FIRMS' RESPONSES TO NUTRITIONAL POLICIES

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Abstract

The aim of this paper is to examine the effects of nutritional policies on the behavior of firms, particularly in terms of food quality and prices, and to assess the potential impacts of such policies from a public health point of view. We determine how new products that are nutritionally improved can emerge in a market where incumbent firms offer competing unhealthy products. We also highlight a non-intentional effect of such policies: if consumer heterogeneity is high, then an information policy may simultaneously provide health benefits to the population as a whole but worsen the health of consumers that are less aware of nutritional effects.
For a given level of nutritional tax, we determine the optimal threshold that firms must meet to avoid taxation. It appears that this threshold must not be too high if the goal of nutritional policies is to increase total health benefits without increasing health disparities between consumers. An increase in the tax level has two opposing effects. On one hand, it improves health benefits for consumers that are less aware of nutrition issues. On the other hand, because it leads to an increase in prices as a result of a reduction in the competition intensity, it decreases the cost-effectiveness of the policy.

Key words

Nutrition policy, product differentiation, firms’ strategies, taxation, quality standards, public health

JEL codes

L15, I18, H23

Introduction

Many links between chronic diseases and food consumption are now well established. Numerous studies have shown that, in combination with sedentary lifestyles, diets characterized by excessive salt, sugar or fat intake are associated with high probabilities of developing some types of cancer and cardiovascular diseases (WHO, 2003). In order combat the development of these food-related diseases, governments enact nutritional policies to change consumers' habits and lead them to healthier food behaviors.

One type of policy is based on education and information campaigns. Generic campaigns like the '5-a-day' campaign and targeted interventions addressing groups, such as children at school, people suffering from chronic diseases or low-income populations, are implemented in many countries to make consumers more aware of the health effects of particular food consumption behaviors. A second type of policy aims at raising consumers' awareness of the nutritional value of various foods through the implementation of nutritional labeling. A third type of policy relies on changes in food prices by either implementing taxes on unhealthy food products or subsidizing healthier foods.

The observed and potential impacts of these policies on consumer behavior have been extensively studied. Generally speaking, these policies seem to have some effects on consumers' food consumption behaviors; however, heterogeneity in consumers' reactions to information campaigns and nutritional labeling is often noted. Consumers with higher income and/or higher levels of education seem to benefit more from generic campaigns and from the inclusion of nutrient information on food packaging (Lusk and Bridgeman, 2009; Baum II and Ruhm, 2009; Rashad, 2006; Variyam, 2008; Drichoutis et al., 2008; Ippolito and Mathios, 1995).

The analysis of the effects of price policies is primarily based on evaluations of direct and cross price elasticities that make it possible to determine the substitutions induced by modifications in relative food prices. The health impacts of these pricing policies are still controversial (Allais et al., 2009; Caraher and Cowburn, 2005; Chouinard et al., 2007; Jacobson and Brownell, 2000; Leicester and Windmeijer, 2004; Mytton et al., 2007;

Nordström and Thunström, 2009; Schroeter et al., 2008; Smed et al., 2007; Strnad, 2005). Some authors suggest that a "fat tax" could induce significant variations in consumers' choices and could contribute to an important reduction in populations' mean Body Mass Index (BMI). However, other authors show that the induced variations are weak or regressive and that households with low incomes are more penalized than other segments of the population. Moreover, taxation of certain food categories can have ambiguous effects in the sense that a positive impact on a specific nutrient can be associated with an unwanted effect on other nutrients.

Some have discussed the combined effects of information and price policies (Marette et al., 2008). It is important to note that the vast majority of research related to nutritional policies focuses on the demand side and only deals with consumer behavior; however, firms' strategies and their incentives to improve the nutritional quality of the foods they sell are a crucial issue for health policy makers because firms' reactions in terms of price and product quality can amplify or reduce the expected impacts of nutritional policies. For example, nutritional education and information campaigns generate opportunities for health-related product differentiation that can lead to market segmentation and price modifications. Such responses can modify the affordability of healthier products, thus affecting their health benefits at the population level. Labeling policies can better inform consumers about the nutrient content of foods but may also lead to price changes or product reformulations that can have either positive or negative effects. "Fat tax" policies can favor product substitutions, but in an imperfect competitive setting such taxes can be partially transmitted to final prices or compensated for by a decrease in product quality that can have unexpected consequences.

Apart from some empirical studies investigating the impacts of mandatory nutritional labeling (Ippolito and Matthios, 1990; Caswell et al., 2003; Mancino et al., 2008; Moorman, 2005) and descriptive studies that assess food supply adaptation (Unnevehr and Jagmanaite, 2008; Mojduszka, E.M, 1999; Ricciuto, 2009; L'Abbé et al., 2009), issues related to firms' strategies in reaction to nutritional policies remain relatively unexplored. The objective of this article is to contribute to a better understanding of the effects of nutritional policies on firms' behavior, and to assess the potential impacts of such policies on public health. More precisely, the goal of this paper is to determine how new products that are nutritionally improved can emerge in a market where incumbent firms offer unhealthy products. Indeed, in reaction to public policies that penalize unhealthy products (i.e., a "fat tax"), incumbent firms can limit the entry of new healthier products by decreasing the prices of the unhealthy products, thus limiting the expected impact of the public policies. Our objective is to specify the conditions under which public authorities can avoid these unintentional effects and thus achieve public health goals.

Health issues are only one of many criteria that impact consumers' food choices. Each individual food decision depends on both immediate benefits, such as taste or the convenience of the product, and long-term consequences on health. To consider the multiple dimensions of consumers' preferences, we propose an analytical approach in a double product differentiation framework (Neven and Thisse, 1989). In this framework, the horizontal differentiation axis describes the product variety, aggregating all of the product characteristics except nutritional quality. The vertical differentiation axis describes nutritional quality. Because consumers' food choices vary according to social groups, we consider two different groups of consumers to account for this heterogeneity in terms of nutritional quality preferences. One group is more aware of health matters and is willing to pay higher prices for a given nutritional characteristic.

On the supply side, we consider a duopoly composed of an incumbent firm that sells an outside good whose characteristics are exogenous (Salop, 1979) and a new entrant firm that can decide to offer a new product of higher nutritional quality. The incumbent firm cannot change its product quality, but its pricing decisions may prevent the other firm from offering a healthier product. By offering a healthier product, the second firm expects to capture some of the willingness to pay of consumers that are aware of health issues. However, it may also lose market share because of the incumbent firm's reaction. The new entrant must decide whether to enter the market or not and determine how to differentiate the new product in terms of variety and nutritional quality to achieve maximal profit. This decision relies on expected gains from demand, costs associated with nutritional quality and the anticipated reactions of the incumbent firm.

