} &= \frac{1}{2} \left((2 - \alpha(x))e_B + \alpha(x)e_G - \alpha(x) \frac{(c - r)(e_G - e_B)}{\bar{\theta}\gamma(a)e_G} \right) & \text{if } \hat{\alpha}_1(a) < \alpha(x) \leq \hat{\alpha}_2(a), \\
E^c &= \frac{1}{3} \left((2 - \alpha(x))e_B + (1 + \alpha(x))e_G - \alpha(x) \frac{c}{\bar{\theta}\gamma(a)} \right) & \text{if } \hat{\alpha}_2(a) < \alpha(x) \leq 1.
\end{aligned}$$

Figure 2 illustrates the effects of the information and awareness-raising campaigns, through $\alpha(x)$ and $\bar{\theta}\gamma(a)$, on environmental quality.¹⁰ The environmental impact of the campaigns is significantly different depending on whether some informed consumers buy the brown product or not (see Table C.1 in Appendix C).

Because the market is segmented before the campaigns (i.e., $\alpha(0) \leq \hat{\alpha}_0(a)$), informing consumers is beneficial for the environment, while making informed consumers more aware of the environmental quality of products is detrimental. The information campaign leads newly informed consumers to abandon the brown product and either stop consuming both the brown and green products or consume only the green product, both behavioral changes that improve environmental quality. However, the awareness-raising campaign will cause some informed con-

⁹The subscript s denotes the segmentation case.

¹⁰To illustrate Figure 2, we use $\bar{\theta} = 1$, $e_G = 1$, $\bar{e} = 2$, $r = 3$, $c = 4$ and $e_B = -0.5$ in panel (a) and $e_B = -2$ in panel (b).

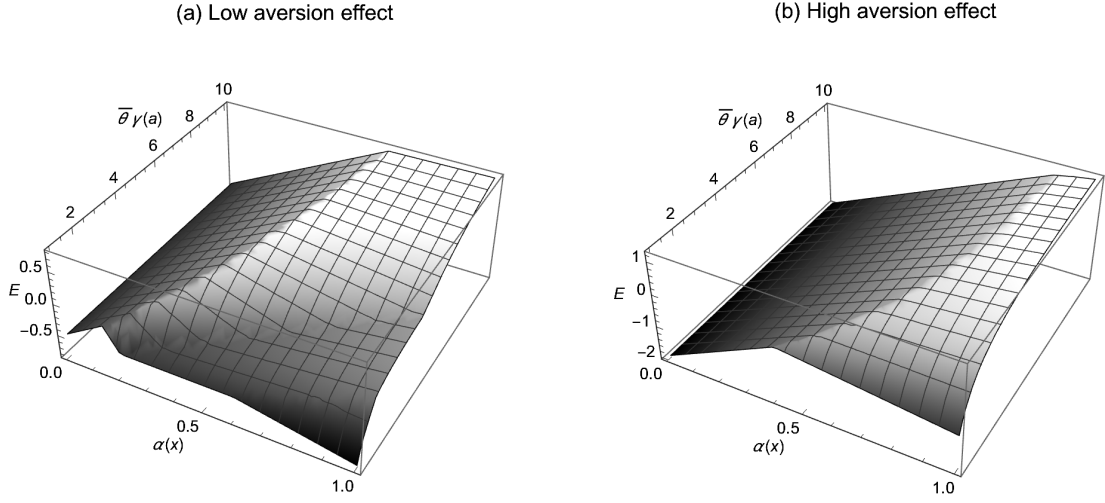


Figure 2: Effects of $\alpha(x)$ and $\gamma(a)$ on environmental quality

sumers who were previously abstaining to consume the green product. This becomes environmentally harmful as soon as the green product exerts a negative impact, even a small one, on environmental quality, while abstention remains the most ecological behavior. The information campaign therefore takes precedence over the awareness-raising campaign. Importantly, however, an increase in the awareness-raising campaign leads to an increase in the maximum fraction of consumers $\hat{\alpha}_0(a)$ compatible with a segmented market. Thus, even if the campaign reduces the quality of the environment for a given x , such that $\alpha(x) \leq \hat{\alpha}_0(a)$, it informs even more consumers while remaining in a segmented market, which in turn leads to an increase in environmental quality.

When the campaigns result in a fragmented market (i.e., $\hat{\alpha}_0(a) < \alpha(x) \leq \hat{\alpha}_1(a)$), raising environmental awareness of informed consumers is always beneficial for the environment, but informing them is not always beneficial. Indeed, after some informed consumers buy the brown product in the fragmented market, informing even more consumers degrades environmental quality if the awareness-raising campaign is insufficient. Such an unexpected situation occurs if

$$\gamma(a) < \frac{r\bar{e}(e_G - e_B) + ce_B(\bar{e} - e_G)}{-\bar{\theta}(e_G - e_B)e_Ge_B} \equiv \hat{\gamma}_3. \quad (20)$$

Therefore, the environmental goal requires launching an effective awareness-raising campaign in such a way as to increase $\gamma(a)$ above the threshold $\hat{\gamma}_3$, allowing the information campaign

also to be effective and, in the same way, directly improve environmental quality by diverting some newly informed consumers away from the brown product. Because $\hat{\gamma}_3$ increases with e_B , an effective information campaign requires either a significant awareness-raising campaign ($\gamma(a) > \hat{\gamma}_3$) or a high aversion effect $|e_B|$ (low $\hat{\gamma}_3$). In addition, because $\hat{\gamma}_3 > \hat{\gamma}_1$, $\hat{\alpha}_1(a) > 1$ when $\gamma(a) > \hat{\gamma}_3$, such that only segmented and fragmented markets are possible. Then, the following lemma holds:

Lemma 1 *The aversion effect $|e_B|$ and the environmental awareness $\bar{\theta}\gamma(a)$ of informed consumers act as substitutes, making the information campaign effective beyond $\hat{\alpha}_0(a)$ through $\gamma(a) > \hat{\gamma}_3$.*

Finally, when the market is fully covered (*i.e.*, $\alpha(x) > \hat{\alpha}_1(a)$), improving environmental quality requires reducing demand for the brown product in favor of the green product. The analysis of demand in Section 3 indicates that this happens either when $\alpha(x) \leq \hat{\alpha}_2(a)$ or when $c/(\bar{\theta}(e_G - e_B)) < \gamma(a) < \hat{\gamma}_2$. However, the level of environmental quality in $\hat{x}_2(a)$ drops sharply as the covered market moves from a corner to an interior solution.¹¹ This is due to the significant decrease in the price of the brown product, which leads to demand for the brown product at the expense of the green product. As a result, environmental quality is maximized for an information campaign that leads to a fraction $\hat{\alpha}_2(a)$ of informed consumers, and an awareness-raising campaign as large as possible.

