The effects of a ”fat tax” on the nutrient intake of French households

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Abstract— **This article assesses the effects of a "fat tax" on the nutrient intake of French households across different income groups using a method that estimates the nutrient elasticities of French households. We estimate a complete demand system by aggregating an individual demand system over cohorts. The use of a cohort model is justified by the incompleteness of our data. We find that a "fat tax" would have ambiguous and extremely small effects on the nutrient intake of French households, and its associated economic welfare costs would be similarly weak.**

Keywords— **Household survey data, demand system, nutrient elasticities.**

I. INTRODUCTION

French food policy authorities are questioning the efficacy of a special tax in foods high in calories, fat, or sugar on household purchases and nutrient intake. This tax is generally called the "fat tax" or "junk food tax". It would probably decrease their consumptions, or at least function as a disincentive to unhealthy eating, and generate revenue earmarked to support health measures: improving diet by subsidizing healthful foods, increasing physical activity, obesity prevention, nutrition education, etc. In this paper, we study the question of the efficacy of a fat tax by estimating a complete food demand system using French household data collected by TNS Worldpanel between 1996 and 2001. Prices and nutrient elasticities are then calculated to determine whether a fat tax can substantially alter French household intake of saturated fat and cholesterol as well as the consequences of such a policy on the intake of other nutrients, and how much it affects household economic welfare in the short term. The study period was chosen to evaluate the effects of the fat tax immediately prior to the implementation of the first national nutrition and health program in France.[1] Thus, the effects of informational programs are removed from our analysis.

The estimation of a complete food demand system allows us to take into account all of the effects of prices and income on consumption and on nutrient intake when evaluating food and health policies (see [1], and [2]). Most of applied research on French household consumption, however, has been based on incomplete food demand systems using either some strong separability assumptions, as in [3], or a methodology developed by [4]. One of the main reasons for using incomplete systems is the difficulty of obtaining complete information -including prices, expenditures, and budget shares-on a large set of food products for all households sampled. Indeed, expenditures, quantities, and supply prices for some food categories for any given household are not recorded in TNS Worldpanel data. To solve the problem of incompleteness of our data, we used the method developed by [5]. It consists in a cohort model obtained by aggregating the Almost Ideal Demand System (AIDS) over cohorts.

The general method developed by [5] is used to estimate nutrient elasticities for 32 nutrients in response to changes in 24 food category prices for the period 1996-2001. In particular, households are segmented into six regions of residence, four income groups, and three age classes. Then, the methodology of [2], which consists of applying a nutrient conversion matrix to the price elasticities, is used to derive nutrient elasticities. Finally, the latter are used to examine whether a fat tax would change household nutrient intake. In similar works, [6] and [7] assessed the impact of fat taxes on U.S. household food purchases but not their nutrient intake. These assessments were based on an incomplete demand system, so only some of the impacts of food policy reforms on household behaviour, and particularly on the substitutions between products encouraged by these reforms, could be assessed.

1. The first program was implemented in 2001.

The household food acquisition data contained in the TNS Worldpanel database have advantages over the results of individual food surveys more commonly used to study the relationship between food and health in France. Households respond over a longer period of time (an average of 4 years in the TNS Worldpanel survey), which enables the observation of long-term behaviors and avoids the well-known biases of individual food surveys. In the individual surveys, respondents may over- or under-report their consumption of certain foods of high or low nutritional value, respectively, either because they wish to lie or because they did in fact increase or reduce their consumption deliberately for the short period of the survey. However, TNS Worldpanel database does not take into account the effects of food purchased away from home and do not reach the level of individual choice. [8] and [9] developed non-parametric methods to decompose a series of household quantities into individual quantities. But, in light of the incompleteness of our database and the errors of approximation that follow from decomposition methods, as underscored by [9], we chose not to use these methods in the present study.

