Reformulation and taxes for healthier consumption: Empirical evidence in the French Dessert market

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Abstract

Noncommunicable diseases (NCDs) led to 74% of all deaths worldwide in 2019. Unhealthy diets are a major driver of NCDs. To discourage consumption of less healthy foods and promote a healthier food environment, many countries have implemented regulatory measures. Fiscal policy is one of these, as taxes have been successful in reducing the consumption of sugar-sweetened beverages. However, policymakers still have little guidance on how to design taxes to promote healthier diets and foods. The objective is to fill this gap by determining the potential equilibrium effects of a tiered sugar-based tax on unhealthy products on consumer purchases, nutrient consumption and welfare, firms' pricing decisions, and firms' profits when firms do or do not engage in product reformulation. In this paper, we develop a structural econometric model that incorporates consumers' substitution patterns across products, takes into account competition among firms, and allows for the possibility that firms respond strategically in terms of pricing and may change the taste of products in response to taxation. Using household scanner data from the French dessert market, we show that the lower the tax threshold, the more efficient the tax policy in terms of sugar consumption reduction, but the larger the reduction in consumer surplus and profits. We also show that there is a certain level of tax threshold at which firms may experience less profit loss from the tax policy if they reformulate, thereby achieving both greater sugar consumption reduction and less consumer welfare loss.

JEL codes: H32, L13, Q18, I18

Key words: Taxation, strategic pricing, product reformulation

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1 Introduction

Noncommunicable diseases (NCDs) were responsible for 74% of all deaths worldwide in 2019 (Institute for Health Metrics and Evaluation (IHME), 2020). The Global Action Plan (GAP) for the Prevention and Control of NCDs 2013-2020 provides a roadmap and menu of policy options to reduce mortality from NCDs and exposure to risk factors (World Health Organization et al., 2013). Under Objective 3 of GAP, one of the policy options proposed is the use of economic instruments, including fiscal policy, to discourage the consumption of less healthy foods and promote a healthier food environment. One particular fiscal policy that has received considerable attention is a tax on sugar-sweetened beverages (SSBs), which was implemented in 38% of countries worldwide in 2019 (World Health Organization et al., 2022). SSB taxes have been effective in reducing purchases of targeted SSBs by an average of -15% through increases in their prices (Andreyeva et al., 2022). Food taxes are less widely implemented, but adoption is increasing, from seven Member States in 2017 to 29 in 2022 (World Health Organization et al., 2022). They have also shown promise in reducing purchases of targeted foods, as observed in Mexico and Hungary.[1] However, due to the narrow scope of the existing taxes, their impact on overall dietary intake is correspondingly small (World Health Organization et al., 2022). Accordingly, health authorities are considering extending them to more unhealthy foods (World Health Organization et al., 2016; Department for Environment, Food and Rural Affairs, 2020; Hepatology, 2020).

To ensure their effectiveness in promoting healthy diets, both by reducing purchases of the targeted products and by encouraging product reformulation, the elements of the tax should be carefully designed (i.e. the type of tax, the coverage of foods and beverages taxed, and the tax rate). However, little is known about the potential equilibrium effects of different designs of a tax on unhealthy products on consumers' purchases, nutrient consumption and welfare, firms' pricing decisions and profits when firms do or do not engage in product reformulation. The main objective of this study is to fill this knowledge gap for an excise tax based on the sugar content of products, with a tier above which the product is taxed. Particularly, the analysis will focus on how and to what extent the level of the sugar tax threshold changes equilibrium market outcomes, and nutrient consumption when firms do

[1] In Mexico, non-essential foods with an energy density greater than 275 kcal/100 g are taxed (World Cancer Research Fund International, 2022). The Hungarian "Public Health Product Tax" targets products high in sugar, salt and/or caffeine (Bíró, 2015; World Cancer Research Fund International, 2022).

or do not engage in product reformulation. This analysis can thus provide important guidance to policy makers seeking to develop effective strategies to promote healthier diets.

We choose this tax design because it is gaining theoretical and empirical recognition (World Health Organization et al., 2022). (Duvaleix-Tréguer et al., 2012) and (Réquillart et al., 2016) show theoretically that a firm prefers to reformulate its product to avoid such a tax, provided that the threshold is not too low, leading to positive health and welfare outcomes. Moreover, a growing body of empirical evidence suggests that this kind of design not only reduce sugar purchase from SSBs and encourages consumers to switch to lower-sugar SSBs (Grummon et al., 2019; Scarborough et al., 2020; Pell et al., 2021; Andreyeva et al., 2022), but also motivates manufacturers to reduce the sugar content of their beverages (Scarborough et al., 2020; Pell et al., 2021; Goiana-da Silva et al., 2020; Stacey et al., 2019). The response to the UK Soft Drinks Industry Levy (SDIL) was closely scrutinized and shows that firms tend to reduce the amount of added sugar to bring the sugar content just below the tax threshold (Scarborough et al., 2020; Pell et al., 2021).

We focus our analysis on the dessert market, i.e. compotes, yogurts, fromages blancs/petits suisses (FBPS) and other dairy desserts (ODD). Desserts are well suited for this analysis because they are important contributors to simple carbohydrate intake. In particular, yogurts and FBPS are the second largest contributors to the sugar intake of French children aged between 1 and 10 years in 2014-2015 (Agence nationale de sécurité sanitaire de l'alimentation, 2017). Second, there is room for product reformulation, as there is great heterogeneity in the sugar content of products within each product family (see Table 2 below). Third, these products consist of several ingredients in addition to sweeteners. This makes the analysis of product reformulation more interesting in the sense that a reduction in the sugar content of a product from added caloric sweeteners may be accompanied by an increase in the content of some other nutrients, such as fat from milk or fructose from fruit. The net impact on health may be positive or negative, depending on the product recipe changes and consumer response to changes in product characteristics, including price.

To achieve our main objective, which is to measure the equilibrium outcomes of different tax designs, we develop and estimate a four-step structural framework that incorporates both consumers behavior, firms' strategic pricing decisions and realistic reformulation responses to the tax that incorporate technical formulation constraints, such as sweetness, texture, fermentation, and gelling processes, as well as regulatory constraints, if any. First, we estimate consumer preferences for price and product characteristics using a random coefficient logit model. This allows us to capture heterogeneity in observed and unobserved consumer preferences and obtain flexible substitution patterns between differentiated products in the market. By understanding consumers' preferences, we can assess how changes in product characteristics, such as price or sugar taste, may affect their choices and purchasing behavior. Second, we develop a supply model that incorporates price competition among firms to estimate the marginal costs and margins associated with each product. Third, we model the recipes of all existing products, determine a technically feasible and sensorially acceptable reformulation scenario, assuming that firms decide to reformulate their products to avoid the tax altogether, and calculate the induced changes in production costs. i.e. reducing the amount of added sugar to bring the sugar content just below the tax threshold, as observed in response to the UK SDIL (Scarborough et al., 2020; Pell et al., 2021). Finally, we propose a counterfactual exercise to evaluate the impact of a one-tiered design tax based on product sugar concentration. Using the structural demand and supply model developed and estimated, we simulate and compare the new market equilibrium under three types of counterfactual scenarios: a taxation scenario, a taxation scenario with reformulation, and a reformulation scenario (based on the same assumption as the second scenario). For these scenarios, we evaluate the effect of different levels of tax thresholds and assume that companies respond strategically in price.

Our results highlight two key findings. First, the choice of the tax threshold strongly affects the share of taxed and reformulated products, the magnitude of the tax-related price increase, and the magnitude of the welfare effects: the lower the tax threshold, the more efficient the tax policy in terms of sugar consumption reduction, but the greater the reduction in consumer surplus and profit. Second, there is a certain level of the tax threshold at which firms may experience less profit loss from the tax policy if they reformulate, thereby achieving both greater sugar consumption reduction and less consumer welfare loss due to smaller tax-related price increases than under the tax policy in which firms do not reformulate.

Overall, firms lose less profit from the tax policy when they reformulate at these tax thresholds, reinforcing the validity of our assumption that firms will behave as observed in response to the UK SDIL. Furthermore, our analysis shows that the tax-with-reformulation scenario allows better targeting the households with the highest consumption level and households with obese individuals, i.e. the at-risk population.

This paper contributes to the existing literature on the reaction of firms facing a regulatory measure. While previous studies have examined the price adjustments firms are likely to make due to taxation (Bonnet and Réquillart, 2013; Nesheim et al., 2018; Allais et al., 2015; Dubois et al., 2018), to our knowledge only one empirical study has integrated the potential changes in product characteristics resulting from policy interventions (Barahona et al., 2023). While they analyzed the equilibrium effects of implementing a warning label and a tax proportional to the amount of sugar in the product, our study focuses on the effects of a tiered sugar-based tax. In contrast to (Barahona et al., 2023), which assumes that sugar is replaced by artificial ingredients to maintain taste as firms reformulate their products, our analysis includes the demand response to changes in product taste due to sugar reduction, which is assumed to be compensated by an increase in milk for yogurt and FBPS, or fruit for compote. Our assumption seems to be a more credible reformulation scenario given the low proportion of dessert products with artificial sweeteners marketed in France (10% in our dataset). We consider that consumer choices may shift as product characteristics, such as sweetness, change in response to the tax. By considering this demand-side response, we can provide a more complete understanding of how consumers may adjust their choices and behavior in the face of tax-induced changes in product taste.

Our study also relates to the existing literature that examines the effects of tax policy on product characteristics. Theoretical analyses have shown that tax policies can induce firms to change the characteristics and composition of their products (e.g., Duvaleix-Tréguer et al., 2012; Réquillart et al., 2016). Thus, the inclusion in our methodology of the possibility for firms to reformulate their products is crucial to obtain an accurate and relevant assessment of the tax, all the more so from the perspective of assessing the consequences of the policy on health. If firms respond to this "quality" incentive by reducing the content of the taxed nutrient, consumers' nutrient intakes will be affected, regardless of whether or not consumers change their consumption of taxed products. According to our results, ignoring the combined effect of price reactions and product reformulation leads us to significantly underestimate the impact of taxes on the intake of taxed nutrients. In our case, integrating these two effects into the analysis yields a change in the estimated reduction in caloric sweetener intake of 37 %, which is of the order of (Bercholz et al., 2022).

The rest of the paper is organized as follows. Section 2 introduces the data and provides a descriptive analysis of the French dessert market. Section 3 describes the models and methodology. Section 4 presents the demand and supply estimates. Section 5 presents the impact of our simulations on consumption, market equilibrium, and profits. Finally, Section 6 focuses on the heterogeneity of the impacts, while Section 7 discusses the validity of our main assumptions and the robustness of our results. In Section 8, we acknowledge some limitations and highlight what could be done in subsequent work.

2 Data and dessert market

We use data from a French representative consumer panel data of 20,144 households collected by KANTAR Worldpanel. This is a home-scan data set providing detailed information on all purchases of food products. In this work we consider all purchases of desserts over the period January-May 2009, corresponding to more than 1,600,000 observations. In particular, quantities, prices, brands, and characteristics of goods are registered. The relevant market is the whole dessert market, except ice cream; a rarely purchased product in France during the period of time chosen accounting for less than 1% of the average dessert budget share over the period. Specifically, we define four broad dessert categories as follows: yogurts (plain; sweetened; flavored; with fruits), Fromages Blancs/Petits suisses - FBPS - (plain; flavored; with fruits),[2] Other Dairy Desserts - ODD - (cream desserts; 'crême brulée' desserts; coffee and chocolate mousses; style custard flans, French rice puddings; floating Island desserts[3]) and fruit compotes or stewed fruits. We classify yogurts and FBPS into brand, fat content, sugar content and flavor categories.[4] We distinguish 13 primary national brands (NBs), and and merge all private label brands into one brand (PL). We get 75 different yogurts and 41 different FBPS. We have nine different compotes defined by brand and sugar content level.[5] ODDs are only brand differentiated. Overall, the household product set is composed of 131 differentiated products. Consumers can substitute the considered products with an alternative product, the so-called 'outside option', which includes other desserts (fruits and pastries), as well as cheese that is a substitute

[2]Fromage blanc is a creamy, soft, fresh, white cheese made with whole, semi-skimmed or skimmed milk. Petit suisse is creamy fresh cheese, with a cylindrical shape, the fat and dry extract contents of which are regulated, often targeted for children.

[3]A classic French dessert that consists of meringue floating on a sea of vanilla custard

[4]We define three fat content categories: full-fat (more than 3% fat for yogurts, more than 5% fat for FBPS), semi-skimmed (between 1% and 3% fat for yogurts, between 2% and 5% fat for FBPS), and skimmed (fat close to 0%); and four sugar content and flavor categories (plain, sweet, flavored, and with fruits) for yogurts and three sugar content and flavor categories (plain, flavored, with fruits) for FBPS.

[5]We define three sugar content categories: pure blended fruit without added sugar; low-added-sugar; and with-added sugar.

for dairy products in desserts in many cases in France. The outside option represents 60% of the entire market on average.[6]

Products' nutritional characteristics are not collected by Kantar. We use data from the French Food Observatory Oqali[7] and other data sources[8] to obtain the ingredient lists and the nutritional composition (values of the sugar, fat, protein and calorie content) of the desserts.

Table 1: **Average prices (€/kg) and market shares (%) by brands and product categories.**

	Compotes		Yogurts		Fromages blancs, petits suisses		Other dairy desserts	
	Price	MS	Price	MS	Price	MS	Price	MS
Firm 1								
Brand 1			2.58	1.78	3.32	1.19	3.08	2.04
Brand 2			2.08	0.56	3.22	0.31	4.01	0.34
Brand 3			4.96	0.13				
Brand 4			3.58	0.59				
Brand 5			2.70	1.92	4.05	0.60		
Firm 2								
Brand 6			2.42	1.19	5.52	0.11	3.87	2.30
Firm 3								
Brand 7			1.95	0.62	2.74	0.54	3.91	0.12
Brand 8			2.23	0.99				
Brand 9			2.30	0.38				
Firm 4								
Brand 10	3.33	0.62	2.75	0.42	2.68	0.09	4.88	0.72
Firm 5								
Brand 11	3.34	0.59					4.67	0.20
Firm 6								
Brand 12			2.94	0.21	3.60	0.08	6.12	0.49
Brand 13			3.71	0.19			3.82	0.20
PL firms	2.28	3.00	1.80	7.21	2.41	3.25	2.72	6.92
All	2.58	4.20	2.24	16.20	2.89	6.16	3.31	13.33

Product categories: Compotes, Yogurts, Fromages blancs, petits suisses, Other dairy desserts.

The reported prices of a brand and a category is the weighted average (using market shares as weights) of the prices of this brand in this category over the different retailers. MS stands for Market Shares.

Table 1 reports weighted average prices and market shares for the four broad dessert categories by brands. Compote, yogurts, FBPS, and ODD account for about 4%, 16%, 6%, and 13% of all dessert purchases, respectively.

[6]The outside option also includes minor brands producing products from the four categories analyzed. All of these minor brands account for only 2% of the whole market. Because we do not have precise information on these brands, we integrate them into the outside option.

[7]Oqali is the French Food Observatory. Its implementation has been entrusted to a research institute, INRAE (French National Research Institute for Agriculture, Food and Environment) and to a food safety agency, ANSES (French Agency for Food, Environmental and Occupational Health and Safety). It aims to monitor changes in processed foods' supply available on the French market, by measuring nutritional quality evolution, over time (nutritional composition and labelling information).

[8]The other data sources could be Open Food Facts, a free, online and crowd-sourced database, or the website of the brands or manufacturers.

Their respective average price per kg is €2.58, €2.24, €2.89, and €3.31. For each of the four product categories, PL brands are the cheapest and have the highest market shares. This is a market feature that is now common for many food product categories and may be due to the fact that consumers no longer perceive large quality differences between PL and NB products. Another feature of this market is the heterogeneity in NB product prices within each category, except for NB compotes that are produced by two firms only. Yogurt prices are the highest for brands that sell products reducing cholesterol (Brand 3), probiotics (Brand 4, Brand 5), and soy milk (Brand 13) yogurts. The other dairy dessert prices range from €2.72 to €6.12 per kg. The large difference in prices is mainly due to the high heterogeneity of the products within the category.