As a result, the information and awareness-raising campaigns must be combined to achieve the highest possible environmental quality with a given budget R . More precisely, the optimal articulation of the two campaigns depends on their relative cost-effectiveness (*i.e.*, their relative environmental effectiveness E_x/E_a compared to their relative cost w_x/w_a). In other words, the saturation of the budget constraint that allows maximizing the environmental quality depends not only on the unit cost of each campaign but also on its marginal impact on environmental quality through $\alpha'(x)$ and $\gamma'(a)$. Proposition 4 defines the optimal campaigns, where $\hat{x}_i(a)$ is the information campaign that leads to informing $\alpha(\hat{x}_i(a)) = \hat{\alpha}_i(a)$ consumers (with $i = 0, 1, 2$), \bar{x} is the information campaign that makes it possible to inform all consumers (*i.e.*, $\alpha(\bar{x}) = 1$), and \hat{a}_3 is the awareness-raising campaign such that $\gamma(\hat{a}_3) = \hat{\gamma}_3$.

¹¹The condition for $E^{cc} > E^c$ in $\hat{\alpha}_2(a)$ is $\gamma(a) < (-3r\bar{e}(e_G - e_B) + c(e_G - 2e_B)) / (\bar{\theta}(e_G - e_B)(e_G + e_B))$ where the upper bound is higher than $\hat{\gamma}_2$. Therefore, as soon as $\hat{\alpha}_2(a) < 1$, this condition is satisfied.

Proposition 4

If the aversion effect $|e_B|$ is significant enough to allow for both segmented and fragmented markets, the optimal information and awareness-raising campaigns are as follows:

- (i) With a small budget $R \leq w_x \hat{x}_0(\hat{a}_3) + w_a \hat{a}_3$, such that $\gamma(a) \leq \hat{\gamma}_3$, to conduct moderate information campaign $\hat{x}_0(a^*)$ and awareness-raising campaign a^* to inform only $\hat{\alpha}_0(a^*)$ consumers and exhaust the budget, $w_x \hat{x}_0(a^*) + w_a a^* = R$, with $a^* \leq \hat{a}_3$.
- (ii) With a higher budget R allowing $\gamma(a) > \hat{\gamma}_3$, the optimal campaigns depend on the relative cost-effectiveness of the information and awareness-raising campaigns:
 - (a) In the case of greater cost-effectiveness of the awareness-raising campaign, to conduct a moderate information campaign $\hat{x}_0(a^*)$ to inform only $\hat{\alpha}_0(a^*)$ consumers and an intensive awareness-raising campaign a^* exhausting the budget, $w_x \hat{x}_0(a^*) + w_a a^* = R$, with $a^* > \hat{a}_3$.
 - (b) In the case of greater cost-effectiveness of the information campaign, to conduct an intensive information campaign \bar{x} to inform all consumers and a moderate awareness-raising campaign exhausting the budget, $w_x \bar{x} + w_a a^{**} = R$, with $\hat{a}_3 < a^{**} < a^*$.

If the aversion effect $|e_B|$ is close to zero, such that the market is covered as soon as a small fraction $\hat{\alpha}_1(a)$ of consumers is informed, the optimal information and awareness-raising campaigns are to inform as many consumers as possible, in the limit of $\hat{\alpha}_2(a^*)$, and to devote the remaining budget to an even more effective awareness-raising campaign: $w_x \min(\hat{x}_2(a^*), \bar{x}) + w_a a^* = R$.

Lemma 1 and Proposition 4 highlight the following two polar cases (illustrated in Figures 2 and demonstrated in Appendix C):

- A high aversion effect $|e_B|$ makes the information campaign effective by diverting the most informed consumers away from the brown product, so that the market cannot be covered and $E^f(\bar{x}, a) > E^s(\hat{x}_0(a), a)$ when $\gamma(a) > \hat{\gamma}_3$. Because $\hat{\gamma}_3$ decreases with the aversion effect, the minimum awareness-raising campaign condition is easy to satisfy. The optimal environmental campaign is then to inform all consumers and to allocate the remaining budget to the awareness-raising campaign. Such campaign strategies (\bar{x}, a^{**}) are indeed

optimal if the relative campaign cost w_x/w_a is low, which incentivizes the NGO to favor the information campaign over the awareness-raising campaign. This leads to a fragmented market with only informed consumers and maximum environmental quality $E^f(\bar{x}, a^{**})$. In contrast, because the information campaign is more effective in the segmented market than in the fragmented market ($E_x^s > E_x^f$), the NGO has an interest in keeping the market segmented and thus favors the awareness-raising campaign over the information campaign whenever the relative campaign cost w_x/w_a is higher. The optimal campaigns $(\hat{x}_0(a^*), a^*)$ is then to increase the information and awareness-raising efforts to keep $\hat{\alpha}_0(a^*)$ informed consumers in the segmented market while exhausting the entire budget. The maximum environmental quality is then $E^s(\hat{x}_0(a^*), a^*) > E^f(\bar{x}, a^{**})$, with $a^* > a^{**}$.

- A small (but not too small) aversion effect $|e_B|$ makes the information campaign less effective, as the least environmentally conscious consumers might be tempted to consume the brown product. The market can be covered as long as the awareness-raising campaign remains modest (with $\gamma(a) \leq \hat{\gamma}_1 < \hat{\gamma}_3$). Then, $E^s(\hat{x}_0(a), a) > E^k(\bar{x}, a)$ for all a and $k = f, cc, c$. The lower the aversion effect, the easier it is to satisfy the condition of a maximum awareness-raising campaign, $\gamma(a) < \hat{\gamma}_3$. The optimal environmental campaign is then to keep the market segmented by informing $\hat{\alpha}_0(a^*)$ consumers and to devote the remaining budget to the awareness-raising campaign a^* .

However, when the aversion effect is so small that the market is covered for a small fraction of informed consumers (because $\hat{\alpha}_0(a)$ and $\hat{\alpha}_1(a)$ tend toward 0), the optimal environmental campaign is to inform the largest number of consumers in the limit of $\hat{\alpha}_2(a^*)$ and to spend the remaining budget on the awareness-raising campaign a^* . Such a campaign reduces as much as possible the consumption of the brown product by uninformed and informed consumers in favor of the green product by the largest possible number of informed consumers.

6 Welfare implications

6.1 Consumer surplus

The impact of the information and awareness-raising campaigns on consumer surplus depends on the type of consumer (informed or not) and the market configuration in the Nash equilibrium.

We provide the expressions for the consumer surplus in [Appendix D](#).