We find fat tax to have ambiguous and extremely small effects on household nutrient intake. The effects are ambiguous because increasing the price of a food to reduce intake of nutrients deemed less desirable for health generally reduces intake of other nutrients deemed good for health. For example, reducing saturated fats and cholesterol by taxing dairy products like cheeses and butter reduces household intake of calcium and potassium. Even more importantly, we find nutrient price elasticities to be remarkably inelastic, as in [8] and [11]. These results call into question the effectiveness of tax policies intended to alter nutrient intake, and are consistent with the conclusions of the [6] and [7] for household food purchases. Tax policies, however, offer the advantage of raising revenue that can be used to finance health measures. Moreover, we find the welfare costs associated with a fat tax on dairy products to be quite weak, and they do not vary much across income class, contrary to the results of [6].

The paper is organized as follows. In section 2, the data and the estimation over cohort of the unobserved data are presented. Section 3 provides the assessments of a fat tax in dairy products in terms of nutrient quantity variations, as well as in terms of households' welfare cost for tax policies and revenue raised. The last section concludes.

II. DATA AND THE ESTIMATION OF THE UNOBSERVED DATA

This section begins with a presentation of the data used and an explanation of why the construction of cohorts is needed to estimate a complete food demand system in France. Then, we present the estimated model. More details are given in [5].

A. The data

The TNS Worldpanel is the principal source of information on food purchases in France. Each annual survey contains weekly food acquisition data of approximately 5,000 households, with an annual rotation of 1/3 of the participants. The households are selected by stratification according to several socioeconomic variables and remain in the survey for a mean period of 4 years. All participating households register grocery purchases through the use of EAN bar codes (Universal Product Code), allowing their purchases to be categorized under such heading as cereals, dairy products, cheese, eggs, sugar, and pastries. To register grocery purchases without a bar code, households are assigned to two groups to alleviate the workload. Each group (half of the survey) is requested to register its "at home" purchases for a restricted set of products: meat, fish, and wine for the first group and fresh fruits and vegetables for the second group. Hence, each group covers a different set of products. Although the two lists together include nearly all possible food products at a very disaggregated level, this method means that purchasing information is never complete for a given household. In other words, expenditures, quantities, and supply prices are missing for some food categories for any given household. This has strong implications for micro-econometric studies of food consumption in France: it means that complete demand systems cannot be estimated for the country. It is then impossible to estimate the total impact of nutritional or price reforms on household behavior, particularly the product substitution that these reforms seek to encourage.

To solve the problem of data availability resulting from data structuring, [5] follow the methodology of [12] by using cohorts to estimate the demand system on TNS Worldpanel data for the period 1996 to 2001. We considered carefully how to categorize different food products. Thus, to facilitate the estimation procedure and to reduce the number of parameters to be estimated, the food items are grouped into 24 categories based on similarities in the nutritional content of the products. Our study, therefore, focuses on the following categories of goods: cereal-based products or grain products, including bread, rolls, biscuits, pastries, pasta, rice, wheat flour, and cereals; potatoes; fresh vegetables; processed vegetables; fresh fruits; processed fruits; nuts; beef and veal; pork; poultry; delicatessen (meat products); eggs; other meats; fish and sea foods; mixed dishes (pizza, choucroute, cassoulet, etc.); dairy products; cheese and butter; oils; sugars; chocolate and sweets; mineral and spring waters; non-alcoholic beverages (fruit juices and soda); alcoholic beverages (including wine); coffee and tea.

Potatoes are not included in fresh or processed vegetables since their nutrient content is very different from that of other vegetables. Moreover, we have chosen to group butter with cheese rather than oils because we wanted to distinguish vegetable fats from animal fats. All the quantities and prices of these categories of goods are expressed in the same unit (kilogram, and French franc per kilogram) to ensure that the demand model used to estimate elasticity is "Closed Under Unit Scaling" (CUUS), meaning that the estimated economic effects are invariant to a simultaneous change in unit, as stressed by [13].

