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Dorothée Brécard, Mireille Chiroleu-Assouline

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The Market for "Harmful Component-Free" Products under Pressure from the NGOs

Abstract

Non-governmental organizations (NGOs) are exerting growing pressure on firms to eliminate product components (such as palm oil) that are harmful to the environment (such as rainforests) or replace such components with NGO-certified sustainable components. Under which conditions does NGO pressure lead firms to eliminate basic components from their products or, alternatively, substitute damaging components with certified sustainable components? What are the ensuing effects on market structure, environmental quality, and social welfare? The paper addresses these issues using a model of two-dimensional vertical product differentiation. It shows that, for an NGO that collects certification fees to accrue its budget and finance its awareness campaign, it may — paradoxically — be optimal to reduce the certified product's market share and eventually evict it.

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

Keywords: NGO, eco-label, environmental quality, product differentiation, palm oil, biofuels.

Dorothée Brécard
Université de Toulon / France
brecard@univ-tln.fr

Mireille Chiroleu-Assouline
Paris School of Economics
University of Paris I Panthéon-Sorbonne
Paris / France
Mireille.Chiroleu-Assouline@univ-paris1.fr

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1 Introduction

"If a company is doing the right thing, we are proud to stand up with them to advocate for solutions. If they are doing the wrong thing, we can campaign against them all around the globe to bring enough pressure to bear that they are forced to do the right thing." This statement from Daniel Kessler, a spokesperson of Greenpeace, the growing pressure that environmental non-governmental organizations (NGOs) exert on firms' strategies.[1] Different NGO campaigns take various forms and have different environmental goals. They often disclose information about the properties of goods purchased by consumers, the sustainability of production processes, and environmental impacts. For example, in 2010, Greenpeace mounted the campaign *"Ask Nestlé to give rainforests a break"*.[2] Relayed largely by social networks, the campaign forced Nestlé to end its partnership with Sinar Mas, the largest palm oil producer in Indonesia, and commit to removing deforestation-related products from its supply chains. In 2015, Greenpeace continued to pressure global consumer goods manufacturers by publishing a report on how companies were keeping promises to stop producing deforestation-dependent palm oil in Indonesia.

Other environmental NGO campaigns with similar goals include the French Greenpeace "zero pesticide" campaign aimed at the France's six largest retailers (Auchan, Carrefour, Casino, Intermarché, Monoprix, Magasins U). Such campaigns resort to the field that Baron (2009) refers to as "private politics," which include tactics ranging from simple information disclosure (Petrakis, Sartzetakis, & Xepapadeas, 2005; Baron, 2011, or Heyes, Lyon, & Martin, 2018) to boycotts campaigns (studied by Innes, 2006; Delacote, 2009; Baron, Neale, & Rao, 2016; Baron, 2016, and Egorov & Harstad, 2017). They have resulted in an increasing number of "component-free products," —that is, products free of damaging components— such as palm oil, pesticides, antibiotics, GMOs, nitrate, and chlorine, as well as paraben-free products used in agri-food products and cosmetic markets and fossil-free products such as green electricity. In the specific case of palm oil, the Roundtable on Sustainable Palm Oil (RSPO), which includes environmental NGOs such as the World Wildlife Foundation (WWF), promotes the growth and use of certified sustainable palm oil (CSPO) as an alternative to non-sustainable palm oil for firms. Firms may prefer this alternative oil for two reasons: First, it does not require the alteration of product texture and second (like biofuels), it is less expensive. We note, however, the effectiveness of such eco-labels in preventing deforestation has been contested (van der Ven, Rothacker, & Cashore, 2018).

In this paper, we ask: Under which conditions does NGO pressure lead firms to eliminate basic components of their products or, alternatively, replace damaging components with certified

[1] https://www.greenbiz.com/blog/2010/04/22/how-ngo-partnerships-changed-over-20-earth-days (accessed 2017/03/01).

[2] http://www.greenpeace.org/international/en/campaigns/climate-change/kitkat/ (accessed 2017/03/01).

sustainable components? What are NGOs' optimal strategies? What are the ensuing effects on market structure and quality of the environment? We address these issues using a two-dimensional vertical product differentiation model.

There is a rich body of theoretical literature on the competition between "green" and "brown" products that studies the efficiency of environmental policies (such as minimum quality standards, voluntary labels, norms, taxation) depending on firms' cost structures, abatement methods, environmental consciousness, information, and consumer altruism. To the best of our knowledge, only a limited number of authors have considered the role of NGOs as certifying organizations that aim to improve environmental quality (Bottega & De Freitas, 2009; Brécard, 2014; Fischer & Lyon, 2014; Bonroy & Constantatos, 2015; Brécard, 2017; Poret, 2019) and the competition issues related to environmental awareness and labels (Conrad, 2005; Ben Elhadj, Gabszewicz, & Tarola, 2015; Ben Elhadj & Tarola, 2015; Heyes & Martin, 2015). Although we too study the conditions of NGO eco-labelling efficiency, we depart by analyzing the role of NGOs more deeply and by explicitly considering the strategic dilemmas they face in fulfilling their objectives. Kraft, Zheng, and Erhun (2013) also explore the issue of NGOs that seek to push industries to replace potentially hazardous components. However, their perspective is somewhat different: They consider NGOs to be pragmatic, such that their objective function takes industrial profits into account and that they have a choice between lobbying regulators or directly influencing the market via consumer sensitivity to the presence of components. Recently, Stathopoulou and Gautier (2019) examined an environmental group's choice to campaign against a polluting firm in such a way that it would shrink consumer demand for the firm's product, or it would form a "green alliance" with the firm to would reduce the cost of implementing a greener technology. We extend their analysis of NGO strategies by considering the possibility that NGOs can directly influence consumers' environmental awareness through information campaigns in addition to disclosing the harmfulness of the component and campaigning to certify other components that are less harmful to the environment.[3] Our model shares features with Bottega, Delacote, and Ibanez (2009), García-Gallego and Georgantzís (2009), and García-Gallego and Georgantzís (2010). Unlike these authors, however, we assume for the sake of simplicity that the level of requirement of the environmental label issued by the NGO is set and that the NGO adjusts the amount of certification fees to achieve its objective of improving the environment. Moreover, we study the

[3]Despite abundant literature on boycotts initiated by NGOs (e.g. Eesley & Lenox, 2006; Baron & Diermeier, 2007; Lenox & Eesley, 2009), we consider that the NGO acts only indirectly to drive out the component harmful to the market environment and does not call for a boycott of the products concerned. As argued by Gupta and Innes (2014), other tactics may be preferred to boycotts in cases (like ours) of very non-competitive markets, in which the product is highly attractive to consumers and where consumers are initially unaware of its environmental consequences.

choices of existing firms and the entry of competitors to produce goods of given environmental quality, and not endogenous, under the impetus of the information campaign conducted by the NGO.

Furthermore, we adapt Garella and Lambertini (2014) original model of bidimensional vertical differentiation. Indeed, there is a technical reason that firms use denounced components: The components (such as palm oil) are crucial to assuring good product texture (e.g., Nutella) known as "organoleptic" quality. Removal of such substances causes significant deterioration of taste. High organoleptic quality is associated with low environmental quality, and vice versa. Therefore, component-free products are viewed as having high environmental quality but low organoleptic quality.. Such an assumption resembles the hypothesis of Mantovani, Tarola, and Vergari (2016)), which is that high intrinsic quality of products generates high polluting emissions. However, we depart from their hypothesis by considering that "good attributes" and "bad attributes" have no presupposed inversely proportional relationship. Moreover, we assume that instead of eliminating harmful components—to the detriment of product textures—firms can replace the components with NGO-certified sustainable components (such as sustainable palm oil) without altering the organoleptic quality of the products. According to Mantovani et al. (2016), consumers have homogeneous preferences for environmental quality and heterogeneous preferences for intrinsic quality; in our model, consumers have heterogeneous preferences for environmental quality and homogeneous preferences for organoleptic quality. That is, environmental attributes are the non-hedonic characteristics in their model, but the hedonic characteristics in our model.

Noting the results of two previously mentioned key articles by García-Gallego and Georgantzís, in order to consider only situations in which the increase in consumers' environmental awareness is unlikely to deteriorate social welfare. On the one hand, García-Gallego and Georgantzís (2009) show that in the context of a duopoly model of vertical differentiation, in which two firms choose their degrees of corporate social responsibility, an increase in consumers' environmental awareness may lead to a shift from complete market coverage to incomplete market coverage, entailing discontinuous jumps in equilibrium quantities, prices, and social welfare. In our paper, we assume the market is always covered, because consumers want to consume goods, but we do not exclude the possibility that NGO campaigns will lead to monopoly situations for one type of firm. However, García-Gallego and Georgantzís (2010) show that enhancing consumers' willingness to pay (WTP) for environmental quality without altering their heterogeneity is likely to favor the greenest products and enhance social welfare, contrary to increasing or reducing consumers' WTP heterogeneity.[4] Therefore, our framework assumes that consumer en-

[4]Such non-uniform changes lead to demand rotations such as those already considered by Johnson and Myatt (2006).

vironmental awareness is homogeneously distributed and that NGOs' campaigns are tantamount to increasing it uniformly. These simplifications allow us to focus on the effects of NGO strategies in the more complex context of competition.

By using this original framework, we show that consumers' relative WTP for environmental quality and organoleptic quality plays a crucial role in the efficiency of NGO campaigns. We also show that the cost structure of eliminating harmful components and replacing them with other components conditions the effectiveness of NGO campaigns.

Further, by building on empirical evidence of the increasing share of some NGO budgets accrued by certification fees (e.g., more than 75% in 2017 for the Marine Stewardship Council [MSC]), Wijen & Chiroleu-Assouline, 2019), we assume that NGO campaign efforts are financed through initial budgets (obtained through membership, donations, and charities) and from fees collected from certification of components. This assumption considers the notion of non-profit revenue diversification (Mitchell & Calabrese, 2019) as well the possible role of a coalition of NGOs that implements various levers for action. It also assumes that rather than exhausting their budgets, NGOs may be subject only to the "non-distribution of profits" constraint, described by Hansmann (1980), which justifies the strong requirement for transparency (Cabedo, Fuertes-Fuertes, Maset-LLaudes, & Tirado-Beltrán, 2018). Indeed, although NGOs are non-profits, they generally have action portfolios among which they distribute their efforts and funding, just as they reserve funds from one year to the next (as shown in the annual accounts of large NGOs). We discuss the potential benefits of such functioning of the green non-profit sector for environmental and social welfare.

Beyond the theoretical novelties of our approach, our main contribution is to show that NGOs may waive the objective of achieving a market in which only the least environmentally harmful products are offered when the cost of developing such products is very high; instead, they may restrict market shares of such products by favoring the entry of new products that use certified components. However, we also show that, in other cases and when initial budgets are sufficiently high, NGOs may prefer to hamper the cost-effectiveness of certified components to increase the market shares of component-free products, or even encourage the creation of monopolies. In such cases, NGOs may use certified components as strategic tools to modify market structures—something they would not do if it they were concerned only with offering certified products without worrying about increasing their budgets through fees.

The remainder of the paper is structured as follows. Section 2 presents the basic model. Section 3 analyzes the effects of information disclosure and awareness-raising campaign of the NGO on consumer and firm choices. Section 4 studies the conditions under which the certified sustainable component is adopted, as a result of the strategies implemented by the NGO. Section

5 proposes further discussion about the main assumptions and results, and Section 6 offers conclusions.

2 The model

2.1 Consumers

In the line with Garella and Lambertini (2014), we assume that consumers decide to buy either one unit or none of the good, which is characterized by two attributes: a non-hedonic (homogeneous) organoleptic characteristic, such as taste or texture, denoted as t_i, and an hedonic (heterogeneous) environmental characteristic, denoted as e_i (with $i = 0, L, M, H$). The latter is related to the component denounced by the NGO. Before information disclosure, consumers are not aware of such a harmful component in the product. The environmental attribute can be qualified as 'neutral'. After information disclosure, consumers have a full understanding of the damaging impact of the component on the environment (and/or the health). Therefore, the environmental characteristic is no longer a neutral attribute but is now a bad attribute.

Consumers' WTP for environmental quality is assumed uniformly distributed over $\left[\underline{\theta}, \overline{\theta}\right]$ before the NGO's campaign. The NGO's campaign increases WTP, which is then defined by the increasing function $\theta(x)$, with x the raising-awareness effort of the NGO. The campaign is therefore a form of persuasive advertising (Bagwell, 2007; van der Made & Schoonbeek, 2009). For the sake of simplicity, we assume that $\theta(x) = \theta + x$: The NGO achieves a uniform WTP increase without altering consumers' heterogeneity.[5] Consumers' WTP for organoleptic quality is constant, denoted as $\rho > 0$, for all consumers. Therefore, consumer preferences are represented by the following utility function

$$u_i(\theta, x) = r + \rho\ t_i + \theta(x)e_i\ - p_i \text{ for } \ i = 0, h, m, l \tag{1}$$

with p_i as the price of the product i, and $r > 0$ as the utility enjoyed by the consumer from consuming one product unit, before the difference in the product's environmental or organoleptic qualities is taken into account. The consumer who is indifferent to consuming the product i or refraining from buying the product at price p_i is characterized by marginal willingness to pay for the environmental quality $\widetilde{\theta}_i = \frac{p_i - r - \rho t_i}{e_i} - x$.

2.2 Firm

We study a market dominated by a flagship product, and therefore we assume that before the NGO's campaign, the market is fully covered by a monopoly producing a good with organoleptic

[5] Under this assumption, social welfare is unlikely to be deteriorated in the duopoly case studied by García-Gallego and Georgantzís (2009) and García-Gallego and Georgantzís (2010).

quality t_0 and an environmental quality perceived as being equal to e_0 by uninformed consumers. The monopoly incurs a unit production cost c_0, which is supposed as null, without loss of generality. The price that maximizes the profit of the monopoly is the maximum price that all consumers are ready to pay for the product: $p_0 = r + \rho\ t_0 + \underline{\theta} e_0$. The profit is then defined by $\pi_0^* = r + \rho\ t_0 + \underline{\theta} e_0$. Because consumers do not pay attention to the environmental quality of the product, we assume that $e_0 = 0$.[6]

After the NGO's campaign, according to the type of good the monopoly decides to supply, the monopoly earns a profit $\pi_i(p_i) = (p_i - c_i)d_i(p_i) - F_i$, where c_i are unit costs and F_i are fixed costs of production, with $i = H, M, L$. We assume that when the firm continues to produce the product with the harmful component, denoted by subscript L, it bears exactly the same unit cost than before the campaign, that is $c_L = 0$ and $F_L = 0$. To switch to a component-free product (denoted as H), the monopoly must engage in research and development (R&D) to innovate a new technology or a new production process. As is usual for differentiation models, we assume that R&D generates only a fixed cost, such as $F_H \geq 0$ and $c_H = 0$. To switch to a certified product (denoted as M), the firm must buy a sustainable component to replace the denounced component; therefore, we assume that it only bears a higher variable production cost than before, equal to $c_M \geq 0$, because it incorporates the component produced under sustainable conditions that imply additional constraints for producers, leading to higher cost. Because the nature of the component is not altered (i.e., sustainable palm oil is not different from palm oil), there is no fixed cost incurred when adopting the intermediate component ($F_M = 0$).[7] Moreover, the firm must pay a label fee, φ, to the NGO per unit of Product M sold.[8]

The NGO's campaign also may foster entry of new firms to the market.[9] By disclosing damaging impacts of the denounced attribute, the campaign creates possibilities of both product differentiation and profit opportunities for new entrants. According to these profit expectations, the market may move toward a duopoly or triopoly structure.

[6] An alternative rationale for this assumption could be that consumers pay attention only to the change in environmental quality as the result of information disclosure and campaign of the NGO.

[7] Our analytical framework is thus a simplified version of the more general framework in which $c_L \leq c_H \leq c_M$ and $F_L \leq F_M \leq F_H$. This makes it possible to isolate the main drivers from competition between the three products: only the variable costs differ between Products L and M, whereas only the fixed costs differ between Products L and H.

[8] Allowing the variable production cost to increase with the environmental quality level e_M would have an impact only if this quality level was endogenous. However, we assume it to be exogenous (Section 2.3).

[9] We consider the case in which each firm produces a single product, and competition between the different possible products therefore involves only the entry of new firms into the market. The results would be qualitatively unchanged if the monopoly chose to offer the different products itself, under differentiated brands. Profit entry conditions would change only marginally.