In the case of segmentation, Firm B captures the entire surplus of uninformed consumers. The surplus of informed consumers does not depend on the fraction of informed consumers $\alpha(x)$ because the monopoly price of the green product is independent of $\alpha(x)$. However, the awareness-raising campaign improves this surplus by increasing the gross utility of consumers of the green product ($r + \theta\gamma(a)e_G$). As a result, total consumer surplus benefits from both the information campaign¹² and the awareness-raising campaign.

In the case of fragmentation, the surplus of the uninformed consumers benefits from an increase in $\alpha(x)$, which causes the price of the brown product to fall. But because they are fewer, their total surplus decreases with $\alpha(x)$. Conversely, total surplus is worsened by an increase in a , which leads to higher prices. In contrast, the surplus of the informed consumers increases with α . Only informed consumers who consume the green product benefit from an increase in a , while those who consume the brown product are worse off with an increase in a . Consequently, the effects of the information and awareness-raising campaigns on total consumer surplus are ambiguous.¹³

In the case of a covered market with a corner solution, the prices are frozen at their limits reached for $\alpha(x) = \hat{\alpha}_1(a)$. Therefore, the surpluses of both types of consumers are independent of $\alpha(x)$. However, they are increasing in a , which favors a decrease in the price of the brown product and an increase in the gross utility of (informed) consumers of the green product not offset by the increase in the price of the green product. The total surplus is therefore improved by the information campaign only if the surplus of the uninformed consumers is lower than that of the informed consumers, while it is always improved by the awareness-raising campaign.

In the case of a covered market with an interior solution, the information campaign positively affects the surplus of uninformed consumers if the production cost of the green product is sufficiently high (such that $c > 3r$) or if the awareness-raising campaign is sufficiently strong relative to the information campaign. However, surplus is always degraded by the awareness-raising campaign. Thus, the surplus of informed consumers is always improved by the information campaign but reduced by the awareness-raising campaign.

¹²This is because $\alpha(x)$ increase the total surplus of the informed consumers.

¹³See [Appendix D](#).

6.2 Profits

The impact of the information and awareness-raising campaigns on profits of both firm is unsurprising, except in the case of a covered market with an interior solution. Indeed, in all the other market configurations, the profit of Firm B decreases and that of Firm G increases as a result of the information and awareness-raising campaigns. Nevertheless, when the information campaign is so effective and the awareness-raising campaign sufficiently limited that the market is covered with an interior solution, the profits of both firms decrease with $\alpha(x)$ because of the intense price competition, which causes the prices to fall. Conversely, because prices are strategic complements, an increase in a leads both firms to increase their prices and then benefit from higher profits.

Consequently, as expected, only Firm G would have an interest in the information and awareness-raising campaigns. As these campaigns have opposite effects on the profits of the two firms, their effect on total industry profits is ambiguous.

7 Discussion

Our model provides a general framework for analyzing and comparing the market effects of consumer information and awareness-raising campaigns on the environmental quality. In particular, we show that the combination of assumptions about the fraction of informed consumers and the shape of consumers' preferences between the two products plays a crucial role in market coverage by conditioning on the possibility that some consumers abstain.

The fundamental difference between our model of vertical differentiation and models in the literature lies in the assumptions made about the perception of the characteristics of the two products offered to heterogeneous consumers. [Heijnen and Schoonbeek \(2008\)](#), [Heijnen \(2013\)](#) and [Van der Made and Schoonbeek \(2009\)](#) assume that both products are more or less harmful to the environment and therefore are downgraded by environmentally sensitive consumers. In this case, consumers who are most sensitive to environmental quality are more likely to abstain from consumption. In contrast, [Buehler and Schuett \(2014\)](#) and [Heyes et al. \(2020\)](#) assume that both products are more or less green, and [García-Gallego and Georgantzís \(2009\)](#) assume that they are offered by firms that are more or less environmentally responsible, which is valued by

consumers. Consumers likely to buy neither product are those who are least sensitive to the environment (in the studies of [García-Gallego and Georgantzís \(2009\)](#) and [Heyes et al. \(2020\)](#), they buy the brown “backstop” good). In the first case, the perceived harm keeps the most conscious consumers away from the two products. In the second case, the high price of green products keeps the least conscious consumers away.

Following that work, and in contrast with [García-Gallego and Georgantzís \(2010\)](#), we argue that the market is not covered in all cases in which the products offered do not correspond to necessary goods or in which substitutes for use exist, but not for the same reasons. Our framework is distinct from studies dealing explicitly with consumer information campaigns that shed light on either the green or brown product ([Feddersen & Gilligan, 2001](#); [Heijnen, 2013](#)) or the difference in damage caused by the two products ([Sartzetakis et al., 2012](#)). Our assumption is that the information campaign conveys to consumers the respective qualities of the two products—not only their quality difference, as [Sartzetakis et al. \(2012\)](#) suggest, but also their absolute level—and encourages consumers to reject the brown product. This aversion effect may stem from a call to boycott the brown product, which leads to a real-world outcome: some consumers abstain because one of the products is unacceptable in their eyes but they nevertheless find the other product too expensive. This represents a certain activism on the part of the most environmentally sensitive consumers, who then prefer to do without the green product if they cannot afford it. Not only does this feature make the model more realistic, but it also allows us to describe the price war that the two companies wage to gain market share among informed consumers. We show that Firm B can only achieve market share if the fraction of informed consumers is intermediate; however, increasing this fraction will not be beneficial for the environment if the NGO’s budget is insufficient to avoid this situation.

Among the studies examining the effects of a consumer awareness-raising campaign in the same duopoly framework as ours, those of [García-Gallego and Georgantzís \(2010\)](#) and [Van der Made and Schoonbeek \(2009\)](#) are diametrically opposed examples, with zero aversion in the former (both products are green) and a strong aversion in the latter (both products are brown). In both cases, the campaign clearly leads to a greening of the market, consistent with the curve obtained for $\alpha = 1$ at the right limit of the graphs in panels (a) and (b) of Figure 2. In addition, we show that for a given fraction of informed consumers, raising awareness is always beneficial

for the environment, unless this fraction is low enough for the market to remain segmented.

To our knowledge, [Sartzetakis et al. \(2012\)](#) and [Brécard and Chiroleu-Assouline \(2024\)](#) are the only researchers to consider the effects of increasing the fraction of informed consumers; however, the analysis by [Sartzetakis et al. \(2012\)](#) assumes that consumers are homogeneous in terms of their environmental sensitivity in a market deemed a priori to be covered.