We then determined the quantities of the 32 nutrients in the 24 food categories, based on consultations with nutritionists and the composition tables of food products developed by [14]. The nutrients of interest are energy (measured in food calories); fat, subdivided into saturated (red meat, egg, whole milk, etc.), monounsaturated (olive oil, canola oil, peanut oil, etc.), and polyunsaturated (oils from corn, soybean, safflower, cottonseed, fish, etc.); cholesterol and alcohol; proteins, subdivided into vegetable and animal protein; carbohydrates; dietary fibres; micronutrients such as vitamin A (retinol and beta-carotene), B vitamins (1, 2, 3, 5, 6, 9, 12), vitamin C, vitamin D, and vitamin E; and minerals (calcium, iron, magnesium, sodium, phosphorus, potassium).

B. Aggregating AIDS model: a cohort model

The AIDS model is based on budget share that cannot be calculated at an household level, partly because total expenditure is unobserved. Nevertheless, [5] show that the TNS Worldpanel dataset has sufficient information to predict its value through an aggregation procedure over cells. They propose a simple model for estimating the total expenditure of each household as well as the shares which will be compatible with the aggregation of the AIDS system. In this subsection, the cohort construction is first presented, and then the aggregated AIDS model is displayed. Readers interested in the aggregation process of the AIDS could find more details in [5].

Cohort construction

The population is split into homogeneous cohorts based on the following three variables:

(1) a geographical variable that indicates the region of residence of the household. Adjacent regions where traditions and food purchasing patterns show significant similarities are grouped together. French regions are compared according to whether they over- or under-consume the 24 homogeneous categories of goods relative to the national average. For example, the North-Pas de Calais, Picardy, and East regions are aggregated into one region since all three show over-consumption of potatoes, butter, animal fats, and meat products and under-consumption of fresh fruits and oils. This approach leads to six regional modalities: Paris and its suburbs; North-Pas de Calais, Picardy, and East regions (Lorraine, Alsace, Champagne-Ardenne); South-East regions (Provence, Alps, Côte d'Azur); South-West regions (Poitou-Charente, Aquitaine, Midi-Pyrenees, Languedoc-Roussillon) with Limousine and Auvergne; Brittany, Western Loire, and Normandy; and the Centre region (Bourgogne, Franche-Comté, Rhône-Alpes, and the Savoy).

(2) A socioeconomic classification of the households constructed by TNS Worldpanel. This

classification scheme comprises four modalities. The first modality contains the households with the highest levels of income; the second includes households whose income is above the national average; the third comprises the households whose income is below the national average; and the fourth contains the households with low income levels.

(3) An age variable indicating the age of the head of the household. The modalities of the variable were chosen to reflect changes in total energy expenditure (TEE) and basal metabolic rate (BMR) with age, assuming a male with normal weight (defined as body mass index 18.5-25.0 kg m^{-2}). [15] show that the TEE is relatively similar up to 60 years of age, beyond which it decreases moderately. Furthermore, [16] find that the decline in BMR with age may not be linear, with a breakpoint occurring around 40 years. For the present study, the age of participating heads of household in 1996 is divided into three modalities: less than 40; between 41 and 54; and above 55. This split was made to ensure that the number of households in a cell is never below 20, the importance of which was emphasized by [17].

This set of variables enables us to detect the likely differences in dietary intake patterns across regions of residence, income, and age. We get 72 cells, which represent typical households for a given region, income level, and age of the head of household, and each cell contains sufficient number of households, as table 1 illustrates.