We compute the prices and the market share for the two products, as well as the new product's quality and variety according to demand characteristics (i.e., the level and heterogeneity in consumers' preferences related to nutritional issues) and policy scenarios. Moreover, we determine the health impacts of the firms' decisions at equilibrium. We assume that at the level of the individual consumer the health benefit is linked to the quality of the product a consumer chooses. From a public health standpoint, the overall population's health depends on the following: (i) the nutritional quality of the marketed products and (ii) the market share of these products. On this basis, we compute a health index that takes into account both nutritional quality and the two products' market shares.

In the first section, we consider an unregulated benchmark case and assess the market equilibrium according to consumer sensitivity to nutritional quality. As intuitively expected, changes in food quality and price depend on the level of consumer sensitivity to nutritional quality, and increases in consumer awareness regarding nutritional issues improve the overall health benefits associated with food consumption. However, we also highlight an adverse effect: if consumer heterogeneity is high enough, an information policy can simultaneously improve health benefits to the population as a whole but worsen the health of consumers that are less aware of nutrition effects.

In the second section, we study the impacts of implementing a nutritional tax. We consider that both firms face such a nutritional tax, but the new entrant may avoid it if the nutritional quality of the new product is above a threshold defined by public authorities. We examine both of the effects of this minimum threshold and the tax level.

The theoretical literature relating to taxation effects in vertically differentiated markets rely on the initial papers of Cremer and Thisse (1994) and Constantatos and Sartzetakis (1999) that demonstrated that an *ad-valorem* tax leads to a decrease in product differentiation and generates jumps in the aggregate quality supplied on the market. Other works focused on the effects of taxes on environmental quality in vertically differentiated markets and raised questions related to the nutritional issues discussed here. Cremer and Thisse (1999) highlight the positive effect of a commodity tax on environmental quality in the context of imperfect competition because it increases the number of active firms. Like Amacher et al. (2004), who found that an under-provision of quality exists when the high-quality firm is more efficient in investing, Lombardini-Riipinen (2005) showed that a duopoly generates insufficient quality in the presence of negative externality. They also found that the use of only one instrument (e.g., an ad-valorem tax, an emission tax or a subsidy) does not achieve the social optimum even if the social welfare increases. The achievement of higher quality requires the use of an ad-valorem tax along with either a subsidy or an emission tax. Conrad (2005) identified three Nash equilibria that depended on both the degree of environmental awareness and the production cost. The effect of an instrument depends on the equilibrium. When consumers exhibit strong levels of environmental concern, either a subsidy to reduce the production cost or an information campaign leads the low-quality firm to produce the environmentally friendly good. In the presence of a high production cost and weak levels of environmental concern, the high-quality firm overproduces the environmentally friendly good and thus the social equilibrium leads to the implementation of a tax. Finally, in an intermediate case, two instruments are needed to achieve the social optimum. García-Gallego and Georgantzís (2009) focus on the incidence of consumer heterogeneity on firms' choices when the vertical differentiation relies on the firm's corporate social responsibility. They show that increasing consumers' environmental awareness can in some cases lead to a decrease in the social welfare that is linked to a decrease in quality. Although this literature investigates environmental issues rather than nutritional ones, such studies are interesting to consider here as they highlight the potential effects of tax policies in a product differentiation framework. In particular, they reveal that firms' responses in terms of price and quality can weaken the impact of public policies in some cases. We discuss this issue in the last section, which considers the case of a tax policy aimed at reducing health externalities.

1. Benchmark modeling

1.1. Assumptions

Health issues are only one of many criteria that determine food consumption choices. Each individual food decision depends on both immediate benefits, such as taste or the convenience of the product, and long-term health-related consequences. To consider the multiple dimensions of consumer preference, we adopt a double differentiation model (Neven and Thisse, 1989).

First we assume that, as in a *vertical differentiation* model, consumers reveal different preferences related to a given nutritional characteristic x. We assume that this characteristic leads to a health benefit that increases with x (e.g., fiber, iron or vitamin content). We denote θ the preference parameter based on nutritional quality. A consumer j gives a level of importance θ_j to the attribute x; the higher the parameter θ_j is, the more sensitive the consumer is to the nutritional attribute. All consumers are aware of this attribute because of nutritional labeling.

As a consumer's food choices vary according to their social groups, we assume the existence of two groups of consumers with different levels of sensitivity to nutritional quality. We assume that the importance θ that a consumer assigns to nutritional quality takes two different values depending on the group the consumer belongs to: θ_1 for group 1 and θ_2 for group *2.* We assume that $\theta_1 = \gamma\theta_2$ with $\gamma \leq 1$. The proportional parameter γ reveals the heterogeneity across the two sub-populations relating to their nutritional quality preferences.

Secondly, as in *horizontal differentiation* models, consumers have heterogeneous preferences over the product variety. This second attribute, denoted y, aggregates all of the other features, (e.g., texture, aroma and convenience) that make the product appealing to consumers. These features are independent of the nutritional quality. These preferences are uniformly distributed on the variety axis $y \in [0,1]$. The closer the product attribute y_i is to the location of consumers' ideal point, the more consumers enjoy consuming product *i*. In this model, it appears as if each consumer bears a transportation cost that is proportional to the distance between his preferred location on the segment [0,1] and the variety value y_i offered by firm *i*. The cost is assumed to be quadratic.

The utility of a consumer of type *j* (defined by θ_j and y_j) who buys a unit of a good with nutritional value x_i at price p_i that is located at y_i is given by:

$$U_j(x_i, y_i) = V + \theta_j x_i - p_i - d(y_j - y_i)^2 \qquad (1)$$

where V denotes the reservation price of each consumer and $d\left(y_j - y_i\right)$ is the transportation cost with $d > 0$.