While we are the first to explicitly consider the joint implementation of information and awareness-raising campaigns, [Van der Made and Schoonbeek \(2009\)](#) and [Heyes et al. \(2020\)](#) combine these two features of consumer behavior through ad hoc assumptions. [Van der Made and Schoonbeek \(2009\)](#) assume that the marginal effect of the awareness-raising campaign is a priori stronger for the more than the less polluting product: the campaign thus accentuates the environmental difference between the two products. In [Heyes et al. \(2020\)](#), the greater the sensitivity of consumers, the greater is the incentive to voluntarily acquire costly information about the products' environmental quality. On the contrary, our model enables us to analyze precisely all the mechanisms involved in the interaction between the two types of campaigns.

8 Conclusion

How does consumers' awareness of the environmental characteristics of products available on the market influence their behavior? Unlike existing literature, which tends to consider either the provision of information to consumers or their sensitization to green products, the present research engages in an in-depth investigation of the interaction between information and sensitization. Our model is based on the coexistence of uninformed consumers, who do not distinguish between green and brown products, and informed consumers, whose WTP for green products is heterogeneous. An original feature of our model is the addition of an aversion effect on the brown product for informed consumers, taking to the extreme the standard assumption that these consumers would simply prefer the green product over the brown one. This explains why, for certain parameter configurations, the market can be uncovered; that is, informed consumers with intermediate WTP refrain from consuming the brown product and do not switch to the green product. We also assume that the green product is not environmentally perfect. Therefore, abstention is beneficial for environmental quality.

We show that information and sensitization campaigns can be mutually reinforcing but, far from being perfect substitutes, in some cases they can also have opposite effects on environmental quality. For a small fraction of informed consumers, leading to a segmented market, increasing this fraction reduces the demand for the brown product while enhancing the demand for the green product. Raising environmental awareness is only useful insofar as it further increases the maximum share of informed consumers compatible with a segmented market. However, as abstention is the greenest behavior, increasing global consumption is detrimental to the environment. Consequently, improving environmental quality requires informing as many consumers as possible while increasing their environmental awareness, to deter these informed consumers from switching to the brown product and, thus, to keep the market segmented. However, when the fraction of informed consumers exceeds the threshold, market fragmentation results; the least informed and environmentally aware consumers buy the brown product, some informed consumers boycott it, and only the most informed and environmentally aware consumers buy the green product. In this case, an information campaign paradoxically increases demand for the brown product if informed consumers are not sufficiently environmentally aware and/or their aversion effect is low. Consequently, improving environmental quality requires increasing the environmental awareness of informed consumers without informing additional consumers. When the fraction of informed consumers is larger, leading to a covered market, reducing the demand for the brown product always benefits the environment. This requires informing a large fraction of consumers, but not necessarily all of them, and sensitizing them as much as possible.

We also show that the optimal information and awareness-raising campaigns for improving environmental quality depend on the degree of the aversion effect. An optimal decision is to inform as many consumers as possible and to devote the remaining campaign budget to increase awareness if the environmental awareness of informed consumers or their aversion effect is high enough to make the information campaign effective. The higher the aversion effect, the lower is the environmental awareness required to make informing as many consumers as possible optimal, in line with the campaign budget. Otherwise, in the case of a medium aversion effect coupled with medium environmental awareness of informed consumers, an optimal information campaign involves informing no more than the maximum (small) fraction of consumers that allows the market to remain segmented and thus avoid informed consumers' consumption of the

brown product. NGOs can thus use the awareness-raising campaign as a complementary tool to improve environmental quality, within the limits of the campaign budget. However, if the aversion effect is close to zero, such that the market is covered for a small fraction of informed consumers, the optimal decision is to combine information and awareness-raising campaigns to divert as many consumers as possible from the brown product.

Although in this article we explicitly consider the case of information and awareness-raising campaigns carried out by environmental NGOs, we argue that most of our results would remain unchanged if the instigator of the campaigns were different. In the case of regulators, whose objective is to maximize social welfare, not only environmental quality, the only difference would be in the trade-off between the two types of campaigns, depending on the relative weight of different social welfare components.

Appendix A Proofs of market configurations according to $\alpha(x)$

Let $\Theta_B \equiv -(r - p_B)/e_B$ be the marginal WTP of the informed consumer who is indifferent between consuming the brown product at price p_B and consuming nothing, let $\Theta_G \equiv (p_G - r)/e_G$ be the marginal WTP of the informed consumer who is indifferent between consuming the green product at price p_G and consuming nothing, and let $\Theta_{BG} \equiv (p_G - p_B)/(e_G - e_B)$ be the marginal WTP of the informed consumer who is indifferent between consuming the brown product at price p_B and consuming the green product at price p_G . As uninformed consumers all consume the (cheapest) brown product in the Nash equilibrium, the market configurations are characterized by four inequalities:¹⁴

- Segmentation: $\Theta_B \leq 0 < \Theta_G < \bar{\theta}\gamma(a) \Leftrightarrow 0 \leq \alpha(x) \leq \hat{\alpha}_0(a)$;
- Fragmentation: $0 < \Theta_B < \Theta_G < \bar{\theta}\gamma(a) \Leftrightarrow \hat{\alpha}_0(a) < \alpha(x) \leq \hat{\alpha}_1(a)$;
- Full coverage with a corner solution: $0 < \Theta_B = \Theta_{BG} = \Theta_G < \bar{\theta}\gamma(a) \Leftrightarrow \hat{\alpha}_1(a) < \alpha(x) \leq \hat{\alpha}_2(a)$; and
- Full coverage with an interior solution: $\Theta_G < \Theta_{BG} < \Theta_B$ and $0 < \Theta_{BG} < \bar{\theta}\gamma(a) \Leftrightarrow \hat{\alpha}_2(a) < \alpha(x) \leq 1$.

We next detail the calculation of the three thresholds $\hat{\alpha}_i(a)$ ($i = 0, 1, 2$).

¹⁴We used *Mathematica* software for all proofs. The data file is available on request.

We derive the thresholds $\hat{\alpha}_0(a)$ and $\hat{\alpha}_1(a)$ from the conditions for a fragmented market, where prices are p_B^f and p_G^m : $0 < \Theta_B$ comes down to $p_B^f < r$, which requires $\alpha(x) > \frac{-\bar{\theta}\gamma(a)e_B}{r - \bar{\theta}\gamma(a)e_B} = \hat{\alpha}_0(a)$; $\Theta_B < \Theta_G$ requires $\alpha(x) < \frac{-\bar{\theta}\gamma(a)e_B e_G}{r e_G + (c - r)e_B} = \hat{\alpha}_1(a)$.