The Aggregated AIDS model

[5] show that the individual AIDS model can be aggregated over cells using the weight for aggregation of household h within cell c defined as the weight of the estimated total expenditure of household h relatively to the estimated total expenditure of the cell he belongs. They show that the aggregated AIDS model has the following form:

$$\hat{w}_{ict} = \mu_{ict} + \sum_{j=1}^{N} \gamma_{ij} \ln \bar{v}_{jrt} + \beta_i \left(\overline{\ln x_{ct}} - \overline{\ln(a(v_{rt}))} \right) \quad [1]$$

where $\hat{w}_{ict}$ stands for the estimated expenditure share of good i at period t of cell c for $i = 1,\ldots,24$, and $c = 1,\ldots,72$, $\ln \bar{v}_{jrt}$ stands for the log unit value of product j over cell c in region r, $\overline{\ln x_{ct}}$ stands for the weighted mean total expenditure over cell c, and $\mu_{ict} = \alpha_{i0} + \bar{Z}_{ct}\alpha_i$ such as $\bar{Z}_{ct}$ is the weighted mean characteristic of a cell, and $\overline{\ln(a(v_{rt}))}$ stands for the weighted mean price index such as

$$\overline{\ln(a(v_{rt}))} = \mu_0 + \sum_{i=1}^{N} \left(\alpha_{i0} + \bar{Z}_{ct}\alpha_i \right) \ln \bar{v}_{irt} + \frac{1}{2} \sum_{i,j=1}^{N} \gamma_{ijt} \ln \bar{v}_{irt} \ln \bar{v}_{jrt} \quad [2]$$

$\bar{Z}_{c,t}$ is composed of two set of variables: i) a set of variables to overcome the induced bias resulting from using an error model to estimate total expenditure of each household, and to correct the likely endogeneity of total expenditure; ii) a set of socio-demographic factors that may influence consumer food choices. Socio-demographic variables include the actual or former occupation category of the household head (self-employed person, white collar worker, *blue collar worker*, no activity); whether (s)he is a retiree; the education level of the principal household earner (no diploma, low degree of diploma, level of bac, *bac, and higher degree*); urbanization (rural, small city less than 10,000 inhabitants, city less than 50,000 inhabitants, *city less than 200,000 inhabitants*, big city, and Paris and its suburbs); the proportion of households in the cell that have a garden, a cellar, and own a home; and the composition of children in the household.[2] The child household composition is characterized by 4 groups: children for age groups 0-5, 6-10, 11-15, and 16-18. We also include the proportion of households in the cell that have at least one child younger than 18. Finally, four-week and annual dummies are introduced in the model. Table 2 displays some descriptive statistics for these variables. These variables are then aggregated over cohorts to provide $\bar{Z}_{c,t}$.

The aggregated AIDS model is estimated using the iterated least squares estimator developed by [18]. It amounts to iterating a serie of ordinary least squares regressions until convergence on the parameters is reached. Within each iteration, the estimation is performed equation by equation, imposing the

[2]The reference modality for each socioeconomic variable is in italics.

additivity, homogeneity and the symmetry constraints. Estimation results and demand elasticities are given in [5]. The elasticities have all a correct sign. As in [8], we do not find that quality-adjusted expenditure and own price elasticities vary systematically across income groups.

Table 2 Proportion of households for each sociodemographic variables

Sociodemographic variables	**Mean**	**Std**
Occupation category of the household head		
Self-employed persons	0.079	0.001
White collar workers	0.374	0.003
Blue collar workers	0.518	0.003
No activity	0.029	0.001
Level of education of the principal household earner		
No diploma	0.159	0.180
Weak diploma	0.351	0.169
Level of Bac	0.176	0.093
Bac and Higher degree	0.314	0.253
Urbanization		
Rural city	0.242	0.143
City less than 10,000 inhabitants	0.120	0.070
City less than 50,000 inhabitants	0.128	0.080
City less than 20,0000 inhabitants	0.144	0.088
Big city	0.226	0.166
Paris and its suburb	0.140	0.316
Child household composition		
Children for age group 0-5	0.181	0.252
Children for age group 6-10	0.210	0.268
Children for age group 11-15	0.248	0.252
Children for age group 16-18	0.160	0.171
Share of households that have at least a child (less 18)	0.418	0.337
Share of households with a garden	0.680	0.174
Share of households with a cellar	0.749	0.115
Share of home owners	0.653	0.173

