Component-free strategy of firms under pressure from the NGOs*

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Abstract

There is a growing pressure of NGOs on firms to have them eliminate a component (as oil palm) harmful for the environment (as rainforests) from their products or to replace such a component with a sustainable substitute component the NGO certifies. Under which conditions NGO's pressure leads a firm to eliminate basic component in its product or, alternatively, to substitute a damaging component with the certified sustainable component? What are the ensuing effects on market structure? This paper addresses these issues using a model of two-dimensional vertical product differentiation.

Keywords: NGO; Eco-label; Environmental quality; Product differentiation

JEL classification: D11; D62; D83; L15; Q58

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 of Daniel Kessler, a spokesperson of Non-Governmental organization (NGO) Greenpeace, illustrates the growing pressure of environmental NGOs on firms' strategies.[1] NGOs' campaigns may take various forms and aim different environmental goals. They often disclose information about the properties of the goods purchased by consumers, the sustainability of the production processes and their environmental impacts. A famous example is the campaign Greenpeace carried out in 2010 to *"Ask Nestlé to give rainforests a break"*.[2] Largely relayed by social network, it forced Nestlé to end its partnership with Sinar Mas, the largest palm oil producer in Indonesia and to commit to remove deforestation from its supply chains. In 2015, Greenpeace continues pressuring on global consumer goods manufacturers by publishing a report revealing how companies were keeping promises to stop deforestation in Indonesia for palm oil. Number other environmental NGOs' campaigns aim similar goals, as the French Greenpeace's "zero pesticide" run amongst the six largest retailers (Auchan, Carrefour, Casino, Intermarché, Monoprix, Magasins U).

These kind of campaigns resort to the field of what Baron (2009) calls as private politics, which include a vast range of tactics, from simple information disclosure (Baron (2011), Petrakis, Sartzetakis, and Xepapadeas (2005) or Heyes, Lyon, and Martin (2016)) to boycotts campaigns (studied by Innes (2006), Baron, Neale, and Rao (2016), Baron (2016), Delacote (2009), and Egorov and Harstad (2015)). They result in an increasing number of 'component-free products', such as oil palm, pesticide, antibiotic, GM, nitrate and also paraben-free products, in agri-food product and cosmetic markets. In the specific case of palm oil issue, the Roundtable on Sustainable Palm Oil (RSPO), including the environmental NGOs such as WWF, promotes the growth and use of certified sustainable palm oil (CSPO) as an alternative of elimination of damaging palm oil for firms. Firms may prefer this option because it avoids altering the texture of the product, contrary to the palm oil elimination. Under which conditions NGO's pressure leads a firm to eliminate basic component in its product or, alternatively, to substitute a damaging component with a certified sustainable component? What are the optimal strategies for the NGOs? What are the ensuing effects on welfare? This paper addresses these issues using a model of two-dimensional vertical product differentiation.

There is a rich theoretical literature on the competition between green and brown products,

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[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).

which studies efficiency of environmental policies (as minimum quality standards, voluntary labels, norms, taxation) depending on cost structure and abatement method of firms and on environmental consciousness, information and altruism of consumers. To the best of our knowledge, only some papers consider the role of NGOs as certifying organizations which aim at improving the quality of the environment (Bottega and De Freitas (2009), Fischer and Lyon (2014), Bonroy and Constantatos (2015), Poret (2016), Brécard (2014), Brécard (2017)) or the competition issues related with environmental awareness and labels (Conrad (2005), Ben Elhadj and Tarola (2015), Ben Elhadj, Gabszewicz, and Tarola (2015), Heyes and Martin (2015)). Altough we study the conditions of NGO's eco-labelling efficiency, we depart from these papers by more deeply analyzing the influence of NGO on consumer preferences and, through this, on firm choice of environmental quality.

Furthermore, we adapt the original model of bidimensional vertical differentiation of Garella and Lambertini (2014). Indeed, the use of the denounced component by the firm is due to technical reason: such a component (as palm oil) is crucial to assure the good product texture (as Nutella), that we refer to as organoleptic quality. Removing such a substance causes a significant deterioration in the taste characteristic. In other words, a high organoleptic quality is associated with a low environmental quality, and reversely. The component-free product is therefore viewed as a product with a high environmental quality but a low organoleptic quality. Such an assumption is close to the hypothesis made by Mantovani, Tarola, and Vergari (2016). Indeed, they assume that high intrinsic quality of a product generates high polluting emissions. However, we depart from their assumption in that the 'good' and the 'bad' attributes have no presupposed inversely proportional relation. Moreover, the harmful component can not only be eliminated, to the detriment of the product texture, but also replaced by a 'sustainable' component (as sustainable palm oil) certified by an NGO, which does not alter the organoleptic quality of the product. Moreover, in Mantovani et al. (2016) model, consumers have homogeneous preferences for the environmental quality and heterogeneous preferences for the intrinsic quality, whereas in our model, consumers have heterogeneous preferences for the environmental quality and homogeneous preferences for the organoleptic quality. In other words, the environmental attribute is the non-hedonic characteristic in their model, but the hedonic one in ours.

Using this original framework, we show how consumers' relative willingness-to-pay (WTP) for environmental quality and for organoleptic quality play a crucial role in efficiency of NGO campaign. The cost structures of elimination of the harmful component and of its replacement by a substitutable component also condition the effectiveness of the NGO campaign.

Moreover we extend our analysis of the strategies used by the NGO to fulfill its objective by considering the possibility for the NGO to directly influence the consumers environmen-

3

tal awareness through an information campaign on top of their disclosure campaign about the harmfulness of the component, and also to certify another component, less harmful for the environment. Our model shares therefore common features with Bottega, Delacote, Ibanez, et al. (2009), García-Gallego and Georgantzís (2009), García-Gallego, Georgantzís, et al. (2010) and Garella and Lambertini (1999). Beyond the theoretical novelties of our approach, our main contribution is to show that, the NGO may waive the objective of achieving a market where only the least environmentally harmful product is offered, when the cost of developing such a product is very high, and may prefer to restrict the market share of this product by favouring the entry of a new competitor with a product using the certified component.

The remainder of the paper is structured as follows. Section 2 presents the basic model. Section 3 analyzes the effects of information disclosure and increasing-awareness campaign of the NGO on consumer and firm choices. Section 4 studies the conditions under which the certified sustainable component is adopted. Section 5 offers conclusions.

2 The model

2.1 Consumers

In the line with Garella and Lambertini (2014), we assume that consumers decide to buy one unit or zero of the good, which is characterized by two attributes: a non-hedonic (homogeneous) organoleptic characteristic, such as taste or texture, denoted t_i, and an hedonic (heterogeneous) environmental characteristic, denoted 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 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 the WTP, which is then defined by the increasing function $\theta(x)$, with x the raising-awareness effort of the NGO. In the present draft, we assume that $\theta(x) = \theta + x$. Consumers' WTP for organoleptic quality is constant, denoted $\rho > 0$, for all consumers. Therefore, consumer preferences are represented by the following utility function

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

with p_i the price of the product i. The consumer indifferent between consuming the product i and refraining from buying at price p_i is characterized by marginal willingness to pay the

environmental quality $\widetilde{\theta}_i = \frac{p_i - \rho t_i}{e_i} - x$.

2.2 Firm

We assume that, before the NGO's campaign, the market is fully covered by a monopoly producing a good with organoleptic quality t_0 and with an environmental quality perceived as being equal to e_0 by the uninformed consumers. The monopoly incurs a unit production cost c_0, which is supposed null, without loss of generality. The price that maximizes the profit of the monopoly is the maximal price that all consumers are ready to pay for the product: $p_0 = \rho \ t_0 + \underline{\theta} e_0$. The profit is then defined by $\pi_0^* = \rho \ t_0 + \underline{\theta} e_0$. Because consumers do not pay attention to the environmental quality of the product, we assume that $e_0 = 0$.[3]

After the NGO's campaign, according to the type of good the monopoly decides to supply, it earns a profit $\pi_i(p_i) = (p_i - c_i)d_i(p_i) - F_i$, with $i = H, M, L$. We assume that, when the firm continues to produce the product with the harmful component, denoted with a subscript L, it bears exactly the same cost than before the campaign, that is $c_L = 0$ and $F_L = 0$. To turn to a component-free product (denoted H), the monopoly has to engage in R&D. As usual in differentiation models, we assume that R&D only generates a fixed cost, such as $F_H \geq 0$ and $c_H = 0$. To turn to a certified product, the firm has to 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 $c_M \geq 0$, and that there is no fixed cost incurred when adopting the intermediate component ($F_M = 0$).[4]

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

2.3 NGO

Knowing a harmful component in the good, the NGO wants to disclose information and to promote consumer awareness of the damaging effect of this component on the environment. Disclosing information is costless but the awareness-raising campaign requires a cost 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 quality of the environment is defined as the sum of

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[3]An alternative assumption could be that consumers only pay attention to the change in environmental quality due to information disclosure and campaign of the NGO.

[4]An alternative assumption could be that the variable production cost increases with the level of environmental quality e_M.

the qualities due to each one, $E_i = e_i d_i$ for $i = L, M, H$. We assume that the NGO has an initial budget B that finances its awareness-raising campaign effort x^2. In case it decides to certify a substitutable component less harmful for the environment, it charges a unit fee φ that accrues to its initial budget, potentially allowing to finance a greater campaign effort. We assume here that the quality of the substitutable component results is exogenously determined (depending on the bargaining power of the NGO and the local producers of this component). As a result, the NGO's program is

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

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 (oil palm for Nutella, coal for electricity)

2. The NGO learns 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 $e = e_L < 0 \leq e_0$. 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 3 options:

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

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

   (c) substituting the harmful component with the certified intermediate component, of quality $e_M > e_0$.

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

6

6. The consumers decide to buy the proposed products or not, the sum of the market shares being potentially less than 1.

We solve the game backwards.