Table 2 provides the caloric sweetener content (denoted 'Content' in the table) and an index of sweetness (denoted 'Taste' in the table) of products per brand and product category. The caloric sweetener content includes both naturally present sweeteners, such as lactose in milk or fructose in fruits, and added caloric sweeteners, such as sugar or glucose. Product sweetness index is our proxy for product 'sugar' taste, including both the quantity of caloric sweeteners and the presence of non-caloric sweeteners. For products that contain some (or only) artificial sweeteners, we proxy their sweetness index by the sweetness of a similar product that does not contain any artificial sweetener. The quantities of caloric sweetener per 100g of the 131 products and the presence of non-caloric sweeteners are retrieved from the ingredients lists and the nutrition facts provided by the French Food Observatory Oqali (see appendix sub-section 9.2 for details).

Table 2 shows a large heterogeneity in the average caloric sweetener content of products by brand within the yogurt and FBPS categories. ODD have the highest content, 17.0g per 100g of products on average, ranging from 11.2 to 20.1g depending on the brand. Yogurts and FBPS have the lowest mean contents, 9.7g and 7.8g, respectively. The average content of compotes is 14.7g. On average, the taste index is greater than the content in caloric sweetener for eight brands over the 13 brands of the yogurt category, and the difference, in some cases, is greater than 50%. In most cases, brands with the lowest caloric sweetener content use artificial sweeteners. As a consequence, the heterogeneity in taste is much lower than the heterogeneity in caloric sweetener content. Table 18 (in the Appendix) provides the fat content of the products. Compotes have virtually no fat (0.3g on average), ODD are characterized by a large heterogeneity in fat content and have the highest content (5.4g on average), followed

Table 2: **Content in caloric sweeteners and sweetness index (taste) by brands and product categories (g / 100g of product).**

	Product categories							
	Compotes		Yogurts		Fromages blancs, petits suisses		Other dairy desserts	
	Content	Taste	Content	Taste	Content	Taste	Content	Taste
Firm 1								
Brand 1			9.96	9.96	9.20	9.20	20.05	20.05
Brand 2			6.42	10.18	4.97	8.09	11.20	17.70
Brand 3			5.27	8.82				
Brand 4			7.33	11.06				
Brand 5			9.72	11.09	8.46	8.46		
Firm 2								
Brand 6			9.11	10.60	19.37	19.37	16.46	16.68
Firm 3								
Brand 7			11.08	11.08	5.91	5.91	16.90	16.90
Brand 8			11.16	13.88				
Brand 9			12.20	12.20				
Firm 4								
Brand 10	14.52	14.52	13.83	13.83	2.80	2.80	15.92	15.92
Firm 5								
Brand 11	14.82	14.82					14.11	14.11
Firm 6								
Brand 12			5.46	7.75	3.29	3.29	17.66	17.66
Brand 13			6.09	6.09			12.10	12.10
PLs	14.77	14.77	9.76	10.79	7.56	7.62	16.76	16.76
Average	14.74	14.74	9.69	10.91	7.77	7.96	16.95	17.15
Min	10.70	10.70	1.50	1.50	2.70	2.70	11.20	11.70
First quartile	11.65	11.65	4.80	6.00	3.60	3.60	14.75	15.20
Median	14.40	14.40	10.15	12.10	4.55	4.55	16.40	16.85
Third quartile	17.53	17.53	13.10	13.50	12.60	12.90	18.60	18.60
Max	18.60	18.60	17.20	17.20	21.60	21.60	22.70	22.70

For each brand and product category, we report the weighted average content of sweetener computed over all the different products of a brand.

by FBPS (4.0g), and lastly, yogurts (2.6g).

Figure 1 shows the distribution of products regarding their sugar content within the French market. Although there are some products in the low-sugar category (4-6g per 100g), the distribution of products is more dense between 12-18g of sugar per 100g of product. Therefore, a taxation scheme with a threshold higher than 6-8g per 100g should encourage the substitution of less sweetened products and reduce the consumption of a wide range of products.

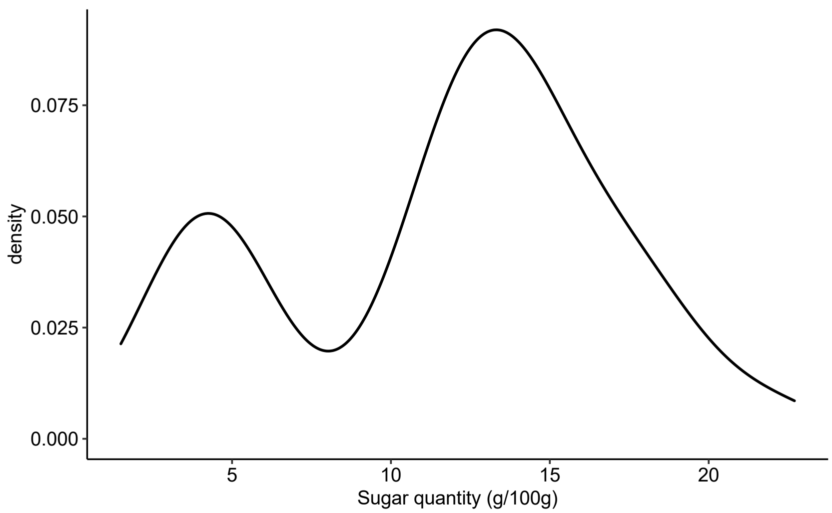

Figure 1: Content of sugar in the dessert market

Overall, according to Table 26, French households buy 32 kgs of desserts (dairy dessert and compote) per year and per capita[9] in our sample, which corresponds to a sugar intake of 3.9 kgs per year and per capita or to an individual consumption of almost 2 tea-spoons per day on average for the dessert consumption. This dessert consumption varies according to the household characteristics. Households without children consume more desserts, 39 kgs on average, resulting in twice the sugar intake from desserts compared to households with children. We also observe a higher consumption when the household is composed of obese individuals or when the household is richer.

[9]The per capita consumption is computed considering adults as one unit and children as 0.5 unit.

3 Models and methods

Our analysis is based on the following methodology. We first consider a flexible demand model to obtain the price elasticities of demand for every product. The model needs to be as flexible as possible, and we therefore opt for a random coefficient logit model (Berry et al., 1995; McFadden and Train, 2000). We estimate the model using individual data and consider the observed and unobserved heterogeneity of consumers. Second, we model the supply side assuming an oligopolistic competition between manufacturers. The model provides estimates of marginal costs and margins. Third, using estimated marginal costs and input price data, we compute the cost change due to the product reformulation scenario assumed. Finally, we present the simulation method used to assess the impact of product reformulation and the impact of the two tax policies with and without reformulation on several market outcomes, such as equilibrium prices, market shares, firm profits, and nutrient consumption.

3.1 The demand model: a random coefficient logit model

We use a random coefficient logit model to estimate the demand model and compute the related elasticities between products. The indirect utility function V_{ijt} for household i buying product j belonging to brand b, denoted $b(j)$, for $j = 1, ..., J_t$, in period t is given by:

$$V_{ijt} = \beta_{b(j)} + \gamma_{c(j)} - \alpha_i p_{jt} + \delta_{Si} S_j + \delta_{Li} L_j + \delta_{SL} S_j L_j + \theta_N N_j + \theta_F F_j + \varepsilon_{ijt}$$

where $\beta_{b(j)}$ is a brand fixed effect that capture time-invariant unobserved brand characteristics, $\gamma_{c(j)}$ is a dessert category fixed effects that controls for time-invariant unobserved household's preferences for the categories, p_{jt} is the price of product j in period t, α_i is the marginal disutility of price for household i, S_j is the sugar taste of product j, and δ_{Si} captures the taste for sugar of the household i, L_j is the fat content of product j, and δ_{Li} captures the preference for fat taste of the household i, δ_{SL} captures consumer preference for fat and sugar taste, N_j is a dummy related to the natural flavor of product j and θ_N captures consumer taste for this characteristic, F_j is a dummy if product j contains fruits in dairy desserts and θ_F captures consumer taste for this characteristic and ε_{ijt} is an unobserved individual error term.

We also allow sugar and fat tastes to vary across households characteristics.

$$\delta_{Si} S_j = \delta_S S_j + \delta_S^c S_j C_i + \delta_S^o S_j O_i$$

$$\delta_{Li}L_j = \delta_L L_j + \delta_L^c L_j C_i + \delta_L^o L_j O_i$$

Households are differentiated according to the presence of children below 18 years-old C_i (household with or without children) and the number of obese individuals within the household O_i (no obese, at least one obese individual or all individuals are obese). The coefficients δ_S^c and δ_L^c allow the marginal effects of sugar and fat taste on the utility function V_{ijt} to shift with the presence of children, and the coefficients δ_S^o and δ_L^o to shift with the number of obese individuals within the household.

In our model, households can have a different price disutility; the α_i varies across households. First, we assume that the distribution of α_i follows a lognormal distribution and is a function of household characteristics with α, α^c, α^o, α^I and σ as parameters:

$$\alpha_i = \exp(\alpha + \alpha^c C_i + \alpha^o O_i + \alpha^I I_i + \sigma \nu_i) \quad \text{where} \quad \nu_i \sim \mathcal{N}(0,1) \text{ captures unobserved consumer attributes}$$

where I_i stands for household's income level, O_i stands for the obesity status of the adults in the household and C_i categorises households according to the presence of children and/or teenager.

The household can decide not to choose one of the considered products. Thus, we introduce an outside option that permits substitution between the considered products and a substitute, define in section 2. The utility of the outside good is normalized to zero. The indirect utility of choosing the outside good is $V_{i0t} = \varepsilon_{i0t}$.

Assuming that ε_{ijt} is independently and identically distributed as an extreme value type I distribution, we are able to write the market share of product j at period t in the following way (Nevo, 2001):

$$s_{jt}(\theta) = \int \frac{\exp(\beta_{b(j)} + \gamma_{c(j)} - \alpha_i p_{jt} + \delta_{Si}S_j + \delta_{Li}L_j + \delta_{SL}S_jL_j + \theta_N N_j + \theta_F F_j)}{1 + \sum_{k=1}^{J_t} \exp(\beta_{b(k)} + \gamma_{c(k)} - \alpha_i p_{kt} + \delta_{Si}S_k + \delta_{Li}L_k + \delta_{SL}S_kL_k + \theta_N N_k + \theta_F F_k)}\, dP_\nu(\nu_i) dP_D(D_i) \tag{1}$$

where P_ν is the cumulative normal distribution function of ν, $D_i = (O_i, I_i, C_i)$ is the vector of demographics, P_D is the cumulative normal distribution function of D and θ is the vector of demand parameters to be estimated.

The random coefficient logit model generates a flexible pattern of substitutions between products that is driven by the different household price disutilities α_i, such that, the own- and cross-price elasticities of the market share s_{jt} take the following forms:

$$\frac{\partial s_{jt}}{\partial p_{kt}} \frac{p_{kt}}{s_{jt}} = \begin{cases} -\frac{p_{jt}}{s_{jt}} \int \alpha_i s_{ijt}(1 - s_{ijt})\, dP_\nu(\nu_i dP_D(D_i)) & \text{if } j = k \\ \frac{p_{kt}}{s_{jt}} \int \alpha_i s_{ijt} s_{ikt}\, dP_\nu(\nu_i dP_D(D_i)) & \text{otherwise,} \end{cases} \tag{2}$$

where s_{ijt} stands for the probability that a household i chooses product j at time t.

3.2 Supply model

We consider F manufacturers that compete in prices on the dessert market. By doing so, we abstract from the role of retailers in setting prices of NBs. We assume that the prices of PLs are chosen by a 'specific' manufacturer representing the retailers price decisions. Formally, a manufacturer maximizes its profit:

$$\Pi_t^f = \sum_{j \in G_{ft}} [M_t(p_{jt} - c_{jt})s_{jt}(p)]$$

where G_{ft} is the set of products that are sold by manufacturer f at period t, M_t is the size of the market at time t, p_{jt} is the final price of product j at time t, c_{jt} is the constant marginal cost to produce and sell product j at time t, $s_{jt}(p)$ is the market share of product j at time t, given the vector of product price p. The first order conditions that determine the prices of products are given by:

$$s_{kt}(p) + \sum_{j \in G_f} (p_{jt} - c_{jt}) \frac{\partial s_{jt}}{\partial p_{kt}} = 0 \quad \forall k \in G_f \tag{3}$$

Using the above conditions, prices, and estimates of the demand model, we are able to recover margins of manufacturers $\gamma_{jt} = p_{jt} - c_{jt}$ and so marginal costs for each product j at time t and we note $\gamma_t(p|\theta)$ the vector of margins.

3.3 Product reformulation scenario and product cost implications

In this section, we describe the exogenous product reformulation assumed, knowing the recipes prior to food reformulation. They are determined using the ingredient lists and nutrition facts provided by the French Food Observatory Oqali (see appendix sub-section 9.2 for details). To simplify the determination of yogurt and FBPS recipes, the quantity of milk is approximated by the quantity of the ingredient "plain yogurt" or "plain FBPS" respectively. Although we know that it takes one litre of milk to make one kilogram of yogurt, the quantity of milk necessary to make one kilogram of FBPS is 2.5 litres.

First, we assume that only items belonging to compotes, yogurts, and FBPS with added sugar are reformulated. The recipes of items in the ODD category are assumed to remain constant, due to their various and complex recipes and because of manufacturers' uncertainty about consumers' reaction to the reformulation of gourmet foods (Sebillotte, 2016). Second, when firms face taxes, we assume that firms decide to fully avoid the tax, where possible: they set the level of the sugar content of their products just below the tax threshold to fully escape the tax, if reaching this level is technically feasible and sensory acceptable for consumers. We also assume that firms compensate sugar reduction by an equivalent increase in the quantity of the ingredient plain yogurt for yogurts, ingredient plain FBPS for FBPS or ingredient fruit for compotes, such as $\Delta Q_{Yogurt,j} = -\Delta Q_{Sugar,j}$ for yogurts, $\Delta Q_{FBPS,j} = -\Delta Q_{Sugar,j}$ for FBPS, and $\Delta Q_{fruit,j} = -\Delta Q_{Sugar,j}$ for compotes. The other ingredients such as fruits in fruity yogurts or FBPS, aroma in flavored yogurts or FBPS, and additives (e.g. preservatives) in compotes, yogurts, and FBPS with added sugar are assumed to be fixed.

If setting product sugar content just below tax threshold is not technically feasible or sensory acceptable, i.e. the resulting added sugar content is below the minimum added sugar level, we assume that the firm sets the level of added sugar of this product to the minimum content in order to mitigate the tax. This minimum amount of added sugar is calculated for all compotes, yogurts, and FBPS with added sugar by minimizing the amount of sweetening ingredients per 100 g of product subject to technical constraints of formulation, such as product sweetness, texture, fermentation, and gelation process, and regulatory constraints if any. The computation of this amount for each reformulated product, including the exact specification of each constraint, is detailed in the appendix sub-section 9.3. The contents in caloric sweeteners and fat after minimizing the amount of added sweeteners, by brand and product category, are reported in Tables 17 and 18, respectively.

As the recipes change with product reformulation, so do the production costs. We specify a linear cost model to infer the change in cost due to a variation in the quantities of the main ingredients of compote, yogurt, and FBPS: sugar, milk and fruit. We assume that the variation in marginal cost due to reformulation Δcc_j for product j follows this linear function :

$$\Delta cc_j = \rho_S \Delta Q_{Sugar,j} + \rho_Y \Delta Q_{Yogurt,j} + \rho_{FBPS} \Delta Q_{FBPS,j} + \rho_F \Delta Q_{Fruit,j} \tag{4}$$

where $\Delta Q_{I,j}$, for $I = Sugar, Yogurt, FBPS, Fruit$ is the variation in the quantity of ingredient I due to reformulation of product j and ρ_I represent the average price of the ingredient I per kilo. We set sugar price at €555 per ton, $\rho_S = 0.555$ (see the report of the European Commission 2013). The price of plain yogurt and plain FBPS is derived from that of milk, taking into account the quantity of milk necessary to make yogurt and FBPS (1 litre of milk to make 1 kilogram of yogurt, and set at 2.5 litres of milk for FPBS). The price of milk is set to €274 per ton, $\rho_Y = 0.274$ and $\rho_{FBPS} = 0.685$ (see the report of the French national inter-professional center for the dairy industry 2014). The average price of fruits for industry is calculated from trade figures in volume and value included in a report of Adepale (2006), the French Association of Elaborated Food Products Companies. We set the price of fruit at €407 per ton on average, $\rho_F = 0.407$.

