Taxing Animal Products for Sustainability: Environmental, Nutritional and Social Perspectives in France

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Abstract

As a base for sustainable taxation policies, we study food demand and the potential substitutions between food groups in France, including disparities among income classes. We built a pseudo-panel from Kantar data (1998-2010) on households purchases for food-at-home, adding their nutritional content and Greenhouse gas emissions. We derive price elasticities by estimating an EASI demand system. Two taxation scenarios are implemented, focusing on (1) environment only, (2) both environment and health. We find undesirable nutritional effects, showing the necessity of a trade-off between environment and nutrition (-18% CO_2eq). The greatest impact is on lower-average income and younger households.

Keywords: EASI demand system, food purchases, socioeconomic inequalities, public policy.

JEL Classification: C35, D12, Q15.

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1 Introduction

Food consumption is estimated to be responsible for 30% of Greenhouse gas emission (GHG) in Europe. To fill the European commitment to reduce GHG emissions by 40% before 2030, changes of diet seem unavoidable. In a global context of increasing pathologies related to nutrition, food policy is now at the double stake of preserving environment (hereafter sustainability) and improving health (here addressed through nutritional objectives). Furthermore, nutrition and health show a strong social gradient (Mackenbach et al. (2008)). Socioeconomic disparities in the purchase basket lead also to differentiated environmental impacts (Boeglin, Bour, and David (2012)). Encouraging an environment-friendly diet through public action must take into account nutritional and social consequences, and food policies should be implemented with those three combined objectives.

Can economic incentives drive environmental sustainability and healthier diets ? Literature and some real life experiences of price policies for health purposes have already addressed some key points: would taxing less healthy products or lowering market prices/subsidizing healthier products increase consumption of desired more healthful products ? Some examples of increasing VAT on unhealthy products (fat, junk food) have been implemented in some countries (France, Allais, Bertail, and Nichèle (2010); Denmark, Smed, Jensen, and Denver (2007); UK, Briggs et al. (2013)) with controversial results in terms of efficiency on the diet and population targeted. In the environmental field, the question whether similar tools could be implemented to encourage both environmental-friendly and healthy food choices raises at least two issues. First, the food groups targeted for environmental reasons may be different than those targeted for health reasons. Second, a price policy may have divergent rationale for implementation, due to price formation: in the environmental framework, price increases result from scarcity due to rarefaction of resources more than from a regulatory policy decision. Besides, a price intervention could be more adequate at the level of producers in case of environment than in the health one (Capacci et al. (2012)). However, the perspective of inducing a more favourable diet for both health and environment through consumer prices is not irrelevant.

Regarding the first issue in the literature, i.e. designing sustainable food policies facing the complexity environment/nutrition, most papers consider policy scenarios or simulate a change in diet dealing with a reduction of meat consumption, since the major toll arises from animal products (McMichael et al. (2007)). In particular, recent studies in UK evaluate the impact of alternative diets lower in red meat and processed meat (Aston, Smith, and Powles (2012)) or different diet scenarios where the largest potential reduction in GHG emissions is achieved by eliminating meat from the diet (35% reduction), followed by changing from carbon-intensive lamb and beef to less carbon-intensive pork and chicken (18% reduction) (Hoolohan et al. (2013)). Scarborough et al. (2012) study the health perspectives of three dietary scenarios based on GHG emissions and finds a potential for substantial improvements. However, less compatibility in objective is not always found. In the French case, Vieux et al. (2013) results are controversial. The impact of different meat reduction scenarios is modest and they emphasize adverse interactions between health and environment aims. Keeping calorie intake constant, when substituting fruit and vegetables for meat in a healthier perspective, GHG emissions may even increase (Masset et al. (2014)). A more global work at the European level considers the consequences of six alternative diets consisting of a 25% or 50% reduction in the consumption of beef, dairy, pork, poultry and eggs, compensated by a higher intake of cereals (Westhoek et al. (2014)). Note that the evaluation of environmental impact is realized mostly through a single indicator (CO_2), which is quite restrictive. Similarly to health where composite indicators have been built such as the Healthy Eating Index (Drewnowski et al. (2009)), some literature environmental index combining various indicators.

These scenarios simulating changes in diets have methodological drawbacks: most of them do not consider a full consumption framework taking into account substitution behaviours. In the French case, both papers cited above modelled various *a priori* hypothesis of substitutions between food groups, which were not based on the estimation of elasticities from a demand system. One reason for this is that they do not deal with the issue of how to obtain this change of diet. Indeed, when we come to the second issue in the literature, i.e. implementing a price policy at the consumer level for lowering GHG emissions, works are rather scarce. The taxation of food products with higher GHG emissions through higher value-added taxes (VAT) on meat and dairy products, or CO_2 emissions level taxes (Edjabou and Smed (2013)), evidences the ambiguity of increasing the price of healthy foods such as low fat sources of animal proteins, for example milk. While waiting for guidelines which would combine health and environmental objectives, the compatibility issue can only be driven by trade-off insights.