In this market for differentiated goods, two firms compete by choosing the two characteristics of their products along with their prices. The incumbent firm, denoted A, sells an outside good whose characteristics are exogenous (Steven C. Salop, 1979). The attributes of this product are normalized to zero; in other words, $x_a = y_a = 0$. Although the incumbent, firm A, cannot change the quality of its product, its pricing decision may prevent firm B from offering a healthier product. The standard product A is processed at a lower production cost because of its low nutritional quality. The new entrant B may decide to offer a new higher nutritional quality product by choosing the level of the attributes x_b and y_b and its selling price. By offering a new healthy product, firm B expects to capture some of the willingness to pay of consumers who are aware of health issues. However, it may also lose market share because of firm A's reaction. The new entrant B decides whether to enter the market and determines how to differentiate the new product in terms of variety and nutritional quality to reach maximal profit. This decision relies on expected gains from demand, costs associated with nutritional quality and the anticipated reactions of the incumbent.

Without loss of generality, the marginal production cost of the variety y_i is normalized to zero. However, the production of a product with nutritional quality $x_i > x_a$ leads to a marginal cost $C(x_i) = \frac{(1+\alpha x_i)^2}{2}$ (where $\alpha \geq 0$).

We assume that firms *A* and *B* sell the same product to both groups of consumers (i.e., the firms are mono-product). Moreover, we assume that they do not change prices to fit either of the two populations. Thus, the prices and attributes x_a, y_a, x_b and y_b are the same for both groups. However, the quantities sold to both sub-markets can be different.

Under these conditions, the utility $U_{j\in k}(A)$ of a consumer *j* belonging to group *k*, *k=1,2,* who consumes product A, and the utility $U_{j\in k}(B)$ of a consumer *j* belonging to group *k, k=1,2,* who consumes product B, are respectively given by :

$$\begin{cases} U_{j\in k}(A) = V - p_a - dy_j^2, k = 1,2 \\ U_{j\in k}(B) = V + \theta_1 x_b - p_b - d\left(y_j - y_b\right)^2, k = 1,2 \end{cases} \quad (2)$$

On this basis, we examine under what conditions a product with higher quality ($x_b > 0$) enters the market and leads to an improvement in the overall population's nutritional state. In our framework, we propose a two-stage entry game. In the first stage, the firm that offers the entrant product chooses the variety and nutritional quality of the product. In the second stage, both firms compete in terms of price.

1.2. The quality-price game

To solve the two-stage entry game described previously, we determine the perfect equilibrium by backward induction. We determine the Nash price equilibrium in the sub-game given the attributes x_b and y_b (firm A's attributes are normalized to zero). Secondly, we determine the optimal attributes x_b and y_b that firm B chooses when entering the market.

We start by determining the market share D_i, as a function of the prices determined at the second stage of the game. We then express both firms' profit $\Pi_i(x_i, y_i, p_i)$ to obtain the equilibrium.

Market share and profits

We identify the location $\tilde{y}_j$ of the consumer who is indifferent between purchasing product A or B in each consumer group by setting equal, for each value θ_j, the two utility functions. This is defined by:

$$V - p_a - d\tilde{y}_j^{\,2} = V + \theta_j x_b - p_b - d(\tilde{y}_j - y_b)^2$$

We then deduce:

$$\tilde{y}_j = \frac{-\theta_j x_b + p_b - p_a + dy_b^{\,2}}{2dy_b} \qquad (3)$$

The demand faced by firms A and B from the two consumer groups 1 and 2 are respectively given by:

$$D_a(p_a, p_b) = \begin{cases} D_{a1} = \dfrac{-\theta_1 x_b + p_b - p_a + dy_b^{\,2}}{2dy_b} \\ D_{a2} = \dfrac{-\theta_2 x_b + p_b - p_a + dy_b^{\,2}}{2dy_b} \end{cases} \qquad (4)$$

$$D_b(p_a, p_b) = \begin{cases} D_{b1} = 1 - \dfrac{-\theta_1 x_b + p_b - p_a + dy_b^{\,2}}{2dy_b} \\ D_{b2} = 1 - \dfrac{-\theta_2 x_b + p_b - p_a + dy_b^{\,2}}{2dy_b} \end{cases} \qquad (5)$$

Using these demand functions and the production cost structure, we determine the profit function for each firm *i*, denoted Π_i ($I = A$ or B):

$$\Pi_i = [p_i - \frac{(1+\alpha\ x_i)^2}{2}]\sum_{j=1}^{2} D_{ij} \qquad (6)$$

The price equilibrium

We determine the price equilibrium for the second stage of the game by simultaneously solving the maximization program for both firms (each firm *i* maximizes its profit with respect to its decision variable p_i where $I = a, b$).

The profit maximization program leads to the following price equilibrium:

$$\begin{cases} p_a = \frac{1}{6}[3+2d\ y_b(2+y_b)+\alpha\ x_b(2+\alpha\ x_b)-x_b(1+\gamma)\theta_2)] \\ p_b = \frac{1}{6}[3+2d\ y_b(4-y_b)+\alpha\ x_b(4+2\alpha\ x_b)+x_b(1+\gamma)\theta_2)] \end{cases} \qquad (7)$$

As expected, product B's price increases as the nutritional attribute x_b increases. It should also be noted that p_a is increasing in y_b. Increases in the variety differentiation relax price competition, leading to an increase in the price of the low quality product p_a.

Characteristics of the entrant product

In the first stage of the game, firm B determines both the optimal level of nutritional quality and the variety attribute. It maximizes its profit with respect to x_b and y_b and has information regarding the sub-game price equilibrium (equation 7). By substituting (7) into (6), we get:

$$\Pi_B(x_b, y_b) = \frac{[2d\ y_b(4-y_b)-\alpha\ x_b(2+\alpha\ x_b)+x_b(1+\gamma)\theta_2]^2}{36dy_b} \qquad (8)$$

The characteristics of product B at equilibrium are stated in the following proposition:

Proposition 1[1]:

(i) If $\theta_2 \leq \frac{2\alpha}{1+\gamma}$*, then firm B chooses* $x^*_{bm} = 0$ *and* $y^*_{bm} = 1$ *in the game's perfect equilibrium.*

[1] Proof is available from the authors upon request

(ii) If $\theta_2 > \frac{2\alpha}{1+\gamma}$*, then firm B chooses attributes such that* $\partial x^*_{bm}/\partial\theta_2 > 0$ *and* $\partial y^*_{bm}/\partial\theta_2 < 0$

where the functions are denoted by:

$$\begin{cases} y^*_{bm} = \frac{2}{3} + \frac{\sqrt{4(-3+8d)\alpha^2 + 12\alpha(1+\gamma)\theta_2 - 3(1+\gamma)^2\theta_2^2}}{6\alpha\sqrt{2d}} \\ x^*_{bm} = \frac{-2\alpha + (1+\gamma)\theta_2}{2\alpha^2} \end{cases}$$

Result (i) states that when the willingness θ_2 is sufficiently small $(\theta_2 \leq 2\alpha/(1+\gamma))$, consumers who exhibit higher levels of health concerns are not willing to pay enough to bear the cost associated with the production of products with improved nutritional quality $x_b > 0$. The optimal entry decision of firm B is then $y^*_{bm} = 1$ and $x^*_{bm} = 0$. The two firms differentiate themselves on the horizontal axis at maximum and reduce their product differentiation at their minimum on the vertical axis (Neven and Thisse, 1989).