Table 3: **Variation in products characteristics due to reformulation**

	Compotes			Yogurts			Fromages blancs, petits suisses		
	Sugar	Lipid	Cost	Sugar	Lipid	Cost	Sugar	Lipid	Cost
Firm 1									
Brand 1				-1.61	0.10	-0.47	-1.59	0.10	0.22
Brand 2				0.00	0.00	-0.00	0.00	0.00	-0.00
Brand 3				0.00	0.00	-0.00			
Brand 4				-0.45	0.01	-0.13			
Brand 5				-0.42	0.02	-0.12	-0.95	0.04	0.13
Firm 2									
Brand 6				-1.11	0.04	-0.33	-5.95	0.79	0.81
Firm 3									
Brand 7				-0.81	0.02	-0.24	-0.16	0.01	0.02
Brand 8				-2.04	0.07	-0.60			
Brand 9				-2.30	0.04	-0.68			
Firm 4									
Brand 10	-2.46	0.00	-0.41	-2.26	0.10	-0.66	0.00	0.00	0.00
Firm 5									
Brand 11	-1.44	0.00	-0.24						
Firm 6									
Brand 12				0.00	-0.00	-0.00	0.00	-0.00	-0.00
Brand 13				-0.40	0.01	-0.11			
PLs	-1.95	0.00	-0.32	-1.28	0.06	-0.38	-0.75	0.05	0.10
Average	-1.96	0.00	-0.32	-1.17	0.05	-0.34	-0.90	0.06	0.12

Variation in sugar and lipid are calculated in grams on the whole market (i.e not only for products which are reformulated)
Variation in cost are in cents.

3.4 Simulation method

We simulate the impact on prices and consumption of excise taxes with or without product reformulation, given the estimated marginal costs, input prices and changes in recipes (if any), as well as the other estimated structural demand parameters. The marginal cost of production is modified by the excise tax, but also by the cost of reformulation. The profit-maximization program for firm f is now given by:

$$\max_{\{p_{kt}\}_{k\in G_f}} \sum_{j\in G_f} (p_{jt} - \tilde{c}_{jt}) M_t s_{jt}(p) \tag{5}$$

where $\tilde{c}_{jt} = c_{jt} + \tau_j + \Delta cc_j$ is the new marginal cost including the per-unit level of the tax τ_j which depends on the caloric sweetener content of product j and Δcc_j.[10] The new price equilibrium vector p_t^* is deduced from the following program:

$$\min_{\left\{p_{jt}^*\right\}_{j=1,..,J_t}} \quad \|p_t^* - \gamma_t\left(p^*/\theta\right) - \tilde{c}_t\|$$

where $\|.\|$ is the Euclidean norm in $\mathbb{R}^J$, $\gamma_t\left(p^*/\theta\right)$ is the vector of manufacturer margins deduced from (5), and the vector $\tilde{c}_t$ is the sum of the vectors of marginal costs obtained from (3), $c_t = (c_{1t},..,c_{jt},..,c_{Jt})$, tax levels, $\tau = (\tau_1,..,\tau_j,..,\tau_J)$, and input variations caused by reformulation, $\Delta cc = (\Delta cc_1,..,\Delta cc_j,..,\Delta cc_J)$.

4 Results on demand and supply

We estimated the demand model using household purchase data, a control function approach for identification issue (see details in the Appendix 9.1) and a simulated maximum likelihood method as in Revelt and Train (1998). Table 19 in the Section 9.4 in the Appendix shows the estimated coefficients of the demand model.

According to Figure 2, we see that the marginal utility of price is heterogeneous due to mainly unobserved household characteristics as the effect of income, obesity status and the presence of children in the price sensitivity is weak ((the estimated standard deviation of the price coefficient in Table 19 is strong whereas the estimated coefficient of the interaction between observed household characteristics and the price variable is small).

Households prefer compote more than the three other dairy dessert categories, on average. They also prefer yogurt with fruit (0.49). Surprisingly, the sweetness of a product decreases household average utility. How-

[10] The tax τ_j is 0 for non-taxed products and there is no reformulation, $\Delta cc_j = 0$.

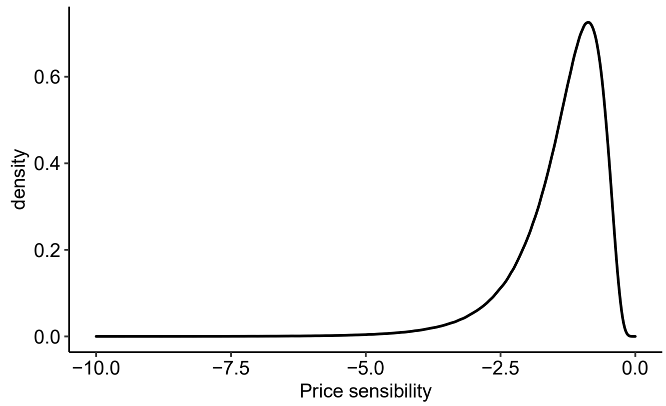

Figure 2: Price preferences by households characteristics

ever, purchasing a fat and sweet dairy dessert increases household average utility (0.86). Figure (3) shows that households draw a positive estimated utility from sugar when the sugar content of products is sufficiently high, particularly for households without children. This positive preference for sugar in high sugar content product is mainly particularly true for the ODD category and the FBPS category at a lower extent (Figure 4). On the contrary, the sugar preference for compote products is very weak. This reflects the observed trend in the market whereby consumers increasingly choose compotes with a low level of sugar.

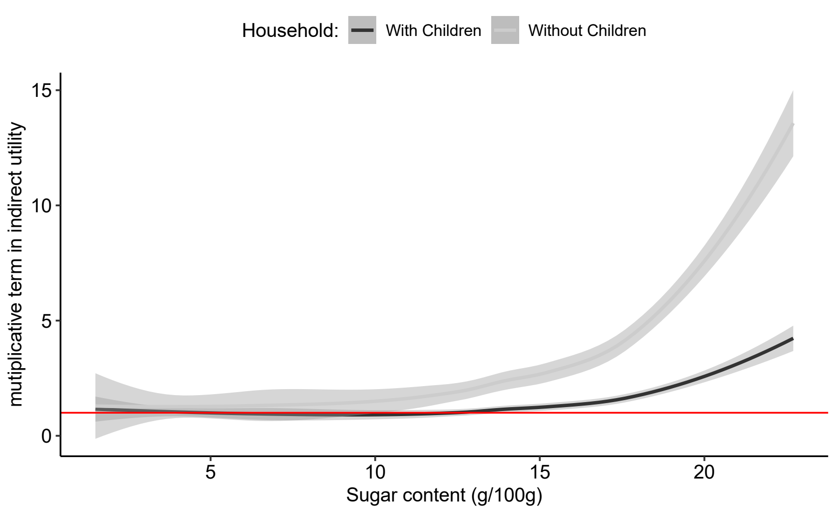

Figure 3: Sugar preferences by households characteristics

Note: The estimated indirect utility of sugar has been regress on sugar quantity. We plot the line y=1 in order to see when it has a positive impact on the indirect utility

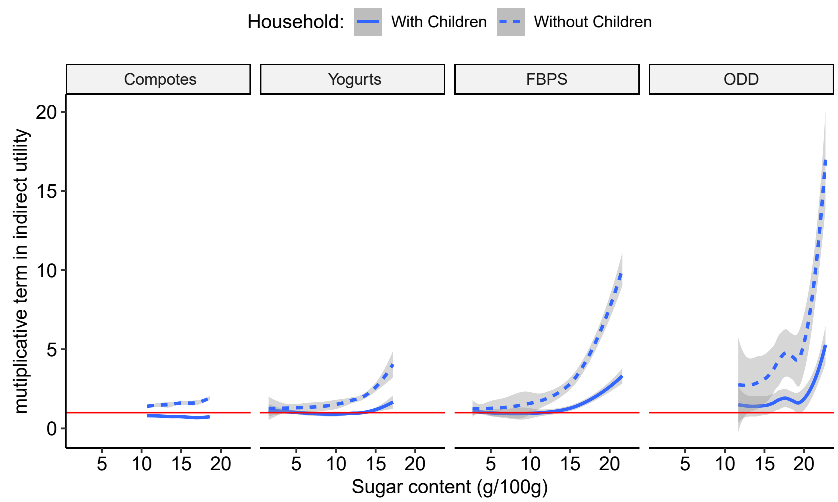

Figure 4: Sugar preferences by households characteristics and category of products

Note: The estimated indirect utility of sugar has been regress on sugar quantity. We plot the line y=1 in order to see when it has a positive impact on the indirect utility

Table 4: **Aggregated own- and cross-price elasticities by product categories.**

	Compotes	Yogurts	Fromages blancs, petits suisses	Other dairy desserts
Compotes	-2.26	0.12	0.12	0.13
Yogurts	0.42	-1.73	0.41	0.41
Fromages blancs, petits suisses	0.20	0.20	-2.32	0.21
Other dairy desserts	0.51	0.48	0.51	-2.17

Note: FFPS, DF stand for fromages blancs and petits suisses, other dairy desserts, respectively.

Using the structural demand estimates, we compute price elasticities for each differentiated product. Table 4 provides aggregated own- and cross-price elasticities by categories.[11] Own-price elasticities are close to -2.2, except for yogurt products for which the demands are less elastic (about -1.7). Cross-price elasticities by food category are also almost equal. There is no second-best product category following a price change in a given dessert category. Consumers shift to another product proportionally to its initial market share. At the brand level (Table 20 in the Appendix), we find that yogurts are less elastic, except for three brands that are characterized by the lowest caloric sweetener contents and, for two of them, high artificial sweetener contents.[12] Consumers react more to a change in prices for these expensive yogurts. For FBPS and ODD, we also find an heterogeneity in

[11]Computational details for aggregated elasticities are provided in Bonnet et al. (2018).

[12]The first brand is specialized in soy products, the second in 'probiotics' products and the third in cholesterol lowering products.

own-price elasticities for NB products. Furthermore, in each category, PL products are less price sensitive than those of NBs, a result which is commonly found.

From the supply model, we deduce the margins and marginal costs (see Table 5). Margins vary from 27% to 73%, and they are higher on average in the yogurt category. This is in line with the empirical literature which typically finds margins in this range (Bonnet et al., 2016). For each product category, PLs have both the lowest marginal cost and the highest percent margin. This latter result is consistent with the theoretical literature showing that percent margins on PLs are likely to be larger than those on NBs (Mills, 1995). In each category, except ODD, marginal costs of brands are, in most cases, similar. Larger marginal costs correspond to brands producing specific products (Brands 3, 4, 13 for yogurt and 6 and 12 for FBPS). In the ODD category, the comparison of marginal costs is more difficult as products are very heterogeneous.

Table 5: **Average margins (%) and marginal costs (€/kg) by brands and product categories.**

	Product categories				
	Compotes	Yogurts	Fromages blancs, petits suisses	Other dairy desserts	All
			Margins		
Firm 1					
Brand_1		53.38	41.77	43.41	46.57
Brand_2		54.98	43.07	36.92	46.84
Brand_3		33.82			33.82
Brand_4		39.53			39.53
Brand_5		47.47	36.88		44.96
Firm 2					
Brand_6		48.10	28.86	36.87	40.37
Firm 3					
Brand_7		56.54	42.41	33.69	48.42
Brand_8		47.23			47.23
Brand_9		46.19			46.19
Firm 4					
Brand_10	37.08	46.72	42.10	29.86	36.69
Firm 5					
Brand_11	36.18			31.09	34.90
Firm 6					
Brand_12		40.20	35.17	27.05	31.40
Brand_13		35.17		33.74	34.45
PLs	59.60	72.79	58.74	58.66	63.82
All	**53.00**	**59.35**	**50.06**	**48.29**	**53.55**
			Marginal costs		
Firm 1					
Brand_1		1.36	1.96	1.77	1.67
Brand_2		0.95	1.88	2.53	1.63
Brand_3		3.33			3.33
Brand_4		2.17			2.17
Brand_5		1.45	2.56		1.71
Firm 2					
Brand_6		1.32	3.94	2.54	2.18
Firm 3					
Brand_7		0.95	1.60	2.60	1.38
Brand_8		1.18			1.18
Brand_9		1.24			1.24
Firm 4					
Brand_10	2.10	1.62	1.55	3.42	2.48
Firm 5					
Brand_11	2.14			3.28	2.43
Firm 6					
Brand_12		1.78	2.34	4.53	3.57
Brand_13		2.43		2.53	2.48
PLs	0.93	0.56	1.03	1.30	0.94
All	**1.27**	**1.04**	**1.53**	**1.91**	**1.43**

Note: The reported marginal cost (margin) of a brand and a category is the weighted average (using market shares as weights) of the marginal cost (margin) of products for each brand in each category.

5 The welfare effects of changing sugar tax threshold level

In this section, we present the impact of three policy scenarios on sugar consumption, consumer welfare, firms' profit, tax revenue, and total welfare for a broad range of tax threshold levels. The objective is to determine the efficiency of such scenarios for the different stakeholders (consumers, firms as well as governments) and enrich public debates about the design of tax policies

First, we consider a tax policy assuming that firms only react in price, called below tax policy without reformulation. We define it as an excise tax proportional to the sugar content of the product if its sugar content is above a given threshold level. The chosen rate of tax is €0.20 per 100g of sugar per kilo of product.[13] Consistently with the sugar content distribution of the two categories in Table 2, we choose a range of tax threshold levels for dairy desserts (6, 8, 10, 12, 14, 16 and 18) and a range of tax thresholds for compote (12,14 and 16). For simplicity of representation, we display our results considering a threshold level for compotes at 12g per sugar for 100g of product. We will discuss how results change with the level of the sugar tax threshold of compote at the end of the section.

Second, we analyze the same tax policy that not only allows for strategic price reactions, but also allows firms to reformulate products based on an exogenous reformulation scenario, called below tax policy with reformulation. This assumed exogenous reformulation scenario involves firms setting the level of the sugar content of their products just below the given tax threshold to fully escape the tax, if reaching this level is technically feasible and sensory acceptable for consumers. If not, it is assumed that firms set the level of added sugar of this product to its minimum content, in order to mitigate tax effects.[14]

The third scenario is only the exogenous reformulation scenario considered in the second policy, called below reformulation. This scenario, which varies with the tax threshold level by construction, is used to disentangle the effects of product reformulation from the effects of the tax-induced product price increase for each tax threshold level.

All variations displayed below are measured against the status quo scenario, i.e. no policy implementation.

[13]This rate leads to roughly 10 to 20% price increase for taxed products.

[14]The minimum content is defined by the existing assortment of products as explained in Section 3.3.

5.1 Impact of policies for consumers

We present in this section the impact of the different policies on sugar consumption and consumers' welfare.

Variations in sugar consumption Figure 5 shows how sugar consumption varies with the level of the sugar tax threshold of dairy desserts for the three policy scenarios. We find that the two tax policies yield stronger sugar consumption reductions than the reformulation policy for all sugar tax threshold levels. There are two explanations. First, ODDs, which have the highest sugar content on average (see Table 2), are not reformulated by assumption in the reformulation scenario. It results that consumers shift away from reformulated desserts toward ODDs, as displayed in Figure 14 in annex. Whereas, ODDs are taxed in the two tax policy scenarios resulting in a reduction in the purchase of ODDs in favor of less sweetened desserts. Second, variations in market shares are overall smaller in the reformulation scenario (up to less than 3% maximum) than in the two tax policies (up to more than 20%) yielding lower reduction in sugar consumption (see Figure 14 in annex). These adjustments are smaller, partly because the change in prices is close to zero (see Figure 8)

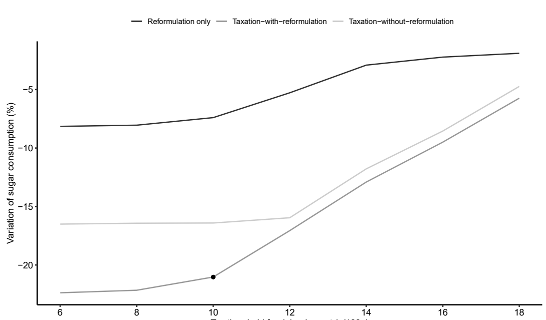

Figure 5: Changes in sugar consumption with respect to dairy dessert tax threshold (set at 12g/100g for compotes) for the three policy scenarios.