III. SIMULATIONS OF FAT TAX

In this section, we examine whether a fat tax policy can alter French household intake of saturated fat and cholesterol. As [6] pointed out, the assessment of the impact of a fat tax policy impacts is relevant only if we assume that the percentage change in targeted food prices is exactly equal to the tax rate. Below, its impact is assessed by calculating (1) the change in nutrient quantities caused by a price variation in a specified food category, (2) the level of revenue raised, (3) the welfare cost of a fat tax in terms of equivalent variation in total household food expenditure. All the values are calculated at the average point over time for a 1% fat tax policy. However, the effects for other fat tax percentages can easily be calculated since changes in quantity and revenue raised are proportional to the fat tax rate.

A. Recommendations Versus Facts for Fats

Carbohydrates, fats, and proteins provide the energy in food.[3] To ensure an adequate daily energy supply and lower the risk of chronic diseases, the National Academic of Sciences recommends that 20-35% of calories in a diet should come from fats and no more than 10% from saturated fats.

However, analysis of the nutrient shares of different foods, which refers to the proportion of nutrient i=1,...,32 contributed by food category j=1,...,24, indicates that the main source of energy is provided by fats: fats and saturated fats contribute, on average, 43.56% and 16.84% of the total caloric intake of high-income and low-income households, respectively.[4] This analysis also indicates that saturated fats provide 42% of total fat intake for high-income households and 40% for low-income households. The individuals nutrient survey INCA, conducted in France in 1999 by AFSSA,[5] see [19], showed that fats contribute, on

2. The energy yield per gram is as follows: Carbohydrate - 4 kcal, Fats - 9 kcal and Protein - 4 kcal.
3. These statistics do not include alcohol.
4. AFSSA is a French public independent organism contributing through monitoring, alert, research and research instigation to the protection and

average, 38.5% of the total caloric intake. This discrepancy can be explained by the over-representation of children (1/3 of the sample), the problem of infrequent consumptions, as well as over- or under-recording of the consumption of certain foods of high or low nutritional value, respectively, in INCA.

B. Which food categories should be taxed to reduce household intake of saturated fat and cholesterol?

The analysis of the nutrient shares of different foods across income levels reveals interesting differences in the sources of fat across income and may, therefore, provide insightful information to food policymakers. For both high- and low-income households, the main source of saturated fat is the cheese-butter category; foods from this group account for 42.36% and 36.40% of total saturated fat intake for the two classes of household, respectively. The two household groups differ in their main source of cholesterol. For high-income households, it is the dairy products and cheese-butter categories, which provide 21.63% of total cholesterol intake, compared to 19.16% for low-income households. The main cholesterol source for low-income households is eggs, accounting for 19.55% of total cholesterol intake compared to 19.54% for high-income households.

Figure 1 provides further support for the results found above by illustrating that, if we want to reduce the amount of saturated fat in household diets, increasing the prices of dairy products, cheese, and butter may be an effective strategy. Surprisingly, we find that grain product prices can be an effective instrument for modifying household fat intake.

However, these instruments also affect calcium. For example, a 1% increase in the price of the cheese-butter category (or in the dairy products category) decreases calcium intake by 0.20% (0.44%) in high-income households and by 0.14% (0.51%) in low-income households (figure 2). This same increase also reduces sodium intake by 0.10% and 0.12%, respectively.