When the willingness to pay θ_2 is sufficiently high ($\theta_2 > 2\alpha/(1+\gamma)$), firm B chooses to produce a product with a higher nutritional quality level ($x^*_{bm} > 0$) to capture the willingness of this consumer group to pay. The nutritional quality is increasing in θ_2, whereas the variety is decreasing in θ_2. The two firms increase their product differentiation regarding nutritional quality and come closer on the variety axis. Price competition is strengthened when firm B reduces its product differentiation relating to variety and consequently, firm A diminishes its price at equilibrium. Firm B relies on the increase in nutritional quality to capture market share even if the price p_b increases. The higher θ_2 gets, the more the profit of firm B increases and the profit of firm A diminishes.

1.3. Impact on consumers' health

Proposition 1 shows that if θ_2 is sufficiently high, the entry of firm B into the market can improve the nutritional quality of the food supply. Knowing prices, the firms' market shares and the characteristics of the products at equilibrium, we can derive the health impact on consumers. We assume that, at the individual consumer level, the health benefit is linked to the quality of the product a consumer chooses. A consumer j that consumes a unit of product A has no health benefit (denoted h_j) because $x_a = 0$. In contrast, a consumer who consumes a unit of product B displays a health benefit h_j that increases with x_b. For simplicity, we assume that health effects are linear[2] and the health benefit h_j of a consumer j when he consumes a unit of product B is $h_j = x^*_{bm}$.

From a public health perspective, the overall population's health depends on (i) the nutritional quality of the marketed products and (ii) the market shares of the different products. On this basis, we can compute a health index that takes into account both nutritional quality and the market shares of the two products. The health state can be improved through two mechanisms: by facilitating product substitution and thus increasing the market share of product B, or by increasing the nutritional quality of product B. On this basis, we can define the health benefit H_T for the whole population, the health benefit H_1 for consumer group 1 and the health benefit H_2 for consumer group 2 as: $H_T = D_b\, x^*_{bm}$, $H_1 = D_{b1}\, x^*_{bm}$, $H_2 = D_{b2}\, x^*_{bm}$. We can then show that:

Corollary 1[3]:

The two following assertions are simultaneously checked:

(i) $\forall \theta_2, \gamma \in]0,1], \partial H_T / \partial \theta_2 > 0$

(ii) There exists $\tilde{\theta}_2$ *such that :* $\partial H_1 / \partial \theta_2 > 0$ *if and only if* $\theta_2 < \tilde{\theta}_2$.

Proof: see Appendix.

Setting θ_1, when θ_2 increases, product A's market share diminishes and product B's market share increases. For the whole population, the simultaneous increase of the nutritional quality x^*_b and the market share D_b has a positive effect on the health criterion H_T. However, this result does not necessarily hold for both consumer groups when $\gamma < 1$. The increase in p_b, linked to the increase in the second group's nutritional awareness θ_2 and the decrease in p_a,

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[2] The nutritional epidemiology literature provides little information to determine the nature of this relationship or whether or not it is linear.

[3] Proof is available from the authors upon request.

reduces the market share D_{b1} and increases D_{a1}. When θ_2 increases but remains lower than a threshold value $\tilde{\theta}_2$, consumers who consume product B benefit from an improvement of their health because of the enhancement of x_b, even if progressively fewer consumers from group 1 purchase product B. In that case, the health benefit H_1 increases because the improvement in the nutritional characteristic of each product exceeds the reduction in the market size. When θ_2 overtakes the threshold $\tilde{\theta}_2$, the effect linked to the reduction in product B's market share exceeds the effect linked to the improvement in product B's quality and H_1 diminishes (see Figure 1).

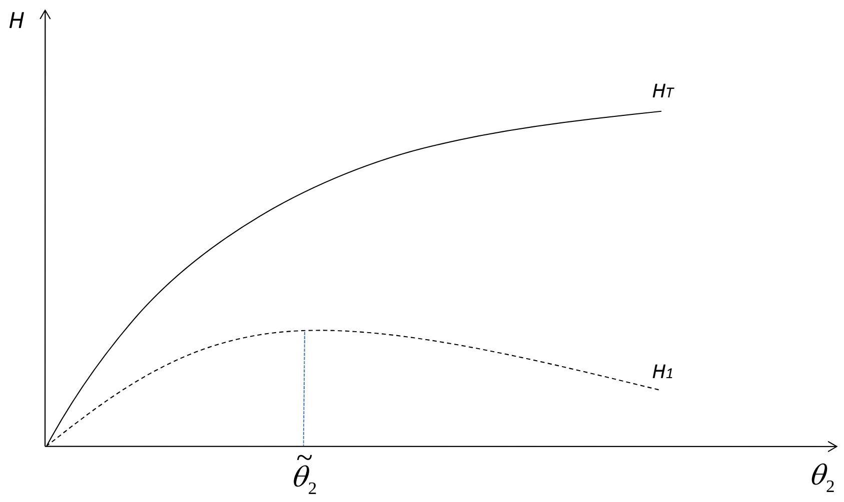

Figure 1

It is important to keep in mind that this result does not rely only on the increasing differentiation of health demand between the two consumer groups (with θ_1 set, γ becomes smaller and smaller). The firms' reactions can amplify this effect. Firm B attempts to capture the increasing willingness to pay by simultaneously increasing x_b and p_b. The incumbent, firm A, prevents the entry of the nutritionally improved product by diminishing its price.

This result has broader implications and contributes to the debate regarding the impact of public campaigns on nutritional information. Governments usually consider information campaigns to be one of the most efficient instruments for changing consumer behavior. If we assume that the increase in θ_2 is the result of a public information campaign that aims to convince consumers to change their food habits (i.e., increase their willingness to pay for nutritional quality), and that the information acquisition and the ability to process it through information campaigns depends on a consumer's type[4] (θ_2 increases with $\gamma < 1$), then corollary 1 and results (i) and (ii) highlight an unexpected potential effect of this instrument.