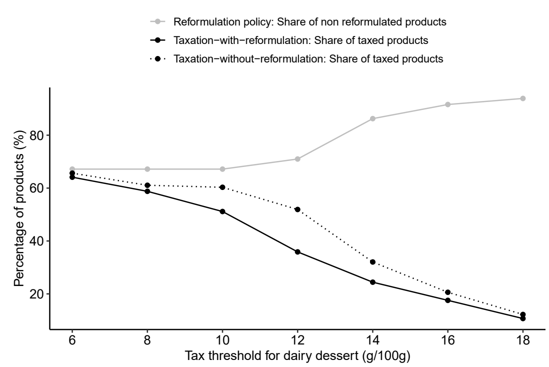

Figure 6: Changes in the shares of taxed products for the tax policies with and without reformulation and non-reformulated products for the reformulation scenario with respect to dairy dessert tax threshold (set at 12g/100g for compotes).

We also find that the higher the threshold level, the lower the decrease in sugar consumption for all policy scenarios considered, as fewer products are taxed/reformulated. However, the change in sugar consumption is not linear. Increasing the tax threshold for dairy desserts from 6 to 10g of sugar per 100g of dairy dessert has a quite small impact on sugar consumption for the tax policy with reformulation (e.g. a less than 0.5 percentage point difference in variation of sugar consumption per 1g increase in the threshold). In contrast, the drop in sugar consumption decreases sharply for a sugar tax threshold above 10g of sugar per 100g of dairy product (e.g. about 2 percentage points in variation of sugar consumption for every 1g per 100g increase in the threshold). A similar pattern of variation in sugar consumption is also found for the tax policy without reformulation in Figure 5, but with a kink at 12g of sugar per 100g of dairy dessert. The non-linear pattern of sugar consumption variation observed for the three policies and the levels of the kink mainly result from the non-linear pattern of the evolution of the share of non-reformulated products and/or taxed products (see Figure 6) and the non linear pattern of tax-related price increase (see Figure 8).

Figure 5 also shows that, particularly below a tax threshold of 10 g of sugar per 100 g of dairy dessert, the tax scenario with reformulation is more efficient in reducing sugar consumption than the tax policy without reformulation. In the tax policy with reformulation, two consumers' responses work in favor of reducing sugar consumption. First, consumers only slightly change their purchases of products that have been reformulated to avoid the tax (see sub-section 7.1), and second they switch to less sweet products due to tax-related price increase of taxed products. Whereas only the latter substitution effect in favor of less sweetened products is at stake for the tax policy without reformulation.[15] The reductions are particularly greater (up to about 10 percentage points difference) for a tax threshold below or equal to 10g of sugar per 100g of dairy dessert because the two consumers' response are at stake for the tax with reformulation. Above this tax threshold level, the reduction in sugar consumption converges between the two tax scenarios as the tax threshold for dairy deserts increases: the proportion of non reformulated products increases and both the changes in price and the proportion of taxed products converge in the two tax scenarios.[16]

Consumer welfare Figure 7 shows how the consumer welfare varies with the sugar tax threshold level of dairy dessert for the three policy scenarios. The curves of the variation in consumer surplus and sugar consumption for the two tax policies have similar shape. However, the percentages of utility loss bring about by the three policy

[15]The effect of the tax on the market share of the outside good is similar with and without reformulation for a tax threshold below or equal to 10g of sugar per 100g of dairy dessert (see Figure 14) and then does not explain the difference in reduction of sugar consumption.

[16]The change in the reduction in sugar consumption is larger in the tax with reformulation than without because the two consumers' responses still apply for compote. The tax threshold for compote is set to 12g per 100g of compote.

scenarios are smaller than the percentages of reduction in sugar consumption. Analogous explanations to those for variation in sugar consumption can be given: (i) The utility losses induced by tax policies are higher than in the reformulation scenario due to the non-reformulation of ODDs, the relatively smaller changes in demand and the much smaller price variations in the reformulation scenario (see Figure 8); (ii) The higher the threshold levels, the fewer products taxed/reformulated, and so the lower the decrease in consumer surplus for the three policy scenarios; (iii) The non-linear pattern of consumer surplus variation mainly results from the non-linear pattern of the evolution of the share of non-reformulated and/or taxed products, and the non linear pattern of tax-related price increase.

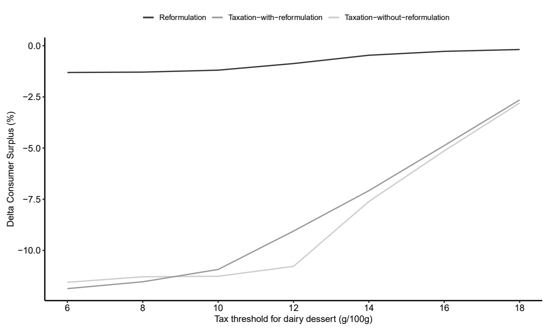

Figure 7: Changes in consumers' welfare with respect to dairy dessert tax threshold (set at 12g/100g for compotes) for the three policy scenarios.

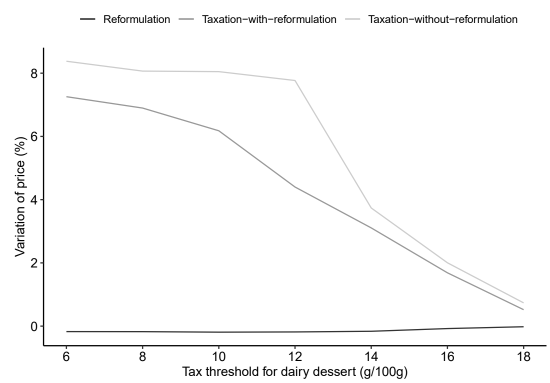

Figure 8: Changes in price with respect to dairy dessert tax threshold (set at 12g/100g for compotes) for the three policy scenarios.

Figure 7 also shows that the utility costs for the two tax policies are almost similar, except for a tax threshold level equal to 12g of sugar per 100g of dairy product where they are lower for the taxation with reformulation. The explanation lies in the magnitudes of the utility costs bring about by tax-related price increase and the consumption of less sweetened and fat products (see demand model estimates reported in Table 19). Specifically, the sum of the disutilities of consuming less sugar and fat, and paying higher prices is smaller in the tax policy with reformulation than without at this tax threshold level: the reduction in fat consumption (see Figure 13 in annex) and the tax-related price increase (see Figure 8) are smaller in the tax policy with reformulation, while the reductions in sugar consumption are almost similar in the two tax scenarios.

5.2 Firms' profit

Figure 9 shows how firms' profit varies with respect to the sugar tax threshold level of dairy dessert for the three policy scenarios. Four main results emerge. First, the two tax policies generate much stronger profit reductions than the reformulation scenario for all sugar tax threshold levels. As we will show in sub-section 7.1, reformulation involves small adjustments in demand due to changes in product recipes and small changes in prices, partly owing to small reformulation costs. In contrast, the tax policy brings about much stronger variations in product market shares (see Figure 14 in annex), notably ODDs that can be strongly taxed, which leads to relatively greater reductions in profit. Second, the lower threshold level, the higher profit loss. The share of taxed products and price increase as the tax threshold falls (see Figures 6 and 8). Third, the marginal impact of modifying the threshold level for dairy desserts is small in the range of 6 to 10 g/100g, but much higher in the range of 10 to 18 g/100g. This result comes mainly from the non linearity in the evolution of the share of taxed products and tax-related price variations (see Figures 6 and 8). Fourth, the reduction in firms' profit are similar in the two tax policies, except for a tax threshold levels equal to 12g of sugar per 100g of dairy product. At this tax threshold, the (negative) impact of tax policy on firms' profit becomes lower when firms reformulate their products than when they do not. This is mainly due to a much lower tax-related product price increases in the tax scenarios with reformulation than without (see Figure 8), yielding lower drops in product market shares and a greater decrease in the market share of the outside good in the tax scenario with reformulation (see Figure 14 in annex).

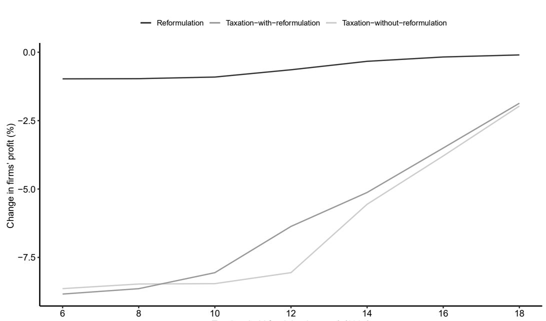

Figure 9: Variation in firms' profits with respect to dairy dessert tax threshold (set at 12g/100g for compotes) for the three policy scenarios.

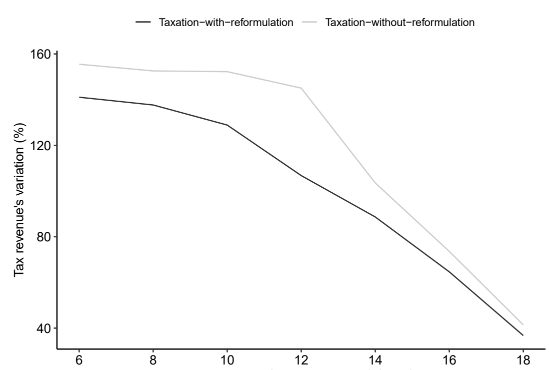

Figure 10: Tax revenue variation with respect to dairy dessert tax threshold (set at 12g/100g for compotes) for the two tax policy scenarios.

5.3 Tax revenue and total welfare

Figure 10 displays how tax revenue varies with the sugar tax threshold level of dairy desserts for the two tax policies. As expected, tax revenue decreases as tax threshold level increases since less products are taxed. Moreover, the amount of tax revenue is smaller for the tax policy with reformulation for all tax threshold levels, as we assume that firms decrease the sugar content of their products to fully escape the tax or to mitigate its effects when this is not possible. The non-linear pattern of tax revenue also results from the non-linear pattern of the evolution of the share of taxed products with respect to tax threshold level.

The tax revenues are high but they are not high enough to outweight the losses of profit and consumer welfare below a tax threshold level of 14g of sugar per 100g of dairy product (see Figure 11). Moreover, the changes in total welfare across tax threshold levels are similar in the two tax policy scenarios.

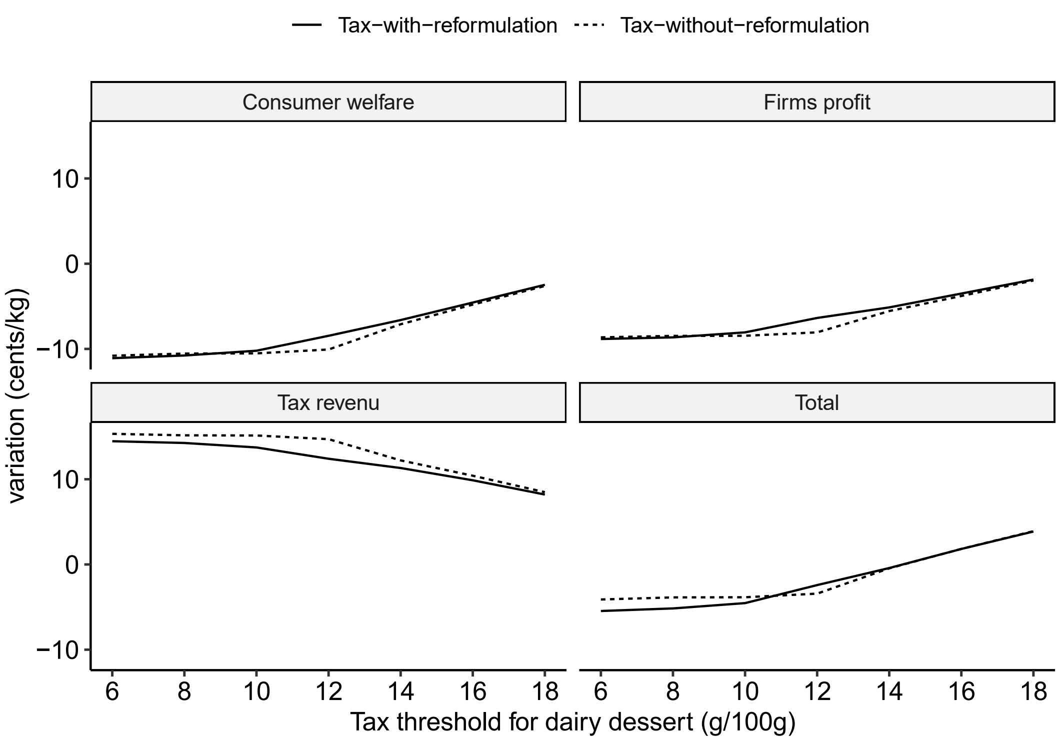

Figure 11: Total welfare with respect to dairy dessert tax threshold (set at 12g /100g for compotes) (€cents /kg)

5.4 The welfare effects of changing the sugar tax threshold for compote

We also analyze how sugar consumption, consumer welfare, firms' profit and tax revenue change with respect to the sugar tax threshold for compote. The variations in sugar consumption for other levels of compote tax thresholds are displayed in Figure 15 in Appendix for the tax policy with reformulation. Only the magnitude of sugar consumption fall varies with the level of the tax threshold of compote: the overall pattern of sugar consumption variation is similar for the three levels of the tax thresholds of compotes. We get similar results for the tax policy scenarios without reformulation. Profit variations are almost identical for compote threshold values equal to 14 and 16g/100g, while they are higher for values equal to 12g/100g (see Figure 17 in Appendix). Regarding Tax revenues, we obtain exactly the same shape (see Figure 18 in Appendix) for the three tax threshold levels, and only the magnitudes of the variations in revenue vary. Analogous explanations to those for the variations in sugar consumption, consumer welfare, firms' profit and tax revenue with respect to dairy tax threshold can be given. The higher the compote threshold, the fewer products taxed/reformulated, the lower the decrease in sugar consumption and consumers' surplus, and profit loss, and the smaller the tax revenue. The non-linear pattern of the variations in the four welfare measures mainly results from the nonlinear pattern of both the variations of the share of non-reformulated/taxed products and tax-related price increase with respect to dairy tax threshold (see Figure 16).

5.5 Key messages

Overall, we find that a tax with reformulation generates greater reductions in sugar consumption than a tax without reformulation in the dessert market when the tax threshold is low enough to affect a large proportion of products. The two tax policies (with and without reformulation) yield the same patterns in the variations of consumers' welfare, firms' profit or tax revenues with respect to sugar tax threshold, except at the sugar tax threshold equal to 12g of sugar per 100g of product where the cost of taxation is larger than the costs of taxation and reformulation for consumers and firms. This is mainly due to a much larger difference in tax-related product price increases and the share of taxed products between the two tax scenarios for this threshold level than for other tax threshold levels (see Figure 8). Symmetrically, tax revenues are greater in the tax policy without reformulation than with reformulation since less products are taxed in latter policy.

Our results highlight two critical findings. The choice of the level of the sugar tax threshold strongly affects the share of taxed and reformulated products, the magnitude of tax-related price increase, and the magnitude of welfare effects: the lower the tax threshold, the most efficient the tax policy in terms of sugar consumption reduction, but the greater decrease in consumers' surplus and profit. Second, there is certain of level of tax threshold for which firms may experience less profit loss from the taxation policy if they reformulate, thereby generating greater sugar consumption reduction and less consumers' welfare losses due to smaller tax-related price increase than under the tax policy without reformulation. We recommend setting the sugar tax threshold based on the sugar content distribution of compotes, yogurts and FBPS in order not only to tax a large proportion of products, but also to maximize the number of products close to but above the threshold so that their reformulation is not too costly.