We derive the thresholds $\hat{\alpha}_2(a)$ from the conditions for a covered market with an interior solution, where prices are p_B^c and p_G^c :

$$\begin{aligned}\alpha(x) &> \frac{\bar{\theta}\gamma(a)(e_G - e_B)(2e_G - e_B)}{\bar{\theta}\gamma(a)(e_G - e_B)(e_G + e_B) + 3r(e_G - e_B) - c(e_G - 2e_B)} = \hat{\alpha}_2(a), \\ c &< \frac{3r(e_G - e_B)}{e_G - 2e_B}, \\ \gamma(a) &< \frac{3r(e_G - e_B) - c(e_G - 2e_B)}{\bar{\theta}(e_G - e_B)(e_G - 2e_B)}.\end{aligned}$$

In the intermediate case in which $\hat{\alpha}_1(a) < \alpha(x) < \hat{\alpha}_2(a)$, the market is covered with a corner solution because the equilibrium prices in a fragmented market, p_B^f and p_G^m , lead to $\Theta_G < \Theta_B$ which contradicts the condition for a fragmented market, and the equilibrium prices in a covered market with an interior solution, p_B^c and p_G^c , lead to $\Theta_G > \Theta_B$ which contradicts the condition for such a covered market. Therefore, we have a corner solution in which the prices are such that $\Theta_G = \Theta_{BG} = \Theta_B$ for all $\alpha(x) \in [\hat{\alpha}_1, \hat{\alpha}_2]$. The only prices that satisfy this equality are prices $p_B^{cc} = p_B^f|_{\alpha(x)=\hat{\alpha}_1}$ and p_G^m .

The conditions for the three thresholds to allow all the market configurations to emerge are $0 < \hat{\alpha}_0 < \hat{\alpha}_1 < \hat{\alpha}_2 < 1$, which require

$$\begin{aligned}-e_B > e_G, r < c &\leq \frac{r(2e_G^2 + e_B^2)(e_G - e_B)}{-e_B(e_G^2 - e_B e_G + e_B^2)} \text{ and } \bar{\theta}\gamma(a) < \frac{3r(e_G - e_B) - c(e_G - 2e_B)}{(e_G - 2e_B)(e_G - e_B)}, \\ \text{or } \frac{r(2e_G^2 + e_B^2)(e_G - e_B)}{-e_B(e_G^2 - e_B e_G + e_B^2)} &< c < \frac{r(e_G^2 + 2e_B^2)(e_G - e_B)}{-e_B e_G - 2e_B}, \\ \text{and } \frac{r(2e_G^2 + e_B^2)(e_G - e_B) + c e_B(e_G^2 - e_B e_G + e_B^2)(e_G - 2e_B)}{-(e_G^2 - e_B^2)e_B e_G} &< \bar{\theta}\gamma(a) < \frac{r(e_G - e_B)(2e_G^2 + e_B^2)}{(e_G^2 - e_B e_G + e_B^2)}, \\ \text{or } -e_B < e_G, r < c &\leq \frac{3r(e_G - e_B)}{e_G - 2e_B}, \text{ and } \bar{\theta}\gamma(a) < \frac{3r(e_G - e_B) - c(e_G - 2e_B)}{(e_G - 2e_B)(e_G - e_B)}\end{aligned}$$

Appendix B Proofs of the effects of x and a on prices and demands in a Nash equilibrium

$f(x, a)$	$\partial f(x, a)/\partial x$	$\partial f(x, a)/\partial a$	$\partial^2 f(x, a)/\partial x \partial a$
Fragmentation			
p_B^f	$\frac{\bar{\theta}\gamma(a)e_B}{2\alpha(x)^2}\alpha'(x) < 0$	$\frac{-(1-\alpha(x))\bar{\theta}\gamma'(a)e_B}{2\alpha(x)} > 0$	$\frac{\bar{\theta}\gamma'(a)e_B\alpha'(x)}{2\alpha(x)^2} < 0$
d_B^f	$-(\frac{1}{2} + \frac{r}{2\bar{\theta}\gamma(a)e_B})\alpha'(x) < 0$ if $\bar{\theta}\gamma(a) > -r/e_B$	$\frac{\alpha(x)r\gamma'(a)}{2\bar{\theta}\gamma(a)^2e_B} < 0$	$\frac{r\gamma'(a)\alpha'(x)}{2\bar{\theta}\gamma(a)^2e_B} < 0$
p_G^m	0	$\frac{\bar{\theta}\gamma'(a)e_G}{2} > 0$	0
d_G^m	$(\frac{1}{2} - \frac{c-r}{2\bar{\theta}\gamma(a)e_G})\alpha'(x) > 0$ if $\bar{\theta}\gamma(a) > (c-r)/e_G$	$\frac{\alpha(x)(c-r)\gamma'(a)}{2\bar{\theta}\gamma(a)^2e_G} > 0$	$\frac{(c-r)\gamma'(a)\alpha'(x)}{2\bar{\theta}\gamma(a)^2e_G} > 0$
Full coverage with corner solution			
p_B^{cc}	0	$\frac{\bar{\theta}\gamma'(a)e_B}{2} < 0$	0
d_B^{cc}	$(-\frac{1}{2} + \frac{c-r}{2\bar{\theta}\gamma(a)e_G})\alpha'(x) < 0$	$\frac{-\alpha(x)(c-r)\gamma'(a)}{2\bar{\theta}\gamma(a)^2e_G} < 0$	$\frac{-(c-r)\gamma'(a)\alpha'(x)}{2\bar{\theta}\gamma(a)^2e_G} < 0$
p_G^m	0	$\frac{\bar{\theta}\gamma'(a)e_G}{2} > 0$	0
d_G^{cc}	$(\frac{1}{2} - \frac{c-r}{2\bar{\theta}\gamma(a)e_G})\alpha'(x) > 0$	$\frac{\alpha(x)(c-r)\gamma'(a)}{2\bar{\theta}\gamma(a)^2e_G} > 0$	$\frac{(c-r)\gamma'(a)\alpha'(x)}{2\bar{\theta}\gamma(a)^2e_G} > 0$
with interior solution			
p_B^c	$-\frac{2\bar{\theta}\gamma(a)(e_G-e_B)}{3\alpha(x)^2}\alpha'(x) < 0$	$\frac{(2-\alpha(x))\bar{\theta}\gamma'(a)(e_G-e_B)}{3\alpha(x)} > 0$	$-\frac{2\bar{\theta}\gamma'(a)(e_G-e_B)\alpha'(x)}{3\alpha(x)^2} < 0$
d_B^c	$(-\frac{1}{3} + \frac{c}{3\bar{\theta}\gamma(a)(e_G-e_B)})\alpha'(x)$	$-\frac{\alpha(x)\gamma'(a)c}{3\bar{\theta}\gamma(a)^2(e_G-e_B)} < 0$	$-\frac{c\gamma'(a)\alpha'(x)}{3\bar{\theta}\gamma(a)^2(e_G-e_B)} < 0$
p_G^c	$-\frac{\bar{\theta}\gamma(a)(e_G-e_B)}{3\alpha(x)^2}\alpha'(x) < 0$	$\frac{(1+\alpha(x))\bar{\theta}\gamma'(a)(e_G-e_B)}{3\alpha(x)} > 0$	$-\frac{\bar{\theta}\gamma'(a)(e_G-e_B)\alpha'(x)}{3\alpha(x)^2} < 0$
d_G^c	$(\frac{1}{3} - \frac{c}{3\bar{\theta}\gamma(a)(e_G-e_B)})\alpha'(x)$	$\frac{\alpha(x)\gamma'(a)c}{3\bar{\theta}\gamma(a)^2(e_G-e_B)} > 0$	$\frac{c\gamma'(a)\alpha'(x)}{3\bar{\theta}\gamma(a)^2(e_G-e_B)} > 0$

Appendix C Proofs of optimal campaigns

Table C.1 summarizes the effects of information and awareness-raising campaigns on environmental quality in each market configuration.