2.3 NGO

With its knowledge of a harmful component in the good, the NGO seeks to disclose information and promote consumer awareness of the damaging effect of the component on the environment. Disclosing information is costless, but the awareness-raising campaign requires a cost that is strictly increasing and convex in effort x, with the quadratic form x^2 ($x \geq 0$). The objective of the NGO is to enhance the quality of the environment under its budget constraint. In the general case of three products coexisting on the market, the overall quality of the environment is the sum of the quality of the environment related to each product, defined as $E_i = e_i d_i$ for $i = L, M, H$. We assume that the NGO has an initial budget B that finances its awareness-raising campaign effort x^2. When it decides to certify a substitutable component that is less harmful to the environment, it charges a unit fee φ that accrues to its initial budget, potentially allowing the financing of a greater campaign effort. We also assume, for the sake of simplicity, that certification is costless for the NGO. Contrary to Bottega and De Freitas (2009), we do not assume that because of the non-profit nature of the NGO, the fee is determined by a non-profit condition; instead, we adopt a broader perspective according to the principle that NGOs are subject only to the "non-distribution of profits" constraint stated by Hansmann (1980) that does not prevent them from reserving funds for other projects, now or in the future. We assume that the quality of the substitutable component is exogenously determined (depending on the respective bargaining power of the NGO and the local producers of this component). As a result, the NGO's program is:

$$\begin{cases} \max\limits_{x,\varphi} \sum\limits_{L,M,H} E_i = \sum\limits_{L,M,H} e_i d_i \\ \text{st } x^2 \leq B + \varphi d_M \end{cases}$$

2.4 Timing of the game and market structure

The game involves a series of stages:

1. Before the NGO's campaign, the monopoly produces a good with an environmental quality index e_0 depending on the use of a given component (e.g. palm oil for Nutella, coal for electricity)

2. The NGO learns of the harmfulness of the component used by the monopoly and decides to campaign (we assume that its objective function will make it profitable to campaign in any case) by disclosing this information, that is $e_L < e_0 = 0$. Disclosure is costless, but influencing the environmental awareness of the consumers is costly.

3. The NGO decides to invest x^2 in order to increase the consumers' willingness to pay for

environmental friendliness and to certify an intermediate component of quality e_M with $e_0 < e_M < e_H$.

4. The monopoly reacts to the information campaign of the NGO. It can choose between three options:

   (a) producing the low-quality good with the same harmful component, and losing profit;

   (b) investing in R&D to produce a free-component good, of quality $e_H > e_0$;

   (c) substituting the harmful component with the certified intermediate component, of quality $e_M \in]e_0, e_H[$.

5. Depending on the choice of the monopoly, other firms can enter the market and offer other varieties of the good. The resulting market structure can thus be a duopoly or a triopoly, as shown in Figure A.1.

6. 4. The consumers decide to buy either one unit of the proposed products or none of the product.

We solve the game backwards.

It is worth noting that similar market structures may originate from different causes. For example, the duopoly (L, H) corresponds to the case in which the initial monopoly decides to maintain Product L denounced by the NGO and a competitor enters the market with Product H, whereas the duopoly (H, L) corresponds to the case where the initial monopoly decides to go for product H leaving a competitor enough space to enter the market with Product L, even though it is shamed by the NGO. In the first case, the monopoly maintains its initial product because choosing Product H would be too costly (high R&D costs) and would induce a lower profit than keeping Product L; the competitor enters if the duopoly profit obtained with Product H is greater than zero, despite the high R&D costs. In the second case, the monopoly chooses Product H (low R&D costs) and the competitor enters as soon as its duopoly profit with Product L is still positive. We analyze the sequence of the game in greater detail in Section 3.4.

3 Information disclosure and awareness campaign

3.1 Monopoly equilibrium with the harmful component-containing product

After the NGO's campaign, when the monopoly continues to produce the same good, consumers consider the denounced component of the product as a bad attribute such as $e_L < e_0$, whereas the organoleptic attribute remains unchanged ($t_L = t_0$). Assuming $e_0 = 0$, the bad attribute is

characterized by a negative quality index, $e_L < 0$. For the sake of simplicity, because e_L is the worst possible environmental quality, we define $e_L \equiv -\overline{e}$.

Definition 1 *The minimum WTP for product L is defined as* $\underline{\omega}_L(x) \equiv r + \rho t_0 - (\overline{\theta} + x)\overline{e}$. *The maximum WTP is* $\overline{\omega}_L(x) \equiv r + \rho t_0 - (\underline{\theta} + x)\overline{e}$.

The equilibrium price is derived from the first order condition of maximization of $\pi_L(p_L) = p_L d_L(p_L)$. It is characterized by:

$$p_L^m(x) = \frac{1}{2}\overline{\omega}_L(x) \tag{2}$$

The monopoly faces a demand equal to:

$$d_L^m(x) = \frac{\overline{\omega}_L(x)}{2(\overline{\theta} - \underline{\theta})\overline{e}} \tag{3}$$

The profit is then defined by: $\pi_L^m(x) = (\overline{\theta} - \underline{\theta})\,\overline{e}\,d_L^m(x)^2$.

In the general case, as a result of information disclosure about the detrimental nature of Product L on the environment, consumers with high WTP for environmental quality could turn away from the harmful component containing product, thereby uncovering the market, but our Assumption 1 prevents this from occurring.[10]

Assumption 1 *The intrinsic valuation of the good r is high enough to ensure that the market remains covered, no matter the strength of the NGO's campaign and the number of firms.*

As soon as $r + \rho t_0 > \underline{\theta}\overline{e}$, which is verified under Assumption 1, Product L remains profitable for the monopoly after information disclosure about the harmful component as long as the NGO does not campaign to increase environmental awareness. When the NGO increases its awareness-raising effort, this translates the space of marginal willingness to pay for environmental quality from $\left[\underline{\theta}, \overline{\theta}\right]$ to $\left[\underline{\theta} + x, \overline{\theta} + x\right]$. Intensification of the campaign urges the monopoly to reduce its price, but meanwhile the demand is reduced. Its profit then decreases with x. Therefore, all other things being equal, Product L remains cost-effective and yields a lower profit than before information disclosure ($\pi_L^m(x) < \pi_0^*(x)$ for all x).[11]

3.2 Monopoly equilibrium with the component-free product

Under NGO pressure, the monopoly can decide to produce the component-free product. It bears the R&D cost F_H. The environmental quality of the component-free product is a good attribute

[10] This assumption not only simplifies the problem but also is well-suited to markets in which consumers would prefer the product to be more environmentally friendly but are not ready to do without it. This is the case in the chocolate spread market, which is our basic example. García-Gallego and Georgantzís (2010) rely on the same assumption.

[11] Conditions of existence are detailed in Appendix B.

$(e_H > e_0 > e_L)$, but its organoleptic attribute is of lower quality $(t_H < t_0)$. Because the component-free product is of the best possible environmental quality, we assume that e_H and e_L are symmetrical with respect to e_0, that is, $e_H = \overline{e}$.

Definition 2 *The minimum WTP for product H is defined as* $\underline{\omega}_H(x) \equiv r + \rho t_H + (\underline{\theta} + x)\overline{e}$. *The maximum WTP is* $\overline{\omega}_H(x) \equiv r + \rho t_H + (\overline{\theta} + x)\overline{e}$.

Monopoly H has an interest in setting a price equal to $\underline{\omega}_H(x)$ and it earns profit $\underline{\omega}_H(x) - F_H$. Assumption 1 ensures that the market is covered.

Cost-effectiveness of Product H requires that the NGO's campaign has sufficient impact. Starting from this threshold, when the NGO intensifies its campaign, the monopoly benefits from higher WTP for the component-free product. It increases its price and earns an improved profit. Therefore, as shown in Figure 1, there is a level of campaign effort above which the monopoly has an interest in switching to the component-free product, insofar as its profit is then higher than $(\pi_H^m(x) \geq \pi_L^m(x))$.

3.3 Duopoly Equilibrium

Depending on the profitability of the market, the introduction of the component-free product can result in a duopoly or a monopoly equilibrium. If we assume that a firm decides to enter the market and to supply a differentiated variety, Assumption 1 ensures that $2r + \rho(t_0 + t_H) \geq 2(\overline{\theta} - \underline{\theta})\,\overline{e}$, that is, the necessary condition for the duopolistic market to be covered. It means the environmental attribute is dominated by the intrinsic valuation of the good and the organoleptic attribute in such a way that the global WTP for environmental qualities is less than the intrinsic valuation of the good augmented by the half the overall WTP for organoleptic qualities. All consumers are ready to pay for their preferred product (at given prices) and the firms act as a differentiated duopoly. Demand functions, expressed as market shares, are then defined as $d_H = \frac{\overline{\theta} - \widetilde{\theta}_{LH}}{\overline{\theta} - \underline{\theta}}$ and $d_L = \frac{\widetilde{\theta}_{LH} - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$, with $\widetilde{\theta}_{LH} = \frac{p_H - p_L + \rho t_0 - \rho t_H}{2\overline{e}}$.

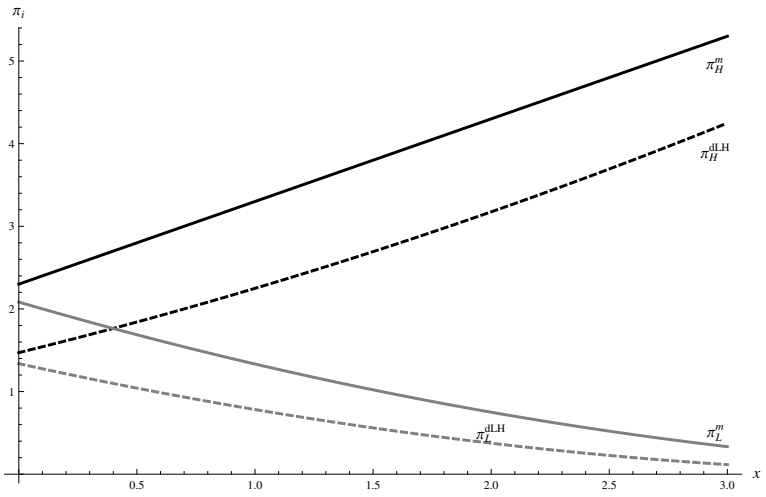
Maximization of profits with respect to price leads to the following Nash equilibrium:

$$\begin{aligned} p_L^{dLH} &= \frac{2(\overline{\theta} - 2\underline{\theta} - x)\overline{e} + \rho t_0 - \rho t_H}{3} \\ p_H^{dLH} &= \frac{2(2\overline{\theta} - \underline{\theta} + x)\overline{e} - \rho t_0 + \rho t_H}{3} \end{aligned} \tag{4}$$

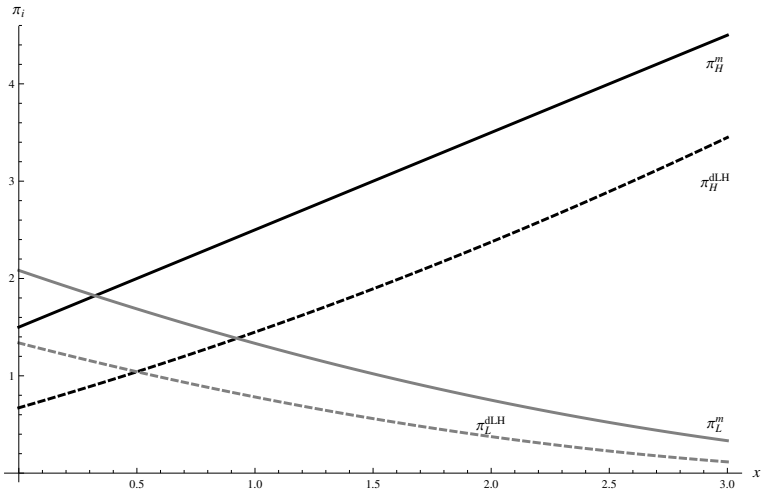
The resulting market shares are then characterized by:

$$d_H^{dLH} = \frac{2(2\overline{\theta} - \underline{\theta} + x)\overline{e} - \rho t_0 + \rho t_H}{6(\overline{\theta} - \underline{\theta})\,\overline{e}} \tag{5}$$

and $d_L^{dLH} = 1 - d_H^{dLH}$. The profits are equal to $\pi_L^{dLH}(x) = 2(\overline{\theta} - \underline{\theta})\,\overline{e}\,{d_L^{dLH}}^2$ and $\pi_H^{dLH}(x) = 2(\overline{\theta} - \underline{\theta})\,\overline{e}\,{d_H^{dLH}}^2 - F_H$.



(a) Low R&D cost F_H



(b) High R&D cost F_H

Figure 1: Effects of NGO's pressure on profit from Product L and Product H

Cost-effectiveness of both products requires that the NGO's campaign effort is neither too low nor too high. Moreover, as illustrated in Figure 1, Product H is more cost-effective than Product L when the campaign effort is higher than a given threshold. Such a threshold crucially depends on the fixed cost of elimination of the harmful component, F_H.[12]

3.4 Sequence of the game with the component-free product

The subgame perfect equilibrium (SPE) of the game depends on the relative profits of the monopolies and the duopoly, displayed in Figure 1. Backward induction implies that the new entrant decides to provide a differentiated product if the duopoly's profits are positive, that is, fulfilled according to a medium campaign effort (defined in Appendix B). The incumbent still has

[12]See details in Appendix B.

an interest in producing Product L when the containing harmful component product is more cost-effective than the component-free product, or in switching to Product H otherwise. Therefore, the SPE (L, H), such that the incumbent still produces Product L and the new entrant supplies Product H, arises when the NGO makes a relatively low campaign effort, whereas the SPE (H, L) occurs when x is higher (in the interval of x allowing duopoly cost-effectiveness). When the campaign effort is relatively large or when the R&D cost is high, the firm decides not to enter and the incumbent opts for the most cost-effective product for a monopoly. Product H is likely to be chosen when the campaign effort is intensive or the R&D cost of harmful component elimination is low.

We can distinguish three cases that represent the interaction between the NGO's campaign and the best strategies of firms:

- All consumers are sufficiently concerned with harmful effects of the denounced component that they have a higher WTP for Product H, despite its lower organoleptic attribute, than for Product L (*i.e.* $\rho(t_0 - t_H) \leq 2\,\underline{\theta}$):[13] If the R&D cost is relatively low, as in Figure 1(a), the NGO only has to disclose information about the damaging component to make the component-free product cost-effective and spur the incumbent to eliminate the denounced component. If the R&D cost is relatively high, as in Figure 1(b), the NGO must conduct a sufficiently forceful campaign to make Product H more profitable than Product L for the incumbent.

- The organoleptic attribute is so damaged by the elimination of the harmful component and/or consumers are so concerned with the product's taste, that at the same price, some consumers prefer Product L to Product H $(\rho(t_0 - t_H) \in [2\,\underline{\theta}\,\overline{e}, 2\,\overline{\theta}\,\overline{e}])$[14], as depicted in Figure 1(b), only a sufficiently effective campaign can encourage the incumbent to produce Product H (and the potential new entrant to provide Product L).

- All consumers are insufficiently concerned with environmental issues to be ready to buy a component-free product; even if it costs the same as Product L $(\rho(t_0 - t_H) \geq 2\,\overline{\theta}\,\overline{e})$,[15] the NGO has no way of promoting consumption and production of the component-free product.

Accordingly, when the initial WTP for the environmental quality is high enough for an effective campaign, the R&D cost of eliminating the denounced component is a critical success factor of the NGO's campaign.

[13] In this first case, $\underline{\omega}_H(0) \geq \overline{\omega}_L(0)$.
[14] In this second case, $\underline{\omega}_H(0) < \overline{\omega}_L(0)$ and $\overline{\omega}_H(0) > \underline{\omega}_L(0)$.
[15] In this third $\underline{\omega}_H(0) \leq \overline{\omega}_L(0)$.

Before any awareness campaign by the NGO (or with a null initial budget B), mere disclosure of the environmental quality of the product of the initial monopoly may already lead to different market structures, depending on the value of the R&D cost, F_H.[16]

Lemma 1 *For a null initial budget, B, and no awareness campaign, there is a threshold for R&D cost, denoted as $\underline{F}_H$, below which the market is a duopoly and above which it remains a monopoly.*

When $F_H \leq \underline{F}_H$, there is a threshold $\hat{F}_H^d \leq \underline{F}_H$ such that the incumbent switches to Product H in case of R&D cost lower than $\hat{F}_H^d$ and still produces Product L if $F_H \in [\hat{F}_H^d, \underline{F}_H]$, meanwhile a competitor enters the market with the other product.

When $F_H > \underline{F}_H$, there iss a threshold $\hat{F}_H^m$ which can be lower or higher than $\underline{F}_H$, such that the monopoly switches to Product H if $\hat{F}_H^m > \underline{F}_H$ and $F_H \in [\underline{F}_H, \hat{F}_H^m]$ and still produces Product L if $\hat{F}_H^m \leq \underline{F}_H$ or $F_H > \hat{F}_H^m > \underline{F}_H$.

with $\underline{F}_H \equiv \dfrac{(2(2\overline{\theta} - \underline{\theta})\overline{e} - \rho t_0 + \rho t_H)^2}{18(\overline{\theta} - \underline{\theta})\,\overline{e}}$, $\hat{F}_H^d \equiv \dfrac{2}{3}\big((\overline{\theta} + \underline{\theta})\overline{e} - \rho t_0 + \rho t_H\big)$ *and* $\hat{F}_H^m \equiv \underline{\theta}\overline{e} + r + \rho t_H - \dfrac{(\underline{\theta}\overline{e} - r - \rho t_0)^2}{4(\overline{\theta} - \underline{\theta})\,\overline{e}}$

Lemma 1 states that market penetration of the component-free product can be favored by a low R&D cost of elimination of the harmful component even before the NGO starts the awareness campaign. Moreover, a specific case arises when the organoleptic quality of Product H is close to that of Product L, in such a way that, before the campaign, the maximum R&D cost compatible with the duopoly cost-effectiveness ($\underline{F}_H$) is lower than the maximum R&D cost, allowing higher cost-effectiveness of Monopoly H than Monopoly L ($\hat{F}_H^m$).[17] In that case, the monopoly has an interest in switching to Product H even without any campaign as long as its fixed cost is too high to trigger entrance of a new firm, but sufficiently low to make production of Product H the most profitable for the monopoly ($F_H \in [\underline{F}_H, \hat{F}_H^m]$). As a consequence, the utility and the intensity of the NGO's optimal campaign highly depends on the R&D cost.