It is worth noting that forms of the same colors in Figure 1 are similar but not strictly equivalent. For example, the case "Duopoly (L,H)" corresponds to the case where the inital monopoly decides to maintain product L denounced by the NGO and a competitor enters the market with product H, whereas "Duopoly (H,L)" corresponds to the case where the inital monopoly decides to go for product H leaving enough space to a competitor 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 going for product H would be too costly (high R&D costs) and induce a lower profit than keeping L, and the competitor enters if the duopoly profit obtained with H is greater than zero, despite the high R&D costs. In the second case, the monopoly decides to move for product H (low R&D costs) and the competitor enters as soon as its duopoly profit with product L is still positive. Depending on the values of parameters, some of the cases described in Figure 1 may be irrelevant, as will be shown in the next sections.
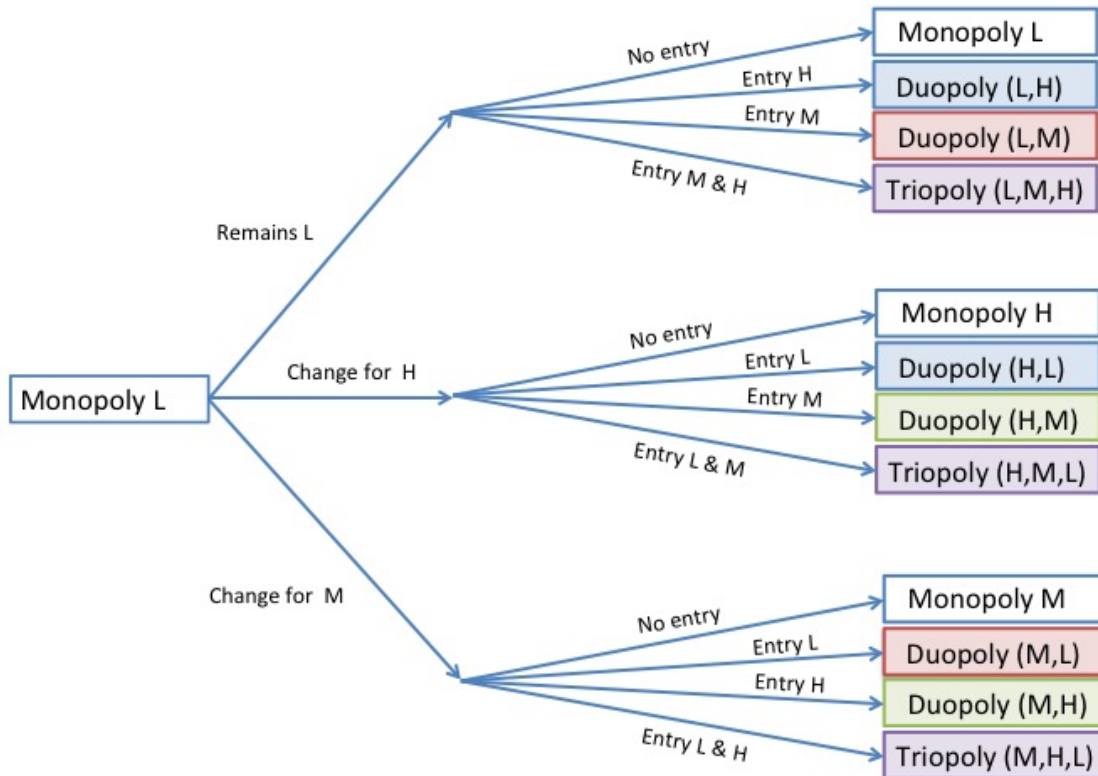

Figure 1: Possible market structures

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 $e_L < e_0$, while 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, as e_L is the worst possible environmental quality, we define $e_L \equiv -\overline{e}$.

As a result of the detrimental nature of product L on the environment, only consumers with a willingness to pay for the environmental quality lower than $\widetilde{\theta}_L = \frac{\rho t_0 - p_L}{\overline{e}} - x$ buy the product. Assuming an uncovered market, the demand is defined by $d_L = \frac{\widetilde{\theta}_L - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$. The profit of the monopoly is $\pi_L(p_L) = p_L d_L(p_L)$.

The equilibrium price is derived from the first order condition of profit maximization. It is characterized by:

$$p_L^m(x) = \frac{1}{2}(\rho t_0 - (\underline{\theta} + x)\overline{e}) \tag{2}$$

The monopoly faces a demand equal to:

$$d_L^m(x) = \frac{\rho t_0 - (\underline{\theta} + x)\overline{e}}{2(\overline{\theta} - \underline{\theta})\overline{e}} \tag{3}$$

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

Denoting $\overline{\omega}_L(x)$ the highest WTP for product L, defined as $\overline{\omega}_L(x) \equiv \rho t_0 - (\underline{\theta} + x)\overline{e}$, Equation (3) shows that the monopoly can only benefit from a positive demand if $\overline{\omega}_L(x)$ is positive. We assume that product L remains profitable for the monopoly after information disclosure about the component as long as the NGO does not campaign to increase the environmental awareness, *i.e.* $\rho t_0 > \underline{\theta}\overline{e}$. Moreover, the market is uncovered if $\overline{\omega}_L(x) < 2(\overline{\theta} - \underline{\theta})\overline{e}$.[5] It can be shown that $\pi_L^*(x) < \pi_0^*(x)$ whatever x.

When the NGO increases its awareness-raising effort, this translates the space of marginal willingness to pay for environmental quality from $[\underline{\theta}, \overline{\theta}]$ to $[\underline{\theta} + x, \overline{\theta} + x]$. Intensification of the campaign urges the monopoly to reduce its price, meanwhile the demand is reduced anyway. Its profit is then decreasing with x. Therefore, all other things being equal, product L remains cost-effective as long as the awareness campaign is not too impactful, *i.e.* $x < \overline{\omega}_L(0)/\overline{e}$.

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[5] When $\overline{\omega}_L(x) > 2(\overline{\theta} - \underline{\theta})\overline{e}$, that is $\rho t_0 > (2\overline{\theta} - \underline{\theta} + x)\overline{e}$, the market is covered and the monopoly has an interest in setting a price equal to the lowest WTP for product L, that is $\rho t_0 - (\overline{\theta} + x)\overline{e}$. In this case, the profit, defined by $\rho t_0 - (\overline{\theta} + x)\overline{e}$, is positive and lower than the initial profit $\rho t_0 + \underline{\theta}e_0$.

3.2 Monopoly equilibrium with the component-free product

Under NGO pressure, the monopoly can decide to produce the component-free product. It bears a R&D cost F_H. The environmental quality of the component-free product is a "good attribute" ($e_H > e_0 > e_L$), 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 $e_H = \overline{e}$.

Only consumers with a willingness to pay for the environmental quality higher than $\widetilde{\theta}_H = \frac{p_H - \rho t_H}{\overline{e}} - x$ buy the product. Assuming an uncovered market, the demand is defined by $d_H = \frac{\overline{\theta} - \widetilde{\theta}_H}{\overline{\theta} - \underline{\theta}}$. The monopoly maximizes $\pi_H(p_H) = p_H d_H(p_H) - F_H$. The equilibrium price is then defined by:

$$p_H^m = \frac{1}{2}((\overline{\theta} + x)\overline{e} + \rho t_H) \tag{4}$$

The demand is :

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

The profit is equal to $\pi_H^m(x) = (\overline{\theta} - \underline{\theta})\,\overline{e}\,d_H^{m2} - F_H$. The highest WTP for product H is defined as $\overline{\omega}_H(x) \equiv (\overline{\theta} + x)\overline{e} + \rho t_H$. The monopoly always benefits from a positive demand since $\overline{\omega}_H(x)$ is positive. The market is uncovered if $\rho t_H < (\overline{\theta} - 2\underline{\theta} - x)\overline{e}$.[6] Note that $\overline{\omega}_H(x)$ is higher than $\overline{\omega}_L(x)$ only when the higher WTP for the "good" environmental attribute of product H outweighs the lower WTP for the organoleptic attribute, *i.e.* when $(\overline{\theta} + \underline{\theta} + 2x)\overline{e} > \rho(t_0 - t_H)$.[7]

When the NGO intensifies its campaign, the monopoly benefits from higher WTP for the component-free product. It increases its price and faces a higher demand. The profit is then increasing with x. Therefore, there exists a minimal effort $\hat{x}$, such as $\pi_H^m(x) \geq \pi_L^m(x)$ when $x \geq \hat{x}$.[8] Hence, the monopoly has an interest in eliminating the component denounced by the NGO if:

$$\frac{\overline{\omega}_H(x)^2}{4(\overline{\theta} - \underline{\theta})\overline{e}} - F_H > \frac{\overline{\omega}_L(x)^2}{4(\overline{\theta} - \underline{\theta})\overline{e}} \tag{6}$$

A necessary condition for cost-effectiveness of the component-free product is then that $\overline{\omega}_H(x) > \overline{\omega}_L(x)$. Let us define the lowest WTP for products H and L as $\underline{\omega}_H(x) \equiv (\underline{\theta} + x)\overline{e} + \rho t_H$ and $\underline{\omega}_L(x) \equiv \rho t_0 - (\overline{\theta} + x)\overline{e}$. We can distinguish three cases to further analyze the necessary conditions for fulfilling Inequality (8):

- When $\rho(t_0 - t_H) \leq 2\underline{\theta}\,\overline{e}$, then $\underline{\omega}_H(0) \geq \overline{\omega}_L(0)$ and all consumers are sufficiently concerned with harmful effects of the denounced component to have a higher WTP for product H,
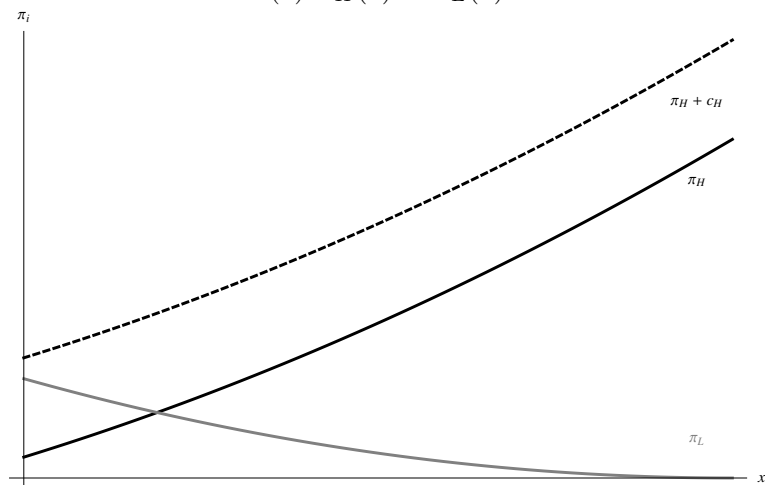
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[6]The market is covered when $\overline{\omega}_H(x) > 2(\overline{\theta} - \underline{\theta})\overline{e}$ or, equivalently, $\rho t_H > (\overline{\theta} - 2\underline{\theta} - x)\overline{e}$. The monopoly has then an interest in setting a price equal to $\underline{\omega}_H(x)$ and it earns profit $\underline{\omega}_H(x) - F_H$.

[7]Note that this condition is fulfilled when the market with Product L is uncovered whereas the market with Product H is covered, *i.e.* $\overline{\omega}_H(x) > 2(\overline{\theta} - \underline{\theta})\overline{e} > \overline{\omega}_L(x)$.

[8]There exists also such a minimal effort when the market is covered.
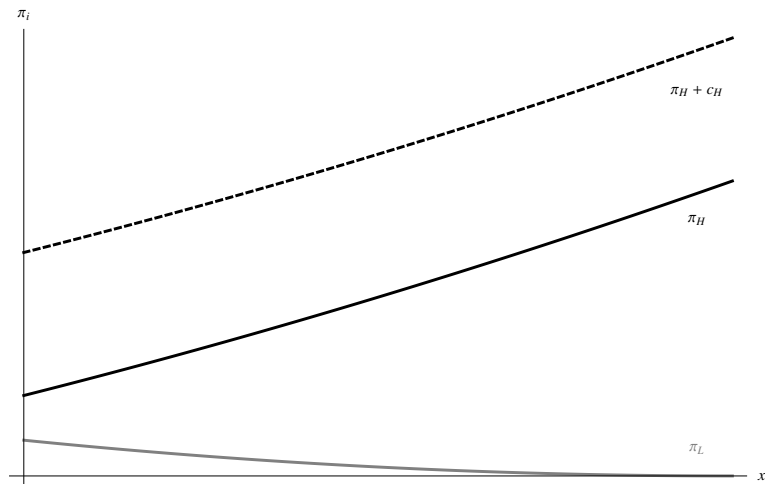
(a) $\overline{\omega}_H(0) > \overline{\omega}_L(0)$

(b) $\overline{\omega}_H(0) < \overline{\omega}_L(0)$

Figure 2: Effects of NGO's pressure on profit from product L and product H

despite its lower organoleptic attribute, than for product L. In such a case, displayed in Figure 2(a), $\pi_H^*(0) + F_H > \pi_L^*(0)$, but $\pi_H^*(0)$ may be higher or lower than $\pi_L^*(0)$ according to the magnitude of the R&D costs:

- If the R&D costs are relatively low, such as $\pi_H^*(0) > \pi_L^*(0)$, the NGO has only to disclose information about the damaging component to make the component-free product cost-effective;

- If the R&D costs are relatively high, such as $\pi_H^*(0) < \pi_L^*(0)$, the NGO must conduct a sufficiently forceful campaign to make the component-free product cost-effective.