6 Heterogeneity of the impact of the taxation policies

In this section, we analyze the heterogeneity of effects induced by the taxation with and without reformulation on prices, market shares and profits by product category, brand and firm, and on nutrient consumption by type of consumer. The analysis is carried out using a single set of tax thresholds: 12g/100g and 10g/100g of sugar for compotes and dairy desserts, respectively. We have chosen these threshold levels because, firstly, they lead to a substantial decrease in sugar consumption (see Figure 5), and secondly, firms have a relative economic interest, albeit a small one, in reformulating products at these tax thresholds levels (see Figure 9).

Table 6 reports the effects of the taxation with reformulation on the share of taxed products and the amount of the tax paid in euros per kilo of product by brand and product category. Given our reformulation scenario all ODDs are taxed, while 56%, 35% and 30% of compotes, yogurts and FBPS are taxed, respectively. There is a strong disparity in the shares of taxed products between brands for yogurt and FBPS categories, due to a strong heterogeneity in product sugar content between brands (see Table 2). In particular, a few brands fully escape the tax: five out of 13 brands of yogurts and three out of eight brands of FBPS. Compotes and ODDs, which are the sweetest products (see Table 2), endure the highest levels of tax, €0.27/kg and €0.34/kg on average, respectively. A similar average amount of tax is levied on yogurts and FBPS (€0.23/kg and € 0.24/kg, respectively).

Effects on prices and profits We found that firms choose to pass more than the tax to consumers in both taxation policies with and without reformulation (see Table 21 in the Appendix). The prices of taxed products increase by about 18% more than the amount of the tax in the two tax scenarios. This result is in line with the analyses of taxation in other food product categories, such as sugar sweetened beverages, butter and margarine, and fresh dairy products (Bonnet and Réquillart, 2013; Nesheim et al., 2018; Allais et al., 2015). Table 7 provides the average price change for each brand in each category in the tax scenario with reformulation. We found that brands experience rather heterogeneous price variations within product category, ranging from 0 to €0.51. Brands whose products are not taxed (i.e. those whose sugar content level is already below the thresholds and those that have been reformulated) experience the smallest changes (max €0.1), as reformulation costs and strategic price reactions of firms for those products are low.

Table 6: **Taxation with product reformulation: Share of taxed products and tax level (€/kg) by brand and product category**

	Compotes		Yogurts		FBPS		ODD	
	Share	Tax	Share	Tax	Share	Tax	Share	Tax
Firm 1								
Brand 1			29%	0.22	50%	0.24	100%	0.40
Brand 2			0%		0%		100%	0.22
Brand 3			0%					
Brand 4			25%	0.21				
Brand 5			50%	0.24	50%	0.22		
Firm 2								
Brand 6			20%	0.26	63%	0.31	100%	0.33
Firm 3								
Brand 7			75%	0.23	20%	0.27	100%	0.34
Brand 8			33%	0.25				
Brand 9			0%					
Firm 4								
Brand 10	33%	0.27	100%	0.23	0%		100%	0.32
Firm 5								
Brand 11	67%	0.28					100%	0.28
Firm 6								
Brand 12			0%		0%		100%	0.35
Brand 13			0%				100%	0.24
PLs	67%	0.26	50%	0.23	30%	0.24	100%	0.33
All	56%	0.27	35%	0.23	30%	0.24	100%	0.34

Note: A proportional tax of €0.20 per 100g of sugar per kilo of product is implemented when product sugar content is above 12g for compote and 10g for other product categories. The reported share of taxed products for a brand is computed as the ratio, in percent, of the market share of taxed products and the total market share of the brand. The reported amount of the tax is a weighted average tax of taxed products, using market shares as weights. FBPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively.

Table 7: **Taxation with product reformulation: Changes in average price (€/kg) and market share (%) across brands and product categories**

	Compotes		Yogurts		FBPS		ODD		All
	Price	MS	Price	MS	Price	MS	Price	MS	MS
Firm 1									
Brand 1			0.03	-5.47	0.01	-5.64	0.51	-27.18	-14.35
Brand 2			0.00	10.30	0.01	11.23	0.28	-9.31	5.03
Brand 3			0.00	12.02					12.02
Brand 4			0.07	5.00					5.00
Brand 5			0.13	-3.98	0.14	-1.66			-3.43
Firm 2									
Brand 6			0.07	1.08	0.51	-33.52	0.43	-18.47	-12.41
Firm 3									
Brand 7			0.34	-16.92	0.03	4.99	0.42	-18.79	-7.92
Brand 8			0.08	-3.91					-3.91
Brand 9			0.00	5.56					5.56
Firm 4									
Brand 10	0.09	-0.81	0.33	-21.43	0.01	9.93	0.38	-14.22	-10.22
Firm 5									
Brand 11	0.26	-10.05					0.43	-13.15	-10.84
Firm 6									
Brand 12			0.01	10.30	0.01	10.59	0.41	-13.95	-5.00
Brand 13			0.00	9.87			0.30	-11.65	-0.99
Pls	0.24	-11.63	0.05	-4.81	-0.01	3.41	0.49	-23.63	-10.90
All	0.23	-9.82	0.08	-3.57	-0.01	1.26	0.50	-21.68	-9.53

Note: A proportional tax of € 0.20 per 100g of sugar is implemented when the sugar content is above 12g for compote and 10g for other product category. The reported change in price of a brand and a category is the weighted average (using market shares as weights) of the change in price of all products from this brand in this category. FBPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively.

Table 8 provides the impact of taxation on firms' profits when firms reformulate (column 'with') or not (column 'without'). Overall, firms undergo profit losses for each product category in the two tax scenarios, except for FBPS. FBPS products are the least sweetened dairy dessert (see distribution statistics in Table 2), and they so experience the lowest price increase in the two tax scenarios (see Table 24). As price changes are highly heterogeneous across firms and firm-categories, so are profit changes. Overall, the lower the average price increase for a firm in a product category, the less the firm is harmed or the more it benefits from the tax (see Tables 8 and 24).

As analyzed in the previous section, overall firms lose less profit from tax policy when they reformulate at these tax thresholds. However, the overall average loss remains in the same order of magnitude between the two scenarios (-8.1% compared to -8.5% without product reformulation). This result holds for all firms, except for firm 1 (see the last two columns of Table 8). However, there is heterogeneity in the differences between the profit loss in the tax scenario with reformulation and the profit in the tax scenario without reformulation across firms and categories, excluding ODDs that are not reformulated.[17] Two opposite effects determine whether a firm benefits or suffers from switching to the tax scenario with reformulation at the product category level: the direct effect that depends on the extent to which reformulation affects its share of taxed products and its relative prices in the category; and the indirect effect which depends on the extent to which the prices of products of competing firms in other categories change. The net effect relies on the strength of the two forces.

We find that a tax scenario without reformulation generates less profit loss than the tax with reformulation for the FBPS category for all firms (except for firm 7, PLs): firms producing FBPS incur a greater indirect effect in the tax scenario with reformulation than in the no reformulation tax scenario. Fewer of their competitors' products are taxed in the former scenario, and the average price reduction resulting from shifting to tax scenario with reformulation is greater for yogurts (-3.08 percentage point (pp)) and compotes (-2.52 pp) than for FBPS (-2.11 pp), as it can be calculated in Table 24. The profit of firm 2 from the production of FBPS is affected to a much greater extent than that of the other firms in the reformulation scenario. Its direct effect is close to zero: it still has the highest share of taxed FBPS products despite reformulation (63%, see Table 6) and price reduction from the shifting to a tax scenario with reformulation is small (0.19 pp, see Table 24). Firm 2 has so a strong economic

[17] Firms producing ODD undergo almost similar profit losses in the two tax scenario as variations in price are similar (15% overall)

Table 8: **Change in firms' profits due to taxation whether firm product reformulation is assumed or not (in %)**

	Product categories								Total	
	Compotes		Yogurts		FBPS		ODD			
Reformulation	Without	With	Without	With	Without	With	Without	With	Without	With
Firm 1			0.19	-0.21	1.68	-1.47	-19.72	-19.73	-4.59	-5.55
Firm 2			-0.77	2.53	-11.76	-30.71	-14.54	-14.53	-10.43	-10.15
Firm 3			-9.63	-2.99	6.80	6.11	-14.73	-14.71	-6.38	-1.70
Firm 4	-7.29	0.73	-13.97	-17.18	11.13	10.57	-11.25	-11.16	-9.59	-7.66
Firm 5	-6.90	-6.64					-9.37	-9.32	-7.60	-7.40
Firm 6			6.89	10.71	11.52	11.08	-10.73	-10.54	-4.09	-2.84
Firm 7	-10.57	-9.55	-5.63	-5.31	0.49	1.78	-19.28	-19.43	-10.29	-9.88
All	-9.65	-7.76	-3.76	-2.79	1.39	0.54	-17.47	-17.53	-8.46	-8.06

Note: A proportional tax of € 0.20 per 100g of sugar per kilo of product is implemented when sugar content is above 12g for compote and 10g for other product categories. Columns 'without' indicate the change in profits when firms do not reformulate their products, and columns 'with' when firms do reformulate their products. Firm 1 owns brands 1 to 5; firm 2 owns brand 6, firm 3 owns brands 7 to 9; firm 4 owns brand 10; firm 5 owns brand 11; and firm 6 owns brands 12 and 13. FBPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively.

interest in that competing products are not reformulated. The profit loss of firm 1 from the production of FBPS is greater in the tax scenario with reformulation because the proportion of FBPS taxed in the tax scenario with reformulation remains the same as in the tax scenario without reformulation for brands 1 and 5 (see Tables 6 and 28). Its direct effect is so close to zero. This is the main reason why, in contrast to the other firms, firm 1 loses less profit overall from the tax policy without reformulation than with reformulation (last two columns of Table 8). In contrast, PL firm experiences a large direct effect for FBPS: the average price reduction resulting from shifting to the tax scenario with reformulation is equal to 2.12 pp. The same mechanisms, but in the opposite direction, apply to firms producing compotes and yogurts. This explains why, in contrast to firms producing FBPS, all firms producing yogurt (except firms 1 and 4)[18] and compote benefit from switching to the tax-with-reformulation scenario at these tax thresholds.

Effect on demand Table 25 presents the impact of the tax on market shares in the two tax scenarios. We found similar patterns of variation as for profit in the two tax scenarios. However, the losses (gains) of market shares are larger (smaller) than the losses (gains) of profit as firms increase their mark-ups for all brands and product categories (see Tables 8 and 25). Same interpretations as for profit hold. (i) All product categories lose market

[18] Firms 4, which owns brand 10, has all its yogurts taxed despite the reformulation (Table 6).

shares, except FBPS in the two tax scenarios (+1.6% and +1.3% without and with reformulation, respectively) for which the change in the average price is much lower than for the other categories (1.8% and -0.3% without and with reformulation, respectively). Overall, the lower the average price increase for a firm in a product category, the less the firm will lose or the more it will gain market shares in the two tax scenarios (see Tables 24 and 25). We found that PLs lose more than the average NBs, despite quite similar levels of tax, which is a consequence of a larger relative price effect of the tax, when evaluated in percentage change.[19] (ii) As price changes are highly heterogeneous across firms and firm-categories, so are market share changes. (iii) The analysis of market share changes between the two tax scenarios is also based on the direct and indirect effects, and the net effect determines whether a firm benefits or suffers from reformulation. We also find that the larger the average price decrease due to switching to the tax-with-reformulation scenario for a firm's products in a given category, the less the firm suffers or the more it benefits from the tax (see Tables 24 and 25).

These variations in market shares lead to decreases in the intake of caloric sweeteners, lipids and calories: 21.1%, 12.4% and 15.9%, respectively (see Table 9). Those values correspond to a yearly per capita reduction of 0.8 kgs of sugar, 0.1 kgs of lipids and 5,252 kcal, equivalent to 14 kcal reduction par day on average. We also find some heterogeneity by household characteristics. Households without children experience higher sugar, fat and calories reductions than households with children in percentage. As their initial consumption is also larger, the nutrient reduction per capita per year for household without children is twice than the nutrient reduction of households with children (1082g versus 494g for sugar intake variation, 179g versus 82g for lipid intake variation, and 6828 calorie versus 3125 calorie for calorie intake variation). Nutrient reductions slightly increase with socio-economic class in percentage but we can observe higher variations in absolute effect for rich households. The percentage change are almost identical whatever the number of obese adults in the household. As it exists a difference in consumption, we observe a small increase in the reduction of sugar, fat and calorie intake per capita and year for households with obese adults. For example, we observe a difference in the reduction of sugar intake by 19% as the table shows -988g for households with all obese individuals compared to -830g for households with no obese individuals. As we have highlighted in Section 5, the decrease in sugar and calorie intake is weaker in

[19] NB prices increase by 5%, 4%, 0%, and 12% for compotes, yogurts, FBPS, and ODD, respectively, whereas PL prices increase by 11%, 3%, 0% and 18% respectively. The price transmission of the tax is slightly lower for PLs than NBs, but this is not sufficient to avoid a larger decrease in market shares (see Table 21).

the tax-without-reformulation scenario (see Table 26) and we observe less heterogeneity across households.

Table 9: **Taxation with product reformulation: Percent change in calories, lipid, and sugar intake**

Households		**Children**		**Social classes**			**Adults obese**		
	All	**With**	**Without**	**Rich**	**Medium**	**Poor**	**None**	**One**	**All**
	Intake from the four product categories								
Sugar	-21.07	-19.80	-21.62	-21.25	-21.07	-20.89	-21.00	-21.01	-21.28
	(-831)	(-494)	(-1082)	(-1031)	(-850)	(-616)	(-830)	(-747)	(-988)
Lipid	-12.40	-10.86	-13.13	-12.72	-12.39	-12.06	-12.37	-12.31	-12.59
	(-138)	(-82)	(-179)	(-171)	(-141)	(-102)	(-137)	(-124)	(-164)
Calorie	-15.89	-14.40	-16.56	-16.16	-15.89	-15.60	-15.84	-15.81	-16.09
	(-5252)	(-3125)	(-6828)	(-6057)	(-5371)	(-3899)	(-5240)	(-4722)	(-6246)

The percentage change in nutrient intakes is calculated over the initial intakes of the market under consideration. The corresponding intakes in grams/calorie per capita per year are in brackets. The per capita consumption of a household is calculated using the following rule: we add one point for an individual 15 years of age or older, and 0.5 point for an individual less than 15 years of age.

Key message Overall, firms lose less profit from tax policy when they reformulate at these tax thresholds. However, this result does not hold systematically at the category-firm level. Switching to the tax-with-reformulation scenario can either benefit or harm a firm. Determining whether it is beneficial or detrimental to the firm's profit in a product category requires to analyze substitution effects within and between product categories, and between taxed and non-taxed products, and the potential firm's ability to escape the tax (e.g., see Finkelstein et al. (2013)). Moreover, our analysis shows that the tax-with-reformulation scenario allows aiming the households who have the highest consumption level. Moreover, we can observe a higher sugar reduction for households with obese individuals. Those taxation policies are then well designed to target specifically population at risk.

7 Implications of assumptions

Along the paper, we made a series of assumptions about the behavior of firms and consumers. In this section, we present their implications on the assessment of nutrient intake variations due to taxation policies. First, we disentangle the mechanisms of the effect of the chosen reformulation policy. Second, we evaluate how our assumptions on the firms' behavior (pricing strategy and product reformulation) change the main results. Third, we discuss the implications of the definition of the outside option on the effect of taxation policies.

7.1 The impact of product reformulation

The reformulation scenarios considered imply a change in the nutritional quality and the price of products (due to change in cost and pricing strategy of firms) and the demand (due to changes in quality of products and prices). To understand which effect of product reformulation predominates, we run three cases that decompose the potential impacts of the product reformulation scenario.

In the first case, we assume that the policy causes no change in market shares. Consumers continue to buy products as if there was no change in taste or price. This provides the mechanical impact of product reformulation. We find that the intake of caloric sweetener decreases by 6.7%, whereas fat intake slightly increases (0.9%) because caloric sweeteners in yogurt and FBPS categories are substituted by plain yogurt and FBPS. Overall, it results in a 2.8% reduction in calorie intake (Table 10).