3.5 Optimal campaign effort

To maximize the quality of the environment, the NGO has an interest in choosing an effort that encourages the monopoly to substitute Product H for Product L or, at least, undertaking an effort that restricts the market share of Product L and makes the entry of Product H cost-effective. The environmental effectiveness of the NGO's campaign crucially depends on its effect on market structure, which in turn relies on the level of R&D cost, F_H, and the extent of

[16] See proof in Appendix C.

[17] We can show that $\hat{F}_H^m$ increases faster with t_H than $\underline{F}_H$, which means that $\hat{F}_H^m > \underline{F}_H$ when t_H is close to t_0.

the reduction in organoleptic quality (relative to the increase in environmental quality) of the component-free product compared with the initial product. Clearly, when all market structures are possible, the "greenest" situation is a monopoly that provides the component-free product in a covered market and the second best situation is a duopoly.[18]

Proposition 1 *For a given F_H, the quality of the environment increases with x until the maximum $\overline{e}$ is reached through Monopoly H in a covered market.*

(See Appendix C for proofs of all propositions in this subsection.

Proposition 1 combined with the NGO's budget constraint, $x^2 \leq B$, entails that the NGO tends to exhaust its budget to make the maximum campaign effort, defined by $x^* = \sqrt{B}$, as long as the component-free product is not the only product on the market. Note that the campaign effort does not depend on environmental quality $\overline{e}$. In other words, the extent to which the component is damaging for the environment does not alter the NGO's behavior, because it must campaign in any case to increase consumer awareness of such damages.

Proposition 2 *For low R&D cost ($F_H \leq \underline{F}_H$), there is a NGO's maximum useful budget, denoted as $\overline{B}^d$, enabling the level of awareness campaign above which the duopoly cannot be profitable,*
with $\overline{B}^d \equiv \left(\dfrac{\rho(t_0 - t_H)}{2\overline{e}} + \overline{\theta} - 2\underline{\theta}\right)^2$.

In the case of a low initial budget ($B \leq \overline{B}^d$), the NGO spends all its budget on the campaign to maximize the market share of Product H in the duopoly market.

In the case of a high initial budget ($B \geq \overline{B}^d$), the NGO spends only $\overline{B}^d$ in the campaign to ensure cost-effectiveness of Monopoly H.

Lemma 1 and Proposition 2 are illustrated by Figure 2,[19] which displays the equilibrium market structures resulting from the R&D cost and the NGO's budget. In Figure 2, the gray lines correspond to the maximum budgets compatible with cost-effectiveness of Product L, that is $\overline{B}^d$ in case of duopoly (H, L) and $\overline{B}^m$ in case of Monopoly L. The black curves illustrate the minimum budgets spent on the campaign that allow cost-effectiveness of Product H. The dashed curves define the minimum budgets that ensure the profit from Product H is higher the profit from Product L.

[18] The overall quality of the environment fulfills inequality $E^{mH}(x) = \overline{e} > E^{dLH}(x) > E^{mL}(x)$, where superscripts mL, mH and dLH respectively denote following market structures: monopoly of Product L, monopoly of Product H and duopoly (L, H) and (H, L).

[19] Figure 2 has been drawn using parameters $\underline{\theta} = 1$, $\overline{\theta} = 4$, $\overline{e} = 1$, $\varphi = 3$, $t_0 = 1$ and $t_H = 1/2$. In this case, $\hat{F}_H^m < \hat{F}_H^d$.

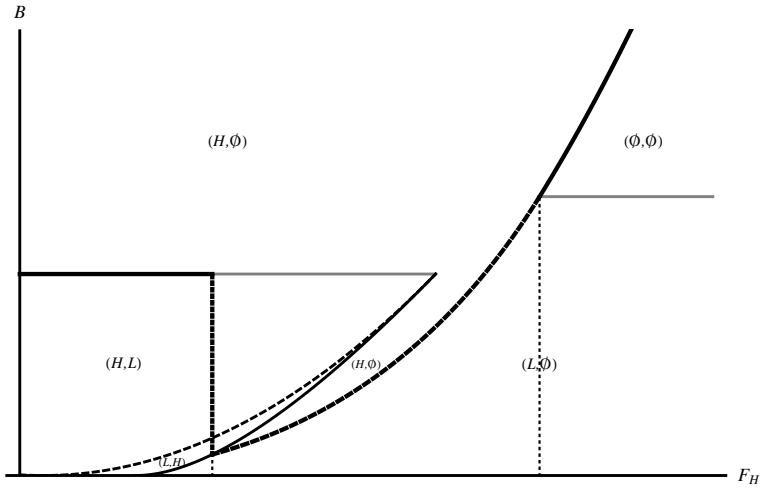


Figure 2: NGO's initial budget, R&D cost and market structures (when $\hat{F}_H^m \leq \underline{F}_H$)

Proposition 2 and Figure 2 show that when the R&D cost and the budget are both relatively low ($F_H \leq \underline{F}_H$ and $B \leq \overline{B}^d$), the campaign is likely to favor a duopoly SPE (H, L), encouraging the incumbent to give up supplying the product containing the harmful component to produce the component-free product. The higher the R&D cost, the higher the initial budget required for duopoly (H, L). If the R&D cost tends to $\underline{F}_H$,[20] and the budget is close to zero, the incumbent still decides to produce Product L while a new entrant provides Product H, that is SPE (L, H). A higher budget and great campaign effort results in greater profit from Product H, at the expense of Product L, leading to duopoly SPE (H, L). When the initial budget is sufficiently high to enable the NGO to campaign extensively ($B \geq \overline{B}^d$), the campaign allows for crowding out Product L and results in a Monopoly H (i.e., SPE $(H, \emptyset)$). The NGO then has no interest in spending more than $\overline{B}^d$ on the campaign, because the best environmental situation is reached with such a budget and spending more would not improve the quality of the environment further.

Proposition 3 *For intermediate R&D cost, such that $F_H \in [\underline{F}_H, \overline{F}_H]$, a rise in initial budget B results in the following impact on market structures:*

- *If $\hat{F}_H^m \leq \underline{F}_H$ and $F_H \in [\underline{F}_H, \tilde{F}_H]$, it reduces the market share of Monopoly L and favors entrance of Product H in a duopoly market if $B > \underline{B}^d(F_H)$.*
- *If $\hat{F}_H^m \leq \underline{F}_H$ and $F_H \in [\tilde{F}_H, \overline{F}_H]$ or $F_H \geq \hat{F}_H^m > \underline{F}_H$, it reduces the market share of Monopoly L and encourages the monopoly to switch to Product H if $B \geq \hat{B}^m(F_H)$, with the NGO spending no more than $\hat{B}^m(F_H)$ on the campaign.*
- *If $\hat{F}_H^m > \underline{F}_H$ and $F_H \in [\underline{F}_H, \hat{F}_H^m]$, the monopoly switches to Product H before the campaign, rendering the campaign unnecessary.*

[20] More precisely, if $F_H \in [\frac{2}{3}((\overline{\theta} + \underline{\theta}\overline{e}) - \rho(t_0 - t_H), \underline{F}_H]$.

with $\tilde{F}_H$ *such that* $\pi_H^m(\tilde{F}_H, \tilde{B}) = \pi_L^m(\tilde{F}_H, \tilde{B})$ *and* $\pi_H^d(\tilde{F}_H, \tilde{B}) = 0$,

$\overline{F}_H \equiv \rho(t_0 + t_H)$

$\underline{B}^d(F_H) \equiv \dfrac{\left(3\sqrt{2(\overline{\theta} - \underline{\theta})\overline{e}F_H + \rho(t_0 - t_H)} - 2(2\overline{\theta} - \underline{\theta})\overline{e}\right)^2}{4\overline{e}^2}$,

and $\hat{B}^m(F_H) \equiv \left(2\overline{\theta} - 3\underline{\theta} + \dfrac{1}{\overline{e}}(r + \rho t_0 - 2\sqrt{(\overline{\theta} - \underline{\theta})(2r + \rho(t_0 + t_H) + (\overline{\theta} - \underline{\theta})\overline{e} - F_H)\overline{e}}\right)^2$.

Proposition 3 states that when the R&D cost is relatively high ($F_H > \underline{F}_H$) and the NGO's budget is relatively low ($B < \underline{B}^d(F_H)$), the potential entrant decides not to enter, neither with Product L nor with Product H because the R&D cost is too high and the campaign is not effective enough to enable Product H to be cost-effective when Product L is provided in the market. Therefore, the incumbent chooses either to switch to the component-free product if the campaign effort is high enough — through $B > \hat{B}^m(F_H)$ — or to continue to produce Product L otherwise. The higher the R&D cost, the higher the initial budget required to trigger switch to Product H. Therefore, a sufficiently large budget allows the NGO to push the incumbent to produce Product H by spending only the part of its budget necessary to reach the frontier $\hat{B}^m(F_H)$ for a given F_H. Moreover, in the specific case in which the organoleptic quality of Product H is close to that of Product L, in such a way that $\hat{F}_H^m > \underline{F}_H$, the NGO' interest is to launch the campaign only in cases of relatively high R&D cost ($F_H \in [\hat{F}_H^m, \overline{F}_H]$).

Proposition 4 *For very high values of the R&D cost* ($F_H > \overline{F}_H$) *and great campaign effort* ($\overline{B}^m < B < \hat{B}^m(F_H)$), *Products* L *and* H *are no longer profitable and the market disappears, with* $\overline{F}_H \equiv 2r + \rho(t_0 + t_H)$ *and* $\overline{B}^m \equiv \left(\dfrac{r + \rho t_0 - \overline{\theta}\overline{e}}{\overline{e}}\right)^2$. *However, Monopoly* H *becomes profitable again as soon as* $B \geq \hat{B}^m(F_H)$.

Proposition 4 states that Product H is not profitable when elimination of the harmful component is too costly and the campaign is not effective enough to enable the monopolist to produce the component-free product.[21] Therefore, in the case of high R&D cost, the only way the NGO can succeed in its campaign to divert consumers from Product L supplied by Monopoly L is to spend its entire budget on the campaign. If it benefits from a budget higher than $\overline{B}^m$, the NGO can remove Product L from the market by spending only $\overline{B}^m$ on the campaign in such a way that there is no longer a market. It must spend at least $\hat{B}^m(F_H)$ is needed to enable Monopoly H to appear.[22]

[21] $\overline{F}_H$ corresponds to the abscissa of the intersection point of the gray and the black lines and $\overline{B}^m$ corresponds to intercept of the gray line in the North-East part of Figure 2.

[22] In our framework, Monopoly H is preferred to no market at all by the NGO and the social planner because of our symmetry assumption about the respective environmental qualities of Products H and L. Had we assumed that $e_L < e_H < 0$, that is, that damage caused by Product H is only lower than damage caused by Product L, the NGO would have preferred no market at all over Monopoly H.

As a result of these mechanisms according to various market structures, the thick bold line in Figure 4 shows the level of the maximum useful budget B for the NGO. When the NGO's initial budget is under the line, there is a need for the NGO to implement another action in order to reach the highest environmental quality. However, if its initial budget is higher, the NGO has no incentive to do so and will not exhaust its budget.

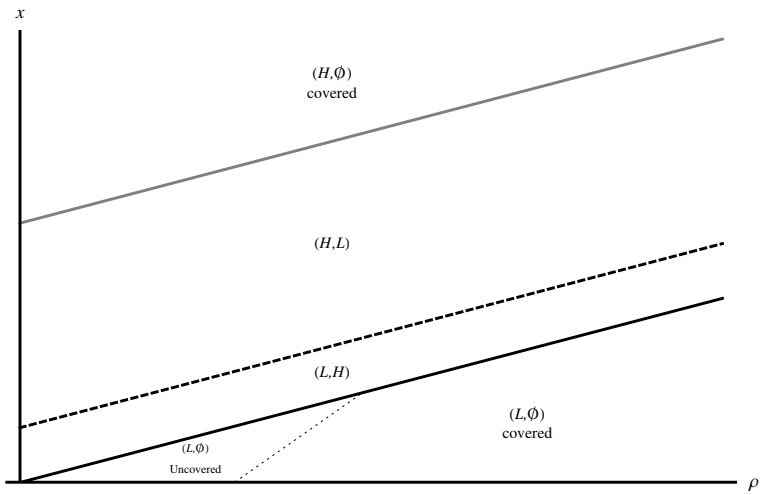


Figure 3: NGO's campaign, WTP for organoleptic quality and market structures

Figure 3 completes previous analysis by showing the market structure is sensitive to WTP for organoleptic quality (for given positive cost F_H and WTP for environmental quality); all other things being equal, the higher WTP for organoleptic quality, the greater the campaign effort (and the initial budget) must be to trigger entry of the component-free product.

In any case, the awareness-raising campaign will not only disclose information on the harmful impact of a product component — thereby undermining consumer perception of the product quality — but also increase consumer WTP for the environmentally friendly product, favoring cost-effectiveness of the component-free product over the component-containing product. However, the campaign may be wasteful when the component-free product requires a very high R&D cost and/or entails too great a degradation of the product's taste (or texture), or when consumers place little importance on the environmental issue raised by the NGO compared with the product's taste. Accordingly, there is room for alternative solutions to reduce environmental impact of the product while better preserving its organoleptic properties.

4 NGO's certification

Under NGO pressure, the incumbent or a new entrant has the possibility of using a sustainable component certified by the NGO. In this case, the firm adopts an NGO's label that discloses the

sustainable nature of the component to the consumers, and supplies Product M. The firm incurs a unit cost c_M and pays a fee φ to the NGO for using the label "sustainable component". The collected fees accrue to the NGO's budget, allowing potentially higher campaign expenditures x^2. By assumption, substituting the sustainable component for the harmful component does not require an R&D investment, so that there is no fixed cost associated with such a product for the monopoly. The sustainable component is a perfect substitute for the harmful component in such a way that the organoleptic attribute of the good is not affected by the substitution ($t_M = t_0$). The environmental quality of the certified product is a good attribute of lower quality than the component-free product ($e_0 < e_M < e_H \Leftrightarrow e_M \in [0, \overline{e}]$).

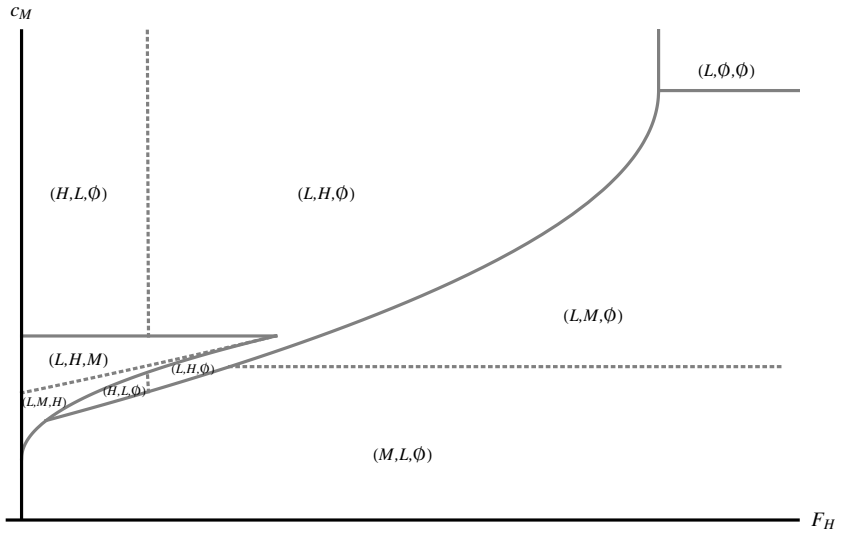


Figure 4: Market structures before the NGO's awareness campaign

The possibility of providing an eco-labeled product expands the range of potential market structures not only after information disclosure about the denounced component, but also after the launch of the awareness campaign. Figure 4 illustrates all the possible initial market structures before the campaign ($x = 0$) according to the production costs of Products M and H, when Product L is cost-effective (see Appendix D for proofs). Indeed, co-existence of Product M and/or H with Product L crucially depends on relative production costs, which determines the market-entry decisions of the third firm (*i.e.* triopoly / not triopoly) and of the second firm (*i.e* duopoly / not duopoly) and the most profitable choice between Products L, M and H of the incumbent (that perfectly anticipates the decision of the next potential entrants).[23] However,

[23]The triopoly area arises from backward induction reasoning such that if a third firm has an interest in entering the market (with H or M), the other firms have also an interest in producing (see Figure A.1). When $c_M + \varphi$ is slightly under the triopoly zone, for a given low F_H, then $\pi_H^t \leq 0$ and Firm F decides not to enter, then Firm E prefers to enter the duopoly market — (L, H), (M, L) or (H, L) — and the incumbent then decides to switch to Product H because π_H^{dLH} is the highest possible profit in the three previously duopoly situations.

when the WTP for organoleptic quality is not sufficiently high to guarantee cost-effectiveness of Product L, information disclosure is likely to lead to a monopoly supplying Product M when $c_M + \varphi$ is sufficiently low and F_H is sufficiently high or a Monopoly H when $c_M + \varphi$ is high and F_H is low. When $c_M + \varphi$ is low, Product H may be prevented from appearing even for low F_H (as in Figure 4) if the WTP for organoleptic quality is sufficiently high, compared to the environmental quality $\overline{e}$ of Product H (see conditions of existence of duopoly (H, L) in Appendix B).