- When $\rho(t_0 - t_H) \in [2\underline{\theta}\,\overline{e}, 2\overline{\theta}\,\overline{e}]$, then $\underline{\omega}_H(0) < \overline{\omega}_L(0)$ and $\overline{\omega}_H(0) > \underline{\omega}_L(0)$ and the organoleptic attribute is so damaged by the elimination of the harmful component and/or consumers are so concerned with the product taste, that, at the same price, some consumers prefer product L to product H. In such a case, depicted in Figure 2(b), $\pi_H^*(0) < \pi_L^*(0)$ and only a sufficiently impactful campaign can make the component-free product profitable for the monopoly.

- When $\rho(t_0 - t_H) \geq 2\overline{\theta}\,\overline{e}$, then $\overline{\omega}_H(0) \leq \underline{\omega}_L(0)$ and 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. In that case, the NGO has no way of promoting consumption and production of the free-component product.

When necessary, the minimal campaign effort is then defined by:

$$
\begin{aligned}
\hat{x} &= \frac{4(\overline{\theta} - \underline{\theta})F_H}{(\overline{\theta} - \underline{\theta})\overline{e} + \rho(t_0 + t_H)} + \frac{\rho(t_0 - t_H)}{2\overline{e}} - \frac{\overline{\theta} + \underline{\theta}}{2} \\
&= \frac{4(\overline{\theta} - \underline{\theta})F_H}{\overline{\omega}_H(0) + \overline{\omega}_L(0)} + \frac{\overline{\omega}_L(0) - \overline{\omega}_H(0)}{2\overline{e}}
\end{aligned}
\tag{7}
$$

3.3 Duopoly Equilibrium

Assume that a firm decides to enter the market and to supply a differentiated variety. There is a consumer, with type $\widetilde{\theta}_{LH}$, who is indifferent between both products. However, depending on their prices and attributes, this consumer may be unwilling to buy one or the other product because $\widetilde{\theta}_L < \widetilde{\theta}_{LH} < \widetilde{\theta}_H$. In this case, the market remains uncovered. Conversely, all consumers buy one unit of the good when $\widetilde{\theta}_H < \widetilde{\theta}_{LH} < \widetilde{\theta}_L$. Let us investigate both cases before addressing the issue of the identity of the producer of each variety.

When the market is uncovered, as in Figure 3a, those consumers who refrain from consuming the good have medium WTP such as $\theta \in [\widetilde{\theta}_L, \widetilde{\theta}_H]$. There is no strategic interaction between firms, which therefore act as monopolies. Using monopoly prices, the condition $\widetilde{\theta}_L < \widetilde{\theta}_H$ boils down
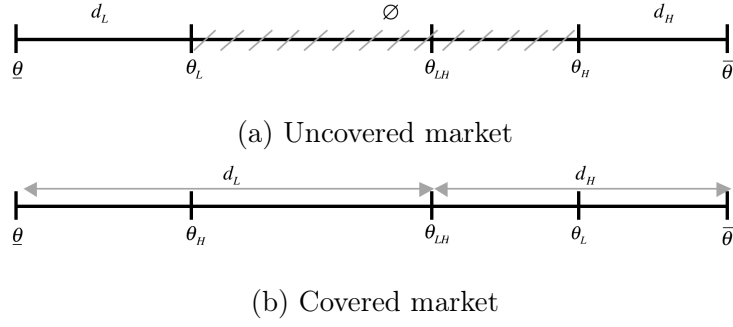
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(a) Uncovered market

(b) Covered market

Figure 3: Market coverage with products L and H

to $\rho(t_0 + t_H) \leq (\overline{\theta} - \underline{\theta})\overline{e}$: The sum of the highest WTP for the high and the low organoleptic qualities must be lower than the sum of the WTP for the high and the low environmental qualities. In other words, the market is uncovered when the environmental attribute dominates the organoleptic attribute. Meanwhile, existence of Monopoly L requires that the WTP for organoleptic quality of Product L is sufficiently high (and the NGO's pressure relatively low), i.e. $\rho t_0 \geq (\overline{\theta} + x)\overline{e}$.

When the market is covered, as in Figure 3b, all consumers are ready to pay for their preferred product (at given prices) and firms act as usual differentiated duopoly. Demand functions 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:

$$
\begin{aligned}
p_L^{dLH} &= \frac{2(\overline{\theta} - 2\underline{\theta} - x)\overline{e} + \rho t_0 - \rho t_H}{3} \\
p_H^{dLH} &= \frac{2(2\overline{\theta} - \underline{\theta} + x)\overline{e} - \rho t_0 + \rho t_H}{3}
\end{aligned}
\tag{8}
$$

The resulting market shares are then characterized by:

$$
\begin{aligned}
d_L^{dLH} &= \frac{2(\overline{\theta} - 2\underline{\theta} - x)\overline{e} + \rho t_0 - \rho t_H}{6(\overline{\theta} - \underline{\theta})\overline{e}} \\
d_H^{dLH} &= \frac{2(2\overline{\theta} - \underline{\theta} + x)\overline{e} - \rho t_0 + \rho t_H}{6(\overline{\theta} - \underline{\theta})\overline{e}}
\end{aligned}
\tag{9}
$$

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

Replacing prices in the condition for covered market ($\widetilde{\theta}_H < \widetilde{\theta}_L$) results in condition $\rho(t_0 + t_H) \geq 2(\overline{\theta} - \underline{\theta})\overline{e}$. Moreover, existence of both firms requires that $\rho(t_0 - t_H) \in [-2(\overline{\theta} - 2\underline{\theta} - x)\overline{e}, 2(\overline{\theta} - 2\underline{\theta} - x)\overline{e}]$ and that F_H is lower than the gross profit of Firm H. Therefore, in this duopoly case, the organoleptic attribute dominates the environmental attribute and the difference in WTP for both organoleptic qualities must remain in a given interval.

What is the nature of the competition when $\rho(t_0 + t_H) \in [(\overline{\theta} - \underline{\theta})\overline{e}, 2(\overline{\theta} - \underline{\theta})\overline{e}]$? Neither the conditions for coexisting monopolies, nor those for duopoly competition are fulfilled. Therefore,

only monopoly L or H is viable in the market. Following the cost-effectiveness conditions shown in previous sections, the monopoly continues supplying product L only if the NGO's campaign is not too forceful and/or if the R&D cost for Product H is sufficiently high (because $\rho(t_0 + t_H) \leq 2\bar{\theta}\,\bar{e}$).[9] Otherwise, the monopoly switches to Product H.
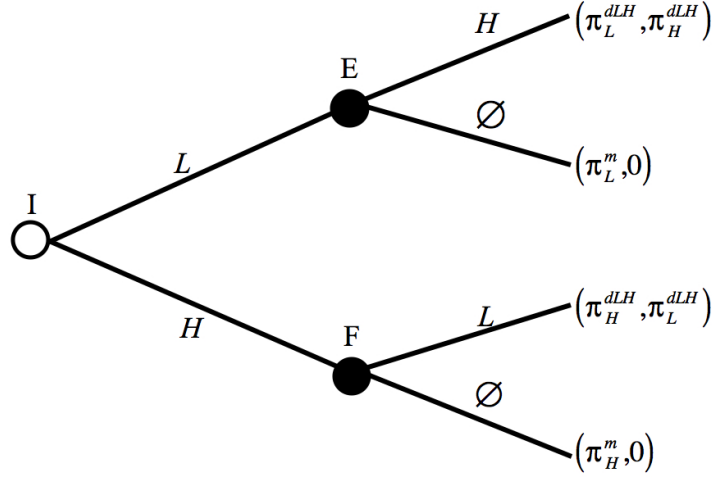

Figure 4: Duopoly game tree with two products

Which of the incumbent and the new entrant provides Product L in cases of duopoly? In the case of environmental attribute dominance (*i.e.* uncovered market), Product L is supplied by the incumbent if $\pi_L^m > \pi_H^m$, whereas the entrant firm provides it otherwise. The incumbent chooses the 'statu quo' case only if the NGO's campaign is not too impactful and/or if the R&D cost for Product H is sufficiently high.[10] Then, a firm decides to enter the market with Product H because $\pi_H^m \geq 0$. Otherwise, the incumbent chooses to eliminate the denounced component and a new entrant provides Product L whenever $\pi_L^m \geq 0$ (*i.e.* $\rho t_0 \geq (\underline{\theta} + x)\bar{e}$).

In the case of organoleptic attribute dominance (i.e. covered market), the subgame perfect equilibrium (SPE) of the game depends on the relative profits of the duopoly (see Figure 4). The new entrant decides to provide a differentiated product if $\pi_i^{dLH} \geq 0$ (with $i = L, H$). The incumbent has then an interest in producing L when $\pi_L^{dLH} \geq \pi_H^{dLH}$ or H otherwise. Therefore, SPE (L, H), such as the incumbent still produces Product L and the new entrant supplies Product H, arises when $F_H > \frac{2}{3}((\bar{\theta} + \underline{\theta} + 2x)\bar{e} - (\rho t_0 - \rho t_H))$, whereas SPE (H, L) occurs when the R&D cost is lower. When the R&D cost, the gap in organoleptic qualities and/or the NGO's campaign do not allow cost-effectiveness of a duopoly, the incumbent opts for the most cost-effective product for a monopoly and the firm decides not to enter.

---

[9]Note that $\rho(t_0 + t_H) \in [(\bar{\theta} - \underline{\theta})\bar{e}, 2(\bar{\theta} - \underline{\theta})\bar{e}]$ implies $\rho(t_0 + t_H) \leq (\bar{\theta} - \underline{\theta})\,\bar{e}$.

[10]Note that $\rho(t_0 - t_H) < \rho(t_0 + t_H) \leq (\bar{\theta} - \underline{\theta})\,\bar{e} < 2\bar{\theta}\bar{e}$.

3.4 Optimal campaign effort

An intensification of the NGO's campaign reduces the market share of Firm L to the benefit of Firm H. As a consequence, in order to maximize the quality of the environment, the NGO has an interest in choosing an effort that encourages the monopoly to substitute Product H to Product L or, at least, an effort that restricts the market share of product L and makes the entry of a competitor H cost-effective. Clearly $E_H^m(x) > E_{LH}^d(x) > E_L^m(x)$.