Because environmental quality $E(x, a)$ is a piecewise linear function of x and a , with $\alpha(x)$ between 0 and 1, and $\gamma(a)$ between 1 and $\bar{\gamma}$, defined by the existence conditions of the different market configurations that vary with a as well, we cannot use the usual optimization method to simply maximize $E^k(x, a)$ with $k = s, f, cc, c$. Instead, we obtain the optimal information and

$E(x, a)$	$E_x = \partial E(x, a) / \partial x$	$E_a = \partial E(x, a) / \partial a$
E^s	$\frac{\alpha'(x)}{2} \left(\bar{e} + e_G - 2e_B + \frac{(c-r)(\bar{e}-e_G)}{\bar{\theta}\gamma(a)e_G} \right)$	$-\alpha(x) \frac{(c-r)(\bar{e}-e_G)\gamma'(a)}{2\bar{\theta}\gamma(a)^2 e_G}$
E^f	$\frac{\alpha'(x)}{2} \left(e_G - e_B + \frac{r\bar{e}(e_G-e_B)+ce_B(\bar{e}-e_G)}{\bar{\theta}\gamma(a)e_B e_G} \right)$	$\alpha(x) \frac{(r\bar{e}(e_G-e_B)+ce_B(\bar{e}-e_G))\gamma'(a)}{-2\bar{\theta}\gamma(a)^2 e_B e_G}$
E^{cc}	$\frac{\alpha'(x)(e_G-e_B)(r+\bar{\theta}\gamma(a)e_G)c}{2\bar{\theta}\gamma(a)e_G}$	$\alpha(x) \frac{(e_G-e_B)(c-r)\gamma'(a)}{2\bar{\theta}\gamma(a)^2 e_G}$
E^c	$\frac{\alpha'(x)}{3} \left(e_G - e_B - \frac{c}{\bar{\theta}\gamma(a)} \right)$	$\alpha(x) \frac{c\gamma'(a)}{3\bar{\theta}\gamma(a)^2}$

Table C.1: Effects of x and a on environmental quality

awareness-raising campaigns through the following:

$$\max_a \left[\max_x E(x, a) \right] \quad \text{subject to } w_x x + w_a a \leq R$$

We thus proceed in two steps: (1) we determine x^* that maximizes $E(x, a)$ for a given a , and (2) we derive a^* that maximizes $E(x^*, a)$ under the budget constraint $w_x x^* + w_a a \leq R$.

Maximization of $E(x, a)$ for a given a

The analysis in Section 5 shows that $E(x, a)$ reaches its maximum for a fraction $\alpha(x)$ of informed consumers equal to either $\hat{\alpha}_0(a)$ or $\min(\hat{\alpha}_2(a), 1)$. Therefore, denoting $\hat{x}_i(a)$ the information campaign that leads to $\alpha(\hat{x}_i(a)) = \hat{\alpha}_i(a)$ and \bar{x} such that $\alpha(\bar{x}) = 1$, we compare $E^s(\hat{x}_0(a), a)$ with $E^f(\bar{x}, a)$ and $E^{cc}(\min(\hat{x}_2(a), \bar{x}), a)$ to characterize the conditions for each optimal x . We define the key environmental quality levels as follows:

$$\begin{aligned}
E^s(\hat{x}_0(a), a) &= \frac{e_B (r(\bar{e} + e_G) - c(\bar{e} - e_G) - \bar{\theta}\gamma(a)(\bar{e} + e_G)e_G)}{2(r - \bar{\theta}\gamma(a)e_B)e_G} \\
E^f(\bar{x}, a) &= \frac{r\bar{e}(e_G - e_B) + ce_B(\bar{e} - e_G) + \bar{\theta}\gamma(a)(\bar{e} + e_G)e_G e_B}{2\bar{\theta}\gamma(a)e_G e_B} \\
E^{cc}(\hat{x}_2(a), a) &= \frac{N}{2e_G (3r(e_G - e_B) - c(e_G - 2e_B) + \bar{\theta}\gamma(a)(e_G - e_B)(e_G + e_B))} \\
\text{with } N &= r(e_G - e_B)(e_G + e_B)(2e_G + e_B) - c(2e_G^3 - 3e_B e_G^2 - e_B^3) \\
&\quad + e_G(e_G - e_B)(2e_G^3 - e_B e_G + 3e_B^2)\bar{\theta}\gamma(a) \\
E^{cc}(\bar{x}, a) &= \frac{1}{2} \left(e_G + e_B - \frac{(c-r)(e_G - e_B)}{\bar{\theta}\gamma(a)e_G} \right)
\end{aligned}$$

We deduce that $E^s(\hat{x}_0(a), a) \leq E^f(\bar{x}, a)$ if $\gamma(a) \geq \hat{\gamma}_3$, a condition that ensures that $E_x^f(x, a) \geq 0$ and prevents a covered market (because $\hat{\gamma}_3 > \hat{\gamma}_1$). However, using the expressions in Table C.1, we can prove that $E_x^s(x, a) > E_x^f(x, a)$. Therefore, x is a more effective tool in a segmented

market than in a fragmented market. As a result, even if $E^s(\hat{x}_0(a), a) \leq E^f(\bar{x}, a)$ for a given a , there exists $a' > a$ such that $E^s(\hat{x}_0(a'), a') \geq E^f(\bar{x}, a)$. As a result, if $\gamma(a) \geq \hat{\gamma}_3$, the information campaign that maximizes environmental quality is either $\hat{x}_0(a')$ or \bar{x} for given a and a' .