A third issue deals with heterogeneity of consumption, meaning in particular different consumption patterns and price sensitivity according to socioeconomic characteristics. A recent paper on Danish data points out that income and education gradients in lifestyle choices vary with age (Ovrum, Gustavsen, and Rickertsen (2014)). Consumption of key products for health consequences such as fruits and vegetables show a widening income gradient with age till 70 years. In the French context, it has been proven to show strong age and generation effects (Hébel and Recours (2007)). Chancel (2014) points out the importance of the generational dimension in consumption patterns and consequent environmental footprint. Some works emphasize that strategies to change meat eating frequencies and meat portion sizes appeal to different segments of consumers which should be addressed in terms of their own preferences. A point of great interest remains in testing the existence of a higher price sensitivity for low income households in order to evaluate the potential of food policies to reduce socioeconomic inequalities. When considering a tax on food prices which involves by nature a regressive content, a specific issue for low income households should take into account food security and the eventual need of a program assistance or compensatory mechanism.

In the perspective of implementing an economic policy combining environmental and nutritional issues in a socially-conscious framework, a food demand study and the potential substitutions between foods is necessary. This article aims at offering a solid base for such policy decisions, which could aim at reducing the carbon content of food purchases with nutritional benefits. Which are the food groups more suitable for a price change ? Where are the more disparities in price responsiveness among income classes ? Are own-price effects the only relevant ? Do cross-price effects matter ? To study food demand, we estimate an Exact Affine Stone Index (EASI) demand system developed by Lewbel and Pendakur (2009) and recently implemented by Zhen et al. (2014) for beverage and food demand. This specification is more flexible than the popular Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) and the subsequent literature. For 21 food groups built according to their environmental and nutritional characteristics, we run expenditure and price elasticities. We obtain these results on four income classes and four age groups in order to assess socioeconomic and life-cycle inequalities in demand. The data cover the period 1998-2010.

Our paper involves several contributions to the study of food demand in a perspective of simulating health and environmental-friendly policies. First, we use the utility-theoretic EASI demand system to characterize household purchases on food and beverage preferences. To our knowledge, this is the first application on French data. Second, we develop this approach on a large panel dataset, an estimation framework which was not addressed till now. Third, we study the implications of social differentiation of food patterns on public policies by taking into account income inequalities and life-cycle effects. It provides detailed results on the eventuality of various patterns of diet substitution and price responsiveness.

This article is organized as follows. Section 2 describes the EASI demand system and section 3 the data and the methodology implemented. Section 4 presents the estimation results and comments the implications for policies. Section 5 concludes.

2 Specification and econometric consumption model

We retain the EASI demand system developed by Lewbel and Pendakur (2009) to describe food demand functions. This approach uses an utility-derived model and non linear Engel curves thus giving more flexibility to the demand specification. It enables to measure socioeconomic inequalities and life-cycle effects in food consumption. Following Zhen et al. (2014), we consider an incomplete demand system to model food-at-home purchases which implies a strong assumption of weak separability. In particular, this implies that we use food expenditure instead of income to design consumer demand (Blundell and Robin (1999)). The EASI demand system share with the AIDS some desirable properties. In particular, it is linear and enables to aggregate over consumer preferences. It also has several advantages because it defines implicit Marshallian demand functions with flexible Engel curves. These demand functions are given by defining the implicit utility as the log of food expenditure deflated by the log Stone price index. Therefore, this specification uses an exact deflator, and not an approximated expenditure.

Here, the EASI demand system is based on cohort observations c[1]. Each cohort budget-shares for food group $i(i = 1, ..., N)$ is defined as the sum over households' budget-shares: $w_{ict} = \frac{1}{N_{ct}} \sum w_{iht}$, for h $(h = 1, ..., H)$ households, $c = 1, ..., C$ cohorts and $t(t = 1, ..., T)$ time periods; w_{iht} is the household h budget-share for food group i and N_{ct} is the number of households within cell c in t. The demand for each food group is defined as a function of prices, food expenditure and socio-demographic characteristics:

$$w_{ict} = \sum_{r=1}^{R} \beta_{ir} (y_{ct})^r + \sum_{l=0}^{L} \alpha_{il} \mathbf{Z_{l,ct}} + \sum_{i=1}^{N} \gamma_i \ln p_{ict} + u_{ict}, \tag{1}$$