Table 10: **Reformulation: Changes in nutrient intake**

	Constant market shares	Constant prices	Endogenous prices
Δ OG	-	+0.3 pp	+0.3 pp
Δ sugar	-6.7%	-7.5%	-7.4%
Δ lipids	+0.9%	-0.5%	-0.5%
Δ calories	-2.8%	-3.7%	-3.8%

Note: OG stands for the outside good and pp stands for percentage point, that is the absolute variation of the outside good market share. The percent change in nutrient intake is computed over the initial intake from the four product categories.

In the second scenario, we assume that prices remain constant, but consumers react to the change in nutrient composition of products. Consumers are aware that products have been reformulated and thus reassess the utility they obtain from the modified product recipes. As shown in Table 19, both sugar and fat taste affect the utility of consumption, but the changes in consumption due to reformulation are small. Compared to the previous scenario, consumers, on average, switch to products with less sugar and less fat, resulting in a slightly higher decrease in caloric sweeteners consumption.

In the third scenario, we allow producers to have strategic price reactions as both demand and production costs have changed. Prices are adjusted but vary only slightly compared to pre-scenario prices, partly owing to small reformulation costs. The production costs of compotes slightly decrease (by less than 1 €cent /kg), those of yogurts remain unchanged, and those of FBPS slightly increase (by less than 1 €cent /kg). This results in almost no change in nutrient consumption compared to the scenario in which prices remain constant.

We conclude that from the three simulations, the main impact of product reformulation on nutrient intake is mechanical. In our setting, adjustments in demand due to the change in product recipes and firms' price reactions have a minor impact.

7.2 Assumption on the firms' behavior

Table 11: **Impact of alternative modelling assumptions on the nutrient intake from the four product categories**

	Passive pricing No reformulation	Strategic pricing no reformulation	Strategic pricing reformulation
Δ sugar	-13.5%	-16.4%	-21.1%
Δ lipid	-10.8%	-12.9%	-12.4%
Δ calorie	-11.7%	-14.1%	-15.9%

We also assess to what extent the modeling assumptions affect the estimated impact of the policy on the change in nutrients intake. Table 11 provides a comparison of the changes in nutrients intake for three alternative modeling assumptions. The first case refers to passive pricing and no reformulation of products. This is a frequent assumption made to evaluate the impact of taxation. The second case refers to strategic pricing without product reformulation. Last, the third case refers to strategic pricing and product reformulation. Given the characteristics of this market and the tax scheme, assuming passive pricing and no reformulation, we estimate that taxation induces a decrease in caloric sweetener intake by 13.5%. Considering strategic pricing leads to an estimated decrease by 16.4%. Finally integrating both strategic pricing and product reformulation leads to an estimated decrease in the caloric sweetener content by 21.1%. In other words, ignoring strategic pricing leads to under-estimate tax impact by 21.5%, while ignoring both strategic pricing and product reformulation leads to under-estimate its impact by 56.3% in relative term.

7.3 The choice of the outside option

The outside option in the demand setting represents an alternative substitute for the consumers outside the product set that defines the relevant market. When consumers face a global price increase and do not want to buy any desserts in the market, it is unlikely that they stop consuming, they rather buy alternative substitutes. In our setup, the outside option includes other desserts (fruits and pastries), as well as cheese that appears to substitute to dairy desserts in many cases in France. We assume that this substitute exerts a weak competition pressure on the French dessert market, its definition then does not affect prices. The choice of the outside option will then have some implications on demand and then on nutrient intake.

When considering the increase in the market share of outside good of 3.8 percentage point due to the tax scenario with reformulation, the consumption of caloric sweeteners still decreases, but more moderately (8.7%), and the consumption of fat increases by 1.5%, as the fat content of the outside good is much higher than the average fat content of the four product categories considered. Overall, there is a fall in calories (-1.8%).[20]

8 Discussion

This paper provides a methodology for assessing the impacts of tax policies on food consumption, taking into account manufacturers pricing strategies and possible changes in the characteristics of taxed products. To the best of our knowledge, this is the first empirical paper incorporating the reformulation of products with an impact in both product's characteristics seen by consumers and in production's cost. According to our results, ignoring the combined effect of price reactions and product reformulation leads us to greatly under-estimate the impact of taxes on the intake of taxed nutrients. In our case, integrating these two effects into the analysis yields a change in the estimated reduction in caloric sweetener intake of 37 %, which is of the order of Bercholz et al. (2022).

In our setting, reformulation is exogenous. We assume that in response to the tax, firms set the caloric sweetener content of their products slightly below the tax threshold, in order to fully escape the tax and, when this is not possible, to the minimum level technically feasible. Reformulation is exogenous but we show that most firms gain by reformulating their products rather than not doing so, as does the industry as a whole. Thus, product

[20] The reported percent changes in nutrient intake including the change in the outside good market share cannot be directly compared with percent changes in nutrient intake in Table 9 as they are computed over the initial intake of the considered market; that is, the J products for the four categories and the $J+1$ products when the outside good is included.

reformulation is a way to partially or fully escape the tax, the amount of which depends on the sweetener content of the product. Even if product reformulation reduces the impact of the tax on prices, and thus reduces the impact of the tax on consumption, we show that it increases the overall impact of the tax on consumption of the taxed nutrient. In other words, the intake of the taxed nutrient (with adverse health effects) decreases more when companies reformulate their products than when they do not reformulate because the amount of the taxed nutrient has decreased.

The reformulation scenario is in some sense conservative as it uses as constraints what is observed on the market. For a given type of a product (e.g., 'sweet yogurt') the content of sweetener of a reformulated product will not be lower than the observed value of a product available on the market. As a consequence, we do not explore further reduction.

However, in our setting, product reformulation is not endogenous, and we cannot claim that the scenario in which all firms reformulate their products is an equilibrium (in terms of characteristics). Modeling how firms endogenously adjust the set of products they offer would involve adding a second stage to the supply model in which firms simultaneously choose product offerings, with the understanding that their actions and the actions of their rivals will affect demand and markups. Firms would solve the problem by calculating the equilibrium profits they are likely to earn under each possible set of product offerings found in the second stage, and then choosing the products that would maximize those profits. We leave these developments to future research.

Some of our results depend on the choice of the outside good; in particular, the overall impact of the scenarios on nutrient intake depends on the choice of the outside option. For example, in this study, the outside option is highly caloric (much more so than the dessert products considered), and consequently the overall impact of taxation on caloric intake is slightly positive. Therefore, some of the results should be interpreted with caution.

In addition, we do not assume that companies can reformulate their products by replacing a caloric sweetener with a non-caloric sweetener to keep the sweetness of the product constant. Evaluating this reformulation scenario would require estimating consumer preferences for non-caloric sweeteners in the demand model. However, only 14 out of 131 products contain non-caloric sweeteners, making it difficult to estimate preferences for non-caloric sweeteners and suggesting that this reformulation scenario may not yet be credible for the dessert market.

Our results also suggest that the design of tax systems to encourage product reformulation is very important for the success of a tax policy. This has already been done in some countries. For example, France has revised the design of its soda tax. Originally, the tax did not depend on the sugar content of the product (and amounted to €0.075 /l). In July 2018, the tax was redesigned as a tiered-tax rate that varies according to the sugar content of a sugar-sweetened beverage.[21] We recommend setting the sugar tax threshold based on the sugar content distribution of compotes, yogurts, and FBPS to not only tax a large proportion of products, but also to maximize the number of products close to but above the threshold so that their reformulation is not too costly.

There are other debates about taxes that are not covered in this paper. In particular, we do not discuss the possible regressivity of taxes and, more generally, the redistributive effects of such taxes versus their corrective effects. Recently, Allcott et al. (2019) showed that 'an optimal resource tax depends on two terms: the corrective benefits and the regressivity costs'. To answer these questions, a more comprehensive model of optimal taxation should be developed. We leave these developments for further work.

[21] In 2020, the tax will be €0.038 /l for products containing less than 1 g of added sugar per 100 ml, gradually increasing to €0.24 /l for products containing 15 g of added sugar per 100 ml, and €0.205 for each gram per 100 ml added above 15 g (Service public, 2018)

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9 Appendix

9.1 Identification of demand estimates

This method relies on the assumption that all product characteristics are independent of the error term ε_{ijt}. However, assuming $\varepsilon_{ijt} = \xi_{jt} + e_{ijt}$ where ξ_{jt} is a product-specific error term varying across periods and e_{ijt} is an individual-specific error term, the independence assumption cannot hold if unobserved factors included in ξ_{jt} (and hence in ε_{ijt}) such as promotions, displays, and advertising are correlated with observed characteristics X_{jt}. For instance, we do not know the amount of advertising expenditure that firms incur each month for their brand. This effect is thus included in the error term because advertising might play a role in the choice of products by households. As advertising is an appreciable share of production costs, it is obviously correlated with prices. To solve the problem that omitted product characteristics might be correlated with prices, we use a control function approach, as in Petrin and Train (2010). We then regress prices on instrumental variables (W_{jt}) and the exogenous variables X_j of the demand equation :

$$p_{jt} = W_{jt}\gamma + X_j\mu + \eta_{jt}$$

where η_{jt} is an error term that captures the remaining unobserved variations in prices. The estimated error term $\widehat{\eta}_{jt}$ of the price equation includes some omitted variables such as advertising variations and promotions that could explain price variations across products and time periods. Prices are now uncorrelated with the new product-specific error term varying across periods ($\zeta_{jt} = \xi_{jt} - \lambda\widehat{\eta}_{jt}$). We then write the equation 1

$$s_{jt}(\theta) = \int \frac{\exp(\beta_{b(j)} + \gamma_{c(j)} - \alpha_i p_{jt} + \delta_{Si}S_j + \delta_{Li}L_j + \delta_{SL}S_jL_j + \theta_N N_j + \theta_F F_j + \lambda\widehat{\eta}_{jt})}{1 + \sum_{k=1}^{J_t}\exp(\beta_{b(k)} + \gamma_{c(k)} - \alpha_i p_{kt} + \delta_{Si}S_k + \delta_{Li}L_k + \delta_{SL}S_kL_k + \theta_N N_k + \theta_F F_k + \lambda\widehat{\eta}_{kt})}\, dP_\nu(\nu_i)dP_D(D_i) \tag{6}$$

where λ is the estimated parameter associated with the estimated error term of the first stage.

In practice, we use BLP's instruments as the total number of competing products offered by the other manufacturers in each category, the percentage of fruit products and plain products, and the average sugar taste offered by the other manufacturers in each category. Table 12 shows the results of the estimation of the price regression. All instrumental variables are significant and the F-test amounts to 12.08, meaning that the instrumental variables are not weak.

Table 12: **Results on Price Equation**

Variable	**Mean (Std)**
Instrumental Variables	
Distance of competing products: nature	0.18 (0.01)*
Distance of competing products: sugar content	0.00 (0.00)***
Number of competing products	-0.16 (0.04)***
Input cost: cream	0.00 (0.00)***
Exogenous Variables of the Utility Function	
Compote	-
Yogurt	0.68 (0.67)
FBPS	-0.88 (0.72)
ODD	-3.03 (0.84)***
Fruit	-0.10 (0.13)
Nature	-0.30 (0.19)
Taste: sweetness	0.04 (0.02)
Taste: fat	0.15 (0.03)***
Interaction sweetness × fat	0.00 (0.00)*
R^2	0.95
IV F-test	12.37 (0.00)
Number of observations	653

* $p < 0.05$, *** $p < 0.001$; Coefficients $\beta_{b(j)}$ not shown.

9.2 Recipe calculation

Step 1: recipe assessment using Oqali dataset

Since nutritional information necessary to determine the recipes is not reported in the Kantar database, we used Oqali database which records the ingredient lists and nutrition facts label as displayed on the packaging, at the branded product level. We used compotes and fruit purees, and milk products Oqali dataset, built in 2009. We documented product characteristics for 476 marketed yogurts, 183 FBPS and 408 compotes and fruit purees. These data were completed by carrying out an Internet research for products not collected by Oqali. This concerned 67 additional products.

To simplify, we considered that each recipe consists of three main ingredients:

- the sweetening ingredients. Different sweeteners can be used to cook the product. Sugar is the most common but glucose syrup, inverted sugar and other types of sweetening ingredients can also be used;
- a matrix ingredient, which substitutes the sweetening ingredients in case of reformulation. The matrix ingredient is plain yogurt for yogurts, plain fromages blancs or petits suisses for FBPS and fruit puree for

compotes;

- a fixed ingredient for which quantity remains constant when reformulating. This corresponds to the aroma used in flavored yogurts or fruits in fruity yogurts, for example.

The amounts of each main ingredient were deduced from both the ingredients list and the nutrition facts. In the ingredients statement, ingredients are listed in descending order of weight. Moreover, in some cases, the ingredients list indicates precisely the quantity of one or several ingredients. Thus, in the best case, all the necessary information to determine the recipe of a product was found in the ingredients list. In other cases, the ingredients list provided some indications that were not precise enough to determine the recipe. In such cases, we used the fact that the nutrient content of a product is the quantity-weighted average of the nutrient content of its ingredients. We were able, in most cases, to determine the quantity of each main ingredients, by solving the system of equations. Otherwise, some realistic hypotheses based on the usual recipe of the product or its ingredients had to be made. When the information displayed on the packaging was not sufficient to determine the recipe without making strong assumptions, the recipe was not estimated and its characteristics have not been taken into account when aggregating data at the group of products' level (see step 2). This was the case for only a few products.

Step 2: Aggregation into the 131 groups of products of our demand model

Individual marketed products recorded in Oqali dataset were assigned to one of the 131 groups of products, as defined in the demand model. Thus, they were aggregated based on their type (yogurts, fromages blancs/petits suisses, compotes, other dairy desserts), brand, aroma (plain, sweetened, flavored, fruits), and nutritional composition (fat and sugar contents). Mean nutritional composition and mean recipe (amounts of sweetening and matrix ingredients) were computed for the 131 groups of products.

9.3 Computation of the minimum amount of added sugar

The minimum amount of added sweeteners to use has then been estimated for each of the following 18 recipes:

- sweet yogurt with skimmed, semi-skimmed, or whole milk;
- flavored yogurt with skimmed, semi-skimmed, or whole milk, and flavored Greek yogurt;
- fruit yogurt with skimmed, semi-skimmed, or whole milk and fruit Greek yogurt;

- fruit petits suisses with semi-skimmed, or whole milk;
- flavored fromages blancs with skimmed milk;
- fruit fromages blancs with semi-skimmed, or whole milk; and
- compotes, diet compotes.

To simplify, we considered that sugar is the only sweetener used when minimizing the amount of added sweeteners. In order to determine the minimum content of sugar technically feasible and sensory acceptable in a given product, we applied an optimization model. Specifically, we minimized the proportion of sugar y_s subject to the technical constraints of formulation, such as product sweetness, texture or other constraints related to manufacturing. Constraints were identified during previous interviews with manufacturers. They are defined in Table 13. The limit values of constraint were derived from Oqali dataset, by neglecting the extreme observations corresponding to very specific recipes. Table 14 reports those extrema and the values set to calibrate the optimization models for the 18 recipes. Ingredient characteristics used in the constraints are shown in table 15. The optimization models were solved using Simplex LP Solving method of Excel Solver, except for fruit dairy products for which we ran the non-linear GRG algorithm, starting from different sets of initial values in order to make sure the solution is not a local optimum. The calculated minimum amount of sugar are reported in Table 16.

Then we assigned the minimum amount of sugar to be added to each of the 131 groups of products defined for the demand model, by matching the recipes.

Tables 17 and 18 provide the mean contents in caloric sweeteners and fat, before and after minimizing the amount of added sweeteners, by brands and product categories.