In the next sections, we investigate Nash equilibria when the certified product is cost-effective, having already characterized other possible Nash equilibria in section 3.

4.1 Monopoly equilibrium with the certified sustainable product

In the case of Monopoly M, only consumers with WTP for the environmental quality higher than $\widetilde{\theta}_M = \frac{p_M - r - \rho t_0}{e_M} - x$ buy the product. By assumption, the market is covered ($\widetilde{\theta}_M \leq \underline{\theta}$), and the monopoly maximizes $\pi_M(p_M) = (p_M - c_M - \varphi) d_M(p_M)$ by setting a price equal to the minimum WTP for Product M, that is to $p_M^m = \underline{\omega}_M(x) \equiv (r + \rho t_0 + \underline{\theta} + x) e_M$. It then earns the profit $\pi_M^m = r + \rho t_0 + (\underline{\theta} + x) e_M - c_M - \varphi$.

When the NGO steps up its campaign, the monopoly benefits from higher WTP for the sustainable product. It increases the product price, thereby earning a higher profit. However, the rise in profit is curbed if the NGO funds its raising campaign effort with an increasing fee.

Because the sustainable product has the same organoleptic attribute as the component-containing product, but is more environmentally friendly, all consumers have a higher WTP for this product than for the component-containing product: *i.e.* $\overline{\omega}_M(x) > \underline{\omega}_M(x) > \overline{\omega}_L(x)$. However, Product M production is more expensive than Product L production. Product M is then more cost-effective than Product L when the unit production cost and the NGO fee are not too high. In addition, Product M is more cost-effective than Product H when $c_M + \varphi$ is relatively low, F_H is relatively high, and the campaign is soft.

For a given R&D cost F_H and unit production cost of Product M $c_M + \varphi$, if the awareness campaign effort x is low, Monopoly L remains the most profitable. By increasing x, the NGO can transform the market structure into a Monopoly M and then into Monopoly H .

4.2 Duopoly equilibria

The existence of a certified sustainable component provides an additional opportunity for a firm to enter the market with a product differentiated from the monopoly's product. Product M can coexist with Product L or Product H, depending not only on gaps in environmental and organoleptic attributes and in production costs, but also on the NGO's behavior.

4.2.1 Duopoly with Products L and M

Our analysis of the duopoly that supplies Products L and M is similar to our analysis in Section 3.3. The consumer indifferent with regards to Products L and M is characterized by $\widetilde{\theta}_{LM} = \frac{p_M - p_L}{\overline{e}+e_M} - x$.[24] Because providing the certified product requires positive unit costs (including the certification fee), and providing the component-free product requires fixed production cost — and the product that uses the harmful component and the product that uses the sustainable components exhibit the same organoleptic quality — the conditions for existence of the duopoly that supplies Products L and M differ from the conditions of the previous case with Products L and H.

It is notable that the organoleptic quality does not play on prices and market shares insofar as both products benefit from the same quality; rather the strategies depend on relative environmental qualities and production costs. The NGO's campaign also leads some consumers to substitute the sustainable-component-containing product for the harmful component-containing product.

Firms L and M share demand in a covered market only if the WTP for the organoleptic quality is sufficiently high, compared to the environmental qualitiy and production costs of Product M and if the NGO's campaign is sufficiently soft, according to:

$$r + \rho t_0 \geq \frac{(2\overline{\theta} - \underline{\theta})\overline{e} + (\overline{\theta} - 2\underline{\theta})e_M}{3} + \frac{2\overline{e} + e_M}{3(\overline{e} + e_M)}(c_M + \varphi) + \frac{\overline{e} - e_M}{3}x \tag{6}$$

As in the case of the duopoly supplying Products L and H, such a condition can be interpreted as the dominance of the intrinsic valuation of the good and the organoleptic attribute over the environmental attribute in consumers' preferences.

4.2.2 Duopoly with Products M and H

There is more likely to be competition between medium and high environmental quality than between Products L and M or L and H. Consumers of both products are localized on the right side of the preference space, although consumers on the left side also buy the medium quality in a covered market. The specificity of the duopoly equilibrium arises from the nature of production costs. Production of the certified product involves only variable costs, including the cost of the certified component and the certification fee, whereas production of the component-free product requires only a fixed cost.

Firms M and H share demand in a covered market only if the WTP for the organoleptic quality is sufficiently high compared to the environmental quality and production costs of Product

[24] It is worth noting that $\overline{e} + e_M$ measures the difference in environmental qualities of Product M (e_M) and Product L ($-\overline{e}$).

M, if the R&D cost F_H is not too high and if the NGO's campaign is sufficiently soft, according to the following set of conditions:

$$3r + \rho t_H + 2\rho t_0 \geq (\overline{\theta} - 2\underline{\theta})\overline{e} - (\overline{\theta} + \underline{\theta})e_M + 2(c_M + \varphi) - (\overline{e} + 2e_M)x \tag{7}$$
$$\overline{F}_H < (\overline{\theta} - \underline{\theta})(\overline{e} - e_M)$$

As in the other cases of duopoly, market coverage is ensured as soon as the intrinsic valuation of the good and the WTP for organoleptic quality are sufficiently high. Paradoxically, by enhancing WTP for environmental quality of all consumers, NGO's behavior penalizes the product containing the sustainable component, through both its campaign effort and its certification fee, which reduce demand for Product M.

4.3 Triopoly equilibrium

High heterogeneity of consumers' WTP for the environmental quality and low production costs may allow the three differentiated products to coexist in the market. Under Assumption 1 allowing full market average, we assume that a third firm enters the market.

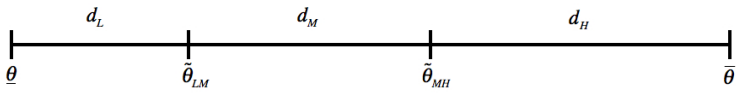


Figure 5: Market coverage with products L, M and H

Figure 5 depicts market sharing, with demand functions defined as $d_H = \frac{\overline{\theta} - \widetilde{\theta}_{MH}}{\overline{\theta} - \underline{\theta}}$, $d_M = \frac{\widetilde{\theta}_{MH} - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$ and $d_L = \frac{\widetilde{\theta}_{LM} - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$. Price competition leads Firm L to adjust its price upwards to the price of Product M, although the price of Product H depends only on the price of Product M, whereas the price of Product M increases with both p_L and p_H.

An increase in x moves the two indifferent consumers towards the left in the preference space $[\underline{\theta}, \overline{\theta}]$, in such a way that the same number of consumers substitute Product M for Product L and Product H for Product M.[25] As a result, the awareness campaign plays only on market shares of the Products L and H.

The triopoly emerges only when differentiation of both organoleptic and environmental quality of the three products is sufficiently large and the cost of the sustainable component and the cost of the harmful component removal are limited.

Accordingly, cost-effectiveness of the product containing the harmful component requires that the NGO's campaign is not too forceful. Moreover, the NGO must ensure that the certification

[25] Indifferent consumers are such that $\frac{\partial \widetilde{\theta}_{ij}}{\partial x} = -\frac{1}{2}$, with $i, j = L, M, H$ and $i \neq j$.

fee does not discourage firms from using the sustainable component. There is a clear trade-off for the NGO between eliminating the product containing the harmful component and fostering the sustainable component.

4.4 The sequence of the game

To explain the sequence of the game, in line with the game tree (Figure A.1), when the NGO campaigns against the denounced component, Figure 6 displays the resulting market structures according to x and $c_M + \varphi$, for intermediate values of F_H.[26]

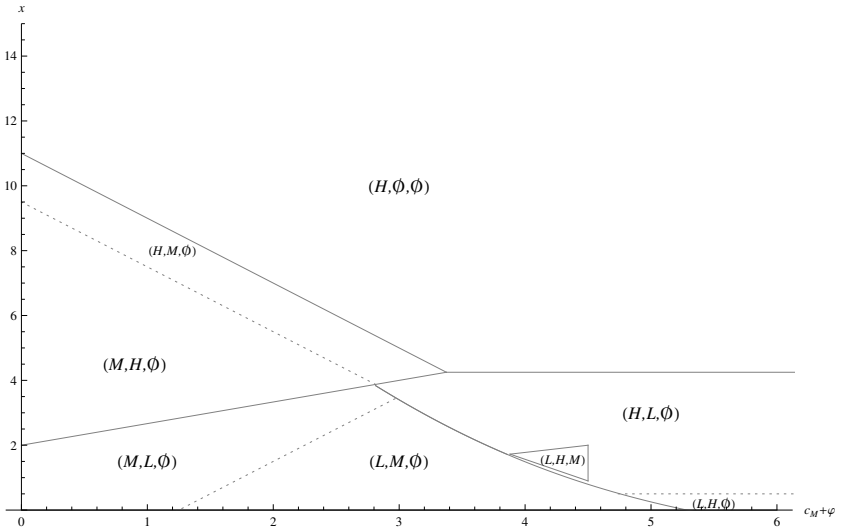


Figure 6: Market structures according to the NGO's strategies for intermediate values of F_H

When the triopoly is cost-effective before the campaign, the third firm F in the game tree, always wants to enter the market. Backward induction highlights that the first entrant, E, chooses the most cost-effective strategy after the incumbent has itself opted for the most cost-effective strategy. Therefore, the SPE is (i, j, k) when $\pi_i^t > \pi_j^t > \pi_k^t \geq 0$, with $i, j, k = L, M, H$ and $i \neq j \neq k$. However, an increase in the campaign effort, x, and/or in the label fee, φ, decreases the demand and the profits from Product M in such a way that production of M no longer is cost-effective in a triopoly market.

When the triopoly is not cost-effective before the campaign, the incumbent's best strategy is to produce the most cost-effective product knowing that Firm E will then decide to enter with the second-best cost-effective product and Firm F will not enter the market. Therefore, according to the game tree in Figure A.1 (Appendix A), six duopoly SPE can be characterized depending on relative profits: SPE is (i, j) when $\pi_i^{dij} \geq \pi_j^{dij} \geq \pi_k^{dik}$, with $i, j, k = L, M, H$ and $i \neq j \neq k$.

[26] Parameters values used: $\underline{\theta} = 1, \overline{\theta} = 4, \overline{e} = 1, e_M = 0.5, t_H = 0.5, t_0 = 2, F_H = 1, \rho = 3, r = 0$.

The scenarios in which Product L remains in the market are most likely to occur when the unit cost and the certification fee for the sustainable component and the R&D cost for the component-free product are relatively high while the NGO campaigns relatively softly. Because the awareness campaign decreases the profit of Firm L to the benefit of its competitor, there is always a campaign effort that makes Products M and H more cost-effective than Product L. The NGO also can foster the certified product by charging a low certification fee. Accordingly, in the SPE (M, H), the incumbent switches to Product M and the entrant produces Product H when the NGO's effort and the certification fee are sufficiently low to favor Product M over Product H (such as $\pi_M^{dMH} \geq \pi_H^{dMH}$)[27] but sufficiently high to favor Product H over Product L (in such a way as $\pi_H^{dMH} \geq \pi_L^{dLM}$). The SPE (H, M) arises when the campaign effort is sufficiently high to foster Product H over Product M (such as $\pi_H^{dMH} \geq \pi_M^{dMH}$) and the certification fee sufficiently low to foster Product M over product L (such as $\pi_M^{dMH} \geq \pi_L^{dLH}$).

The NGO can discourage entry into the market by making a very high campaign effort while forcing the incumbent to stop using of the denounced component. The incumbent retains its monopoly situation and chooses to switch to Product H if F_H is moderate (as in Figure 6) or to Product M if $c_M + \varphi$ is low and F_H is high.

Thereby, the NGO's budget decisions about the funds spent in the awareness-raising campaign and the funds raised by the certification fee are crucial determinants of the market structure and of the more or less environmentally-friendly nature of the products supplied in the market. Figure 6 clearly shows the impacts of increasing separately either x or φ, for given F_H.

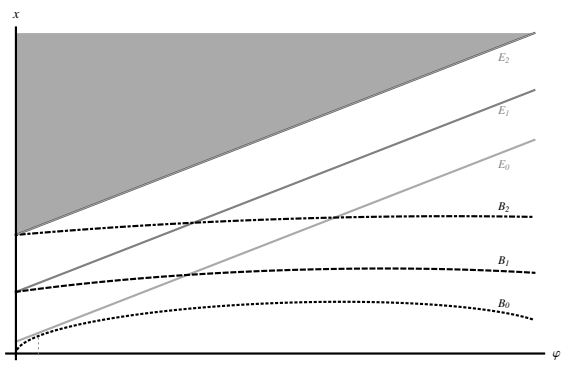
4.5 Optimal NGO's strategy

By choosing the values of its instruments, the NGO is able to influence market structure $s \in S$, where S is the set of possible market structures represented in Figure 6, and the level of the environmental quality is E^s. The NGO's program is characterized as follows:

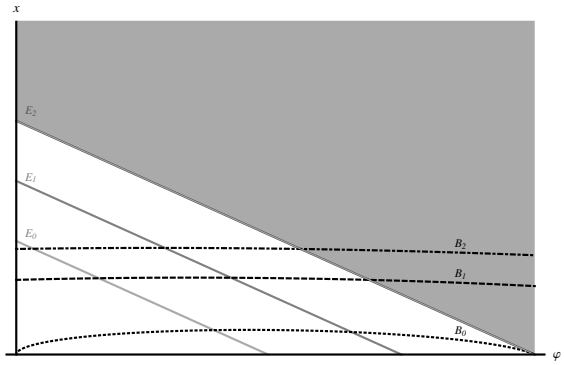
$$\max_{s \in S} \left\{ \max_{x,\varphi} E^s(x, \varphi) \qquad \text{st } BC^s \equiv x^2 - B - \varphi d_M^s \leq 0 \right\}$$

To find the NGO's optimal strategy, depending on its initial budget, B, we first compute the values of x and φ that maximize the environmental quality E^s in each market structure. Next we analyze whether these values are compatible with the existence conditions of the considered market structure or whether they lead to another market structure. This calculation provides the NGO's optimal strategy to achieve the 'greenest market structure'.

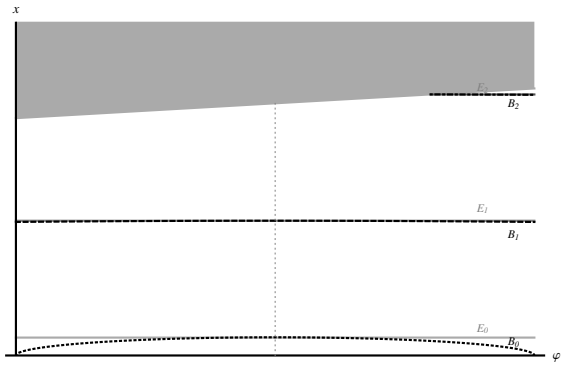
[27] $\pi_M^{dMH} \geq \pi_H^{dMH}$ involves $x \leq \frac{2(\rho t_0 - \rho t_H) - (\overline{\theta} + \underline{\theta})(\overline{e} - e_M) + 3F_H - 2(c_M + \varphi)}{2(\overline{e} - e_M)}$



(a) Duopoly (L, M)



(b) Duopoly (M, H)



(c) Triopoly

Figure 7: NGO's Optimal strategies.

4.5.1 Duopoly (L,M)

We assume that the NGO faces a duopoly before the campaign (*i.e.*, low to medium F_H and low $c_M + \varphi$ in Figure 6). As shown in the previous section, the incumbent produces the most cost-effective product knowing that Firm E produces the second-best cost-effective product and Firm F does not enter the market. The resulting six possible duopoly SPEs entail different levels of overall environmental quality.

Before the campaign, the market structure is likely to be a duopoly (L, M) or (M, L), for low level of unit cost c_M and medium R&D cost F_H (see Figure 6 and Appendix D). In this case, demand equations (D.8) result in the following overall environmental quality:

$$E^{dLM} = -\overline{e}d_L^{dLM} + e_M d_M^{dLM} = \frac{(2\overline{\theta} - \underline{\theta})e_M - (\overline{\theta} - 2\underline{\theta})\overline{e} - c_M - \varphi + (\overline{e} + e_M)x}{3(\overline{\theta} - \underline{\theta})} \tag{8}$$

By intensifying its campaign effort x, the NGO increases the quality of the environment by crowding out Product L to the benefit of Product M but increasing φ to finance the increasing effort plays in the opposite direction.