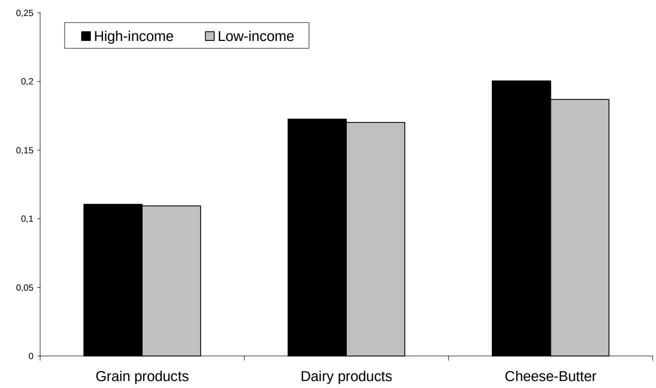

Fig. 1 Highest absolute saturated fat price elasticities (all negative).

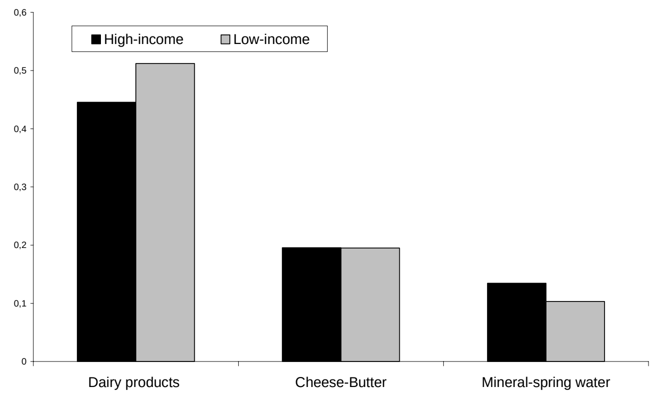

Fig. 2 Highest absolute calcium price elasticities (all negative).

Reducing cholesterol intake in household diets also has ambiguous effects. A 1% increase in the prices of eggs, dairy products, and the cheese-butter category reduces cholesterol intake by 0.08%, 0.22%, and 0.14%, respectively. However, as shown for saturated fat, a 1% increase in the price of the cheese-butter category reduces calcium intake. Thus, increasing the price of eggs may be the solution to reduce cholesterol in household diets, but it may be less effective than increasing the price of the cheese-butter category for decreasing saturated fat.

improvement of public health, animal health and welfare, vegetal and environmental health.

C. The Effects of a Fat Tax

The effects of imposing a fat tax on dairy products and the cheese-butter category on household behaviour were also assessed by [6], [7], [20] and [21] for Great Britain and the U.S. To the best of our knowledge, the present study is the first time that such an assessment has been carried out in France.

(1) **Impact on nutrient intake**. The change in nutrient quantity n caused by a price variation in food category i, ΔQ_n, is calculated as in [6], such as $\Delta Q_n = \tau Q_n Nut_{n,i}$,where τ is the ad valorem tax rate, ΔQ_n is the average intake of the nutrient n, and Nut stands for the (l×N) matrix of nutrient elasticities, showing the effects on l=32 nutrients in response to changes in N=24 food prices. If the tax affects a subset I of food categories, then $\Delta Q_n = \tau Q_n \sum_{i \in I} Nut_{n,i}$.

Table 3 Reduction in 4-weeks specific nutrient quantities per household implied by a 1 percent tax on dairy products and/or cheese-butter (in gram if not specified)

Tax Base	Nutrient	Well-to-do	Modest
Cheese-butter			
	Energy (kcal)	112.38	164.42
	Saturated Fat	3.27	4.87
	Cholesterol	0.20	0.30
	Calcium	0.65	1.04
	Phosphorus	0.63	0.97
	Sodium	0.80	1.20
Cheese-butter and dairy Products			
	Energy (kcal)	165.01	255.60
	Saturated Fat	6.08	9.31
	Cholesterol	0.52	0.79
	Calcium	2.22	3.78
	Phosphorus	1.80	3.02
	Sodium	1.29	2.08

Table 3 reports the average effects of a 1% tax on cheese-butter category on the intake of specific nutrients across income. The calculations suggest that the tax induces very small dietary changes, as also reported by [6] and [7]. In particular, the tax would reduce, on average, saturated fat intake over a four-week period by 3.27 grams and 4.87 grams among high- and low-income households, respectively. To provide a sense of the magnitude of this effect, the average saturated fat intake for high- and low-income households is 1630 grams and 2607 grams, respectively. An additional and positive effect of this tax would be to reduce the quantity of sodium in household diets. However, the tax would also reduce the intake of calcium and phosphorus, especially in low-income households, as seen in the table 3. Implementing a fat tax on cheese-butter and dairy products produces larger effects, but they are still quite small and ambiguous (see table 3).