Moreover, if $\gamma(a) \leq \hat{\gamma}_1$, the market is covered when $\alpha(x) \geq \hat{\alpha}_1(a)$ and the environmental quality-level equations show that the value of a , such that $E^s(\hat{x}_0(a), a) = E^{cc}(\hat{x}_2(a), a)$, corresponds to a real root of a second-degree polynomial in $\bar{\theta}\gamma(a)$. We can show that this polynomial has two real roots, only one of which is greater than $\bar{\theta}$. We denote this root as $\bar{\theta}\hat{\gamma}_4$ (whose expression is of no interest) and deduce that $E^s(\hat{x}_0(a), a) \geq E^{cc}(\hat{x}_2(a), a)$ if $\bar{\theta}\gamma(a) \leq \bar{\theta}\hat{\gamma}_4$. A similar reasoning applies to $E^s(\alpha_0(a), a) = E^{cc}(\bar{x}, a)$. We can show that $E^s(\hat{x}_0(a), a) \geq E^{cc}(\bar{x}, a)$ if $\bar{\theta}\gamma(a)$ is higher than a threshold, denoted $\bar{\theta}\hat{\gamma}_5 \geq \bar{\theta}\hat{\gamma}_4$.

Figure C.1 illustrates the results; it shows the thresholds for $\bar{\theta}\gamma(a)$ as a function of e_B , by setting $\bar{e} = 2$, $e_G = 1$, $r = 3$, and $c = 4$.

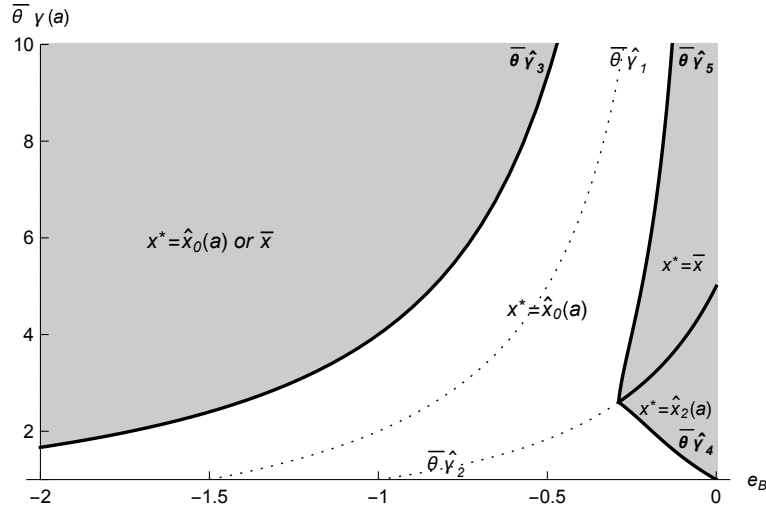


Figure C.1: Thresholds for $\bar{\theta}\gamma(a)$ according to e_B

Maximization of $E(x^*, a)$ under the budget constraint

The analysis of $E^k(x, a)$ in Section 5 also shows that $E^k(x, a)$ is an increasing function of a for a given x in all market configurations, except a segmented market. Therefore, the optimal awareness-raising campaign is to increase a as much as the budget constraint allows. The optimal information and awareness-raising campaigns are then

- (i) $(\hat{x}_0(a^*), a^*)$, with $w_x \hat{x}_0(a^*) + w_a a^* = R$ if $\gamma(a^*) \leq \hat{\gamma}_3$, and $\gamma(a^*) \notin [\hat{\gamma}_4, \hat{\gamma}_5]$ (i.e., the white area in Figure C.1);

- (ii) $(\hat{x}_0(a^*), a^*)$, with $w_x \hat{x}_0(a^*) + w_a a^* = R$ if $\gamma(a^*) > \hat{\gamma}_3$, and $E^s(\hat{x}_0(a^*), a^*) > E^f(\bar{x}, a^{**})$, with $a^{**} < a^*$ and $w_x \bar{x} + w_a a^{**} = R$ (i.e., the gray area on the northwest side of Figure C.1);
- (iii) (\bar{x}, a^{**}) , with $w_x \bar{x} + w_a a^{**} = R$ if $\gamma(a^{**}) > \hat{\gamma}_3$, and $E^f(\bar{x}, a^{**}) > E^s(\hat{x}_0(a^*), a^*)$, with $a^{**} < a^*$ and $w_x \hat{x}_0(a^*) + w_a a^* = R$; and
- (iv) $(\min(\hat{x}_2(a^*), \bar{x}), a^*)$, with $w_x \min(\hat{x}_2(a^*), \bar{x}) + w_a a^* = R$ when $\gamma(a^*) \in [\hat{\gamma}_5, \hat{\gamma}_6]$ (i.e., the gray area on the right-hand side of Figure C.1).

Case (iv), in which $\gamma(a^*) \in [\hat{\gamma}_4, \hat{\gamma}_5]$, occurs only when e_B is close to 0 and the market is covered for a small fraction $\alpha(x)$, because $\hat{\alpha}_0(a)$ and $\hat{\alpha}_1(a)$ tend toward 0. Moreover, $\hat{\alpha}_2(a)$ tends toward $2\bar{\theta}\gamma(a)e_G/(3r - c + \bar{\theta}\gamma(a))$, which is higher than 1 if $\bar{\theta}\gamma(a) > (3r - c)/e_G$.

Appendix D Effects of the campaigns on consumer surplus

Table D.1 summarizes the effects of the information and awareness-raising campaigns on the welfare components in all possible market configurations, where CoS means "corner solution," and InS means "interior solution," and the symbol \pm means that the effect of the variable can be positive or negative depending on certain conditions on the parameters of the model. As we already detailed the effects of the campaigns on profits and environmental quality previously, we analyze only their effects on consumer surplus here.

	Segmentation		Fragmentation		Coverage CoS		Coverage InS	
W	x	a	x	a	x	a	x	a
CS_U	0	0	+	-	0	+	\pm	-
CS_{BI}	/	/	+	-	0	+	\pm	\pm
CS_{GI}	0	+	0	+	0	+	\pm	\pm
CS	+	+	\pm	\pm	\pm	+	\pm	-
π_B	-	0	-	-	-	-	-	+
π_G	+	+	+	+	+	+	-	+
δE	+	-	\pm	+	\pm	+	\pm	+
$-\sigma(x, a)$	-	-	-	-	-	-	-	-