Monopoly H can never be reached, even with the help of the NGO, when the organoleptic quality of Product H is too degraded compared to Product L, that is when $\rho(t_0 - t_H) \geq 2\bar{\theta}\bar{e}$, and/or when the cost for eliminating the denounced component, F_H, is too high. However, in the opposite case, the NGO's campaign increases cost-effectiveness of Product H and favors its entry in the market. Moreover, the NGO maximizes the net benefit of the campaign, i.e. the quality of the environment under its budget constraint $x^2 \leq B$. Because the environmental quality increases with x, the NGO always prefers to exhaust its budget and to make a campaign effort defined by $x^* = \sqrt{B}$. Note that the campaign effort does not depend on the environmental quality $\bar{e}$, which measures the loss/gain in perceived environmental quality of the product due to the presence/absence of the denounced attribute. In other words, the extent to which the component is damaging for the environment does not alter the NGO's behavior, since it must campaign in any case to increase consumer awareness of such damages.

Even though the campaign effort results in the transformation of Monopoly L into Monopoly H, the resulting market structure also depends on the potential entry of a competitor offering Product L, which can be cost-effective for a new entrant although it is less profitable for the incumbent. Therefore, the environmental effectiveness of the NGO's campaign crucially depends on its effect on market structure, which, in turn, relies upon the level of R&D cost, F_H and upon the extent of the reduction in organoleptic quality (relative to the increase in environmental quality) of the component-free product compared to the initial product.

Figure 5 depicts the effect of the NGO's campaign on market structure according to R&D cost for environmental quality F_H. The gray line corresponds to the maximal campaign effort compatible with cost-effectiveness of Product L, that is $x_L^0 \equiv Min[x_{L0}^m, x_{L0}^d]$. The black curve illustrates the minimal campaign effort necessary for cost-effectiveness of Product H, that is $x_H^0 \equiv Max[x_{H0}^m, x_{H0}^d]$. The dashed curves defines the minimal campaign effort such as $\pi_H(x) \geq \pi_L(x)$, that is $\hat{x} \equiv Max[\hat{x}^m, \hat{x}^d]$. The figure has been drawn using value of $\rho(t_0 + t_H))$ consistent with a covered duopoly. Lower $\rho(t_0 + t_H))$ would simply increase the intercept, preventing SPE (L, H) with low F_H. More precisely, using previous results, the different thresholds for x can be
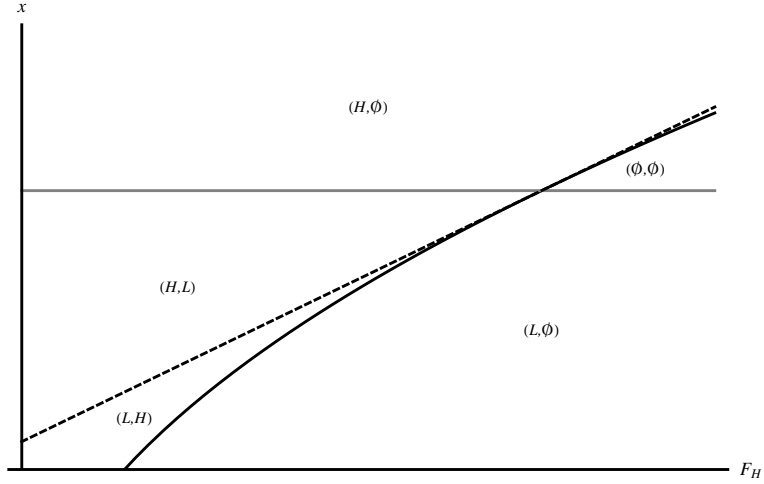
14

Figure 5: NGO's campaign, R&D cost and market structures

defined as follows:[11]

$$x_{L0}^m \equiv \frac{\rho t_0}{\overline{e}} - \underline{\theta}$$

$$x_{L0}^d \equiv \frac{\rho(t_0 - t_H)}{\overline{e}} + \overline{\theta} - 2\underline{\theta}$$

$$x_{H0}^m \equiv \frac{2\sqrt{(\overline{\theta} - \underline{\theta})\overline{e}F_H}}{\overline{e}} - \overline{\theta}$$

$$x_{H0}^d \equiv \frac{3\sqrt{2(\overline{\theta} - \underline{\theta})\overline{e}F_H} + \rho(t_0 - t_H)}{2\overline{e}} + \overline{\theta} - 2\underline{\theta}$$

$$\hat{x}^m \equiv \frac{\rho(t_0 - t_H) - (\overline{\theta} + \underline{\theta})\overline{e}}{2\overline{e}} + \frac{4(\overline{\theta} - \underline{\theta})F_H}{(\overline{\theta} - \underline{\theta})\overline{e} + \rho(t_0 + t_H)}$$

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

When $\rho(t_0 + t_H) \leq (\overline{\theta} - \underline{\theta})\overline{e}$, the campaign is likely to encourage the incumbent to give up supplying the product containing the harmful component to produce the component-free product. In this case, SPE (H, L) is likely to happen for low F_H and $x < x_L^0$: Difference between both thresholds $x_{L0}^m - \hat{x}^m$ is positive when:

$$F_H \leq \frac{\left((\overline{\theta} - \underline{\theta})\overline{e} + \rho(t_0 + t_H)\right)^2}{8(\overline{\theta} - \underline{\theta})\overline{e}}$$

When the NGO campaigns sufficiently extensively $(x > x_L^0)$, Product L is removed from the market and the incumbent remains a monopoly, but supplies Product H (that is SPE $(H, \emptyset)$).

---

[11]Note that, in the case of covered duopoly, we have $x_{L0}^d \leq x_{L0}^m$, $x_{H0}^d \geq x_{H0}^m$ and $\hat{x}^d \geq \hat{x}^m$, whereas the opposite inequalities are fulfilled in other cases.

15

Therefore, as shown in Figure 5, for low values of R&D cost F_H, through information disclosure on damaging component, the NGO has the power to transform Monopoly L into an uncovered Duopoly (H, L) where the incumbent offers Product H while a new entrant offers Product L. As its initial budget B increases, the campaign can totally crowd out Product L and result in a Monopoly H. However, for high values of F_H, information disclosure is not enough to remove Product L, but, as the budget and the campaign effort increase, Product L becomes non profitable and the incumbent disappears from the market before Product H becomes cost-effective. In this range $[x_L^0, \hat{x}]$, no monopoly can be profitable and there is no market anymore (that is SPE $(\emptyset, \emptyset)$).

When $\rho(t_0 + t_H) \geq (\overline{\theta} - \underline{\theta})\overline{e}$, the awareness campaign favors entry of Product H in the market and prompts some consumers to substitute Product H for Product L. Moreover, an increasing effort x rises the R&D cost threshold beyond which Product L is more cost-effective than Product H (i.e. the dashed curve). Therefore, if it has a sufficient budget, the NGO favors the SPE (H, L) by campaigning sufficiently greatly (i.e. $x > \hat{x}$). Meanwhile, by reducing the market share of the product containing the denounced component, the NGO enhances the average environmental quality of the products sold. Scenario (H, L) is therefore more environmentally friendly than Scenario (L, H). As in the previous case, in the case of large budget, the NGO makes a high campaign effort $(x > x_L^0)$ which removes Product L from the market and leads to Monopoly H.
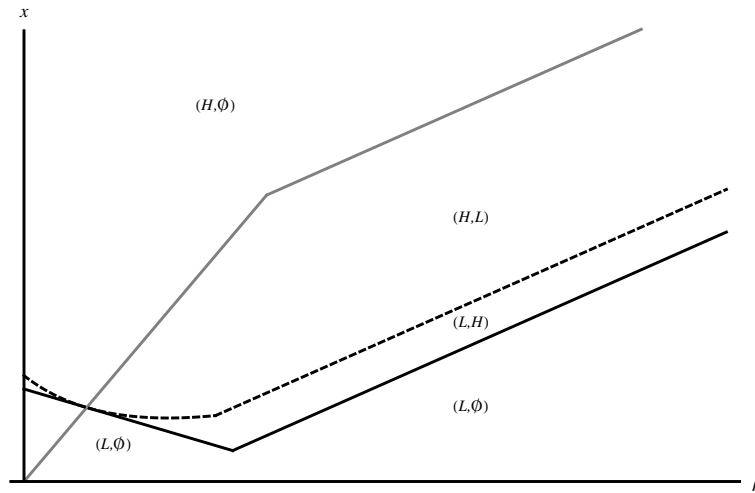

Figure 6: NGO's campaign, WTP for organoleptic quality and market structures

Figure 6 completes previous analysis by showing how the market structure is sensitive to WTP for organoleptic quality (for a given a positive cost F_H and WTP for environmental quality): All other things being equal, the higher WTP for the organoleptic quality, the greater the campaign effort 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 component of a product, 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 against 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 a too large degradation of the product taste (or texture), or when consumers place little importance to the environmental issue raised by the NGO in comparison to the product taste. Accordingly, there is a room for alternative solutions to reduce environmental impact of the product, while better preserving its organoleptic properties.

4 NGO's certification

4.1 Monopoly equilibrium with the certified sustainable product

Under NGO pressure, the monopoly has the possibility to use a sustainable component certified by the NGO. In this case, the monopoly adopts an NGO's label, which discloses the sustainable nature of the component to the consumers. The firm incurs a unit cost c_M and a fee φ paid 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.[12] By assumption, substituting the sustainable component for the harmful one does not require a 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 to 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 ($e_0 < e_M < e_H \Leftrightarrow e_M \in [0, \overline{e}]$).

Only consumers with a willingness to pay the environmental quality higher than $\widetilde{\theta}_M = \frac{p_M - \rho t_0}{e_M} - x$ buy the product. Assuming an uncovered market, the demand is defined by $d_M = \frac{\overline{\theta} - \widetilde{\theta}_M}{\overline{\theta} - \underline{\theta}}$. The monopoly maximizes $\pi_M(p_M) = (p_M - c_M - \varphi)d_M(p_M)$. The equilibrium price is then defined by:

$$p_M^m(x) = \frac{\rho t_0 + (\overline{\theta} + x)e_M + c_M + \varphi}{2} \tag{10}$$

The demand is :

$$d_M^m(x) = \frac{\rho t_0 + (\overline{\theta} + x)e_M - c_M - \varphi}{2(\overline{\theta} - \underline{\theta})e_M} \tag{11}$$

The monopoly benefits from a positive demand if $\overline{\omega}_M(x) \equiv (\overline{\theta} + x)e_M + \rho t_0 \geq c_M + \varphi$. The market is uncovered if $\overline{\omega}_M(x) \leq c_M + \varphi + 2(\overline{\theta} - \underline{\theta})e_M$.[13] The profit is then equal to $\pi_M^m(x) = (\overline{\theta} - \underline{\theta})e_M d_M^{m\,2}$.

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[12]Contrary to Bottega and de Freitas (2009), we do not assume that, because of the nonprofit nature of the NGO, the fee has to cover the awareness campaign of the NGO, x^2.