Figure 7(a) depicts the best strategies of the NGO.[28] The bell-shaped curves are the iso-

[28] Figures 7(a) to 7(c) have all been drawn using the same set of parameters as in Figure 6, allowing the existence

budget curves, with three levels of initial budget $B_0 < B_1 < B_2$ and the increasing lines as the overall environmental quality, with the three levels of overall environmental quality $E_0 < E_1 < E_2$ that can be reached with each budget. The shadow area is the set of (φ, x) incompatible with the duopoly market structure, for a given c_M. The slope of the iso-environment curve is positive and independent of the NGO's strategy although the slope of the iso-budget curve at the origin (when $\varphi = 0$) decreases with the level of initial budget.

A low initial budget (such as $B_0 \equiv 0$) leads to the interior solution, in which the NGO chooses to combine a fee and a campaign whereas a higher budget (as B_1) leads to the corner solution, in which the NGO prefers not to claim a certification fee from Firm M, favoring demand for the sustainable product, and to use its entire initial budget in the awareness-raising campaign. In the first case, the increase in campaign effort made possible by the additional budget provided by fees has a more powerful effect in decreasing the market share of Product L than the increase in fees on decreasing the market share of Product M. But, in the second case, any level of fees decreases the market share of Product M without any other impact on the market structure.

An even higher budget (as B_2) leads the NGO to campaign and to charge a certification fee such that Product L is removed from the market (at the intersection of curves B_2 and E_2). According to Figure 6, the resulting market structure anticipated by the NGO and the firms should be a duopoly (M, H) and the NGO must adapt its strategy to this case.[29]

Proposition 5 *For the low unit cost c_M and intermediate R&D cost F_H leading to a duopoly (L, M) or (M, L),*

- when $B < \overline{B}^{dLM}$, the NGO chooses to bill a fee for the certified component to increase its campaign effort and to reduce the market share of Product L.

- when $\overline{B}^{dLM} \leq B \leq \overline{\overline{B}}^{dLM}$, the NGO maximizes the market share of the certified component by billing a zero fee and spending its entire initial budget in campaign effort.

- when $B \geq \overline{\overline{B}}^{dLM}$, the NGO chooses the level of fee that allows it to finance a campaign effort sufficient to crowd out Product L.

with $\overline{B}^{dLM} \equiv \left(\frac{(2\overline{\theta}-\underline{\theta})(\overline{e}+e_M)+c_M}{6(\overline{\theta}-\underline{\theta})-\overline{e}-e_M}\right)^2$ *and* $\overline{\overline{B}}^{dLM} \equiv \left(\overline{\theta} - 2\underline{\theta} + \frac{c_M}{\overline{e}+e_M}\right)^2$

4.5.2 Duopoly (M,H)

When the NGO's decision to mount a relatively high campaign effort leads to a cost-effective duopoly (M,H), demands are then defined by Equations (D.13) and the global quality of the

of all market structures, depending on x and φ.

[29] It is worth noting that the game is static and that the SPE results from anticipations of the firms on the NGO strategies and the resulting market structures.

environment is characterized by:

$$E^{dMH} = e_M d_M^{dMH} + \overline{e} d_H^{dMH} = \frac{(2\overline{\theta} - \underline{\theta})\overline{e} + (\overline{\theta} - 2\underline{\theta})e_M - \rho(t_0 - t_H) + c_M + \varphi + (\overline{e} - e_M)x}{3(\overline{\theta} - \underline{\theta})} \quad (9)$$

Unlike the case of the duopoly (L, M), intensifying the campaign effort x and increasing φ exert positive effects on the overall environmental quality because both effects relatively crowd out Product M to the benefit of Product H, until Firm M is ejected from the market.

In this case, the NGO is unlikely to choose an interior solution because, facing both greenest products, it is in the interest of the NGO to favor Product H at the expense of Product M (when R&D cost F_H is sufficiently low). Figure 7(b) shows that because the campaign effort and a label fee are perfect substitutes for the NGO, the iso-environment curve decreases with φ and crosses the iso-budget curves in the area in which duopoly (M,H) is cost-effective. Therefore, for a positive initial budget, the NGO should implement a strategy $(\varphi^{dMH*}, x^{dMH*})$ of removing Product M (*i.e.* the intersections of curves B_i and E_2 such that $E^{dMH} = E^{mH} = \overline{e}$).

Proposition 6 *The duopoly cases (M,H) or (H,M) never emerge because the NGO always favors the greenest product, H, whatever its positive initial budget.*

The label is therefore useless when R&D cost F_H is sufficiently low to allow cost-effectiveness of the component-free product. The resulting market structure is then Monopoly H. The NGO must adapt its strategy to this case by setting the fee and the campaign effort at levels such that Product M is not cost-effective in the duopoly (H, M). The quality of the environment, equal to $\overline{e}$, is at the highest possible level. Such a result is paradoxical because the label fee is used by the NGO only to deter firms from using the eco-labeled component.

However, a high R&D cost could make Monopoly M an interesting alternative for the incumbent and the NGO.[30] In this case, the quality of the environment is e_M and the NGO cannot improve it. Therefore the optimal fee and campaign are such that Product M is cost-effective in the case of monopoly but not in the case of duopoly (H, M).

4.5.3 Triopoly

The triopoly can be cost effective either before the campaign or following the NGO's decision provided that F_H is relatively low and c_M is moderate. Using demand equations (D.20), overall environmental quality can be expressed as:

$$E^t = -\overline{e} d_L^t + e_M d_M^t + \overline{e} d_H^t = \frac{\overline{e}(\overline{\theta} - \underline{\theta} + 2x) + e_M(\overline{\theta} - \underline{\theta}) - \rho(t_0 - t_H)}{2(\overline{\theta} - \underline{\theta})} \quad (10)$$

[30] When F_H is higher than that assumed for drawing Figure 6, there is an Area $(M, \emptyset, \emptyset)$ between Area $(H, M, \emptyset)$ and Area $(H, \emptyset, \emptyset)$.

Quality depends only on x because any increase in φ lowers the demand for Product M but increases equally the sum of the market shares of Product L and Product H. Symmetrically, intensifying the campaign effort contributes to crowding out Product L for the benefit of Product M and increasing the demand for Product H at the expense of Product M, the final effect being neutral for the demand of Product M. Depending on its initial budget B, the NGO can increase its campaign effort x and φ as long as the fee does not become excessive for the profitability of the certified product M.

Figure 7(c) shows that when the NGO has a relatively low initial budget (B_0 or B_1), its best strategy is to set a fee φ^{t*} that is even higher, because c_M is low and environmental quality e_M is high (see proof in Appendix E). Because a high budget allows the NGO to undertake a more effective campaign without receiving additional fees, a high budget (as $B_2 \geq \underline{B}^d(F_H)$ as defined in Proposition 3) prompts the NGO to prevent cost-effectiveness of Product L by choosing $(\hat{\varphi}^{t*}, x^*)$ at the limit of the shadow area (i.e. the intersection of curves B_2 and E_2). In the latter case the market structure becomes a duopoly (H, L) and the NGO exhausts its initial budget in the campaign ($x^* = \sqrt{B}$). The higher the initial budget, the lower the market share of Product L will be to the benefit of Product H that could monopolize the market.

Proposition 7 *In the triopoly case,*

- when $B < \underline{B}^d(F_H)$, the NGO sets a fee φ^{t*} to increase its campaign effort, which reduces the market share of Product L to the benefit of Product H;

- when $B \geq \underline{B}^d(F_H)$, the NGO sets a fee $\hat{\varphi}^{t*}$ that crowds out Product L as the third firm in the triopoly, and the market structure is then the duopoly (L, H), in which the NGO exhausts its initial budget to favor Product H.

In this case, there is a counterintuitive result: When the initial budget is high enough, the NGO's optimal strategy is to eliminate Product L from the triopoly, but by doing so, it eliminates the triopoly case and *de facto* Product M because the most profitable market structure is the duopoly (L, H).

4.6 Overview of the optimal strategies for the NGO

When the NGO cannot propose any certified sustainable component, its only strategy is to spend its initial budget, partly or entirely, to finance an awareness campaign to maximize the market share of the greenest product and eventually eliminate the denounced component. For this strategy to be successful, the R&D required to offer a harmful component-free product must be affordable, i.e. F_H must be low, but also consumers must not be put off by a difference in organoleptic quality, and they must be prepared to pay enough for better environmental quality.

This will be all the more likely as the NGO's initial B budget is high, allowing it to make a major x campaign effort to raise consumer awareness.

However, the denounced component is still produced in a duopoly when the R&D cost F_H is low, differentiation of organoleptic quality is high, but differentiation of environmental quality is low and the budget is insufficient to finance the needed campaign effort. In that case, the certification fees of a sustainable component could provide additional budget to the NGO and enable it to continue its campaign.

A third case also can occur, in which neither the brown product nor the green product is produced, because the R&D cost, the budget and the campaign effort are too high, but not high enough to render the green monopoly cost-effective. In that case again, increasing the NGO's budget could be a solution.

As we have shown, the NGO supply of a sustainable component triggers new market opportunities for the incumbent and new entrants even before the NGO's campaign. Labeling is an interesting alternative for the NGO for high R&D cost F_H of elimination of the denounced component and low unit cost of the sustainable component c_M, for high differentiation of organoleptic quality, and low-medium budget and campaign effort. The optimal fee is positive when the NGO benefits from a low initial budget, faces a duopoly (M, H) because Product M is the lowest environmental quality, or faces a triopoly. However, the NGO often will use the certification fee strategically to maximize market share of Product H at the expense of Product M and spend only its initial budget B.

4.7 Social welfare consequences

Social welfare SW^* in any market structure denoted by *, expressed in monetary units, is defined as the sum of consumers' surplus, firms' profits, NGO's surplus and environmental quality:

$$SW^* \quad = \quad CS_H^* + CS_M^* + CS_L^* + \pi_H^* + \pi_M^* + \pi_L^* + \delta E^* + S_{NGO}^*$$

with CS_i^* the surplus of consumers purchasing Product i in the market structure *, π_i^* firm i's profit $(i = H, M, L)$, δE^* the level of positive externality due to environmental quality (with marginal valuation δ) and S_{NGO}^* the NGO's surplus, defined as $B + \varphi^* d_M^* - x^{*2}$.

As in other articles that focus on changes in environmental awareness (García-Gallego & Georgantzís, 2010 or Mantovani et al., 2016), the expression of the sum of the consumers' surplus and the firms' profits can be reduced to the sum of several components: total intrinsic valuation for the good $\left(\overline{\theta} - \underline{\theta}\right) r$, total WTP for the product they eventually buy $\sum_i \left[\int_{\Theta_i^*} (\rho t_i + \theta e_i)\, d\theta\right]$ (where Θ_i^* stands for the support of the demand for Product i), net of the production and certification costs, and the feel-good (or warm-glow) effect induced by the awareness campaign $x^* \sum_i \left[\int_{\Theta_H^*} e_i d\theta\right]$. This yields the following expression for social welfare:

$$
\begin{aligned}
SW^* \quad = \quad & \left(\overline{\theta} - \underline{\theta}\right) r + \int_{\Theta_H^*} \left(\rho t_H + \theta \overline{e}\right) d\theta + \int_{\Theta_M^*} \left(\rho t_0 + \theta e_M\right) d\theta + \int_{\Theta_L^*} \left(\rho t_0 - \theta \overline{e}\right) d\theta \\
& -(F_H^* + (c_M + \varphi^*) d_M^*) \\
& +(B + \varphi^* d_M^* - x^{*2}) \\
& +(\delta + x^*) \left[\int_{\Theta_H^*} \overline{e} d\theta + \int_{\Theta_M^*} e_M d\theta - \int_{\Theta_L^*} \overline{e} d\theta \right]
\end{aligned}
$$

Insofar as the strategies implemented by the NGO often affect in the opposite direction the profit of firms, the surplus of consumers, and the environmental impact of the product traded on the market, the optimal social solution cannot be determined in a general way by conducting simple welfare comparisons between different market structures. Indeed, the respective weights of the economic and environmental components of social welfare depend on the valuation of the quality of the environment δ.

It is nevertheless interesting to examine the influence of the NGO's strategy on the different components of welfare. Figure 8 represents the evolution of the quality of the environment, the net surplus of consumers, the profit of industry, the total surplus at initial consumers' preferences, the feel-good effect on consumers, and the economic part of social welfare including the feel good effect (for, under the pressure of the NGO for different values of its initial budget B.

As Figure 8 shows, discontinuities appear for each component of welfare with each change in market structure. As the consumer's initial budget B increases and the environment improves, the consumer's surplus (calculated with his initial preferences, i.e., excluding the feel-good effect) decreases as the result of the exploitation by firms of their market power. Nevertheless, the profit of firms is reduced to almost zero by the strategy of the NGO in the case of the degenerated duopoly (M, H) returning to a positive level only when the Monopoly H regime is introduced. The total surplus improves overall, but remains constrained in the degenerated duopoly (M, H), whereas social welfare, excluding environmental externalities, improves even more as the feel-good effect progresses when it enters the duopoly (M, H) and radically improves when the degenerated duopoly becomes an H monopoly.

5 Discussion

5.1 Relevance of the analysis for other markets and other components

We chose the example of chocolate and hazelnut spread made with palm oil as an illustration, but the question studied in this article is obviously broader and concerns many markets and components that are harmful to the environment. In particular, our model allows us to analyze

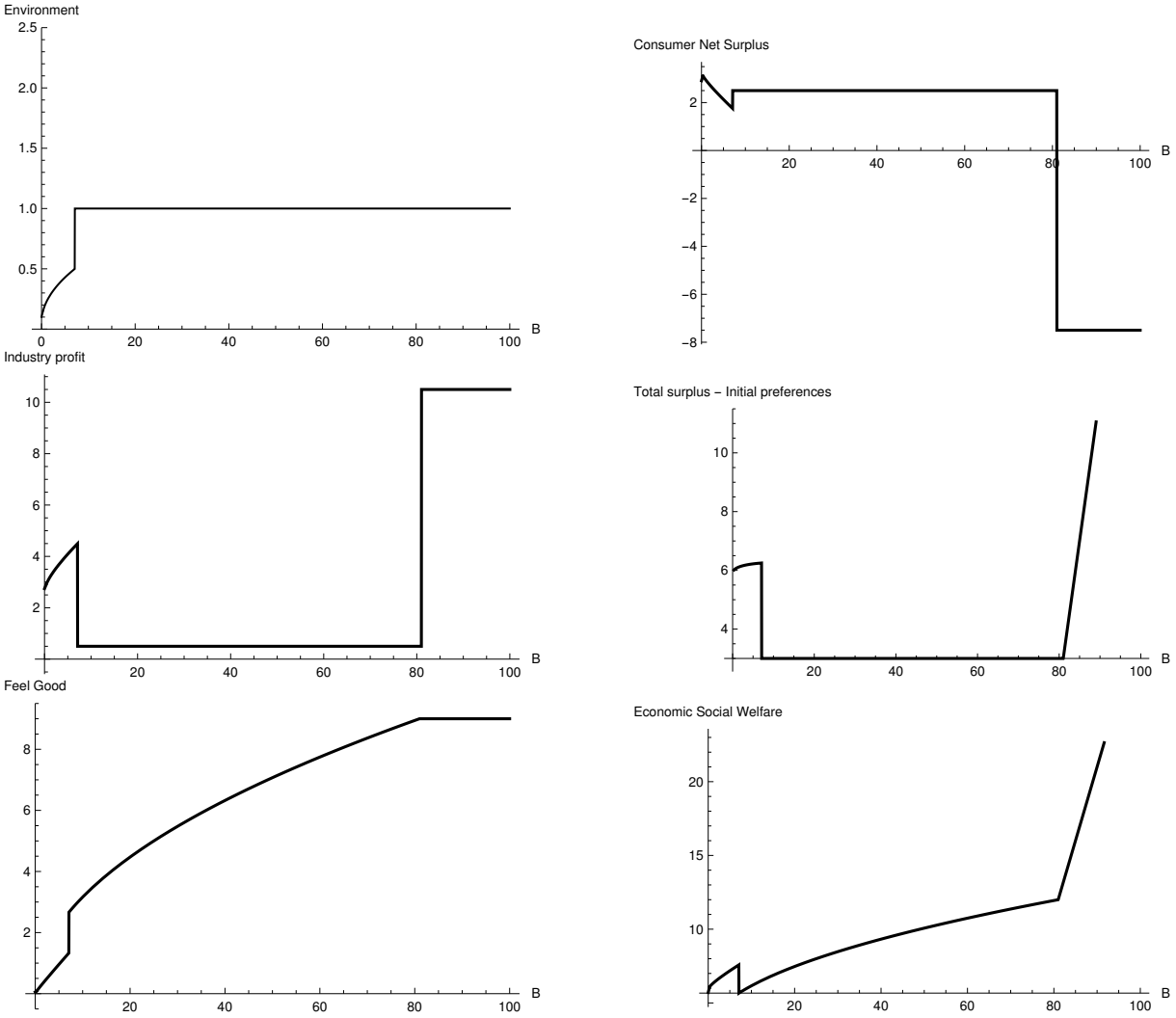


Figure 8: Welfare components under NGO's pressure.

the behaviors observed in similar markets with specific consumer preferences. Palm oil is used as an essential ingredient in the food industry, particularly in the manufacture of biscuits and cosmetics (palm oil and its derivative is used in 70% of cosmetics products), and in the composition of biofuels. In those cases, however, the initial market structure is more oligopolistic than monopolistic. But the most important difference may be in consumer preferences.