Table D.1: Effects of x and a on welfare components

Depending on the market configuration of the Nash equilibrium, we define the resulting surplus

of uniformed and informed consumers as follows:

$$CS_U^s = 0, \quad (D.1)$$

$$CS_I^s = \frac{(r - c + \bar{\theta}\gamma(a)e_G)^2}{8\bar{\theta}\gamma(a)e_G}, \quad (D.2)$$

$$CS_U^f = \frac{r}{2} + \frac{(1 - \alpha(x))\bar{\theta}\gamma(a)e_B}{2\alpha(x)}, \quad (D.3)$$

$$CS_I^f = \frac{(\alpha(x)r + (1 - \alpha(x))\bar{\theta}\gamma(a)e_B)^2}{-8\alpha(x)^2\bar{\theta}\gamma(a)e_B} + \frac{(r + \bar{\theta}\gamma(a)e_G - c)^2}{8\bar{\theta}\gamma(a)e_G}, \quad (D.4)$$

$$CS_U^{cc} = \frac{-e_B(c - r + \bar{\theta}\gamma(a)e_G)}{2e_G}, \quad (D.5)$$

$$CS_I^{cc} = \frac{-e_B(-r + \bar{\theta}\gamma(a)e_G + c)^2}{8\bar{\theta}\gamma(a)e_G^2} + \frac{(r + \bar{\theta}\gamma(a)e_G - c)^2}{8\bar{\theta}\gamma(a)e_G}, \quad (D.6)$$

$$CS_U^c = \frac{(1 - \alpha(x))(-\alpha(x)(c - 3r) - (2 - \alpha(x))\bar{\theta}\gamma(a)(e_G - e_B))}{3\alpha(x)}, \quad (D.7)$$

$$CS_I^c = r + \frac{((7e_G + 2e_B)\alpha(x)^2 - 10(e_G - e_B)\alpha(x) + e_G - e_B)\bar{\theta}\gamma(a)}{18\alpha(x)^2} - \frac{2(4\alpha(x) + 1)c}{\alpha(x)} + \frac{c^2}{\bar{\theta}\gamma(a)(e_G - e_B)}, \quad (D.8)$$

where the first term in the equations characterizing CS_I^f and CS_I^{cc} corresponds to the surplus of the informed consumers who consume the brown product and the second term corresponds to the surplus of the informed consumers who consume the green product. Next are demonstration elements in the case when the effects of x and a on surpluses are ambiguous.

In the case of fragmentation, using Equations (D.3) and (D.4), we can define the total consumer surplus as

$$CS^f = \frac{r - \alpha(x)c}{4} + \frac{\alpha(x)(-(e_G - e_B)r^2 - 2ce_Br + c^2e_B)}{8\bar{\theta}\gamma(a)e_Ge_B} + \frac{\bar{\theta}\gamma(a)(\alpha(x)^2e_G + 3(1 - \alpha(x))^2e_B)}{8\alpha(x)}.$$

The derivatives of the consumer surplus with respect to x and a are

$$\begin{aligned} \frac{\partial CS^f}{\partial x} &= \left(\frac{-c}{4} + \frac{-r^2e_G + (c - r)^2e_B}{8\bar{\theta}\gamma(a)e_Ge_B} + \left(e_G - 3e_B \frac{1 - \alpha(x)^2}{\alpha(x)^2} \right) \bar{\theta}\gamma(a) \right) \alpha'(x), \\ \frac{\partial CS^f}{\partial a} &= \frac{\gamma'(a)}{8\alpha(x)\bar{\theta}} \left(3(1 - \alpha(x))^2\bar{\theta}^2e_B + \alpha(x)^2\bar{\theta}^2e_G + \frac{\alpha(x)^2(r^2e_G - (c - r)^2e_B)}{\gamma(a)^2e_Ge_B} \right). \end{aligned}$$

As the second and third terms within the parentheses of $\partial CS^f / \partial x$ are positive, the consumer

surplus is an increasing function of x as soon as the (negative) first term, and thus the unit cost of production c , is sufficiently low (within the bounds defined by Assumption 2). As the first and third terms of $\partial CS^f/\partial a$ are negative, the consumer surplus is a decreasing function of a as soon as the (positive) second term is sufficiently low. Nevertheless, the conditions on $\alpha(x)$ and $\gamma(a)$ and the four parameters of the model for the consumer surplus to be a decreasing or increasing function of x and a are difficult to detail.

In the case of a covered market with a corner solution, the condition for the total surplus to be an increasing function of x is $CS_U^{cc} < CS_I^{cc}$, which can be written as a second-degree polynomial in $z \equiv \bar{\theta}\gamma(a)e_G$:

$$P(z) = (e_G + 3e_B)z^2 - 2(e_G - e_B)(c - r)z + (e_G - e_B)(c - r)^2 > 0,$$

whose discriminant $\Delta = -16(c - r)^2(e_G - e_B)e_B$ is positive. The polynomial thus has two real roots, defined as $z_i = \left((c - r)(e_G - e_B) \pm (c - r)\sqrt{(e_G - e_B)e_B} \right) / (e_G + 3e_B)$, both of which are positive if $e_G + 3e_B > 0$ or only one of which is positive if $e_G + 3e_B < 0$. In both cases, $P(z) > 0$ if $z < z_1$, which we can rewrite as

$$0 < \bar{\theta}\gamma(a)e_G < \frac{(c - r) \left(e_G - e_B - \sqrt{-e_B(e_G - e_B)} \right)}{3e_B + e_G}.$$

In the case of a covered market with an interior solution, the condition for the surplus of uninformed consumers to be an increasing function of x is

$$(c - 3r)\alpha(x)^2 + (e_G - e_B)(2 - \alpha(x)^2)\bar{\theta}\gamma(a) > 0,$$

and the condition for the surplus of informed consumers to be an increasing function of x is

$$\alpha(x)c - (e_G - e_B)(1 - 5\alpha(x))\bar{\theta}\gamma(a) > 0.$$

The condition for the total surplus is then

$$\frac{\partial CS^c}{\partial x} = \frac{\alpha'(x)}{18} \left(4c(1 - 3r) - 18r(1 - 2\alpha(x)) \right) + \frac{c^2}{(e_G - e_B)\bar{\theta}\gamma(a)}$$

$$+ \frac{(12(e_G - e_B)\alpha(x)^3 - (17e_G - 26e_B)\alpha(x)^2 + 11(e_G - e_B))\bar{\theta}\gamma(a)}{\alpha(x)^2} \Big) > 0.$$

The conditions on $\alpha(x)$ and $\gamma(a)$ and the four parameters of the model for the consumer surplus to be a decreasing or increasing function of x are thus difficult to detail. However, the surplus of uninformed and informed consumers (i.e., the total surplus) is unambiguously decreasing in a :

$$\begin{aligned} \frac{\partial CS^c}{\partial a} &= \frac{\gamma'(a)}{18\alpha(x)\bar{\theta}} \left(\left((11 - 2(1 - \alpha(x))(10 - 3\alpha(x))\alpha(x))e_B - (11 - 20\alpha(x) + 17\alpha(x)^2 - 6\alpha(x)^3)e_G \right) \bar{\theta}^2 \right. \\ &\quad \left. - \frac{\alpha(x)^2 c^2}{\gamma(a)^2 (e_G e_B)} \right) < 0. \end{aligned}$$

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