[13]When $\overline{\omega}_M(x) > c_M + 2(\overline{\theta} - \underline{\theta})e_M$, the market is covered. The monopoly sets a price equal to $\underline{\omega}_M(x)$ and earns profit $\underline{\omega}_M(x) - c_M - \varphi$.
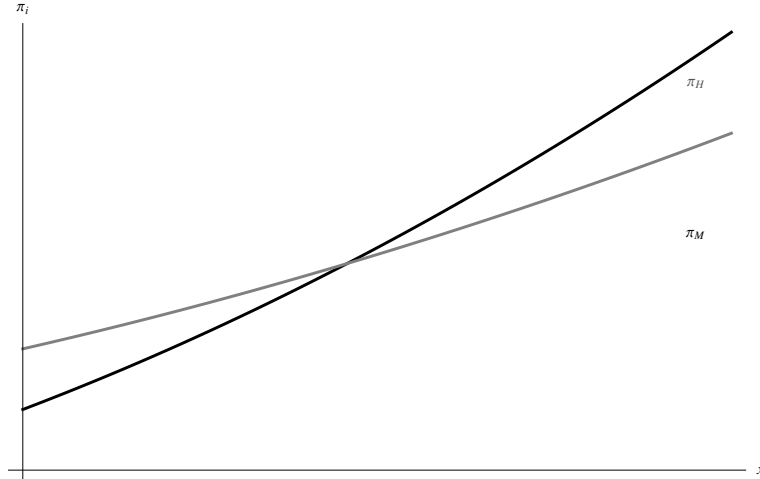
Figure 7: Effect of NGO's pressure on Monopoly profit

When the NGO steps up its campaign, the monopoly benefits from higher WTP for the sustainable product. It increases its price and faces a higher demand, earning then 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, while being more environmentally friendly, all consumers have a higher WTP for this product than for the component-containing one (i.e. $\overline{\omega}_M(x) > \underline{\omega}_M(x) > \overline{\omega}_L(x)$, where $\underline{\omega}_M(x) \equiv (\underline{\theta} + x)e_M + \rho t_0$). 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:

$$\frac{(\overline{\omega}_M(x) - c_M - \varphi)^2}{4(\overline{\theta} - \underline{\theta})e_M} > \frac{\overline{\omega}_L(x)^2}{4(\overline{\theta} - \underline{\theta})\overline{e}} \tag{12}$$

A sufficient condition for cost-effectiveness is that $c_M + \varphi \leq (\overline{\theta}e_M + \underline{\theta}\overline{e})$. Such a condition ensures that $\pi_M^m(0) > \pi_L^m(0)$. Because $\pi_M(x)$ follows an increasing curve whereas $\pi_L(x)$ decreases with x, it also guaranties that $\pi_M^m(x) > \pi_L^m(x)$.[14]

The certified product is more profitable than the component-free product if:

$$\frac{(\overline{\omega}_M(x) - c_M)^2}{4(\overline{\theta} - \underline{\theta})e_M} > \frac{\overline{\omega}_H(x)^2}{4(\overline{\theta} - \underline{\theta})e_H} - c_M \tag{13}$$

Because $\pi_H^m(x)$ follows also an increasing curve with x but with a lower slope than $\pi_M^m(x)$, as in Figure 7, there exists a NGO's campaign effort, denoted $\tilde{x}$, below which the previous inequality is fulfilled.

---

[14]When $c_M + \varphi \geq (\overline{\theta}e_M + \underline{\theta}\overline{e})$, because $\pi_M^m(\frac{\rho t_0}{\overline{e}} - \underline{\theta}) > \pi_L^m(\frac{\rho t_0}{\overline{e}} - \underline{\theta}) = 0$, there exists a minimal campaign effort above which $\pi_M^m(x) > \pi_L^m(x) \geq 0$.

18

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 on gaps in environmental and organoleptic attributes and in production costs, but also depending on NGO's behavior. For the moment, assume that the market is not sufficiently large for allowing entry of a third cost-effective firm.

4.2.1 Duopoly with Products L and M

The analysis of the duopoly supplying products L and M is quite similar to the analysis carried on in Section 3.3. The consumer indifferent between products L and M is characterized by $\widetilde{\theta}_{LM} = \frac{p_M - p_L}{\overline{e} + e_M} - x$.[15] Because providing the certified product requires positive unit costs (including the certification fee) although providing the component-free product requires fixed production cost, meanwhile products using the harmful and the sustainable components exhibit the same organoleptic quality, the conditions for existence of a duopoly supplying products L and M differ from the previous case with products L and H.

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 $\rho t_0 \geq c_M + \varphi - (\overline{\theta} + x)e_M$).

When the market is fully covered by a duopoly ($\widetilde{\theta}_L < \widetilde{\theta}_M$), demand functions are defined as $d_M = \frac{\overline{\theta} - \theta_{LM}}{\overline{\theta} - \underline{\theta}}$ and $d_L = \frac{\theta_{LM} - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$. Maximization of profits with respect to prices leads to the following Nash equilibrium:

$$
\begin{aligned}
p_L^{dLM} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e} + e_M) + c_M + \varphi}{3} \\
p_M^{dLM} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e} + e_M) + 2(c_M + \varphi)}{3}
\end{aligned}
\tag{14}
$$

Demands are then written as:

$$
\begin{aligned}
d_L^{dLM} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e} + e_M) + c_M + \varphi}{3(\overline{\theta} - \underline{\theta})(\overline{e} + e_M)} \\
d_M^{dLM} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e} + e_M) - c_M - \varphi}{3(\overline{\theta} - \underline{\theta})(\overline{e} + e_M)}
\end{aligned}
\tag{15}
$$

The profits are then equal to $\pi_i^{dLM}(x) = (\overline{\theta} - \underline{\theta})(\overline{e} + e_M)d_i^{dLM\,2}$ with $i = L, M$. It is worth noting that the organoleptic quality does not play on prices and market shares insofar as both

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

products benefit from the same quality. The strategies rather 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.

The condition for covered market can be written:

$$\rho t_0 \geq \quad \frac{(2\overline{\theta} - \underline{\theta} + x)\overline{e} + (\overline{\theta} - 2\underline{\theta} - x)e_M}{3} + \frac{(2\overline{e} + e_M)(c_M + \varphi)}{3(\overline{e} + e_M)} \tag{16}$$

Firms L and M share demand in a covered market only if the WTP for the organoleptic quality is sufficiently high, compared to environmental qualities and production costs of Product M. As in the case of duopoly supplying products L and H, such a condition can be interpreted as a dominance of the organoleptic attribute over the environmental attribute in consumers' preferences.

4.2.2 Duopoly with Products M and H

Competition between the medium and the high environmental quality is more usual than competition between Product L and M or H. Consumers of both products are localized on the right side of the preference space, although consumers on the left side refrain from consuming the good or buy the medium quality. The specificity of the duopoly equilibrium arises from the nature of production costs. Production of the certified product only involves variable cost, including the cost of the certified component and the certification fee, whereas production of the component-free product only requires a fixed cost. For the sake of simplicity, we only focus on the covered market case.[16].

When the market is covered by a duopoly, 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:

$$
\begin{aligned}
p_M^{dMH} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e} - e_M) + \rho t_0 - \rho t_H + 2c_M + 2\varphi}{3} \\
p_H^{dMH} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e} - e_M) - \rho t_0 + \rho t_H + c_M + \varphi}{3}
\end{aligned}
\tag{17}
$$

Demands are then defined by:

$$
\begin{aligned}
d_M^{dMH} &= \frac{(\overline{\theta} - 2\underline{\theta} - x)(\overline{e} - e_M) + \rho t_0 - \rho t_H - c_M - \varphi}{3(\overline{\theta} - \underline{\theta})(\overline{e} - e_M)} \\
d_H^{dMH} &= \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e} - e_M) - \rho t_0 + \rho t_H + c_M + \varphi}{3(\overline{\theta} - \underline{\theta})(\overline{e} - e_M)}
\end{aligned}
\tag{18}
$$

The profits are then equal to $\pi_M^{dMH}(x) = (\overline{\theta} - \underline{\theta})(\overline{e} - e_M)d_M^{dMH^2}$ and $\pi_H^{dMH}(x) = (\overline{\theta} - \underline{\theta})(\overline{e} - e_M)d_H^{dMH^2} - F_H$. The condition for market coverage, $\widetilde{\theta}_M \leq \underline{\theta}$, can be written as $\rho t_H + 2\rho t_0 \geq$

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[16]The results of the less tractable case of uncovered market can be obtained on request from the authors

$(\overline{\theta}-2\underline{\theta}-x)\overline{e}-(\overline{\theta}+\underline{\theta}+2x)e_M+2(c_M+\varphi)$. As in the other cases of duopoly, market coverage requires that WTP for organoleptic quality are sufficiently high. Existence of the duopoly also imposes upper limits on the production cost, the certification fee and the NGO's effort. Paradoxically, by enhancing WTP for environmental quality of all consumers, NGO's behavior penalizes the product containing the sustainable component, both through its campaign effort and through the certification fee, which reduces demand for Product M.

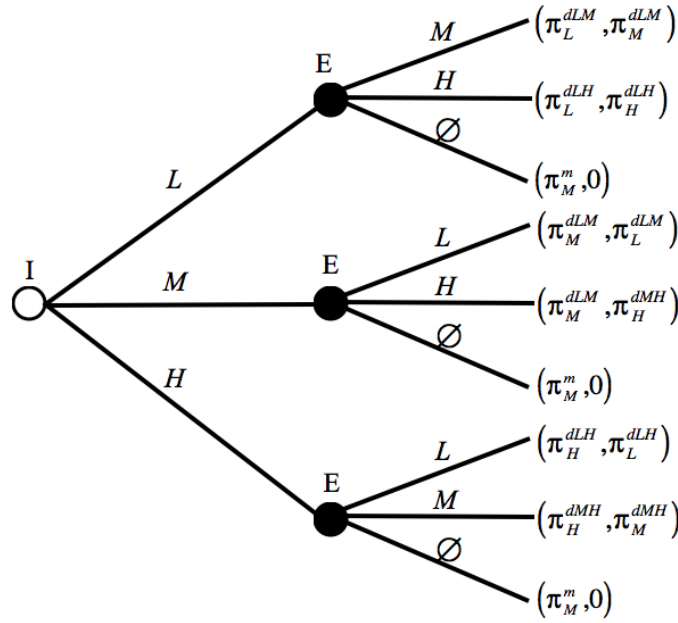### 4.2.3 The sequence of the duopoly game

Figure 8: Duopoly game tree with three products

Which of both firms supplies the product containing the certified component? In the case of uncovered market, the incumbent decides to use the certified component instead of the harmful component as soon as $c_M + \varphi \leq \overline{\theta}e_M + \underline{\theta}\overline{e}$ because $\pi_M^m > \pi_L^m$. In addition, when the NGO's campaign is relatively soft (such as $x < \widetilde{x}$) the incumbent has an interest in using the certified component rather than eliminating the harmful component because $\pi_M^m > \pi_H^m$. The new entrant chooses then to supply Product L if $\pi_L^m > \pi_H^m$ and Product H otherwise. As previously explained, the firm opts for Product L if NGO's campaign is not too impactful (such as $x < \widetilde{x}$) and/or if the R&D cost for Product H is sufficiently high.