Assuming that the acquisition and processing of information are different for the two consumer groups and that the information campaign generates a substantial increase in group 2's willingness to pay (i.e., θ_1 and θ_2 increase but γ strongly decreases), we can then observe increased health benefits for the whole population (represented by the sum of the health benefits of the two groups) and a deterioration in the health state of the population that is less aware of the nutritional dimension (group 1).

2. Tax policy assessment

It has been shown previously that information policies can generate an unsettling ethical side effect. Specifically, the health of the whole population improves because of the health benefits experienced by only one of the two consumer groups. In this section, we examine whether a taxation scheme may be more efficient than an information policy in improving consumers' health and investigate whether it removes or reduces these unexpected and biased effects. To improve the nutritional quality of the products offered by firms, the taxation must be designed as a "penalty" instrument for firms that do not meet the minimum nutritional quality standard defined by the regulator[5]. In the following section, we include this instrument in our benchmark model to examine the effects of this indirect tax.

We assume that the regulator defines a minimum quality threshold x_{min} and reveals it to the firms. All products i whose characteristic x_i is less than x_{min} face an *ad-valorem* tax t. In this framework, product A always faces the tax. We also keep in mind that product A is an *outside good*, and thus the incumbent firm cannot change its initial characteristics. Firm B manages competition with the incumbent A by adjusting its two instruments (x_b and y_b) with respect to the minimum quality threshold enforced by the regulator. When setting the tax level t, firm

[4] Numerous studies have established that consumer reaction to information campaigns and nutritional labelling is also heterogeneous (Lusk and Bridgeman, 2009; Baum II and Ruhm, 2009; Rashad, 2006; Variyam, 2008).

5 When labeling is mandatory, as it is in many countries, such a tax might not be difficult to set up. Brownell et al. (2009) proposed this type of tax for soft drinks. Products face the tax when the sugar content is above 1 g of sugar / ounce (30 ml).

B's choices depend on the minimum nutritional quality threshold $x_{\min}$ as described below. The profit, demand and price functions are given in the Appendix.

- When the minimum quality threshold is slightly restrictive ($x_{\min} < x_{bm}^*$), firm *B* chooses not to face the tax and the optimal characteristics are given by $(\tilde{x}_b ; \tilde{y}_b)$.

- When the minimum quality threshold is more restrictive ($x_{\min} > x_{bm}^*$), two cases occur. We denote $\bar{x}_b$ as the minimum quality threshold for which firm B is indifferent between choosing the quality threshold $x_{\min}$ or coping with the *ad-valorem* tax. When the regulator chooses an intermediate value for the nutritional threshold $x_{bm}^* < x_{\min} < \bar{x}_b$, firm B chooses the minimum quality threshold and its profit is higher than if it paid the tax. The optimal characteristics are given by ($x_{\min} ; y_b(x_{\min})$). When $x_{\min} > \bar{x}_b$, firm B decides to face the tax instead of choosing to produce a nutritional quality equal to $x_{\min}$. The optimal characteristics are given by $(\hat{x}_b ; \hat{y}_b)$.

We summarize the results in the following proposition:

Proposition 2[6] : *If* $\theta_2 < \frac{2\alpha_b}{1+\gamma}$, *then product B's characteristics are* $x_b^*=0$ *and* $y_b^*=1$. *If* $\theta_2 > \frac{2\alpha_b}{1+\gamma}$, *then product B's characteristics are given by:*

$$x_b^* = \begin{cases} \tilde{x}_b = x_{bm}^* & \text{if } x_{\min} < x_{bm}^* \\ x_{\min} & \text{if } x_{bm}^* \le x_{\min} < \bar{x}_b \\ \hat{x}_b = \dfrac{(1-t)(1+\gamma)\theta_2 - 2\alpha}{2\alpha^2} & \text{if } x_{\min} \ge \bar{x}_b \end{cases}$$

[6] Proof is available from the authors upon request

$$y_b^* = \begin{cases} \tilde{y}_b(\tilde{x}_b) = \dfrac{2}{3} + \dfrac{\sqrt{4(-3+8d(1-t))\alpha^2 + 12\alpha(1-t)(1+\gamma)\theta_2 - 3(1-t)(1+\gamma)^2\theta_2^2}}{6\alpha\sqrt{2d(1-t)}} & if\ x_{\min} < x_{bm}^* \\ y_b(x_{\min}) = \dfrac{2}{3} + \dfrac{\sqrt{2}\sqrt{8d(1-t) + 3\left[-t + (1-t)\left(\alpha x_{\min}(2+\alpha x_{\min}) - x_{\min}(1+\gamma)\theta_2\right)\right]}}{6\sqrt{d(1-t)}} & if\ x_{bm}^* < x_{\min} < \overline{x}_b \\ \hat{y}_b(\hat{x}_b) = \dfrac{2}{3} + \dfrac{\sqrt{4(-3+8d(1-t))\alpha^2 + 12\alpha(1-t)(1+\gamma)\theta_2 - 3(1-t)^2(1+\gamma)^2\theta_2^2}}{6\alpha\sqrt{2d(1-t)}} & if\ x_{\min} \geq \overline{x}_b \end{cases}$$

Impacts on the nutritional quality and variety

- When the minimum quality threshold is low, firm B chooses the quality $\tilde{x}_b$ that it adopts without constraints (as in the benchmark model). By doing so, it avoids being taxed (cf. Figures 2a and 2b, area 1). As a consequence, firm B takes advantage of this competition scenario by reducing the distance between products B and A on the horizontal axis.

- When the quality threshold is more restrictive ($x_{bm}^* \leq x_{\min} < \overline{x}_b$), firm B chooses the nutritional quality threshold $x_{\min}$ (cf. Figure 2a and 2b, area 2). It thus produces a higher nutritional quality than in the benchmark and avoids taxation. However, when the nutritional quality threshold increases, the variety y_b increases as well. Firm B offsets the increase in nutritional quality by a growing differentiation of variety. Thus, price competition is softened.
- When the quality standard is very restrictive ($x_{\min} \geq \overline{x}_b$), firm B forgoes the quality standard and faces the tax (cf. Figure 2a and 2b, area 3). It then chooses a lower nutritional quality level than the benchmark nutritional quality, x_{bm}^*.