With regard to biofuels, for example, in Europe, regulations promote the incorporation of biofuels into motor vehicle fuels and many countries, including France, have set a target incorporation rate that determines subsidy eligibility. [31] The biofuel market is by definition covered, by harmful components (palm oil and soybean oil), certified sustainable components (same oils produced by small plantations), and advanced biofuels (obtained from crop residues or non- food feedstocks). There is no organoleptic difference in fuel use depending on the type of biofuel incorporated—in our model, $t_H = t_0$, or equivalently $\rho = 0$. However, this simplification does not qualitatively change the outcomes of the model; it merely reduces the efforts required for the NGO to improve the environmental quality F_H (and likely high c_H, contrary to our basic assumption) and c_M, this market clearly is characterized by the impossibility of switching to a sustainable component, and *a fortiori* to advanced biofuels without a vigorous NGO campaign. In the real world, this campaign has been directed toward European authorities and national governments and has resulted in progressively greater restriction of use of standard palm oil (Product L) and greater promotion of sustainable biofuels (Product M). The cosmetics case is similar; it is characterized by low WTP for organoleptic quality and increasing substitution of harmful palm oil by certified oil, rather than component-free products, unless NGO campaigns have been strong.

On the contrary, in the electricity market, electricity obtained from fossil primary energy represents our Product L, whereas renewable energy leads to Product H. In the field of renewable energies, the standard case often studied in the literature occurs when the certified product is H instead of M, because it is clearly 100% renewable. Eco-labels may be provided by NGOs using the fees to finance projects and for advocacy.[32] In such cases, eco-labelling may increase the price of renewable energy and limit the market share of H product. A case very similar to ours occurs when renewable natural gas — biomethane — is certified (Green-e® Renewable Fuels label[33] created since 1997, by the nonprofit Center for Resource Solutions[34]). Bio-methane

[31] The European Commission's recent phase-out by 2030 does not mean a ban on palm oil in biofuels since EU Member States will still be able to import and use palm oil-based biodiesel, but it will no longer be considered renewable energy counting towards their renewable targets or will no longer be eligible for the corresponding subsidies. https://ec.europa.eu/energy/sites/ener/files/documents/2_en_act_part1_v3.pdf, accessed on 23/08/2019.

[32] https://www.ekoenergy.org/our-results/, accessed on 23/08/2019.

[33] https://www.green-e.org/renewable-fuels, accessed on 23/08/2019

[34] https://resource-solutions.org/.

represents our Product M because it is considered to be carbon neutral but emits the same local pollutants as other natural gases.

The fishing industry also is a relevant example of our framework: A large number of retailers (e.g., Walmart, Carrefour) and companies (Unilever as the first) have committed to not selling or using fish caught in a non-sustainable way. Sustainable labeling schemes (such as the MSC or Friends of the Sea) are the results of efforts by NGOs to warn consumers and supply the market with credible alternative products. Because the production and certification costs of sustainable fish are significantly high, and consumers' WTP for sustainable fish is low, despite the number and sizes of NGOs' awareness campaigns), the market share of labeled fish remains lower than expected (Wijen & Chiroleu-Assouline, 2019).

5.2 The non-profit sector

In the real world, NGOs often differ according to the levers they use to influence the environment. Some NGOs conduct aggressive campaigns to denounce corporate behavior (e.g., Greenpeace denouncing the use of environmentally harmful components). Others (WWF, Environmental Defense Fund) conduct general or specific consumer awareness campaigns and some define labels allowing the marketing of certified products (RSPO, MSC, Forest Stewardship Council [FSC]). They also pursue mixed strategies, as those analyzed in this paper, but this is not the case in general.

Our assumption of a single NGO carrying out these activities simultaneously allows us to represent what would happen in the event that different NGOs joined forces to carry out these actions in a cooperative way. This setting allows us to describe the optimal approach for the activist sector as a whole. It is therefore particularly interesting to analyze the effects on market structure, the environment, and social well-being of this coalition compared with situations in which NGOs act independently.

First, if the non-profit sector consists of several NGOs competing to raise funds (initial B budget) to finance their awareness campaigns, the same amount collected from their supporters will have a reduced impact, because of our realistic assumption of decreasing returns of budget spent. However, because we assume that certification fees can help finance awareness campaigns, we introduce reverse incentives into a coalition to compare it with independent NGOs. Indeed, if NGOs are concerned only with improving the quality of the environment by offering certified products, they set their fees at the lowest possible levels (by covering certification costs, as in Bottega and De Freitas (2009)) to maximize Product M's market share. A coalition, however, has an incentive to charge positive net fees if the effect of increasing the cost of production of Product M is more than offset by the increased environmental sensitivity of consumers. The

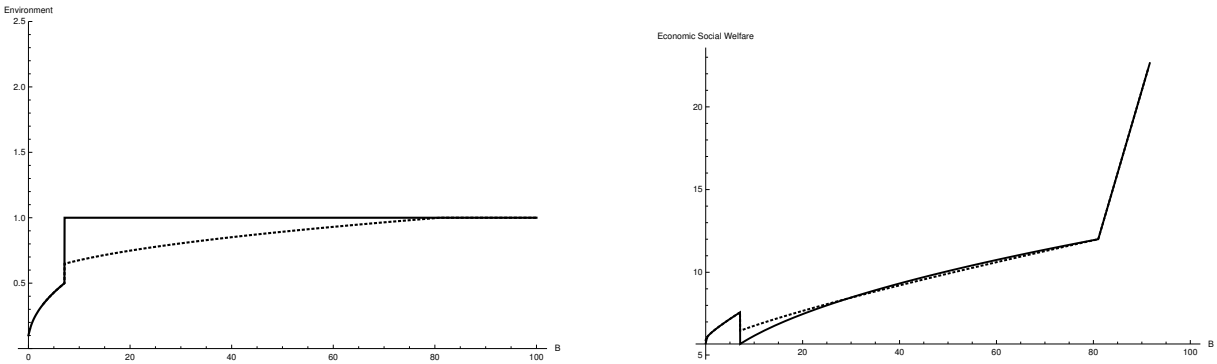


Figure 9: Welfare components under pressure of cooperative or independent NGOs.

coalition uses the revenue from fees to boost its campaign even at the cost of evicting the product M.

Figure 6 shows the potential impact of increasing either x or ϕ, for a given F_H. When cost conditions allow a duopoly (L, M) or (M, L) to appear, independent NGOs will decide to bill null fees to maximize Product M's market share, possibly crowding out Product L and reaching duopoly (M, H) with a low probability of success because their initial budget is not accrued by fees. In contrast, a cooperative non-profit sector will increase fees both to potentialize the awareness campaign and reach a duopoly (H, L). For given F_H, c_M and B, the coalition obtains a clearly better environmental result than the independent NGOs (see Figure 9).

When the initial conditions lead to a duopoly (M, H), the coalition can spend more than the fragmented non-profit sector, as result of the fees, and thus is more likely to lead to Monopoly H. Also in this case, the coalition does better than the non-cooperative NGOs. As shown in Figure 8, the economic component of social welfare evolves in a mirror image, deteriorating only gradually if NGOs act independently. The more the environmental externality has an important δ weight in economic terms, the more cooperation between NGOs is preferable, according to the criterion of social welfare, to independent action, for intermediate budget levels (that is, not allowing reach of the monopoly).

If independent action is not efficient, why do NGOs choose in many cases to act separately? A possible explanation lies in other motivations, such as fair trade or development aid for poor producers in developing countries, that lead them to support and certify sustainable palm oil instead of simply promoting palm-free products.

6 Conclusion

In this paper, we adopt a two-dimensional vertical product differentiation model to determine the conditions under which pressure from an NGO is likely to lead a monopoly to eliminate a basic

component of its product or, alternatively, substitute a damaging component with a certified sustainable component.

We find that in the absence of a certified sustainable component, the NGO prefers elimination of the harmful component, because it leads to the best environmental quality. However, we also find that the NGO does not always exhaust its initial budget, which can be counterproductive to reaching the greenest situation (i.e., the green monopoly H).

We also find that rather than investing in an awareness campaign, the NGO may choose to increase consumers' WTP for component-free products, despite the taste degradation of the products, or propose use of a certified component that is less harmful to the environment. One of our main results is that the NGO may prefer to favor the entry of a competitor using the certified component and restrict the market share of the least environmentally harmful product, when it is unable to establish a monopoly situation because of high R&D costs or low initial budgets. By collecting fees, the NGO is able to intensify its awareness campaign, leading to a duopoly or a triopoly. However, often the NGO will use the fees strategically to maximize market share of one product at the expense of another product.

Finally, by comparing welfare across different market structures, we find that the more environmental externalities are highly valued, the more likely optimal social solutions can be achieved through NGO cooperation.

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Appendix

A Sequence of the game with certification

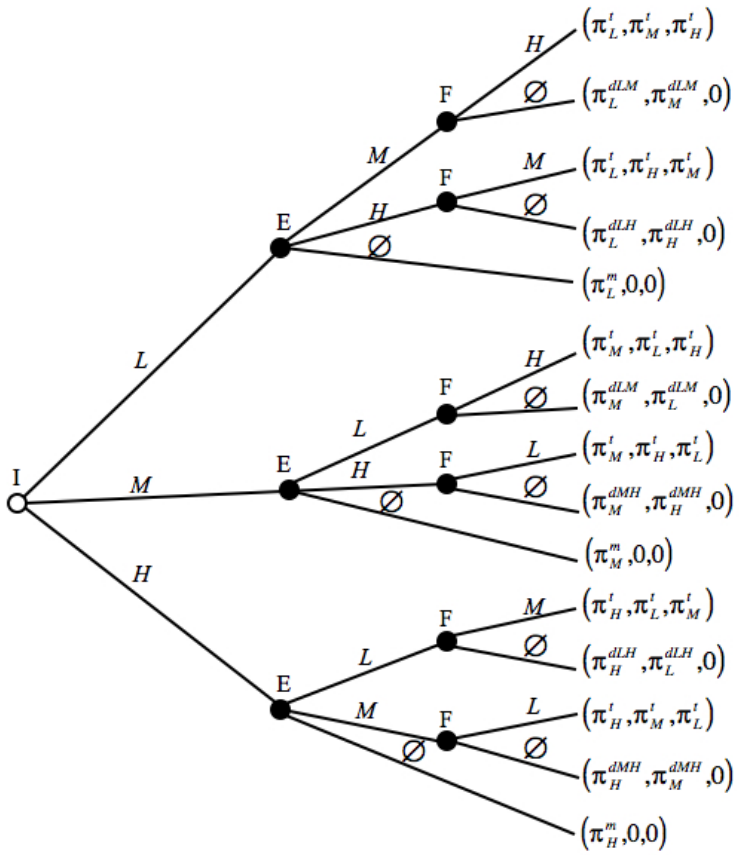

Figure A.1: The game tree

Notes:

I denotes the incumbent, E the first entrant and F the third firm;

Each profit π is indexed by H, L or M, indicating the product chosen by the firm and bearing the symbol of the market structure: m for a monopoly, dij for a duopoly (i, j), and t for the triopoly.

B Conditions of existence and market coverage after information disclosure

Conditions of existence and market coverage of monopoly L

The maximum campaign effort allowing cost-effectiveness of product L is defined as follows:

$$x_{L0}^{m} \equiv \frac{\overline{\omega}_L(0)}{\overline{e}} \tag{B.1}$$

Moreover, the market is covered by Assumption 1, and the monopoly has an interest in setting a price equal to the lowest WTP for product L, that is $\underline{\omega}_L(x)$. In this case, the profit, defined by $\underline{\omega}_L(x)$, is positive and lower than the initial profit $r + \rho t_0 + \underline{\theta} e_0$.

It can be shown that $\pi_L^m(x) < \pi_0^*(x)$ for all x.

Conditions of existence and market coverage of monopoly H

In the case of monopoly H, only consumers with a willingness to pay (WTP) for the environmental quality higher than $\widetilde{\theta}_H = \frac{p_H - r - \rho t_H}{\overline{e}} - x$ buy the product.

Using the equilibrium price in an uncovered market, that is equal to $\overline{\omega}_H(x)/2$, the condition for covered market is: $\widetilde{\theta}_H = \dfrac{(\overline{\theta} + x)\overline{e} - r - \rho t_H}{2\overline{e}} < \underline{\theta}$. The market is thus covered for $x = 0$ when Assumption 1 is fulfilled.

The minimum campaign effort allowing cost-effectiveness of product H is then defined as follows:

$$x_{H0}^{m} \equiv \frac{F_H - r - \rho t_H}{\overline{e}} - \underline{\theta} \tag{B.2}$$

Because $\pi_H^m(x)$ is increasing in x whereas $\pi_L^m(x)$ is decreasing in x , there is a minimum effort $\hat{x}^m$, such that $\pi_H^m(x) \geq \pi_L^m(x)$ when $x \geq \hat{x}^m$. This minimum effort is defined as follows:

$$\hat{x}^m \equiv 2\overline{\theta} - 3\underline{\theta} + \frac{r + \rho t_0 - 2\sqrt{(\overline{\theta} - \underline{\theta})(2r + \rho(t_0 + t_H) + (\overline{\theta} - \underline{\theta})\overline{e} - F_H)\overline{e}}}{\overline{e}} \tag{B.3}$$

Conditions of existence and market coverage of duopoly LH

There is a consumer, with type $\widetilde{\theta}_{LH}$, who is indifferent between both products. All consumers buy one unit of the good when $\widetilde{\theta}_H < \widetilde{\theta}_{LH} < \widetilde{\theta}_L$.

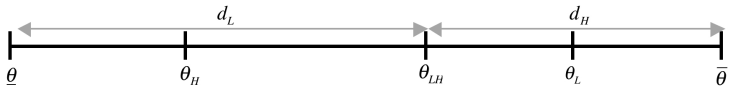

Figure B.2: Market sharing with products L and H

Existence of both firms requires that the NGO's campaign effort remains in interval $[x_{H0}^d, x_{L0}^d]$,

where both thresholds are defined as follows:

$$x^d_{H0} \equiv \frac{3\sqrt{2(\overline{\theta}-\underline{\theta})\overline{e}F_H} + \rho(t_0 - t_H)}{2\overline{e}} - 2\overline{\theta} + \underline{\theta} \tag{B.4}$$

$$x^d_{L0} \equiv \frac{\rho(t_0 - t_H)}{2\overline{e}} + \overline{\theta} - 2\underline{\theta} \tag{B.5}$$

Cost-effectiveness of the duopoly (L, H) also necessitates that F_H is lower than $(\overline{\theta} - \underline{\theta})/(2\overline{e})$. Moreover, Product H is more cost-effective than Product L when the campaign effort is higher than the following threshold:

$$\hat{x}^d \equiv \frac{\rho(t_0 - t_H) - (\overline{\theta} + \underline{\theta})\overline{e}}{2\overline{e}} + \frac{3F_H}{4\overline{e}} \tag{B.6}$$

C Proofs related to the information disclosure and campaign game

Proof of Lemma 1

In a duopoly, in the absence of any NGO campaign increasing the WTP for the component-free Product H, this product can be more cost-effective than Product L if and only if

$$\begin{aligned}
\pi^{dLH}_H(0) &\geq \pi^{dLH}_L(0) \\
2(\overline{\theta} - \underline{\theta})\,\overline{e}\,\left(d^{dLH}_H(0)^2 - d^{dLH}_L(0)^2\right) &\geq F_H \\
2(\overline{\theta} - \underline{\theta})\,\overline{e}\,\left(2d^{dLH}_H(0) - 1\right) &\geq F_H \\
\hat{F}^d_H \equiv \frac{2}{3}\big((\overline{\theta} + \underline{\theta})\overline{e} - \rho t_0 + \rho t_H\big) &\geq F_H
\end{aligned}$$

The market becomes a duopoly if and only if it is profitable for a new entrant to supply Product H:

$$\begin{aligned}
\pi^{dLH}_H(0) &\geq 0 \\
\underline{F}_H \equiv \frac{(2(2\overline{\theta} - \underline{\theta})\overline{e} - \rho t_0 + \rho t_H)^2}{18(\overline{\theta} - \underline{\theta})\,\overline{e}} &\geq F_H
\end{aligned}$$

It is easy to show that $\hat{F}^d_H < \underline{F}_H$.