Table 13: **Technical constraints of formulation**

Constraint	Description	Mathematical transcription
Texture	In order to obtain a satisfying texture, the dry extract of the product has to be in a certain scale of values	$B^{-} \leq \frac{(B_m * y_m + B_s * y_s)}{(y_m + y_s)} \leq B^{+}$ where B_i is the dry extract of ingredient i
Sweetness	In order to obtain a satisfying taste, the sweetness of the product has to be in a certain scale of values	$S^{-} \leq \frac{(S_m * y_m + S_s * y_s)}{(y_m + y_s)} \leq S^{+}$ where S_i is the sweetening power of ingredient i
Quantity	The sum of the proportions of each ingredient must be equal to 100%	$y_m + y_s + y_f = 100\%$ Due to other ingredients encountered such as water or starch, this constraint has been released for sweet and flavored dairy product with skimmed milk, as follows: $y_m + y_s + y_f \leq 100\%$
Fermentation	Sweetening ingredients, in too high proportion, can inhibit the growth of bacteria, and thus the fermentation process	$\frac{B_s * y_s}{(y_m + y_s)} \leq F^{+}$ where B_s is the dry extract of the sweetening ingredient
Gelation	Sweetening ingredients, in too high proportion, can dilute milk proteins and thus hinder the gelation process	$\frac{y_m * Prot_m}{(y_m + y_s)} \geq G^{+}$ where $Prot_m$ is the protein content of matrix ingredient
Regulatory	According to French regulations, fermented milks (such as yogurts) may be supplemented with ingredients (sugar, flavorings, fruit preparations, additives) to give it a specific flavor, provided that this addition does not exceed 30% of the weight of the finished product	$y_s + y_f \leq 30\%$

Note.: fermentation and gelation constraints could have been released in the case of fruit dairy products because part of the sugar can be added after fermentation and gelation, via the fruits mix.

Table 14: **Constraints specifications**

Recipe	**Matrix ingredients**	**Fixed ingredients**	B^{-}	B^{+}	S^{-}	S^{+}	F^{+}	G^{+}
Sweet yogurt with skimmed milk	Plain yogurt with skimmed milk	-	18.6%	18.9%	10.6	12	11.7%	3.50%
Sweet yogurt with semi-skimmed milk	Plain yogurt with semi-skimmed milk	-	19.5%	22.4%	9.7	11.9	11.7%	3.85%
Sweet yogurt with whole milk	Plain yogurt with whole milk	-	21.1%	22.1%	9.4	14.2	11.7%	3.80%
Flavored yogurt with skimmed milk	Plain yogurt with skimmed milk	Aroma 0.5%	18.6%	18.9%	10.7	12	11.8%	3.50%
Flavored yogurt with semi-skimmed milk	Plain yogurt with semi-skimmed milk	Aroma 0.5%	18.0%	21.3%	8.3	11.8	11.8%	3.80%
Flavored yogurt with whole milk	Plain yogurt with whole milk	Aroma 0.5%	20.4%	22.6%	9.3	11.2	11.8%	3.63%
Flavored Greek yogurt	Plain yogurt with whole milk and cream	Aroma 0.5%	21.4%	24.8%	9.0	13.3	11.8%	3.38%
Fruit yogurt with skimmed milk	Plain yogurt with skimmed milk	Fruits $\leq 13\%$	18%	19.4%	9.5	10	16.1%	4.10%
Fruit yogurt with semi-skimmed milk	Plain yogurt with semi-skimmed milk	Fruits $\leq 7.4\%$	19.4%	24.3%	9.2	14.4	16.1%	3.60%
Fruit yogurt with whole milk	Plain yogurt with whole milk	Fruits $\leq 19\%$	20.3%	27.4%	8.7	16.3	16.1%	3.50%
Fruit Greek yogurt	Plain yogurt with whole milk and cream	Fruits $\leq 9\%$	22%	29.3%	8.5	16.9	16.1%	3.30%
Fruit "petit suisses" semi-skimmed milk	Plain "petit suisses" semi-skimmed milk	Fruits $\leq 7\%$	25.7%	26%	11.4	16.3	-	-
Fruit "petit suisses" whole milk	Plain "petit suisses" whole milk	Fruits $\leq 13\%$	25.58%	30.1%	13	15.7	-	-
Flavored fromages blancs with skimmed milk	Plain fromages blancs with skimmed milk	Aroma 0.5%	21.3%	22.8%	10.9	11.8	-	-
Fruit fromages blancs with semi-skimmed milk	Plain fromages blancs with semi-skimmed milk	Fruits $\leq 8\%$	22.95%	30.4%	8.3	18.1	-	-
Fruit fromages blancs with whole milk	Plain fromages blancs with whole milk	Fruits $\leq 10\%$	28.2%	33.4%	11.6	19.3	-	-
Compotes	Fruit puree	Additives such as ascorbic acid 0.1%	19.4%	30.1%	16.5	26.8	-	-
Diet compotes	Fruit puree	Additives such as ascorbic acid 0.1%	17.4%	23.1%	14.5	21.5	-	-

Table 15: **Dry extract, sweetening power and protein content of ingredients**

Ingredient	**Type of ingredient**	**Dry extract** B_i	**Sweetening power** S_i	**Protein content** $Prot_i$
Plain yogurt with skimmed milk	Matrix ingredient (m)	11.70%	1.42	4.50%
Plain yogurt with semi-skimmed milk	Matrix ingredient (m)	12.30%	1.39	4.25%
Plain yogurt with whole milk	Matrix ingredient (m)	14.30%	1.36	4.20%
Plain yogurt with whole milk and cream	Matrix ingredient (m)	15.75%	1.21	3.92%
Plain "petit suisses" semi-skimmed milk	Matrix ingredient (m)	16.3%	0.576	-
Plain "petit suisses" whole milk	Matrix ingredient (m)	19.5%	0.544	-
Plain fromages blancs with skimmed milk	Matrix ingredient (m)	13.2%	0.680	-
Plain fromages blancs with semi-skimmed milk	Matrix ingredient (m)	16.3%	0.576	-
Plain fromages blancs with whole milk	Matrix ingredient (m)	19.5%	0.544	-
Fruit puree	Matrix ingredient (m)	15.3%	12.70	-
Sugar	Sweetening ingredient (s)	100%	100	-

Table 16: **Optimized minimum amount of added sugar**

Recipe	**Minimum amount of added sugar** $Y_s min$
Sweet yogurt with skimmed milk	9.5%
Sweet yogurt with semi-skimmed milk	8.4%
Sweet yogurt with whole milk	8.2%
Flavored yogurt with skimmed milk	9.5%
Flavored yogurt with semi-skimmed milk	7.0%
Flavored yogurt with whole milk	8.0%
Flavored Greek yogurt	7.8%
Fruit yogurt with skimmed milk	7.1%
Fruit yogurt with semi-skimmed milk	7.5%
Fruit yogurt with whole milk	6.0%
Fruit Greek yogurt	6.8%
Fruit "petit suisses" with semi-skimmed milk	10.4%
Fruit "petit suisses" with whole milk	10.9%
Flavored fromages blancs with skimmed milk	10.2%
Fruit fromages blancs with semi-skimmed milk	7.3%
Fruit fromages blancs with whole milk	10.0%
Compotes	4.8%
Diet Compotes	2.5%

Table 17: **Content in caloric sweeteners before and after reformulation by brands and product categories (g/100g of product)**

	Product categories							
	Compotes		Yogurts		Fromages blancs, petits suisses		Other dairy desserts	
	Before	After	Before	After	Before	After	Before	After
Firm 1								
Brand_1			9.96	7.97	9.20	6.92	20.05	20.03
Brand_2			6.42	6.42	4.97	4.97	11.20	11.20
Brand_3			5.27	5.26				
Brand_4			7.33	6.64				
Brand_5			9.72	8.86	8.46	7.03		
Firm 2								
Brand_6			9.11	7.65	19.37	11.31	16.46	16.45
Firm 3								
Brand_7			11.08	9.83	5.91	5.42	16.90	16.90
Brand_8			11.16	8.79				
Brand_9			12.20	9.90				
Firm 4								
Brand_10	14.52	11.87	13.83	11.60	2.80	2.80	15.92	15.83
Firm 5								
Brand_11	14.82	13.14					14.11	14.01
Firm 6								
Brand_12			5.46	5.46	3.29	3.29	17.66	17.61
Brand_13			6.09	5.69			12.10	12.10
PLs	14.77	12.64	9.76	7.93	7.56	6.34	16.76	16.73
Average	14.74	12.59	9.69	8.06	7.77	6.30	16.95	16.85
Min	10.70	10.70	1.50	1.50	2.70	0.00	11.20	11.20
First quartile	11.65	11.65	4.80	4.80	3.60	3.60	14.75	14.75
Median	14.40	12.56	10.15	9.85	4.55	4.50	16.40	16.40
Third quartile	17.53	13.44	13.10	10.84	12.60	10.49	18.60	18.60
Max	18.60	15.80	17.20	13.36	21.60	15.65	22.70	22.70

Note: Products are reformulated when the sugar content exceeds 12 g for compotes and 10 g for other product categories in order to reduce the amount of the tax or even avoid it altogether, if possible. These reformulations take place within the limits calculated in part 9.3.

Table 18: **Fat Content before and after reformulation by brands and product categories (g/100g of product)**

	Compotes		Yogurts		Fromages blancs, petits suisses		Other dairy desserts	
	Before	After	Before	After	Before	After		
Firm 1								
Brand_1			4.12	4.23	5.56	5.75	5.74	5.70
Brand_2			0.10	0.10	0.10	0.10	0.90	0.90
Brand_3			0.64	0.64				
Brand_4			0.84	0.80				
Brand_5			2.62	2.54	3.15	3.22		
Firm 2								
Brand_6			2.17	2.20	8.11	8.04	7.03	7.14
Firm 3								
Brand_7			4.77	5.19	2.42	2.38	2.20	2.20
Brand_8			1.90	1.87				
Brand_9			1.40	1.44				
Firm 4								
Brand_10	0.46	0.41	3.66	3.77	3.00	3.00	8.57	8.60
Firm 5								
Brand_11	0.50	0.51					3.21	3.17
Firm 6								
Brand_12			1.03	1.04	2.88	2.88	7.42	7.43
Brand_13			2.40	2.41			2.10	2.10
PLs	0.26	0.27	2.52	2.42	4.20	4.11	4.65	4.82
Average	0.32	0.32	2.56	2.48	4.03	3.95	5.36	5.48
Min	0.20	0.20	0.00	0.00	0.00	0.00	0.80	0.80
First quartile	0.28	0.28	0.90	0.90	2.20	2.20	2.95	2.95
Median	0.30	0.30	2.15	2.20	3.30	3.32	5.65	5.65
Third quartile	0.53	0.53	3.30	3.31	6.50	6.73	8.40	8.40
Max	0.90	0.90	10.10	10.10	9.50	10.09	12.50	12.50

Product categories

Note: Products are reformulated when the sugar content exceeds 12 g for compotes and 10 g for other product categories in order to reduce the amount of the tax or even avoid it altogether, if possible. These reformulations take place within the limits calculated in part 9.3.

9.4 Results of the random coefficient logit model

Table 19: **Results of the random coefficient logit model.**

	Estimate (std)
Price	
α	0.130*** (0.000)
Without children	0.029*** (0.000)
Middle income	0.013*** (0.000)
Poor income	0.031*** (0.000)
One obese	0.009*** (0.000)
All obese	0.017*** (0.000)
σ	0.547*** (0.000)
Compote	-
Yogurt	-1.434*** (0.000)
FFPS	-1.005*** (0.000)
ODD	-0.184*** (0.000)
Fruit in Yogurt	0.491*** (0.000)
Nature	0.010*** (0.000)
Sugar taste	-0.023*** (0.000)
Without children	0.051*** (0.000)
One obese	-0.002*** (0.000)
All obese	-0.006*** (0.000)
Fat taste	0.022*** (0.000)
Without children	-0.012*** (0.000)
One obese	0.004*** (0.000)
All obese	0.002*** (0.000)
Sugar taste* Fat taste	0.857*** (0.000)
Error term	0.509*** (0.000)
LL	-3,677,800
Number of observations	1,528,220
Coefficients $\beta_{b(j)}$ not shown	

Note: FFPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively. *** means that coefficients are significant at 1% level.

9.5 Additional tables and figures

Table 20: **Average own-price elasticities by brands and product categories.**

	Compotes	Yogurts	Fromages blancs, petits suisses	Other dairy desserts
Firm 1				
Brand 1		-2.29	-2.76	-2.65
Brand 2		-2.08	-2.70	-3.10
Brand 3		-3.45		
Brand 4		-2.91		
Brand 5		-2.43	-3.10	
Firm 2				
Brand 6		-2.26	-3.69	-2.97
Firm 3				
Brand 7		-1.94	-2.46	-3.07
Brand 8		-2.18		
Brand 9		-2.23		
Firm 4				
Brand 10	-2.78	-2.39	-2.44	-3.45
Firm 5				
Brand 11	-2.80			-3.33
Firm 6				
Brand 12		-2.57	-2.90	-3.86
Brand 13		-2.94		-3.02
PLs	-2.19	-1.85	-2.26	-2.37
All	-2.37	-2.13	-2.52	-2.68

Note: The reported own-price elasticity of a brand and a category is the weighted average (using market shares as weights) of the own-price elasticity of products of this brand in this category.

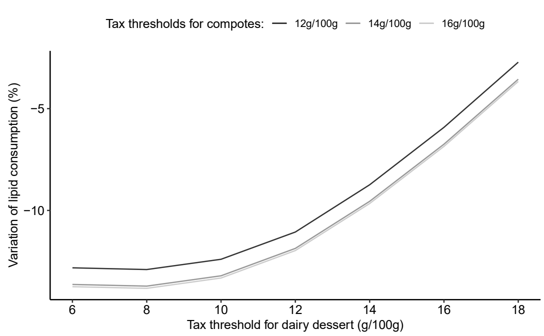

Figure 12: Changes in fat consumption with respect to dairy dessert tax threshold for the tax policy with reformulation

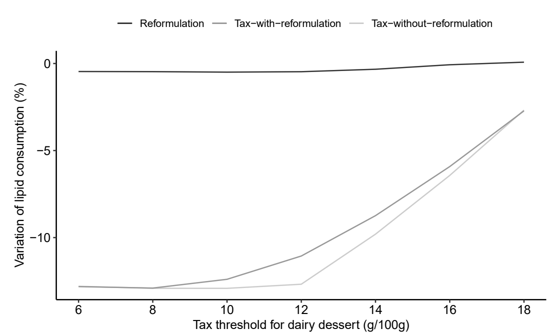

Figure 13: Changes in fat consumption with respect to dairy dessert tax threshold (set at 12g/100g for compotes) for the three policy scenarios

Table 21: **Taxation with and without product reformulation: Average pass-through rates across brands and product categories.**

	Product categories							
	Compotes		Yogurts		Fromages blancs, petits suisses		Other dairy desserts	
	with	without	with	without	with	without	with	without
Firm 1								
Brand 1			1.22	1.22	1.23	1.19	1.22	1.21
Brand 2							1.19	1.19
Brand 3								
Brand 4			1.21	1.20				
Brand 5			1.22	1.22	1.21	1.19		
Firm 2								
Brand 6			1.20	1.21	1.19	1.14	1.18	1.17
Firm 3								
Brand 7			1.24	1.24	1.21	1.19	1.18	1.17
Brand 8			1.22	1.22				
Brand 9				1.22				
Firm 4								
Brand 10	1.18	1.19	1.19	1.21			1.16	1.15
Firm 5								
Brand 11	1.19	1.19					1.17	1.15
Firm 6								
Brand 12							1.14	1.13
Brand 13				1.16			1.19	1.18
PLs	1.16	1.18	1.15	1.18	1.15	1.14	1.18	1.17
All	1.17	1.19	1.19	1.20	1.19	1.16	1.18	1.18

Note: A proportional tax of € 0.20 per 100g of sugar is implemented when sugar content is above 12g for compote and 10g for other product categories. The average pass-trough of a brand for a product category is computed by taking the average of the pass-trough of the taxed products of the brand and category. Hence a brand without any products or any taxed products have a blank display.

Table 22: **Change in the average amount of tax paid by product category and by firm due to product reformulation (in € cents /kg)**

Product category	Δ tax	Firm	Δ tax
Compotes	-5.34	Firm 1	-2.36
Yogurts	-5.32	Firm 2	-2.55
FBPS	-3.64	Firm 3	-8.43
ODD	0.00	Firm 4	-5.76
		Firm 5	-2.16
		Firm 6	-1.78
		Firm 7	-3.07

Note: A proportional tax of € 0.20 per 100g of sugar is implemented when sugar content is above 12g for compote and 10g for other product categories.