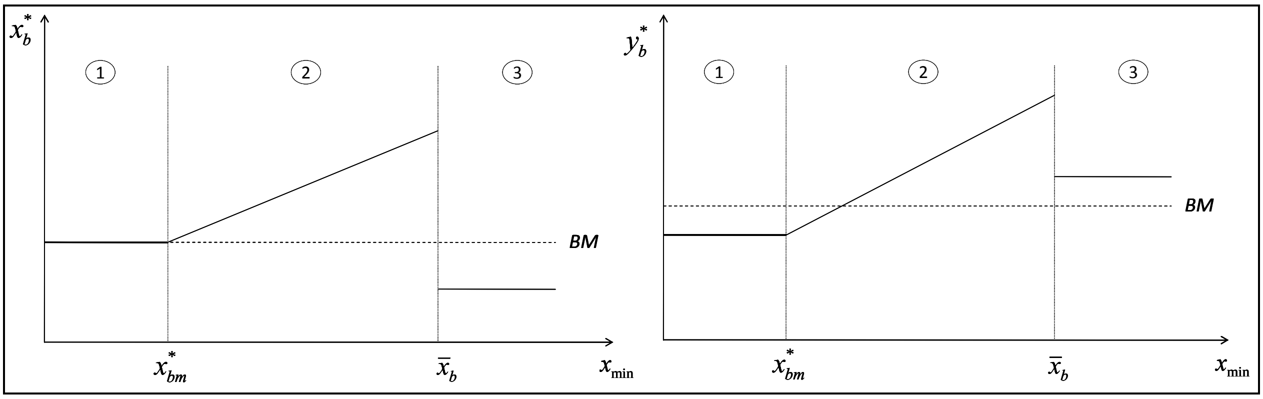

Figure 2a Figure 2b

It is obvious that the nutritional tax provides a strategic advantage to the entrant firm B when firm B agrees to meet the minimum quality standard. If the threshold $x_{\min}$ is lower than the benchmark quality x_{bm}^* then this competitive advantage does not modify the quality of the products available on the market. However, it alters the variety location and thus affects price competition. When the regulator defines a restrictive quality threshold that is too high, firm B is not able to meet it. The product quality will then be lower than the quality observed in the benchmark case. The regulator can only encourage an improvement of product B's quality for intermediate values of the nutritional quality threshold.

Impacts on prices and quantities

In most of the situations examined, prices p_a and p_b are higher than the observed prices in the benchmark model (cf. Figures 3a and 3b).

In area 1, the price p_a increases because firm A transfers part of the tax to consumers. Because it avoids taxation, firm B gains a competitive advantage. As a result of this competitive advantage, it reduces the variety differentiation by moving closer to y_a and it increases p_b without varying the nutritional quality x_b. The variation of the price ratio p_a / p_b induced by the tax faced by firm A and the reduction in the variety differentiation leads some consumers to switch from product A to B. In this area, product B's market share is thus higher than the market share observed in the benchmark.

In area 2, when x_{min} increases, firm B transfers some of the cost associated with the improvement in product B's nutritional quality to consumers. As product B moves further on the horizontal axis (y_b increases), the competition intensity diminishes, and the price of the taxed product A increases. In this area, product B's market share diminishes as x_{min} increases. Firm B's market share is higher than the observed market share in the benchmark only if $x_{\min} < \overline{x}_b$.

In area 3, firm B faces the tax and chooses a quality x_b lower than the quality it produces without constraint. Price p_b is thus lower than the price observed in the benchmark, and its market share is greater.

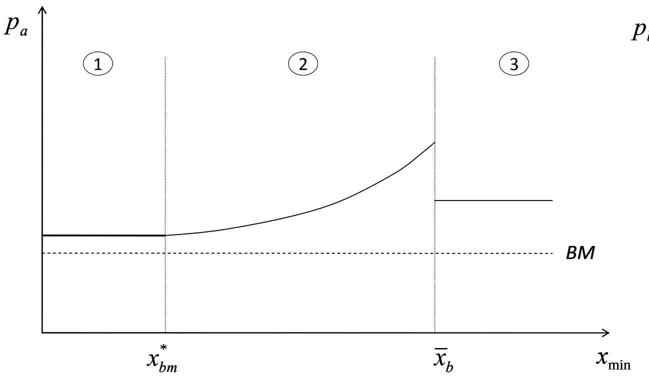

Figure 3a

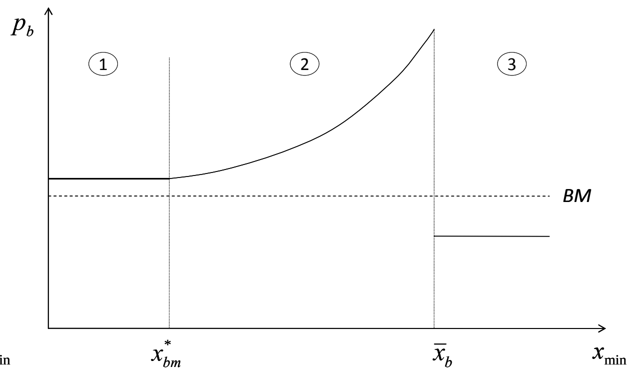

Figure 3b

Impacts on health benefits

In general, product B's market share D_b in the whole population decreases as the nutritional quality standard x_{min} increases, whereas the product's quality is increasing (as long as $x_{\min} < \overline{x}_b$). The health effects depend on the relative variation of D_b and x_b in each of the identified areas (cf. Figure 4a).

In area 1, the overall health benefits H_T increase in comparison to the benchmark. Some consumers move from product A to product B because of the change in the price ratio p_a / p_b. Compared with the benchmark, the quality of product B has not changed.

In area 2, product B's market share D_b diminishes and the nutritional quality x_b increases. Here, the quality effect dominates; even if fewer consumers purchase product B, the improvement in the quality x_b alone can increase H_T.

In area 3, the quality x_b, product B's market share and the overall health benefits, H_T, are lower than in the benchmark.