where p_{ict} is the price for food group i, cohort c at period t ; y_{ct} is an implicit utility level at the cohort level and for each time period t. Its polynomial degree r enables the flexibility of Engel curves; $\mathbf{Z_{l,ct}}$ include $l(l = 1, ..., L)$ socio-demographic characteristics; β, α and γ are the parameters to estimate; and u_{ict} is the residual. More precisely, the implicit utility level is given by:

$$y_{ct} = \ln(x_{ct}) - \sum_{i=1}^{N} w_{ict} \ln p_{ict} + \frac{1}{2} \sum_{i,j=1}^{N} \gamma_{ij} \ln p_{ict} \ \ln p_{jct}. \tag{2}$$

Plugging Equation (2) into (1) gives a demand system which is not restricted by Gorman rank conditions. It can be see that Engel curves depend on each food group through β parameters, which illustrate the shape of the Engel curve. The polynomial degree r is empirically chosen to fit the data thus giving flexibility to the demand system. This specification enables to exploit the unobserved heterogeneity through the error term. Note that because w appears on both sides of the demand equations, controlling for endogeneity enables to obtain efficient results.

3 Data

3.1 Data description

We use Kantar Worldpanel data from 1998 to 2010. Each annual survey contains weekly food acquisition data for an average of 15,000 households, with an annual rotation of one third of the participants. The households are selected by stratification according to several socioeconomic variables, and remain in the survey for a mean period of four years. All participating households

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[1] This is justified by the structure of our data, see section 3.

register the grocery purchases through the use of bar codes. From 1998 to 2008, to register grocery purchases without a bar code, each household is assigned to one of two groups to alleviate its workload. Each group (half of the survey) is requested to register its purchases for a restricted set of products: meat, fish, and wine for the first group, and fresh fruits and vegetables for the second group. For 2009 and 2010, the two sub-groups are associated into a single group. Hence, the survey gives the food purchases for more than 8,000 households for 169 periods of four weeks spanning over 1998 to 2010. We grouped food items into 21 categories taking into account the environmental emissions and the nutritional contents of the products (according to Masset et al. (2014) results), consumer preferences and consumer willingness to substitute products within categories of foods, see Table 1.

Table 1: Food Groups Sample Mean Budget-Shares and log-prices

	Food Groups	Labels	Budget shares (w_i)		log-price ($\ln p_i$)	
			Mean	Std. Dev	Mean	Std. Dev.
1	Juices	Juic	0.051	0.011	-11.235	0.893
2	Alcohol	Alc	0.100	0.025	-10.752	1.134
3	Soft drinks	Soda	0.039	0.011	-11.715	0.949
4	Bottled water	Wat	0.055	0.010	-12.814	0.918
5	Coffee and tea	Cof	0.046	0.007	-9.795	1.249
6	Fresh fruits and vegetables	FF&V	0.027	0.005	-12.432	1.230
7	Grains and condiments	Grains	0.015	0.004	-10.221	1.251
8	Plant-based foods high in fats	VHF	0.027	0.005	-10.63	1.106
9	Plant-based dishes	VD	0.038	0.009	-9.690	1.090
10	Plant-based foods high in sugar	VHS	0.038	0.009	-11.213	1.072
11	Starchy foods	Starch	0.023	0.003	-12.101	1.099
12	Processed fruits and vegetables	PF&V	0.023	0.003	-11.992	1.130
13	Beef	Beef	0.087	0.020	-9.175	1.107
14	Other meats (lamb, chicken, pork)	OM	0.059	0.009	-10.670	1.020
15	Cooked meats	CM	0.047	0.006	-10.462	1.139
16	Animal-based foods high in fats	AHF	0.027	0.004	-10.834	1.091
17	Cheese	Cheese	0.079	0.020	-10.524	1.058
18	Fish and seafoods	Fish	0.056	0.013	-9.831	1.032
19	Yogurts	Yogurt	0.062	0.014	-12.266	0.961
20	Prepared mixed meals	PrepM	0.049	0.010	-10.897	1.112
21	Prepared desserts	PrepD	0.052	0.008	-11.306	1.082

Nutrients characteristics are those of Vieux et al. (2013), and concern more than 500 food products. For each product, the selected nutrients presented here are energy intake (measured in food calories), and proteins, plant-based proteins, animal proteins, saturated fats, cholesterol, vitamin B12, vitamin D, iron and sodium.