Table 23: **Decrease in the average amount of tax paid by product category and by firm due to product reformulation (in (%))**

Product category	Δ tax	Firm	Δ tax
Compotes	23.40	Firm 1	12.95
Yogurts	35.76	Firm 2	9.71
FBPS	33.71	Firm 3	46.01
ODD	0.00	Firm 4	21.85
		Firm 5	9.00
		Firm 6	8.61
		Firm 7	13.98

A proportional tax of € 0.20 per 100g of sugar is implemented when sugar content is above 12g for compote and 10g for other product categories.

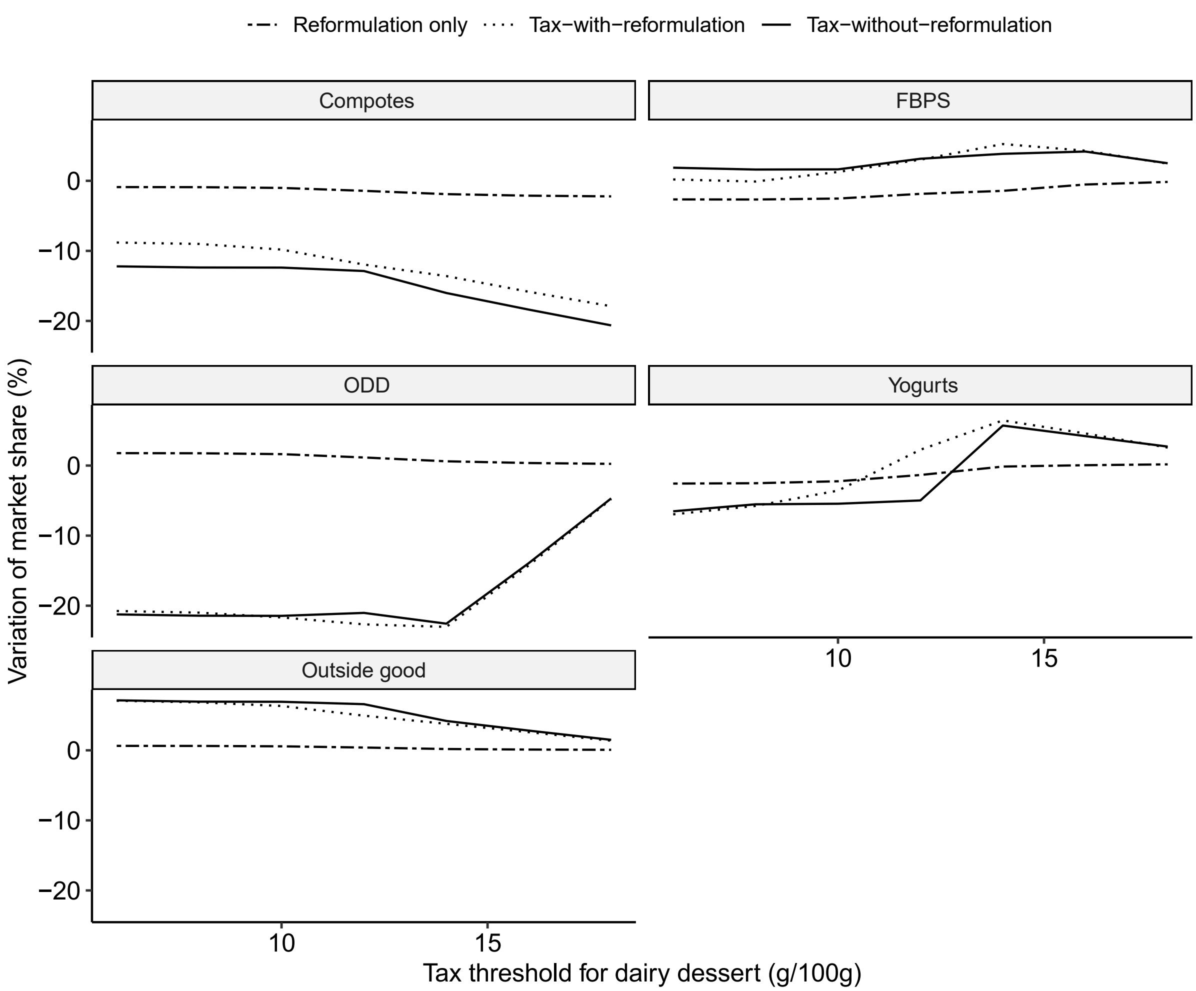

Figure 14: Changes in the market shares by dessert category with respect to dairy dessert tax threshold (set at 12g/100g for compotes) for the three policy scenarios

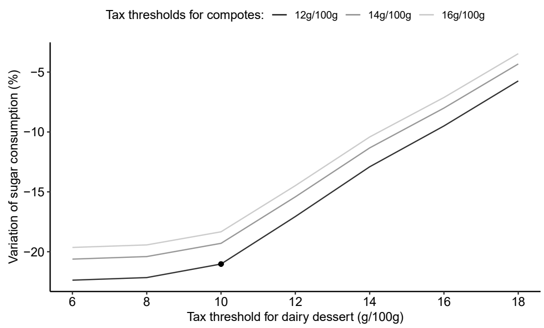

Figure 15: Changes in sugar consumption with respect to dairy dessert tax threshold and three levels of sugar tax threshold (12, 14 and 16g/100g of compotes) for the tax policy with reformulation

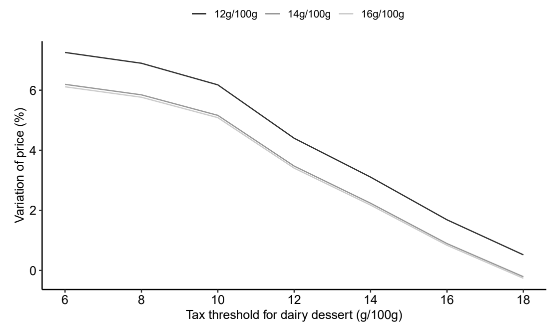

Figure 16: Changes in price with respect to compote tax threshold for the tax policy with reformulation

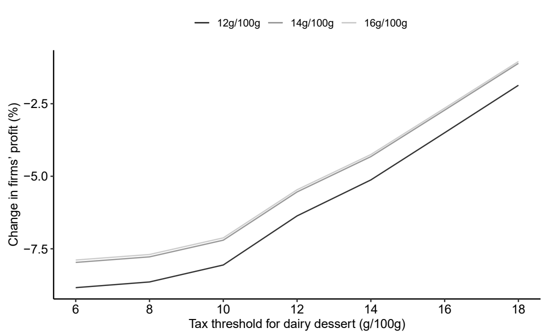

Figure 17: Changes in firms' profit with respect to dairy dessert tax threshold and three levels of sugar tax threshold (12, 14 and 16g/100g of compotes) for the tax policy with reformulation.

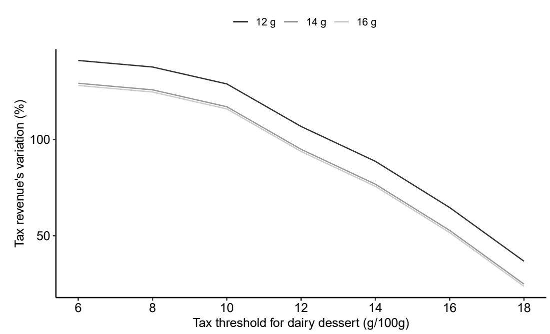

Figure 18: Changes in tax revenue with respect to dairy dessert tax threshold and three levels of sugar tax threshold (12, 14 and 16g/100g of compotes) for the tax policy with reformulation

Table 24: **Change in firms' price due to taxation whether product reformulation is assumed or not (in %)**

	Product categories								Total	
	Compotes		Yogurts		FBPS		ODD			
Reformulation	Without	With	Without	With	Without	With	Without	With	Without	With
Firm 1			4.02	2.73	2.42	1.26	15.43	15.47	5.73	4.69
Firm 2			6.04	2.87	9.28	9.09	10.98	11.13	7.82	6.13
Firm 3			13.16	6.78	1.09	1.08	10.77	10.89	10.30	5.56
Firm 4	9.30	2.56	15.01	12.02	0.16	0.24	7.70	7.78	8.77	5.88
Firm 5	8.71	7.78					9.21	9.32	8.65	8.01
Firm 6			0.40	0.19	0.09	0.16	6.55	6.72	1.94	1.60
Firm 7	12.72	10.61	6.88	2.81	1.69	-0.43	17.95	18.16	9.33	7.31
All	11.58	9.06	6.83	3.75	1.79	-0.32	15.02	15.20	8.05	6.18

Note: A proportional tax of € 0.20 per 100g of sugar per kilo of product is implemented when sugar content is above 12g for compote and 10g for other product categories. Columns 'without' indicate the change in price when firms do not reformulate their products, and columns 'with' when firms do reformulate their products. Firm 1 owns brands 1 to 5; firm 2 owns brand 6, firm 3 owns brands 7 to 9; firm 4 owns brand 10; firm 5 owns brand 11; and firm 6 owns brands 12 and 13. FBPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively.

Table 25: **Change in firms' market shares due to taxation whether product reformulation is assumed or not (in %)**

	Product categories								Total	
	Compotes		Yogurts		FBPS		ODD			
Reformulation	Without	With	Without	With	Without	With	Without	With	Without	With
Firm 1			-1.43	-1.44	0.72	-1.99	-24.56	-24.62	-6.78	-7.40
Firm 2			-3.08	1.08	-15.07	-33.52	-18.28	-18.47	-13.14	-12.41
Firm 3			-14.03	-6.14	5.95	4.99	-18.54	-18.79	-10.20	-4.48
Firm 4	-10.90	-0.81	-18.96	-21.43	10.70	9.93	-14.08	-14.22	-12.94	-10.22
Firm 5	-10.40	-10.05					-13.01	-13.15	-11.06	-10.84
Firm 6			6.44	10.09	11.24	10.59	-13.22	-13.28	-4.83	-3.65
Firm 7	-13.09	-11.63	-6.10	-4.81	1.57	3.41	-23.31	-23.63	-11.75	-10.90
All	-12.39	-9.82	-5.45	-3.57	1.64	1.26	-21.45	-21.68	-10.43	-9.53

Note: A proportional tax of € 0.20 per 100g of sugar per kilo of product is implemented when sugar content is above 12g for compote and 10g for other product categories. Columns 'without' indicate the change in market share's when firms do not reformulate their products, and columns 'with' when firms do reformulate their products. Firm 1 owns brands 1 to 5; firm 2 owns brand 6, firm 3 owns brands 7 to 9; firm 4 owns brand 10; firm 5 owns brand 11; and firm 6 owns brands 12 and 13. FBPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively.

Table 26: **Taxation without product reformulation: Percent change in calories, fat, and sugar intake**

Households		**Children**		**Social classes**			**Adults obese**		
	All	**With**	**Without**	**Rich**	**Medium**	**Poor**	**None**	**One**	**All**
	Intake from the four product categories								
Sugar	-16.45	-16.47	-16.45	-16.26	-16.45	-16.70	-16.33	-16.46	-16.64
	(-649)	(-410)	(-823)	(-789)	(-664)	(-492)	(-646)	(-585)	(-773)
Lipid	-12.92	-12.17	-13.27	-12.99	-12.91	-12.85	-12.86	-12.86	-13.09
	(-144)	(-92)	(-181)	(-174)	(-147)	(-109)	(-143)	(-130)	(-170)
Calorie	-13.98	-13.55	-14.17	-13.93	-13.98	-14.05	-13.89	-13.95	-14.16
	(-4620)	(-2941)	(-5843)	(-5612)	(-4725)	(-3512)	(-4594)	(-4168)	(-5495)

The percentage change in nutrient intakes is calculated over the initial intakes of the market under consideration. The corresponding intakes in grams per capita per year are given in brackets. The per capita consumption of a household is calculated using the following rule: we add one point for an individual 15 years of age or older, and 0.5 point for an individual less than 15 years of age.

Table 27: **Initial per capita consumption per type of household**

Households		**Children**		**Social classes**			**Adults obese**		
	All	**With**	**Without**	**Rich**	**Medium**	**Poor**	**None**	**One**	**All**
Dessert	32	21	39	39	33	24	32	29	38
Sugar	3.9	2.5	5.0	4.9	4.0	3.0	4.0	3.6	4.6
Lipid	1.1	0.8	1.4	1.3	1.1	0.8	1.1	1.0	1.3
Calorie	33.1	21.7	41.2	40.3	33.8	25.0	33.1	29.9	38.8

Intake in kg, per capita, per year, computed over the considered market. The per capita consumption of a household is calculated using the following rule: we add one point for an individual 15 years of age or older, and 0.5 point for an individual less than 15 years of age.

Table 28: **Taxation without product reformulation: Share of taxed products and tax level (€/kg) by brand and product category**

	Compotes		Yogurts		FBPS		ODD	
	Share	Tax	Share	Tax	Share	Tax	Share	Tax
Firm 1								
Brand 1			57%	0.27	50%	0.30	100%	0.40
Brand 2			0%		0%		100%	0.22
Brand 3			0%					
Brand 4			50%	0.22				
Brand 5			50%	0.26	50%	0.26		
Firm 2								
Brand 6			40%	0.27	63%	0.43	100%	0.33
Firm 3								
Brand 7			75%	0.25	20%	0.29	100%	0.34
Brand 8			67%	0.28				
Brand 9			100%	0.24				
Firm 4								
Brand 10	67%	0.32	100%	0.28	0%		100%	0.32
Firm 5								
Brand 11	67%	0.33					100%	0.28
Firm 6								
Brand 12			0%		0%		100%	0.35
Brand 13			50%	0.21			100%	0.24
PLs	67%	0.32	57%	0.27	50%	0.26	100%	0.33
All	67%	0.32	50%	0.27	37%	0.28	100%	0.34

Note: A proportional tax of €0.20 per 100g of sugar per kilo of product is implemented when product sugar content is above 12g for compote and 10g for other product categories. The reported share of taxed products for a brand is computed as the ratio, in percent, of the market share of taxed products and the total market share of the brand. The reported amount of the tax is a weighted average tax of taxed products, using market shares as weights. FBPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively.

Table 29: **Taxation without product reformulation: Changes in average price (€/kg) and market share (%) across brands and product categories**

	Compotes		Yogurts		FBPS		ODD		All	
	Price	MS	Price	MS	Price	MS	Price	MS	Price	MS
Firm 1										
Brand 1			0.11	-4.77	0.08	-1.58	0.51	-27.11	0.23	-13.11
Brand 2			0.00	10.75	0.00	11.59	0.28	-9.31	0.01	5.33
Brand 3			0.00	12.14					0.00	12.14
Brand 4			0.13	0.47					0.13	0.47
Brand 5			0.14	-3.36	0.16	-0.41			0.15	-2.66
Firm 2										
Brand 6			0.15	-3.08	0.51	-15.07	0.42	-18.28	0.27	-13.14
Firm 3										
Brand 7			0.36	-16.54	0.03	5.95	0.42	-18.54	0.23	-7.31
Brand 8			0.22	-11.26					0.22	-11.26
Brand 9			0.31	-17.11					0.31	-17.11
Firm 4										
Brand 10	0.31	-10.90	0.41	-18.96	0.00	10.70	0.38	-14.08	0.33	-12.94
Firm 5										
Brand 11	0.29	-10.40					0.43	-13.01	0.32	-11.06
Firm 6										
Brand 12			0.01	10.92	0.00	11.24	0.40	-13.98	0.05	-4.79
Brand 13			0.06	1.64			0.30	-11.33	0.17	-4.91
Pls	0.29	-13.09	0.12	-6.10	0.04	1.57	0.49	-23.31	0.21	-11.75
All	0.30	-12.39	0.15	-5.45	0.05	1.64	0.50	-21.45	0.22	-10.43

Note: A proportional tax of € 0.20 per 100g of sugar is implemented when the sugar content is above 12g for compote and 10g for other product category. The reported change in price of a brand and a category is the weighted average (using market shares as weights) of the change in price of all products from this brand in this category. FBPS and ODD stand for fromages blancs and petits suisses, and other dairy desserts, respectively.