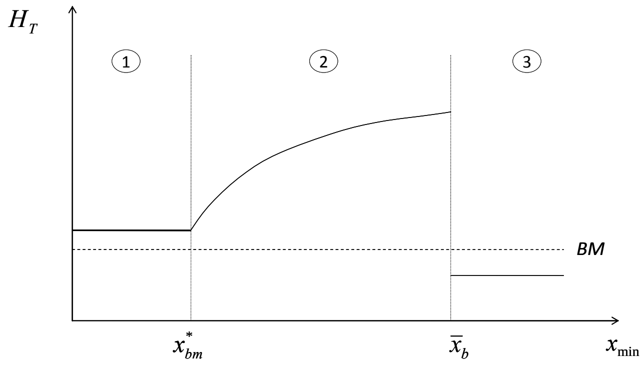

Figure 4a

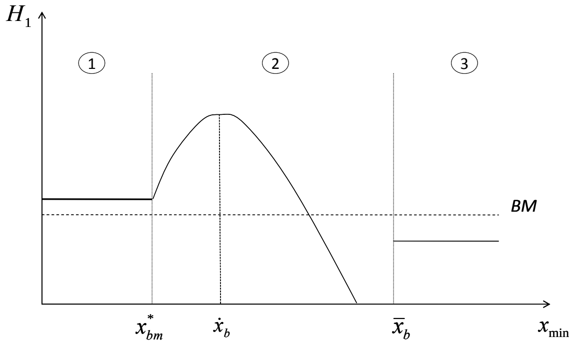

Figure 4b

The results for consumer group 1 (cf. Figure 4b) differ from those observed for the overall population. In area 2, when x_{min} increases, the quality effect dominates the decrease in the market share D_{b1} and the health benefits for consumers who purchase product B are greater than the health losses linked to the consumers who give up product B as a result of its increase in price. These effects reverse at $x_{\min} = \dot{x}_b$, at which point the loss in the market share D_{b1} leads to a deterioration in consumer group 1's health. The quality standard that maximizes the health benefit for consumer group 1 is thus lower than the quality standard that maximizes the health benefit for the whole population. Furthermore, if the standard is too restrictive, the health benefits for consumer group 1 deteriorate and become lower than that observed in the benchmark. Health inequalities (represented by the ratio H_2 / H_1) become larger in area 2 (cf. Figure 5). When the minimum quality threshold $x_{\min} < \dot{x}_b$, the health gain with respect to the benchmark relies on both the increase in product B's market share and the improvement in quality. As a consequence, the health disparity is reduced. When $\dot{x}_b < x_{\min} < \overline{x}_b$, the health gain relies only on the increase in nutritional quality, and fewer consumers purchase product B when compared to the benchmark.

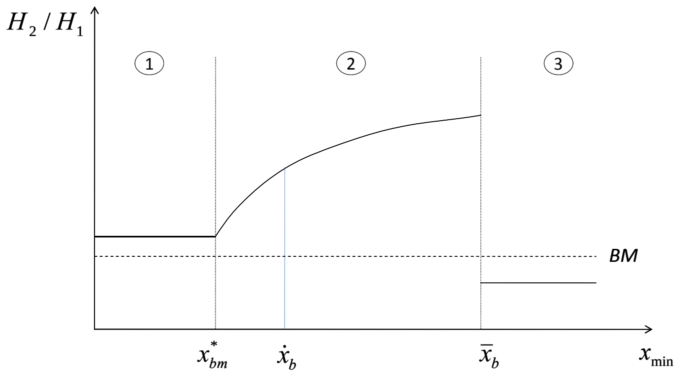

Figure 5

2.2. Impacts of the tax rate

Previously, the tax level was assumed to be a constant. We now examine how our results change with changes in the tax level.

When the minimum quality threshold is not strongly restrictive ($x_{min} < \bar{x}_b$), an increase in the tax level does not affect the nutritional quality; however, it changes the competition in terms of variety. Firm B chooses the nutritional quality x_{bm}^* if $x_{min} < x_{bm}^*$ and x_{min} if $x_{bm}^* < x_{min} < \bar{x}_b$ while the variety y_b decreases with the tax t (Figure 6). The greater the tax becomes, the more firm B is able to choose a variety close to y_a and the more the incumbent firm A is penalized. Furthermore, firm B is able to increase its market share. Both prices p_a^* and p_b^* increase.

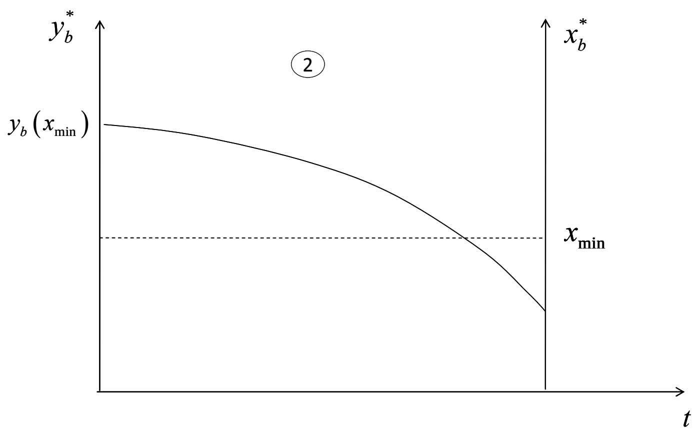

Figure 6

When the minimum quality standard is strongly restrictive ($x_{\min} > \overline{x}_b$), both firms face the increase in the tax level. Firm B decreases both its nutritional quality and its variety with the tax.

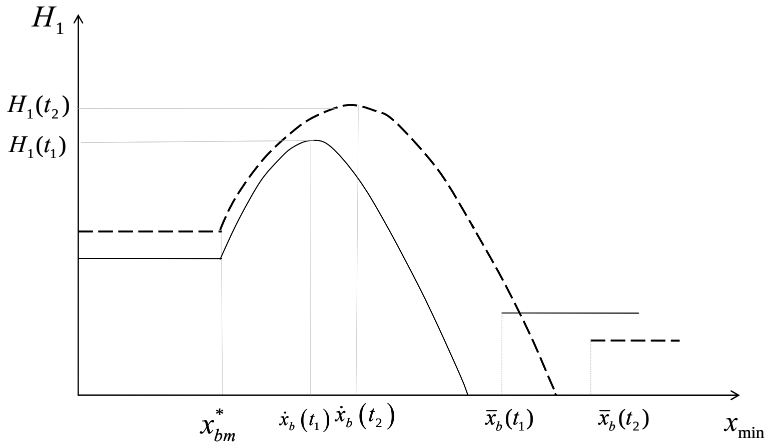

Figure 7

The tax level produces two opposing effects on health benefits. The increases in the tax improve the overall health benefits, but this improvement varies between the consumer groups. The higher the tax, the greater the potential health benefits are for population 1 ($\dot{x}_b(t_1) < \dot{x}_b(t_2)$, Figure 7). Thus, increases in the tax level reduce the health inequalities.