Environmental data[2] are collected by Greenext, an environment consultancy, to assign the environmental impact of products through Life Cycle Analysis. The data set delivers, for 311 products, the environmental impact of producing these products. They are illustrated by the following three variables : (1) CO_2 relates to the impact on climate change (in gram of CO_2 per 100g); (2) SO_2 relates to air acidification (in gram of SO_2 per 100g); (3) N relates to Nitrates outputs (in gram of N per 100g).

3.2 Cohort Construction

We define 48 cohorts to capture both income effects, life-cycle effects, and regional heterogeneity. They are constructed on the following variables:

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[2] Version of the data set 06/11/2013.

1. Four income classes, based on family income corrected by consumption units according to OECD scale (Gardes et al. (2005); Allais, Bertail, and Nichèle (2010)): modest, lower average, upper average, well-off;
2. Four age classes based on the age of household head: under 30 years old, 31-45, 46-60, over 61;
3. Three regions with significant differences over food groups consumptions and expenditure: Paris and its suburbs; the North and East; the South and the West[3].

Hence household data are aggregated to obtain a pseudo panel and recover the total food-at-home expenditure (Allais, Bertail, and Nichèle (2010)). Therefore, our data do not include infrequency of purchase issue, contrary to Tiffin and Arnoult (2010). Here we consider that the absence of purchase during a time period is a true zero corresponding to non consumption. Hence, this dataset is made by 48 cohorts and 169 time periods, i.e. 8112 observations. The descriptive statistics of this sample are presented in Table 2.

Table 2: Proportion of Households for Each Sociodemographic Variable

Sociodemographic Variables	Mean	Std. Dev.
Without child	0.501	0.333
With at least one child (<15)	0.338	0.308
Low degree diploma	0.417	0.167
Level of baccalaureate	0.153	0.084
Baccalaureate and higher degree	0.235	0.204
Home owners	0.527	0.246
Socio-professional category		
Farmers	0.012	0.023
Craftsmen	0.025	0.023
Executives	0.127	0.149
Intermediary profession	0.185	0.137
Employees	0.174	0.115
Workers	0.176	0.159
Retired	0.261	0.364

At the cohort level, and for each time period, we compute for the food purchases: the total emissions (in terms of SO_2, CO_2 and N) and the nutrient intakes, see column (a) of Table 3. Based on the food purchase basket, these values enable to compute the contribution of each food group to the full emissions (resp. nutrient intakes).

3.3 Descriptive Statistics

The set of sociodemographic variables available in our data allows to characterize the modest households (lowest income group) as those living with income per unit of consumption inferior to 1500€/month, whose reference person has an education level inferior or equal to baccalaureate, mainly blue collars or retired. The majority of these households include children under 16 years. The level of equipment is inferior compared to other income groups: on average, these households have at home less computers, or dishwashers. These characteristics induce budget and food purchases disparities, which can be translated in terms of nutritional content and environmental impact.

Socioeconomic disparities in food purchases, nutritional content and environmental impact At the global level, we observe a structure of purchases where food products including animal content represent the major part of the budget (55.6%). This structure varies with age and income classes.

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[3] Variation between regions is very low (see Allen (2010)) hence with three regions we capture the main differences on food consumption.

Table 3: Environmental Emissions, Nutrient Intakes and Percentage of Quantity Change in Total Purchased with 20 % Targeted Taxes

		Average Household Purchases Daily Equivalent Descriptive Statistics (a)		**Percentage of Quantity Change** Impact of Tax (%) (b)	
Variable	Unit	Mean	Std. Dev.	ENV	ENV-NUT
Environmental Emissions					
CO_2	g eq. CO_2	3913.817	1313.980	-9.987	-8.224
SO_2	g eq. SO_2	44.615	14.790	-16.621	-13.877
N	g eq. N	15.120	4.769	-10.286	-7.297
Nutrient Intakes					
Energy	kcal	3081.496	833.159	-8.858	-5.499
Proteins	g	102.641	26.915	-17.034	-8.283
Vegetal Proteins	g	22.680	8.927	-2.286	-2.236
Animal Proteins	g	78.178	21.250	-21.502	-9.941
Saturated fats	g	58.885	15.776	-15.596	-12.510
Cholesterol	mg	494.838	143.36	-18.767	-9.924
Vitamin B12	μg	7.152	1.839	-20.586	-8.586
Vitamin D	μg	2.498	0.755	-18.767	-5.432
Iron	mg	18.500	26.876	-6.409	-3.917
Sodium	mg	3868.042	2304.655	-12.515	-8.956

Among youngest households (with a head of less than 30 years), animal products represent a lesser share in modest (49.6%) than in well-off households (52.6%)[4]. Concerning the nutritional content, note that those disparities vanish: the share of animal source food products in total energy remains around 45.5%. Similarly, the share of animal proteins in total proteins does not vary with income class, around 76.5%. Among the 21 food and beverage groups, plant-based fats and yogurts are the two largest sources of energy. This remains true for the two lowest income classes, while cheese overpasses yogurts in both higher income classes (well-off and upper-average households).