In the case of covered market by the duopoly, the best incumbent's strategy is to produce the most cost-effective product knowing that the firm will then decide to enter with the second best cost-effective product. Therefore, according to the game tree in Figure 8, six duopoly SPE

can be characterized depending on relative profits:

- (L, M) if $\pi_L^{dLM} \geq \pi_M^{dLM} \geq \pi_H^{dLH}$,

- (L, H) if $\pi_L^{dLH} \geq \pi_H^{dLH} \geq \pi_M^{dLM}$,

- (M, L) if $\pi_M^{dLM} \geq \pi_L^{dLM} \geq \pi_H^{dMH}$,

- (M, H) if $\pi_M^{dMH} \geq \pi_H^{dMH} \geq \pi_L^{dLM}$,

- (H, L) if $\pi_H^{dLH} \geq \pi_L^{dLH} \geq \pi_M^{dMH}$,

- (H, M) if $\pi_H^{dMH} \geq \pi_M^{dMH} \geq \pi_L^{dLH}$.

The scenarios where Product L remains in the market are the most likely 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, meanwhile the NGO campaigns relatively softly. Because the awareness campaign decreases the profit of Firm L to the benefit of its competitor, there always exists a campaign effort which makes Products M and H more cost-effective than product L. The NGO can also foster the certified product by charging a low certification fee. Accordingly, in 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 $\pi_M^{dMH} \geq \pi_H^{dMH}$)[17], but sufficiently high to favor Product H over product L (in such a way as $\pi_H^{dMH} \geq \pi_L^{dLM}$). 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 $\pi_M^{dMH} \geq \pi_L^{dLH}$). Thereby, the NGO's budget decisions on the funds spent in the awareness-raising campaign and the funds raised by the certification fee is a crucial determinant of the more or less environmentally-friendly nature of the products supplied in the market.

4.3 Triopoly equilibrium

A large heterogeneity of consumers' WTP for the environmental quality may allow the three differentiated products to coexist in the market. Assume that $\overline{\theta} - \underline{\theta}$ is sufficiently high to trigger entry of a third firm and that the market is fully covered by the three mono-product firms.

Figure 9 depicts market sharing, with demand functions defined as $d_H = \frac{\overline{\theta} - \widetilde{\theta}_{MH}}{\overline{\theta} - \underline{\theta}}$, $d_M = \frac{\widetilde{\theta}_{MH} - \widetilde{\theta}}{\overline{\theta} - \underline{\theta}}$ and $d_L = \frac{\widetilde{\theta}_{LM} - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$. Profit maximization with respect to prices leads to the following reaction

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[17] $\pi_M^{dMH} \geq \pi_H^{dMH}$ involves $x \leq \frac{2(\rho t_0 - \rho t_H) - (\overline{\theta} + \underline{\theta})(\overline{e} - e_M) + 3F_H - 2(c_M + \varphi)}{2(\overline{e} - e_M)}$
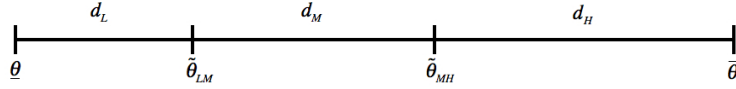
Figure 9: Market coverage with products L, M and H

functions:

$$p_L = \frac{1}{2}(p_M - (\underline{\theta} + x)(\bar{e} + e_M)) \tag{19}$$

$$p_M = \frac{1}{4\bar{e}}(p_H(\bar{e} + e_M) + p_L(\bar{e} - e_M) + (\rho t_0 - \rho t_H)(\bar{e} + e_M) + 2(c_M + \varphi)\bar{e})$$

$$p_H = \frac{1}{2}(p_M - (\bar{\theta} + x)(\bar{e} - e_M) - (\rho t_0 - \rho t_H)) \tag{20}$$

Price competition leads Firm L to adjust its price upwards to the price of Product M, although the price of Product H only depends on the price of Product M, while the price of product M increases both with p_L and p_H. Such reaction functions result in the following Nash equilibrium:

$$p_L^t = \frac{(-6(\underline{\theta} + x)\bar{e} + (\bar{\theta} - \underline{\theta})(\bar{e} - e_M) + \rho t_0 - \rho t_H)(\bar{e} + e_M) + 4(c_M + \varphi)\bar{e}}{12\bar{e}} \tag{21}$$

$$p_M^t = \frac{((\bar{\theta} - \underline{\theta})(\bar{e} - e_M) + \rho t_0 - \rho t_H)(\bar{e} + e_M) + 4(c_M + \varphi)\bar{e}}{6\bar{e}}$$

$$p_H^t = \frac{(6(\bar{\theta} + x)\bar{e} + (\bar{\theta} - \underline{\theta})(\bar{e} - e_M))(\bar{e} - e_M) - (\rho t_0 - \rho t_H)(5\bar{e} - e_M) + 4(c_M + \varphi)\bar{e}}{12\bar{e}}$$

Demands are then defined by:

$$d_L^t = \frac{(-6(\underline{\theta} + x)\bar{e} + (\bar{\theta} - \underline{\theta})(\bar{e} - e_M) + \rho t_0 - \rho t_H)(\bar{e} + e_M) + 4(c_M + \varphi)\bar{e}}{12(\bar{\theta} - \underline{\theta})(\bar{e} + e_M)\bar{e}} \tag{22}$$

$$d_M^t = \frac{((\bar{\theta} - \underline{\theta})(\bar{e} - e_M) + \rho t_0 - \rho t_H)(\bar{e} + e_M) - 2(c_M + \varphi)\bar{e}}{3(\bar{\theta} - \underline{\theta})(\bar{e} + e_M)(\bar{e} - e_M)\bar{e}}$$

$$d_H^t = \frac{(6(\bar{\theta} + x)\bar{e} + (\bar{\theta} - \underline{\theta})(\bar{e} - e_M))(\bar{e} - e_M) - (\rho t_0 - \rho t_H)(5\bar{e} - e_M) + 4(c_M + \varphi)\bar{e}}{12(\bar{\theta} - \underline{\theta})(\bar{e} - e_M)\bar{e}}$$

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

Without getting into detailed analysis of demand functions, Equations 22 and profits suggest that the triopoly can only emerge when differentiation in both organoleptic and environmental quality of the three products is sufficiently large. Moreover, the cost of the sustainable component and the cost of the harmful component removal must be limited. The awareness campaign only plays on market shares of the products L and H: An increase in x moves the three indifferent consumers towards the left in the preference space $[\underline{\theta}, \bar{\theta}]$, in such a way that the same number of consumers substitute Product M for L and H for M.[18] Accordingly, cost-effectiveness of the

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

product containing the harmful component requires that the NGO's campaign is not too forceful.[19]. Moreover, the NGO must ensure that the certification fee does not discourage firms from using the sustainable component.[20] There is a clear trade-off for the NGO between eliminating the product containing the harmful component and fostering the sustainable component.
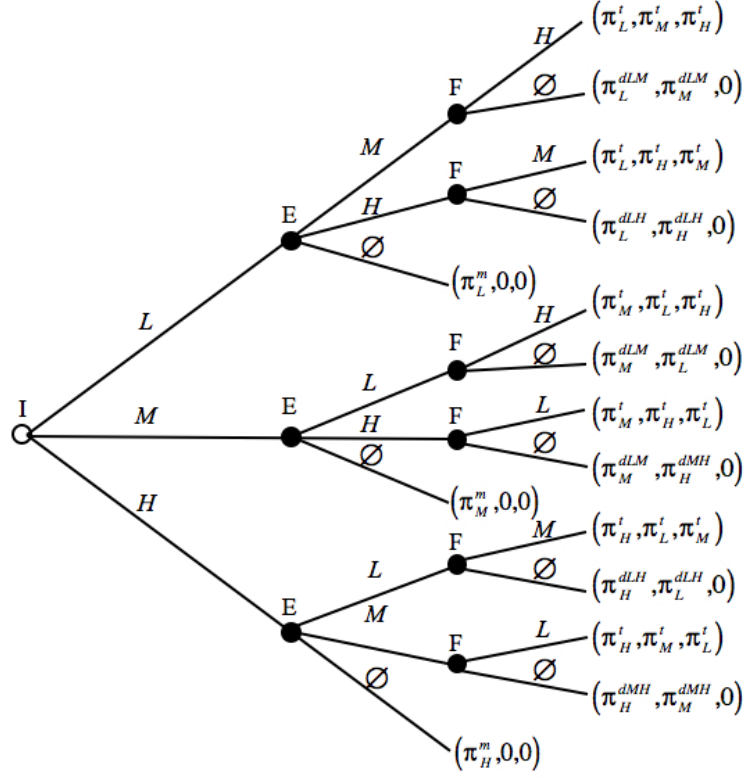

Figure 10: Triopoly game tree

The triopoly gameplay is illustrated in Figure 10. When the triopoly is cost effective, the third firm, called '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 $i \neq j \neq k$.

---

[19]The condition for positive market share of Product L is $x < \frac{\rho t_0 - \rho t_H - 6\theta\overline{e} - (\overline{\theta} - \underline{\theta})(\overline{e} - e_M)}{6\overline{e}} + \frac{2(c_M + \varphi)}{3(\overline{e} + e_M)}$.

[20]The condition for positive market share of Product M is $c_M + \varphi < \frac{((\overline{\theta} - \underline{\theta})(\overline{e} - e_M) + \rho t_0 - \rho t_H)(\overline{e} + e_M)}{2\overline{e}}$.

4.4 Optimal NGO's strategy

By choosing the values of its instruments, the NGO is able to influence the market structure $s \in S$, where S is the set of possible market structures represented in Figure 8, and the level of the environmental quality E.

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

We compute thus the values of x and φ that maximize the environmental quality E^s in each market structure, we verify if these values are compatible with the existence conditions of the considered market structure and conclude by picking the market structure that allows the NGO to obtain the highest environmental quality.

We consider here only covered markets for the triopoly and the duoply cases. In case of uncovered markets (which is not studied in this paper), the duopolies and triopolies would be changed into simultaneous monopolies.

4.4.1 Triopoly cases (L,M,H), (M,L,H) and (H,L,M)

Among the six different possible triopoly cases, it is easy to show that the NGO will in any case have an incentive to induce entry of a more environmentally-friendly firm in a duopoly where the incumbent or the second competitor still produces L, which allows us to focus only on three triopoly cases: (L, M, H), (M, L, H) and (H, L, M). In each of these cases, demands are defined by the same equations 22 and profits are defined by $\pi_L^t(x)$, $\pi_M^t(x)$ and $\pi_H^t(x)$.

By construction,

- the first case (L, M, H) is submitted to $\pi_L^t(x) > \pi_M^t(x) > \pi_H^t(x) > 0$,

- the second one (M, L, H) to $\pi_M^t(x) > \pi_L^t(x) > \pi_H^t(x) > 0$,

- and the third one (H, L, M) to $\pi_H^t(x) > \pi_L^t(x) > \pi_M^t(x) > 0$

Global environmental quality writes:

$$E^t = -\overline{e}d_L^t + e_M d_M^t + \overline{e}d_H^t = \frac{\overline{e}(\overline{\theta} - \underline{\theta} + 2x) + e_M(\overline{\theta} - \underline{\theta}) - \rho(t_0 - t_H)}{2(\overline{\theta} - \underline{\theta})} \qquad (23)$$

It only depends 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 L for the benefit of M and to increase the demand for H at the expense of M, the final effect being neutral for the demand of M.