3. Discussion

The main goal of this paper was to assess the effects of nutritional policies that aim to modify consumer food choices by taking into account firms' reactions to nutritional policies, particularly in terms of product quality and price. From this analysis, we were able to determine a health index that makes it possible to introduce a cost-benefit analysis of these public policies.

The modeling proposed here is based on several assumptions that are important to keep in mind. First, we assumed that consumers' decisions result from a trade-off that depends on two types of product characteristics in addition to the price of the marketed products: a dimension quantifying nutritional quality, for which consumers are assumed to have a heterogeneous willingness's to pay; and a variety dimension that expresses differences in consumers' preferences for the combined non-nutritional characteristics of the products.

Second, we considered a duopoly comprised of an incumbent firm that markets a product with fixed quality and variety characteristics and a firm entering the market that can decide to introduce a healthier product to the market. Here, we adopted an assumption used by Salop (1979), who investigated the conditions of entry for new products when the incumbent firm only reacted by adjusting price. Thus, we aimed to determine the conditions of introduction for a new, nutritionally improved product when the incumbent firm markets a product without nutritional benefit but is able to obstruct the entry of the new product by adjusting its pricing reaction.

Finally, we examined the health effects on the population by proposing a health index in which the population's health is improved either by the increase in the nutritional quality from the new product or by an increase in its market share.

Within this framework, we were particularly interested in a public intervention based on a nutritional tax, the implementation of which is accompanied by the quality efforts carried out by the firms. Thus, whereas the incumbent firm is systematically taxed because it always produces a null quality, the entering firm can be exempted from tax if the product it markets is of a quality that is higher than the minimum threshold defined by the public authorities. Public authorities thus have two ways to influence the firms' behavior: by adjusting the minimum quality threshold of the new product and the level of the tax. A priori, the interest of such a taxation policy is to let the firms choose their responses and decide either to accept the tax and not attempt to produce a higher quality product or to avoid the tax by improving the quality of the marketed product.

Initially, we determined the firms' decisions relating to price, quality and variety at the market equilibrium in the absence of public intervention. Naturally, as soon as a fraction of the population is willing to pay for a higher nutritional quality, the entering firm may find it beneficial to offer a product that is differentiated from the product already available on the market. The stronger the willingness of the more health-conscious population is to pay for the nutritional dimension, the higher the nutritional quality chosen by the entrant firm, but the closer the two products will be on the variety axis. One finds a classical result of double differentiation models: at equilibrium the firms choose a maximum differentiation on one axis and a minimal differentiation on the other. To limit its loss of market share related to the entry of the new product, the incumbent firm can decrease the price of the low quality product. From a public health point of view, two effects must be considered: the positive effect associated with the introduction of a higher nutritional quality product and the negative effect associated with the drop in price of the low quality product. Interventions seeking to better inform consumers influence this equilibrium and the degree of heterogeneity between the consumer groups. Thus, if this degree of heterogeneity is strong, the increase in the willingness of consumers, who are already sensitive to health issues, to pay pushes the entering firm to raise its level of quality and its price. Therefore, the product becomes progressively less accessible to consumers that are less sensitive to health issues, leading these consumers to rely more largely on the low quality product. A drop in the price of the low quality product reinforces this effect.

Compared to an unregulated situation, taxation policies allow for increases in health benefits related to food consumption under some conditions.

Of course, the minimum threshold defined by the authorities that allows the entering product to avoid taxation must be higher than the quality spontaneously chosen by the firm in the unregulated situation. However, the minimum threshold of quality imposed on the entering firm must remain moderate. Beyond a certain threshold, the entering firm will prefer to pay the tax; in such a case, the quality of the new product will be lower than the benchmark quality. As a result, the health benefits for the whole population will be weaker than in an unregulated case. Furthermore, when the threshold is too high, the health benefit decreases most significantly for the population that is not sensitive to the health issue (even if the benefit for the whole population continues to grow). Thus, if the minimum threshold is too high, the non-sensitive consumers are disproportionately penalized and health disparities within the population will be increased.

This result is due to the fact that the tax, if the entering firm decides to avoid it, gives an advantage to the new firm and penalizes the incumbent firm. The new entrant can then produce a higher quality product than in the unregulated case while at the same time getting a larger market share and increasing its price. The incumbent firm that bears the taxation transfers a part of this tax to the final price. However, this price increases more slowly than the high quality product price, as the incumbent firm tries to limit its loss of market share. If the minimum threshold remains moderate, the health effect resulting from the improvement in the differentiated product quality dominates the health degradation that results from the consumption displacement toward the low quality product. Beyond a certain threshold, the phenomenon is reversed.

Increases in the tax level improve the health benefit for the whole population while reducing health disparities. This result is due to the fact that the tax does not have an effect on the nutritional quality chosen by the entering firm but affects its variety choice. The greater the taxation level, the more the incumbent firm is penalized and the closer the products will be in terms of variety. The health benefit induced by the tax is thus related to the increase in the market share of the new product and not to any increase in its nutritional quality. Conversely, increasing the minimum quality threshold causes a beneficial effect (assuming this threshold is not too high) by increasing the quality of the new product (of course, the market share of the new product decreases as the minimum threshold increases).

From a public health perspective, it seems that authorities should not implement an excessively high minimum quality threshold and should instead implement a high tax. However, this conclusion must be tempered by considering the economic impact of taxation. Indeed, it has been shown that the prices of the two products will increase when the tax level increases. An increase in health benefits, particularly among consumers that are less sensitive to nutritional issues, may be observed; however, an increase in food expenditures will also be observed, particularly among the less sensitive consumers. Thus, an increase in the tax level can reduce health disparities but increase economic disparities.

The robustness of this study's results should be evaluated by further investigating some complementary issues. For example, at this stage we have assumed that the health effect was a linear function of the products' nutritional quality. If we assume a nonlinear function, the results of this study would likely be affected. In addition, we assumed that the two dimensions, the product quality and variety, were independent. It would be interesting to examine a case in which the improvement of nutritional quality affects the taste of the products and thus affects their positioning in the variety category.

In addition, it would be interesting to analyze the combined effects of an information policy (which alters consumer preferences for nutritional quality) and a taxation policy in more detail while remaining within the framework adopted in this paper. We have shown that an information policy may induce an increase in health disparities whereas taxation policy can, under certain conditions, reduce them. It would be interesting to identify the optimal policy-mix, particularly when one considers that the tax revenues can be used to fund the information policy. These issues will be further investigated in later research.

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