When the market is a monopoly, the frontier between Monopoly H and Monopoly L is given by

$$\begin{aligned}
\pi^m_H(0) &\geq \pi^m_L(0) \\
\pi^m_H(0) &\geq (\overline{\theta} - \underline{\theta})\,\overline{e}\,d^m_L(0)^2 \\
\underline{\omega}_H(0) - F_H &\geq (\overline{\theta} - \underline{\theta})\,\overline{e}\,\Big(\frac{\overline{\omega}_L(0)}{2(\overline{\theta} - \underline{\theta})\overline{e}}\Big)^2 \\
\underline{\theta}\overline{e} + r + \rho t_H - F_H &\geq (\overline{\theta} - \underline{\theta})\,\overline{e}\,\Big(\frac{r + \rho t_0 - \underline{\theta}\overline{e}}{2(\overline{\theta} - \underline{\theta})\overline{e}}\Big)^2 \\
\hat{F}^m_H \equiv \underline{\theta}\overline{e} + r + \rho t_H - \frac{(\underline{\theta}\overline{e} - r - \rho t_0)^2}{4(\overline{\theta} - \underline{\theta})\,\overline{e}} &\geq F_H
\end{aligned}$$

Proof of Proposition 1

Because the R&D cost F_H is a fixed cost, the market share of Product H only depends only on the WTP for both qualities. The NGO's awareness campaign x always decreases the market share of Monopoly L (eq. 3), and always increases the market share of Product H in a duopoly (eq. 5). According to Assumption 1, the duopoly market is covered and any decrease in demand for Product L is covered by an increase in demand for Product H. The environmental quality is maximized when the market is covered by Monopoly H. The overall quality of the environment fulfills inequality $E^{mH}(x) = \overline{e} > E^{dLH}(x) > E^{mL}(x)$, where superscripts mL, mH and dLH respectively denote following market structures: monopoly of Product L, monopoly of Product H and duopoly (L, H) and (H, L).

Proof of Proposition 2

Appendix B shows that existence of both firms requires that the NGO's campaign effort remains in interval $[x^d_{H0}, x^d_{L0}]$. As soon as $F_H < (\overline{\theta} - \underline{\theta})/2\overline{e}$, $x^d_{H0} < x^d_{L0}$.

For low F_H, x^d_{L0} is therefore the maximum useful campaign effort to reach Monopoly H. $\overline{B}^d = \left(x^d_{L0}\right)^2 = \left(\frac{\rho(t_0 - t_H)}{2\overline{e}} + \overline{\theta} - 2\underline{\theta}\right)^2$.

Proof of Proposition 3

When $\hat{F}^m_H \leq \underline{F}_H$, Lemma 1 states that for $x = 0$, $\forall F_H \in [\underline{F}_H, \tilde{F}_H]$, Monopoly L remains on the market after information disclosure. However, any increase of the initial budget allows the NGO to campaign and to reduce its market share because $d^m_L(x) = \frac{r + \rho t_0 - (\underline{\theta} + x)\overline{e}}{2(\overline{\theta} - \underline{\theta})\overline{e}}$ (eq. 3). But, as this share decreases, it increases the minimum WTP for Product H: $r++\rho t_H + (\overline{\theta} + x)\overline{e}$. Product H may thus become profitable, either for a new entrant in a duopoly, or for the incumbent who will switch to Monopoly H.

Let us define $\tilde{F}_H$ and $\tilde{B}$ such that $\pi^m_H(\tilde{F}_H, \tilde{B}) = \pi^m_L(\tilde{F}_H, \tilde{B})$ and $\pi^{dLH}_H(\tilde{F}_H, \tilde{B}) = 0$.

For $F_H < \tilde{F}_H$, when $B > \tilde{B}$, earning money with Product H becomes possible for a new entrant in a duopoly, but not for a monopoly H as soon as the campaign is sufficiently powerful, that is for $B > \underline{B}^d(F_H)$ such that $\pi^{dLH}_H(F_H, \underline{B}^d(F_H)) = 0$.

$$\pi^{dLH}_H(x) = 2(\overline{\theta} - \underline{\theta})\,\overline{e}\left(\frac{2(2\overline{\theta} - \underline{\theta} + x)\overline{e} - \rho t_0 + \rho t_H}{6(\overline{\theta} - \underline{\theta})\,\overline{e}}\right)^2 - F_H$$

$$x^d_{H0}(F_H) \equiv \frac{3\sqrt{2(\overline{\theta} - \underline{\theta})\overline{e}F_H} + \rho(t_0 - t_H) - 2(2\overline{\theta} - \underline{\theta})\overline{e}}{2\overline{e}} \text{ and } \underline{B}^d(F_H) = \left(x^d_{H0}(F_H)\right)^2$$

In the opposite case, when $F_H \geq \tilde{F}_H$, entry is deterred and the monopoly turns into Monopoly H as soon as the campaign is sufficiently powerful, ie for $B > \hat{B}^m(F_H)$ such that $\pi^m_H(F_H, \hat{B}^m(F_H)) \geq \pi^m_L(\hat{B}^m(F_H))$. It was already shown (Appendix B) that the level of campaign effort equalizing

both monopoly profits is $\hat{x}^m$. The necessary budget is thus $\hat{B}^m(F_H)$ defined as

$$\hat{B}^m(F_H) = \left(\hat{x}^m\right)^2 \equiv \left(2\overline{\theta} - 3\underline{\theta} + \frac{r + \rho t_0 - 2\sqrt{(\overline{\theta}-\underline{\theta})(2r+\rho(t_0+t_H)+(\overline{\theta}-\underline{\theta})\overline{e}-F_H)\overline{e}}}{\overline{e}}\right)^2$$

When $\underline{F}_H < \hat{F}_H^m$, according to Lemma 1, $\forall F_H \in [\underline{F}_H, \hat{F}_H^m]$, the monopoly switches to Product H after information disclosure, even for $x = 0$. Increasing the campaign effort is useless.

Proof of Proposition 4

There are limits $\overline{F}_H$ and $\overline{B}^m$ such that $\forall F_H \geq \overline{F_H}$ and $\forall B \geq \overline{B}^m$, Products L and H are both non profitable anymore and the market disappears, with $\overline{F}_H \equiv 2r + \rho t_0 + \rho t_H$ and $\overline{B} \equiv \left(\overline{\omega}_L(0)/\overline{e}\right)^2$. $\overline{B}^m$ is defined as the level of initial budget for which Monopoly L is no more cost-effective ($\pi_L^m(\overline{B}^m) = 0$ and $\overline{F}_H$ corresponds to the abscissa of the intersection point of the null profit line for Monopoly L and the null profit curve for Monopoly H ($\pi_H^m(\overline{F}_H, \hat{B}^m) = 0$).

D Conditions of existence of different market structures including supply of a certified product

Conditions of existence of duopoly with Products L and M

When the market is fully covered by a duopoly $(L, M, \emptyset)$ or $(M, L, \emptyset)$, demand functions are defined as $d_M = \frac{\overline{\theta}-\theta_{LM}}{\overline{\theta}-\underline{\theta}}$ and $d_L = \frac{\theta_{LM}-\underline{\theta}}{\overline{\theta}-\underline{\theta}}$, with $\widetilde{\theta}_{LM} = \frac{p_M-p_L}{\overline{e}+e_M} - x$.[35] Maximization of profits with respect to prices leads to the following Nash equilibrium:

$$\begin{aligned} p_L^{dLM} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e}+e_M) + c_M + \varphi}{3} \\ p_M^{dLM} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e}+e_M) + 2(c_M + \varphi)}{3} \end{aligned} \tag{D.7}$$

Demands are then written as:

$$\begin{aligned} d_L^{dLM} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e}+e_M) + c_M + \varphi}{3(\overline{\theta}-\underline{\theta})(\overline{e}+e_M)} \\ d_M^{dLM} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e}+e_M) - c_M - \varphi}{3(\overline{\theta}-\underline{\theta})(\overline{e}+e_M)} \end{aligned} \tag{D.8}$$

The profits are then equal to $\pi_i^{dLM}(x) = (\overline{\theta}-\underline{\theta})(\overline{e}+e_M){d_i^{dLM}}^2$ with $i = L, M$.

Cost-effectiveness of Product M requires that its unit cost of production, $c_M+\varphi$, is sufficiently low to ensure that $d_M^{dLM} \geq 0$, that is:

$$c_M + \varphi \leq (2\overline{\theta} - \underline{\theta} + x)(\overline{e}+e_M) \tag{D.9}$$

[35] Two monopolists co-exist in an uncovered market when $\widetilde{\theta}_L < \widetilde{\theta}_M$. Using monopoly prices, this condition is written as: $\rho t_0 < (\overline{\theta}-\underline{\theta})\frac{e_M}{\overline{e}+e_M} + (c_M+\varphi)\frac{\overline{e}}{\overline{e}+e_M}$. The WTP for the organoleptic quality has to be relatively low, but sufficiently high to allow cost-effectiveness of both monopolies (*i.e.* $\rho t_0 \geq (\underline{\theta}+x)\overline{e}$ and $\rho t_0 \geq c_M + \varphi - (\overline{\theta}+x)e_M$).

Denoting $C_M \equiv c_M + \varphi$ and $\overline{C}_M^{dLM}$ the maximum unit cost allowing cost effectiveness of Product M before the campaign ($x = 0$), we deduce from the previous inequality that:

$$\overline{C}_M^{dLM} \equiv (2\overline{\theta} - \underline{\theta})(\overline{e} + e_M) \tag{D.10}$$

Existence of both firms requires that the NGO's campaign effort remains in interval $[x_{M0}^{dLM}, x_{L0}^{dLM}]$, where both thresholds are defined as follows:

$$\begin{aligned} x_{L0}^{dLM} &\equiv \overline{\theta} - 2\underline{\theta} + \frac{c_M + \varphi}{\overline{e} + e_M} \\ x_{M0}^{dLM} &\equiv -2\overline{\theta} + \underline{\theta} + \frac{c_M + \varphi}{\overline{e} + e_M} \end{aligned} \tag{D.11}$$

Conditions of existence of duopoly with Products M and H

When the market is covered by a duopoly $(M, H, \emptyset)$ or $(H, M, \emptyset)$, demand functions are defined as $d_H = \frac{\overline{\theta} - \widetilde{\theta}_{MH}}{\overline{\theta} - \underline{\theta}}$ and $d_M = \frac{\widetilde{\theta}_{MH} - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$, with $\widetilde{\theta}_{MH} = \frac{p_H - p_M + \rho t_0 - \rho t_H}{\overline{e} - e_M} - x$. Price competition results in the following Nash equilibrium:

$$\begin{aligned} p_M^{dMH} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e} - e_M) + \rho t_0 - \rho t_H + 2c_M + 2\varphi}{3} \\ p_H^{dMH} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e} - e_M) - \rho t_0 + \rho t_H + c_M + \varphi}{3} \end{aligned} \tag{D.12}$$

Demands are then defined by:

$$\begin{aligned} d_M^{dMH} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e} - e_M) + \rho t_0 - \rho t_H - c_M - \varphi}{3(\overline{\theta} - \underline{\theta})(\overline{e} - e_M)} \\ d_H^{dMH} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e} - e_M) - \rho t_0 + \rho t_H + c_M + \varphi}{3(\overline{\theta} - \underline{\theta})(\overline{e} - e_M)} \end{aligned} \tag{D.13}$$

The profits are then equal to $\pi_M^{dMH}(x) = (\overline{\theta} - \underline{\theta})(\overline{e} - e_M){d_M^{dMH}}^2$ and $\pi_H^{dMH}(x) = (\overline{\theta} - \underline{\theta})(\overline{e} - e_M){d_H^{dMH}}^2 - F_H$.

Cost-effectiveness of Product M requires that its unit cost of production, $c_M + \varphi$, is sufficiently low to ensure that $d_M^{dLM} \geq 0$, that is:

$$c_M + \varphi \leq (\overline{\theta} - 2\underline{\theta} - x)(\overline{e} - e_M) + \rho t_0 - \rho t_H \tag{D.14}$$

Denoting $\overline{C}_M^{dMH}(x)$ the maximum unit cost allowing cost effectiveness of Product M, we deduce from the previous inequality that:

$$\overline{C}_M^{dMH}(x) \equiv (\overline{\theta} - 2\underline{\theta} - x)(\overline{e} - e_M) + \rho t_0 - \rho t_H \tag{D.15}$$

Moreover, profitability of Product H requires that $F_H < (\overline{\theta}-\underline{\theta})(\overline{e}-e_M)d_H^{dMH2}$. Such a condition leads, for a given F_H, to define the following minimum unit cost:

$$\underline{C}_H^{dMH}(x) \equiv 3\sqrt{(\overline{\theta}-\underline{\theta})(\overline{e}-e_M)F_H} - (\overline{e}-e_M)(2\overline{\theta}-\underline{\theta}+x) + \rho t_0 - \rho t_H \tag{D.16}$$

Comparing Equation (26) and (27) shows that, without any effort campaign, the duopoly (M,H) appears as far as $F_H < \overline{F}_H^{dMH} \equiv (\overline{\theta}-\underline{\theta})(\overline{e}-e_M)$.

Moreover, $\overline{C}_M^{dMH}(x)$ decreases with x as $\underline{C}_H^{dMH}(x)$, that increases with F_H.

Existence of both firms requires that the NGO's campaign effort remains in interval $[x_{H0}^{dHM}, x_{M0}^{dMH}]$, where both thresholds are defined as follows:

$$\begin{aligned} x_{M0}^{dMH} &\equiv \overline{\theta} - 2\underline{\theta} + \frac{\rho t_0 - \rho t_H - c_M - \varphi}{\overline{e}-e_M} \\ x_{H0}^{dHM} &\equiv -2\overline{\theta} + \underline{\theta} + \frac{\rho t_0 - \rho t_H - c_M - \varphi}{\overline{e}-e_M} + \frac{3\sqrt{(\overline{e}-e_M)(\overline{\theta}+\underline{\theta})F_H}}{\overline{e}-e_M} \end{aligned} \tag{D.17}$$

Triopoly

With a triopoly market structure, demand functions are defined as $d_H = \frac{\overline{\theta}-\widetilde{\theta}_{MH}}{\overline{\theta}-\underline{\theta}}$, $d_M = \frac{\widetilde{\theta}_{MH}-\widetilde{\theta}_{LM}}{\overline{\theta}-\underline{\theta}}$ and $d_L = \frac{\widetilde{\theta}_{LM}-\underline{\theta}}{\overline{\theta}-\underline{\theta}}$. Maximization of the triopoly's profits with respect to prices leads to the following reaction functions:

$$\begin{aligned} p_L &= \frac{1}{2}(p_M - (\underline{\theta}+x)(\overline{e}+e_M)) \\ p_M &= \frac{1}{4\overline{e}}(p_H(\overline{e}+e_M) + p_L(\overline{e}-e_M) + (\rho t_0 - \rho t_H)(\overline{e}+e_M) + 2(c_M+\varphi)\overline{e}) \\ p_H &= \frac{1}{2}(p_M - (\overline{\theta}+x)(\overline{e}-e_M) - (\rho t_0 - \rho t_H)) \end{aligned} \tag{D.18}$$

Such reaction functions result in the following Nash equilibrium:

$$\begin{aligned} p_L^t &= \frac{(-6(\underline{\theta}+x)\overline{e} + (\overline{\theta}-\underline{\theta})(\overline{e}-e_M) + \rho t_0 - \rho t_H)(\overline{e}+e_M) + 4(c_M+\varphi)\overline{e}}{12\overline{e}} \\ p_M^t &= \frac{((\overline{\theta}-\underline{\theta})(\overline{e}-e_M) + \rho t_0 - \rho t_H)(\overline{e}+e_M) + 4(c_M+\varphi)\overline{e}}{6\overline{e}} \\ p_H^t &= \frac{(6(\overline{\theta}+x)\overline{e} + (\overline{\theta}-\underline{\theta})(\overline{e}-e_M))(\overline{e}-e_M) - (\rho t_0 - \rho t_H)(5\overline{e}-e_M) + 4(c_M+\varphi)\overline{e}}{12\overline{e}} \end{aligned} \tag{D.19}$$

Demands are then defined by:

$$\begin{aligned} d_L^t &= \frac{(-6(\underline{\theta}+x)\overline{e} + (\overline{\theta}-\underline{\theta})(\overline{e}-e_M) + \rho t_0 - \rho t_H)(\overline{e}+e_M) + 4(c_M+\varphi)\overline{e}}{12(\overline{\theta}-\underline{\theta})(\overline{e}+e_M)\overline{e}} \\ d_M^t &= \frac{((\overline{\theta}-\underline{\theta})(\overline{e}-e_M) + \rho t_0 - \rho t_H)(\overline{e}+e_M) - 2(c_M+\varphi)\overline{e}}{3(\overline{\theta}-\underline{\theta})(\overline{e}+e_M)(\overline{e}-e_M)\overline{e}} \\ d_H^t &= \frac{(6(\overline{\theta}+x)\overline{e} + (\overline{\theta}-\underline{\theta})(\overline{e}-e_M))(\overline{e}-e_M) - (\rho t_0 - \rho t_H)(5\overline{e}-e_M) + 4(c_M+\varphi)\overline{e}}{12(\overline{\theta}-\underline{\theta})(\overline{e}-e_M)\overline{e}} \end{aligned} \tag{D.20}$$

The profits are characterized by $\pi_L^t(x) = (\overline{\theta} - \underline{\theta})(\overline{e} + e_M){d_M^t}^2$, $\pi_M^t(x) = \frac{(\overline{\theta}-\underline{\theta})(\overline{e}+e_M)(\overline{e}-e_M)}{2\overline{e}}{d_M^t}^2$ and $\pi_H^t(x) = (\overline{\theta} - \underline{\theta})(\overline{e} - e_M){d_H^t}^2 - F_H$.