In these cases, the NGO's program is simply

$$
\begin{cases}
\max_{x,\varphi} E^t \\[2mm]
\text{st } x^2 \le B + \varphi d_M^t
\end{cases}
$$

Whatever its initial budget B, the NGO can increase its campaign effort x as much as it wishes as long as the fees do not become excessive for the profitability of the certified product M.
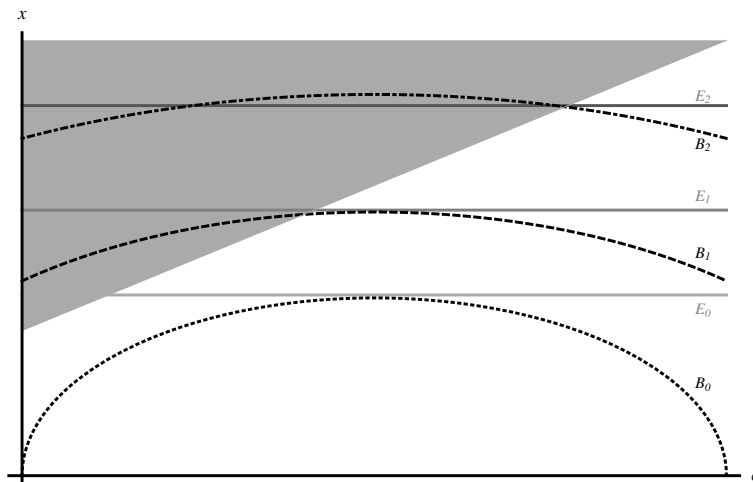

Figure 11: NGO's Optimal strategies in the triopoly case

Figure 11 shows the trade-off faced by the NGO:[21] The bell-shaped curves are the iso-budget curves, with $B_0 < B_1 < B_2$ three levels of initial budget, and the horizontal lines are the global environmental quality straights, with $E_0 < E_1 < E_2$ the three levels of global environmental quality that can be reached with each budget. The shadow area is the set of (φ, x) incompatible with the triopoly market structure. Figure 11 shows that when the NGO has a relatively low initial budget (B_0 or B_1), its best strategy is to set (φ^{t*}, x^{t*}) allowing to reach the maximum of the iso-budget curve:

$$
\varphi^{t*} = -\frac{1}{2}\overline{e} + \frac{(\overline{e} + e_M)[(\overline{\theta} - \underline{\theta})(\overline{e} - e_M) + \rho(t_0 - t_H)]}{4\overline{e}} \tag{24}
$$

$$
x^{t*} = \sqrt{B + \varphi^* d_M^t(\varphi^*)} \tag{25}
$$

Figure 11 also shows that a high budget (as B_2) prompts the NGO to remove Product L by choosing (φ, x) at the limit of the shadow area (*i.e.* the intersection of curves B_2 and E_2). In the latter case, we have to turn to duopoly cases (M, H) and (H, M) in order to further study the NGO's best strategies.

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[21]Figures 11 to 13 have all been drawn using the same set of parameters, allowing the existence of all market structures. In particular, F_H is assumed low.

4.4.2 Duopoly cases (L,M) and (M,L)

In each of these cases, demands are defined by Equations 15 and profits are π_i^{dLM} $(i = L, M)$. By construction,

- the first case (L, M) is submitted to $\pi_L^{dLM}(x) > \pi_M^{dLM}(x) > \pi_H^{dLH}(x)$ and $\pi_H^t(x) < 0$

- the second one (M, L) to $\pi_M^{dLM}(x) > \pi_L^{dLM}(x) > \pi_H^{dMH}(x) > 0$ and $\pi_H^t(x) < 0$.

Global environmental quality writes:

$$E^{dLM} = -\overline{e}d_L^{dLM} + e_M d_M^{dLM} = \frac{(2\overline{\theta} - \underline{\theta} + x)(\overline{e} + e_M) - c_M - \varphi}{3(\overline{\theta} - \underline{\theta})} \tag{26}$$

In the duopoly (L, M), intensifying the campaign effort x increases the environmental quality by crowding out Product L to the benefit of Product M, but this intensification is allowed by an increase in φ, that plays in the opposite.

The NGO's program is the simplified one

$$\begin{cases} \max_{x,\varphi} E^{dLM} \\ \text{st } x^2 \leq B + \varphi d_M^{dLM} \end{cases}$$

The first order conditions are characterized by:

$$\begin{cases} \dfrac{\frac{\partial(\varphi d_M^{dLM})}{\partial \varphi}}{2x} = \dfrac{\frac{\partial E^{dLM}}{\partial \varphi}}{\frac{\partial E^{dLM}}{\partial x}} \\ B + \varphi d_M^{dLM} - x^2 = 0 \end{cases}$$

The best strategy of the NGO is then implicitly defined as follows:

$$\begin{cases} 6(\overline{\theta} - \underline{\theta})x^{dLM*} = (2\overline{\theta} - \underline{\theta} + x)(\overline{e} + e_M) - c_M - 2\varphi^{dLM*}) \\ B + \varphi^{dLM*}d_M^{dLM}(\varphi^{dLM*}, x^{dLM*}) - x^{dLM*2} = 0 \end{cases} \tag{27}$$

Figure 12 depicts the best strategies of the NGO: With a low budget (such as B_0), the NGO chooses to combine a fee and a campaign $(\varphi^{dLM*}, x^{dLM*})$ in order to maximize the quality of the environment. With a higher budget (as B_1), the NGO prefers not to claim a certification fee to Firm M, favoring demand for the sustainable product, and to use its entire initial budget in the awareness-raising campaign (*i.e.* $x = \sqrt{B}$). 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). The resulting market structure may be Monopoly M and the NGO has to adapt its strategy to this case.
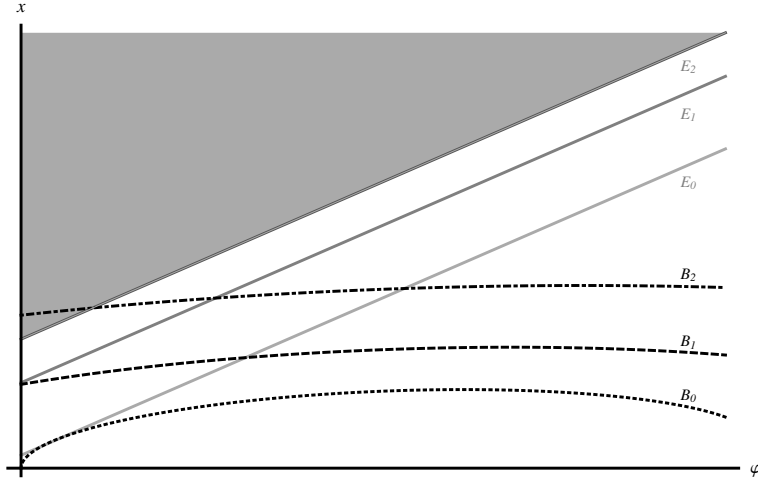
Figure 12: NGO's Optimal strategies in the Duopoly (L,M) case

4.4.3 Duopoly cases (M,H) and (H,M)

In each of these cases, demands are defined by Equations 18 and profits are π_i^{dMH} $(i = M, H)$. By construction,

- the first case (M, H) is submitted to $\pi_M^{dMH}(x) > \pi_H^{dMH}(x) > \pi_L^{dLM}(x) > 0$ and $\pi_L^t(x) < 0$,

- the second one (H, M) to $\pi_H^{dMH}(x) > \pi_M^{dMH}(x) > \pi_L^{dHL}(x) > 0$ and $\pi_H^t(x) < 0$.

Global environmental quality writes:

$$E^{dMH} = e_M d_M^{dMH} + \bar{e} d_H^{dMH} = \frac{\bar{e}(2\bar{\theta} - \underline{\theta} + x) - e_M(\bar{\theta} - 2\underline{\theta} - x) + c_M + \varphi}{3(\bar{\theta} - \underline{\theta})} \tag{28}$$

The main difference with the duopoly (L, M) is that, in case of a duopoly (M, H) 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.

The NGO's program is:

$$\begin{cases} \max_{x,\varphi} E^{dMH} \\ \text{st } x^2 \leq B + \varphi d_M^{dMH} \end{cases}$$

The first order conditions are then:

$$\begin{cases} \dfrac{\frac{\partial(\varphi d_M^{dMH})}{\partial \varphi}}{2x} = \dfrac{\frac{\partial E^{dMH}}{\partial \varphi}}{\frac{\partial E^{dMH}}{\partial x}} \\ B + \varphi d_M^{dMH} - x^2 = 0 \end{cases}$$

The NGO's best strategy is then implicitly defined by:

28

$$
\begin{cases}
\varphi^{dMH*} &= \dfrac{(\overline{\theta} - 2\underline{\theta})(\overline{e} - e_M) + \rho\,(t_0 - t_H) - c_M}{2} - \dfrac{6(\overline{\theta} - \underline{\theta}) + (\overline{e} - e_M)(\overline{e} + e_M)}{2(\overline{e} + e_M)}x^{dMH*} \\
&\quad B + \varphi^{dMH*}d_M^{dMH}(\varphi^{dMH*}, x^{dMH*}) - x^{dMH*2} = 0
\end{cases} \tag{29}
$$

Because the certified component does not alter the organoleptic quality of the product, unlike the component-free product, Product M benefits from a competitive advantage over product H (although Product M is of lower environmental quality than Product H). Equation 29 shows that the higher willingness-to-pay for the organoleptic quality (i.e. $\rho t_0 - \rho t_H$) allows the NGO to increase its certification fee.
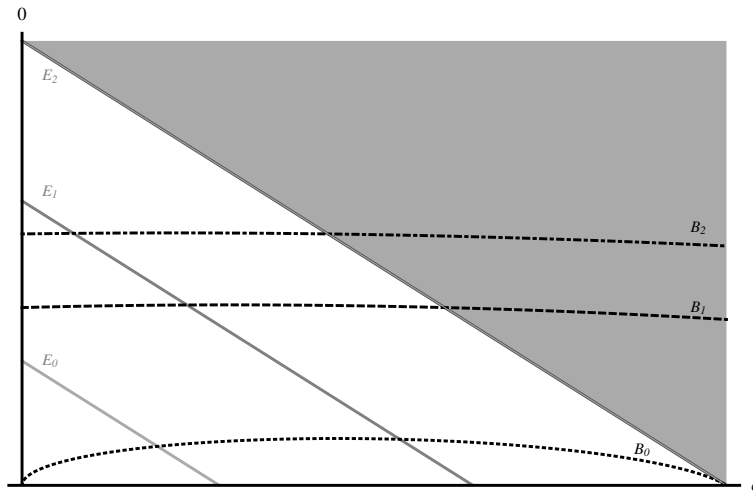

Figure 13: NGO's Optimal strategies in the Duopoly (M,H) case

Figure 13 shows that when the NGO faces both greenest products, it is in its interest to favor Product H at the expense of Product M, when R&D cost F_H is sufficiently low. Note that B_0 is supposed null in Figure 13, so that the solution where the NGO does not campaign neither charge a fee is very specific. With a positive initial budget, the NGO should implement a strategy $(\varphi^{dMH*}, x^{dMH*})$ removing Product M (i.e. the intersections of curves B_i and E_i for $i = 1, 2$). The resulting market structure may then be Monopoly H and the NGO has to adapt its strategy to this case.