(2) **Revenue raised**. Despite the small impact on nutrient intake, the two taxes generate substantial revenue equal to $\Delta Q_n = \tau \ln \bar{v}_n \sum_{i \in I} Q_n (1 + \tau Nut_{n,i})$, where $\ln \bar{v}_n$ is the average price over time and regions of the food category n. We find that the tax on the cheese-butter category (or the two categories of cheese-butter and dairy products together) raises an average of 0.18 (0.44) euros per household per four-week period. [6] found that households pay slightly less than $0.17 per four-week period if a 1% tax on dairy products together is implemented. Given that the 1999 census counted 23.8 million households in France, this corresponds to 4.2 and 10.47 million euros per four-week period for a tax on the butter-cheese category and on both the butter-cheese and dairy products categories, respectively.

(3) **The impact on short-run welfare**. The short-run welfare cost is defined as the fall in total household food expenditure that a household living in an environment with no tax is willing to accept while remaining indifferent to living in an environment with a tax. This definition means that the welfare assessment does not include the long-term effects of the tax on household physical health. Its derivation for the aggregated AIDS is developed in [5]. The costs are weak, and total household food expenditure falls to the same extent for both high- and low-income households. We estimate that a low- and high-income

household would be willing to accept on average a total household food expenditure reduction of 0.12 (0.25) euros and 0.11 (0.24) euros per four-week period, respectively, instead of facing a tax on the butter-cheese category or on both categories of butter-cheese and dairy products. Contrary to the results of [6], the welfare costs do not vary much across income class. To compare our results with those of [6], we simulate the welfare effects of a 10% tax applied to dairy products together. We get that the average household is willing to accept a total household food expenditure reduction of 35.68 euros per year, while [6] found a reduction of $22.11. The welfare cost is higher than those reported by [6], but their equivalent variation results are obtained by using an incomplete demand model over dairy products only.

IV. CONCLUSION

This paper questioned the relevance of a fat tax policy in influencing households' nutrient intakes by estimating a complete demand model. We find that price nutrient elasticities are highly inelastic, as [8] and [9] also found for the U.S. We conclude that a fat tax policy is unsuitable for substantially affecting the nutrient intake of French households.

All assessments of fat tax policy so far have assumed a fixed set of food products, thereby excluding the possibility of changes in the food industry in response to a fat tax policy. If a tax is implemented, how would the food industry hedge the tax? Would the food industry change the nutritional quality of the taxed products to smooth retail prices and avoid a decrease in sales? Would the food industry modify the composition of the taxed products by substituting them for more expensive components and/or implementing new industrial production processes, thereby making the innovative product less affordable for low-income households? These likely strategies would aggravate socio-economic disparities in the nutritional quality of food selection and may have major implications for health since nutrition is related to the development of certain chronic diseases. Thus, food policymakers need to keep in mind that a fat tax policy may have perverse effects by exacerbating nutritional disparities among consumers

Finally, we wonder whether a fat tax could be used as a credible threat to urge on voluntary approaches by food industries to reduce saturated fat in food products. We calculate that if saturated fat in dairy products together is voluntary reduced by 1%, the saturated fat intake would fall on average by 11.51 grams per household per four-week period, all else equal (particularly prices[6] and average quantities consumed). It is more three times efficient than increasing the prices of dairy products together: the prices should increase by 3.52% to get a similar variation.

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