Cost-effectiveness of Product M in a triopoly before the campaign involves a maximum unit cost, deduced from condition $d_M^t \geq 0$, defined as follows:

$$\overline{C}_M^t \equiv \frac{\big((\overline{\theta} - \underline{\theta})(\overline{e} - e_M) + \rho t_0 - \rho t_H\big)(\overline{e} + e_M)}{2\overline{e}} \tag{D.21}$$

The condition for cost effectiveness of Product H before the campaign $\pi_H^t(0) \geq 0$ can be translated as a minimum unit cost, denoted $\underline{C}_M^t$, for a given R&D cost F_H, defined as:

$$\underline{C}_M^t \equiv 3\sqrt{(\overline{\theta} - \underline{\theta})(\overline{e} - e_M)F_H} + \frac{\overline{e}(\overline{e} - e_M)(\underline{\theta}(\overline{e} + e_M) - \overline{\theta}(7\overline{e} + e_M) + (5\overline{e} - e_M)\overline{e}(\rho t_0 - \rho t_H)}{4\overline{e}^2} \tag{D.22}$$

Moreover, conditions $C_M \leq \overline{C}_M^t$ and $C_M \geq \underline{C}_M^t$ imply a maximum R&D cost compatible with the triopoly, defined as follows:

$$\overline{F}_H^t \equiv \frac{(\overline{e} - e_M)\big(\underline{\theta}(\overline{e} + e_M) - \overline{\theta}(3\overline{e} + e_M) + \rho t_0 - \rho t_H\big)^2}{16(\overline{\theta} - \underline{\theta})\overline{e}^2} \tag{D.23}$$

Therefore, the triopoly market structure can only emerge before the campaign for $C_M \in [\underline{C}_M^t, \overline{C}_M^t]$ and $F_H \leq \overline{F}_H^t$. Product L is also cost effective when both other products are cost effective if we assume that $(\overline{\theta} - \underline{\theta})(\overline{e} - e_M) + \rho t_0 - \rho t_H > 2\underline{\theta}\overline{e}$ because d_L^t is an increasing function of C_M and $d_L^t > 0$ when $C_M = \underline{C}_M^t$ as long as the previous condition is fulfilled.

Existence of the three firms requires that the NGO's campaign effort remains in interval $[x_{H0}^t, x_{L0}^t]$, where both thresholds are defined as follows:

$$\begin{aligned} x_{L0}^t &\equiv -\frac{6\underline{\theta}\overline{e} + (\overline{\theta} - \underline{\theta})(\overline{e} - e_M) - (\rho t_0 - \rho t_H)}{6\overline{e}} + \frac{2(c_M + \varphi)}{3(\overline{e} + e_M)} \\ x_{H0}^t &\equiv -\frac{6\overline{\theta}\overline{e} + (\overline{e} + e_M)(\overline{\theta} - \underline{\theta}) - (\rho t_0 - \rho t_H)}{6\overline{e}} - \frac{4(c_M + \varphi)\overline{e} - (\rho t_0 - \rho t_H)}{6(\overline{e} - e_M)} \\ &\quad + \frac{2\sqrt{(\overline{e} - e_M)(\overline{\theta} - \underline{\theta})F_H}}{\overline{e} - e_M} \end{aligned} \tag{D.24}$$

Conditions on production costs for market structures before the campaign (Figure 4)

According to backward induction reasoning, the triopoly is a Nash equilibrium when a third firm has an interest in entering the market (with H or M) and the other firms also have an interest in producing (see Figure A.1), that is when $\pi_i^t > 0$ for all $i = L, M, H$. In Figure 4[36], the triopoly area corresponds to the kind of triangle on the west of the graph, with $\underline{C}_M^t$ the growing

[36] Figure 4 has been drawn using parameters $\underline{\theta} = 1$, $\overline{\theta} = 4$, $\overline{e} = 1$, $e_M = 1/2$, $\rho = 3$, $t_0 = 2$ and $t_H = 1/2$.

curve that reaches threshold $\overline{C}_M^t$ for F_H equal to $\overline{F}_H^t$. When $c_M + \varphi$ is outside this range, the third firm decides not to enter either because C_M is too low to allow cost-effectiveness of Product H (*i.e.* $C_M < \underline{C}_M^t$ and $\pi_H^t \leq 0$) or C_M is too high to allow cost-effectiveness of Product M (*i.e.* $C_M > \overline{C}_M^t$ and $\pi_M^t \leq 0$). The market structure can therefore be a duopoly.

In the case of covered market by the duopoly, the incumbent's best strategy is to produce the most cost-effective product knowing that another firm will then decide to enter with the second best cost-effective product.

Duopoly with Products L and M is a Nash equilibrium before the campaign if $C_M \leq \overline{C}_M^{dLM}$. In Figure 4, this threshold corresponds to the horizontal line in the North-East of the graph. Moreover, duopoly $(M, L, \emptyset)$ is the SPE of the game if $\pi_M^{dLM}(x) > \pi_L^{dLM}(x)$, that implies $c_M + \varphi \leq (\overline{\theta} + \underline{\theta} + 2x)(\overline{e} + e_M)$. Therefore, the maximum unit cost triggering the incumbent to switch to M before the campaign is defined as $\hat{C}_M^{dLM} \equiv (\overline{\theta} + \underline{\theta})(\overline{e} + e_M)$. A higher cost leads the incumbent to still produce L meanwhile the new entrant supplies M. In Figure 4, threshold $\hat{C}_M^{dLM}$ corresponds to the horizontal dotted line.

Existence of SPE $(L, M, \emptyset)$ requires non-deviation condition $\pi_M^{dLM}(0) > \pi_H^{dLH}(0)$, that can be written:

$$\frac{\big((2\overline{\theta} - \underline{\theta} + x)(\overline{e} + e_M) - c_M - \varphi)\big)^2}{9(\overline{\theta} - \underline{\theta})(\overline{e} + e_M)} > \frac{\big(2(2\overline{\theta} - \underline{\theta} + x)\overline{e} - \rho t_0 + \rho t_H\big)^2}{18(\overline{\theta} - \underline{\theta})\,\overline{e}} - F_H \tag{D.25}$$

Denoting $\hat{C}_M^d$ the maximum unit cost leading the new entrant to produce M rather than H to compete with Product L before the campaign ($x = 0$), we deduce from the previous inequality that:

$$\hat{C}_M^d \equiv \frac{2\overline{e}(2\overline{\theta} - \underline{\theta})(\overline{e} + e_M) - \sqrt{2\overline{e}(\overline{e} + e_M)\big(- 18\overline{e}(\overline{\theta} - \underline{\theta})F_H + (2\overline{e}(2\overline{\theta} - \underline{\theta}) - \rho(t_0 - t_H))^2\big)}}{2\overline{e}} \tag{D.26}$$

Note that when $F_H = \underline{F}_H$ (such that $\pi_H^{dLH} = 0$), the term under the square root is equal to zero and $\hat{C}_M^d$ is equal to $\overline{C}_M^{dLM}$. In Figure 4, $\hat{C}_M^d$ corresponds to the growing curve, between areas of duopoly $(L, H, \emptyset)$ and duopoly $(L, M, \emptyset)$, ending with a vertical line for $F_H = \underline{F}_H$ and $\hat{C}_M^d = \overline{C}_M^{dLM}$.

Existence of SPE $(M, L, \emptyset)$ requires non-deviation condition $\pi_L^{dLM}(0) > \pi_H^{dMH}(0)$, that implies:

$$\frac{\big((\overline{\theta} - 2\underline{\theta} - x)(\overline{e} + e_M) - c_M - \varphi\big)^2}{9(\overline{\theta} - \underline{\theta})(\overline{e} + e_M)} > \frac{\big((2\overline{\theta} - \underline{\theta} + x)(\overline{e} - e_M) - \rho t_0 + \rho t_H + c_M + \varphi\big)^2}{9(\overline{\theta} - \underline{\theta})\,(\overline{e} - e_M)} - F_H \tag{D.27}$$

Denoting $\tilde{C}_M^d$ the maximum unit cost leading the new entrant to produce L rather than H to compete with Product M before the campaign ($x = 0$), we deduce from the previous inequality

that:

$$\tilde{C}_M^d \equiv \frac{(\overline{e}+e_M)\big(-(\overline{e}-e_M)(2\overline{\theta}+\underline{\theta})+\rho t_0-\rho t_H\big)}{2e_M} + \frac{\sqrt{(\overline{e}-e_M)(\overline{e}+e_M)\big(18e_M(\overline{\theta}-\underline{\theta})F_H+(-3e_M(\overline{\theta}-\underline{\theta})+\overline{e}(\overline{\theta}+\underline{\theta})-\rho t_0-\rho t_H))^2\big)}}{2e_M} \tag{D.28}$$

In Figure 4, threshold $\tilde{C}_M^d$ does not appear because, with our parameters, $\tilde{C}_M^d > \hat{C}_M^d$ and the non deviation conditions are both fulfilled when $c_M + \varphi \leq \hat{C}_M^d$.

Duopoly with products L and H is a Nash equilibrium before the campaign if non-deviation condition $\pi_H^{dLH}(0) \geq \pi_M^{dLM}(0)$ is fulfilled, that implies $C_M \geq \hat{C}_M^d$, and if Product H is cost effective, that requires $F_H \leq \underline{F}_H$. Second non-deviation condition $\pi_L^{dLH}(x) \geq \pi_M^{dMH}(x)$ is characterized as follows:

$$\frac{\big(2(\overline{\theta}-2\underline{\theta}-x)\overline{e}+\rho t_0-\rho t_H\big)^2}{18(\overline{\theta}-\underline{\theta})\,\overline{e}} \geq \frac{\big((\overline{\theta}-2\underline{\theta}-x)(\overline{e}-e_M)+\rho t_0-\rho t_H-c_M-\varphi\big)^2}{9(\overline{\theta}-\underline{\theta})(\overline{e}-e_M)} \tag{D.29}$$

Denoting $\breve{C}_M^d$ the minimum unit cost leading the new entrant to produce L rather than M to compete with Product H before the campaign ($x = 0$), we deduce from the previous inequality that $\breve{C}_M^d$ is defined as follows :

$$\breve{C}_M^d \equiv (\overline{\theta}-2\underline{\theta})(\overline{e}-e_M)+\rho t_0-\rho t_H-\frac{\sqrt{2(\overline{e}-e_M)\overline{e}\big(2(\overline{\theta}-2\underline{\theta})\overline{e}+\rho t_0-\rho t_H))^2\big)}}{2\overline{e}} \tag{D.30}$$

In Figure 4, threshold $\breve{C}_M^d$ does not appear because, with our parameters, $\breve{C}_M^d < \hat{C}_M^d$ and the non-deviation conditions are both fulfilled when $c_M + \varphi \geq \hat{C}_M^d$. Moreover, the SPE is $(L, H, \emptyset)$ when $F_H \in [\hat{F}_H, \underline{F}_H]$ and $(H, L, \emptyset)$ if $F_H < \hat{F}_H$. Threshold $\hat{F}_H$ corresponds to the vertical dotted line in Figure 4.

Duopoly with products M and H is a Nash equilibrium before the campaign if $C_M \in [\underline{C}_M^{dMH}, \overline{C}_M^{dMH}]$ and $F_H < \overline{F}_H^{dMH}$. Non deviation condition for SPE $(M, H, \emptyset)$ is $\pi_H^{dMH}(0) \geq \pi_L^{dLM}(0)$, that requires $C_M > \tilde{C}_M^d$. Non deviation condition for SPE $(H, M, \emptyset)$ is $\pi_M^{dMH}(0) \geq \pi_L^{dLH}(0)$, that involves $C_M < \breve{C}_M^d$. In Figure 4, these SPE do not emerge because, with our parameters, $\breve{C}_M^d \leq \underline{C}_M^{dMH} \leq \overline{C}_M^{dMH} < \tilde{C}_M^d$ and the second firm has an interest in deviating from H to L if the incumbent supplies M and in deviating from M to L if the incumbent supplies H.

E Proofs related to the certification and campaign game

Proof of Proposition 5

The first-order conditions (FOC) for an interior solution of the NGO's program implicitly

define the NGO's best strategies, denoted x^{dLM*} and φ^{dLM*}.[37]

$$\begin{cases} x^{dLM*} = \dfrac{(2\overline{\theta} - \underline{\theta})(\overline{e} + e_M) - c_M - \varphi^{dLM*}}{6(\overline{\theta} - \underline{\theta}) - (\overline{e} + e_M)} \\ x^{dLM*2} = B + \varphi^{dLM*} \dfrac{(2\overline{\theta} - \underline{\theta} - x^{dLM*})(\overline{e} + e_M) + c_M + \varphi^{dLM*}}{3(\overline{\theta} - \underline{\theta})(\overline{e} + e_M)} \end{cases}$$

The interior solution applies only when the initial budget is lower than a given threshold, denoted $\overline{B}^{dLM}$. Above this initial budget, the marginal rate of substitution of x to φ that keeps the environmental quality constant is lower than the implicit relative price exhibited by the budget constraint (i.e. $\frac{\partial E^{dLM}}{\partial \varphi} / \frac{\partial E^{dLM}}{\partial x} < \frac{\partial BC^{dLM}}{\partial \varphi} / \frac{\partial BC^{dLM}}{\partial x}$).[38] The first FOC is not fulfilled and the best strategy of the NGO is the corner solution such that the NGO provides the label for free and makes a campaign effort $x^{dLM*} = \sqrt{B}$. (i.e. $\frac{\partial E^{dLM}}{\partial \varphi} / \frac{\partial E^{dLM}}{\partial x} < \frac{\partial BC^{dLM}}{\partial \varphi} / \frac{\partial BC^{dLM}}{\partial x}$). Using the budget constraint, $\varphi = 0$ and $x^{dLM} = \sqrt{B}$, the budget threshold can be defined as follows:

$$\overline{B}^{dLM} = \left(\frac{(2\overline{\theta} - \underline{\theta})(\overline{e} + e_M) + c_M}{6(\overline{\theta} - \underline{\theta}) - \overline{e} - e_M} \right)^2 \tag{E.31}$$

Product L is no more cost-effective as soon as $x \geq x_{L0}^{dLM} \equiv \overline{\theta} - 2\underline{\theta} + \frac{c_M + \varphi}{\overline{e} + e_M}$. For $\varphi = 0$, it defines the upper budget threshold above which any further increase in the campaign eff-ort x by the NGO would transform the duopoly (L, M) into a duopoly (M, H):

$$\overline{\overline{B}}^{dLM} = \left(\overline{\theta} - 2\underline{\theta} + \frac{c_M}{\overline{e} + e_M} \right)^2 \tag{E.32}$$

Proof of Proposition 6

Because campaign effort and label fee are perfect substitutes for the NGO (Equation 9, Figure 7(b)), for a positive initial budget, there is no interior solution and the NGO should implement a strategy $(\varphi^{dMH*}, x^{dMH*})$ of removing Product M, such that $d_M^{dMH} = 0$ and $E^{dMH} = E^{mH} = \overline{e}$, as follows:

$$\begin{cases} x^{dMH*} = \sqrt{B} \\ \varphi^{dMH*} = (\overline{\theta} - 2\underline{\theta})(\overline{e} - e_M) + \rho\,(t_0 - t_H) - (\overline{e} - e_M)\sqrt{B} - c_M \end{cases} \tag{E.33}$$

Proof of Proposition 7

When the NGO has a relatively low initial budget ($B < \underline{B}^d(F_H)$), its best strategy is to set

[37] The expression of x^{dLM*} and φ^{dLM*} can be obtained on request upon the authors.

[38] The first FOC is $\frac{\frac{\partial E_M^m}{\partial \varphi}}{\frac{\partial E_M^m}{\partial x}} = -\frac{1}{\overline{e} + e_M} = \frac{\frac{\partial BC_M}{\partial \varphi}}{\frac{\partial BC_M}{\partial x}} = \frac{c_M + 2\varphi^{dLM*} - (2\overline{\theta} - \underline{\theta} + x^{dLM*})(\overline{e} + e_M)}{(6(\overline{\theta} - \underline{\theta})x^{dLM*} + \varphi_M^{m*})(\overline{e} + e_M)}$

(φ^{t*}, x^{t*}) allowing to fulfill the FOC:

$$\begin{aligned} \varphi^{t*} &= -\frac{1}{2}c_M + \frac{(\overline{e}+e_M)[(\overline{\theta}-\underline{\theta})(\overline{e}-e_M)+\rho(t_0-t_H)]}{4\overline{e}} \\ x^{t*} &= \sqrt{B + \frac{(\overline{\theta}-\underline{\theta})(\overline{e}-e_M)(\overline{e}+e_M)+\rho(t_0-t_H)-2c_M\overline{e}}{24(\overline{\theta}-\underline{\theta})(\overline{e}-e_M)(\overline{e}+e_M)\overline{e}}} \end{aligned} \tag{E.34}$$

This interior solution is characterized by fee φ^{t*} that is all the higher as c_M is low and environmental quality e_M is high.

Because a high budget allows the NGO to undertake a more effective campaign, when $B \geq \underline{B}^d(F_H))$, meanwhile E^t does not depend on φ and increases with x, the NGO tries to prevent cost-effectiveness of Product L by choosing $(\hat{\varphi}^{t*}, \hat{x}^{t*})$ at the limit of the shadow area in Figure 7(c), where $d_L^t = 0$, and the market structure become a duopoly.