4.4.4 Monopoly M

The demand addressed to Monopoly M is defined in Equation 11 and yields profit π_M^m. The market structure remains a monopoly M under the conditions $\pi_M^m(x) \geq \pi_L^m(x)$ and $\pi_M^m(x) \geq \pi_H^m(x)$, and also $\pi_L^{dLM}(x) \leq 0$ and $\pi_H^{dMH}(x) \leq 0$.

To improve the quality of the environment, the NGO has an interest in choosing an effort that encourages the monopoly to substitute product M or H to product L. The certification fee

helps to finance a campaign effort higher than with the only initial budget. It also influences the monopoly's choice between product M or H.

When $E_H \geq E_M$, it is in the NGO's interest to exhaust its budget and not to propose label e_M with fee φ. Because E_H grows faster with x than E_M, such a case arises when $\overline{\theta}(\overline{e} - e_M) \geq \rho(t_0 - t_H) - c_M - \varphi$ (such as $E_H \geq E_M \ \forall x$) and $x \geq \tilde{x}$ (such as $\pi_H^m(x) \geq \pi_M^m(x)$).

If $\overline{\theta}(\overline{e} - e_M) < \rho(t_0 - t_H) - c_M - \varphi$ then $E_M \geq E_H$ for $x = 0$ and for all campaign effort lower than $\breve{x}$ defined as follows:

$$\breve{x} \equiv \frac{\rho(t_0 - t_H) - c_M - \varphi}{\overline{e} - e_M} - \overline{\theta} \tag{30}$$

The NGO promotes then the certified component and the monopoly adopts it when $x < \tilde{x}$. In this case, any increase in φ decreases E_M, while increasing the NGO's budget until a given threshold defined as $\overline{\varphi} \equiv \frac{1}{2}((\overline{\theta} + x)e_M + \rho t_0 - c_M)$. Therefore, the NGO maximizes the environmental quality under the budget constraint and the incentive constraints $\pi_M^*(x) > \pi_L^*(x)$, fulfilled when $c_M + \varphi \leq (\overline{\theta}e_M - \underline{\theta}\overline{e})$, and $\pi_M^m(x) \geq \pi_H^m(x)$. Its program is:

$$\begin{cases} \max_{x,\varphi} E_M^m = e_M d_M^m \\ \text{st } BC_M \equiv x^2 - B - \varphi d_M^m \leq 0 \\ x > \tilde{x} \end{cases}$$

The first order conditions (FOC) for an interior solutions are:

$$\begin{cases} \dfrac{\frac{\partial E_M^m}{\partial \varphi}}{\frac{\partial E_M^m}{\partial x}} = -\dfrac{1}{e_M} = \dfrac{\frac{\partial BC_M}{\partial \varphi}}{\frac{\partial BC_M}{\partial x}} = \dfrac{c_M + \varphi_M^{m*} - (\overline{\theta} + x_M^{m*})e_M - \rho t_0}{(4\overline{\theta} - \underline{\theta})x_M^{m*} - \varphi_M^{m*})e_M} \\ \varphi_M^{m*} = \rho t_0 + (\overline{\theta} + x_M^{m*})e_M - c_M - 4(\overline{\theta} - \underline{\theta})x_M^{m*} \end{cases}$$

It can be shown that the NGO's budget constraint is binding, that is the NGO spends its whole budget including the fee in financing its campaign effort. Below a given initial budget, denoted $\overline{B}_M$, the best strategy of the NGO is characterized by :

$$x_M^{m*} = \frac{\rho t_0 + \overline{\theta}e_M - c_M + \sqrt{Be_M(8(\overline{\theta} - \underline{\theta}) - e_M) + (\rho t_0 + \overline{\theta}e_M - c_M)^2}}{8(\overline{\theta} - \underline{\theta}) - e_M} \tag{31}$$

$$\varphi_M^{m*} = \rho t_0 + (\overline{\theta} + x_M^{m*})e_M - c_M - 4(\overline{\theta} - \underline{\theta})x_M^{m*} \tag{32}$$

In this case, the initial budget must be raised with a certification fee in order to foster the monopoly to use the sustainable component and to maximize the environmental quality. In particular, if the initial budget was equal to zero, the NGO was unable to urge the monopoly to change from product L to product H without extra revenues but it is now possible, thanks to the collected fees, to obtain a move towards the sustainable component with a campaign effort

such that

$$x_M^{m*}\big|_{B=0} = \frac{2(\rho t_0 + \overline{\theta} e_M - c_M)}{8(\overline{\theta} - \underline{\theta}) - e_M} \tag{33}$$

Whatever the level of the sustainable standard, the NGO's optimal strategy leads to environmental quality $E_M^{m*} = 2x_M^{m*}$

When $B \geq \overline{B}_M$, the NGO does not need the fee and only campaign with an effort $x^m = \sqrt{B}$ exhausting its initial budget. Such a corner solution arises from the fact that the slope of the iso-environment curve is positive and independent of the NGO's strategy (and equal to $1/e_M$) although the slope of the iso-budget curve at the origin (when $\varphi = 0$) decreases with the budget constraint. For initial budget higher than $\overline{B}_M$, the highest quality of the environment is then reached with $\varphi = 0$. In other words, the marginal rate of substitution of x to φ which keeps the environmental quality constant is lower than the implicit relative price exhibited by the budget constraint (i.e. $\frac{\partial E_M^m}{\partial \varphi}/\frac{\partial E_M^m}{\partial x} < \frac{\partial BC_M}{\partial \varphi}/\frac{\partial BC_M}{\partial x}$). Using the budget constraint, $\varphi = 0$ and $x^m = \sqrt{B}$, the budget threshold can be defined as follows:

$$\overline{B}_M = \left(\frac{\rho t_0 + \overline{\theta} e_M - c_M}{4(\overline{\theta} - \underline{\theta}) + e_M}\right)^2 \tag{34}$$

The maximal quality of the environment is then $E_M^{m*} = 2\sqrt{B}$.
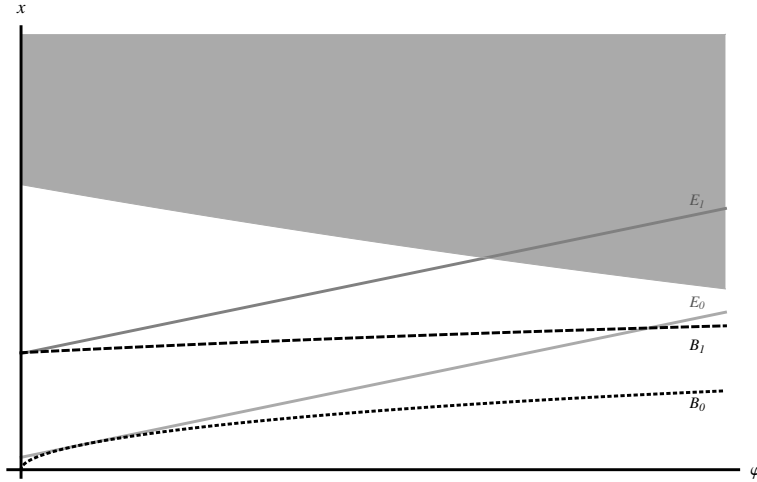

Figure 14: NGO's Optimal strategies in the Monopoly M case

Figure 14 illustrates the NGO's arbitrage between the campaign effort and the certification fee.[22] In the shadow area, the incentive constraint is not fulfilled. The iso-budget curve B_0 corresponds to the zero initial budget case. In this case, the maximal level of environmental

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[22]In order to allow positive market shares and profits for Monopoly M and/or Monopoly H according to the values of x and φ, the differentiation in organoleptic quality has been assumed lower than for previous figures, while cost c_M and F_H have been assumed higher than before.

quality that can be reached is E_0, that is the highest iso-environment curve tangent to the iso-budget curve. The budget B_1 is higher than $\overline{B}_M$ and the maximal level of environmental quality, E_1, is attained using only the initial budget.

Welfare comparison between the different market structures remain to be conducted in order to determine the optimal social solution.

5 Conclusion

This paper has adopted a two-dimensional vertical product differentiation to determine the conditions under which the NGO's pressure is more likely to lead a monopoly to eliminate basic component in its product or, alternatively, to substitute a damaging component with a certified sustainable component. The NGO may trade-off between investing in an awareness campaign to increase the consumers' willingness to pay for component-free products, despite their taste degradation, or to propose a certified component less harmful for the environment than the former one. One of the main results of the paper is that the NGO may prefer to favor the entry of a competitor using the certified component and to restrict the market share of the least environmentally harmful product, when establishing it in a monopoly situation is unreachable, because of high R&D costs or in case of a too low NGO's initial budget. The fees collected allow the NGO to intensify its awareness campaign and a duopoly or a triopoly may occur.

Appendix

5.1 Social welfare

Welfare usually refers to the sum of consumer surplus, firm profits and social cost (or benefit) of degradation (or improvement) of the quality of the environment: $W_i(x) = CS_i(x) + \pi_i(x) + \delta E_i(x)$, where CS_i denotes the surplus of consumers of product i and δ the marginal environmental damage, that is, the monetary valuation of marginal degradation (or improvement) of quality of the environment E_i (with $\delta \geq 0$).

In the case of Monopoly L, consumption of the component-containing product leads to the following consumer surplus:

$$CS_L^m(x) = \frac{1}{4}(\overline{\theta} - \underline{\theta})(\rho t_0 - (\underline{\theta} - 3x)\overline{e})d_L^*(x) \tag{35}$$

Therefore, the social welfare is defined by:

$$W_L^m(x) = \frac{1}{4}(\overline{\theta} - \underline{\theta})(\rho t_0 - (\underline{\theta} - 3x)\overline{e})d_L^*(x) + (\overline{\theta} - \underline{\theta})\overline{e}\,d_L^*(x)^2 - \delta\,\overline{e}d_L^*(x) \tag{36}$$

In the case of Monopoly H, consumption and production of the component-free product entails the following consumer surplus:

$$CS_H^m(x) = \frac{1}{4}(\overline{\theta} - \underline{\theta})(\rho t_H + (\overline{\theta} - 3x)\overline{e})d_H^m(x) \tag{37}$$

The social welfare is characterized by:

$$W_H^m(x) = \frac{1}{4}(\overline{\theta} - \underline{\theta})(\rho t_H + (\overline{\theta} - 3x)\overline{e})d_H^*(x) + (\overline{\theta} - \underline{\theta})\,\overline{e}\,d_H^m(x)^2 - c\,\overline{e}^2 + \delta\,\overline{e}d_H^m(x) \tag{38}$$

In the case of Monopoly M, when buying the certified product, consumers benefit from the following surplus:

$$CS_M^m(x) = \frac{1}{4}(\overline{\theta} - \underline{\theta})(\rho t_0 + (\overline{\theta} - 3x)e_M - c_M - \varphi)d_M^m(x) \tag{39}$$

The social welfare is then defined by:

$$W_M^m(x) = \frac{1}{4}(\overline{\theta} - \underline{\theta})(\rho t_0 + (\overline{\theta} - 3x)e_M - c_M - \varphi)d_M^*(x) + (\overline{\theta} - \underline{\theta})e_M\,d_M^m(x)^2 + \delta\,e_Md_M^m(x) \tag{40}$$

The environmental quality is then equal to:

$$E_M = \frac{\rho t_0 + (\overline{\theta} + x)e_M - c_M - \varphi}{2(\overline{\theta} - \underline{\theta})} \tag{41}$$

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