Concerning the environmental impact of purchases, our computation amounts to 1.43 tons CO2 eq. or 3.9kg per household. Figure **??** shows that animal products account only for half of these emissions, near the half for nitrates but 3/4 of SO_2 impact. Highest CO_2 emissions come from modest households (3.9kg) compared to well-off ones (3.4kg). Combining with age, we observe higher emissions with age 45-60, the least among upper-average and well-off households of less than 30 years. Quite similarly, highest SO_2 emissions come from modest households with age 30-45 and 45-60 and the least among upper-average and well-off households of less than 30 years. For nitrate emissions, the results are only slightly different: highest values are observed for modest households with age 30-45 and 45-60, and the least for well-off households less than 30 and 30-45 years. In comparison for CO2 emissions, Chancel (2014)'s work based on French overall consumption found significant life-cycle effects, since older cohorts were the more emitting. Income effects showed that richer were emitting more than poorer.

This is in tune with the range of disparities observed in the calorie and protein contents. The larger environmental emissions and calories content found in modest households purchases correspond to different food patterns, in particular between food-at-home and food-away-from-home. In a previous analysis of French budget data, Caillavet, Lecogne, and Nichèle (2009) found that the budget share for food consumed at home is higher for modest households. Moreover, the demographic composition of the households may differ between the different income and age

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[4] Detailed tables per income and age classes are available upon request.

classes.

4 Estimations and Results

Given we do not observe the price paid by households within the data, they are approximated by using food groups expenditures and quantities purchased. This gives unit values instead of real prices. Indeed, demand estimates are very sensitive to measurement units (Moschini (1995)), therefore we follow Crawford, Laisney, and Preston (2003) to compute them from a first stage estimation. Unit value regressions are made for each food group at the cohort level by regressing unit values on the log-food-at-home expenditure ($\ln(x)$), log-quantities ($\ln(q)$), income classes, time period dummies[5], and three variables illustrating households durable ownership. These latter variables are fryer, dish washer, and freezer[6]. As for the demand system, they are constructed by cohort and indicate the proportion of each household owning these equipments. Estimation results are available upon request. We use a Fixed Effects (FE) estimator, which produce unbiased and consistent parameters estimates with $T = 169$. We find that quantity parameters are all negative and significant at the level of 5%[7]. For example, a 1 % increase of quantity of juices reduces their demand by 0.10%. Food expenditure coefficients are always positive and significant. For juices, alcohol, bottled water, beef, other meats and cheese, our estimates indicates that a 1% increase of food-at-home expenditure increases the unit value of this food group by more than 1%, *ceteris paribus*.

The demand system includes each food group unit values, food-at-home expenditure, and the socio-demographic variables presented in Table 2. The demand system is estimated without the last equation (for prepared desserts) whose parameters are recovered by using the theoretical restrictions (symmetry, homogeneity and adding-up).We demeaned variables to estimate a SURE demand system. For each value of r (starting from 1 to 6), we run an iterated 3SLS estimator. Based on Wald tests, we retain $r = 4$. Here, 72% of the polynomial degree coefficients are significant. Lewbel and Pendakur (2009) and Zhen et al. (2014) retained $r = 5$ based on Wald test for the last degree. We also have 87% significant coefficients for prices. Estimation results are available upon request, and are used to compute several kind of elasticities.

Food Group Elasticities Expenditure, compensated own and cross-price elasticities of food groups are presented in Table 4. They are computed for the sample median of each variable. To measure socioeconomic inequalities, we compute them at the median value of each income and life-cycle classes.

To measure the impact of price variations on household purchases, first, we compute the *food expenditure elasticities* (e_i^{EX}) as follows:

$$e_i^{EX} = (diag(W))^{-1}[(I_J + BP')^{-1}B] + 1_J,$$

where W is a vector of budget shares, $B = \sum_{r=1}^{R} \tilde{\beta}_{ict,r}\overline{y}_{ct}^{r}$, P= $\ln p_{ict}$.

The elasticities are conform with economic theory in the sense that we find positive food expenditure elasticities. At the global level, we observe higher elasticities (slightly over 1) for soft drinks, coffee and tea, and plant-based foods high in fats.

Disaggregated by income and age classes, food expenditure elasticities do not show much variation[8]. There is more variability among food groups than among income and age classes. Among

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[5] We have 169 time periods, which are constructed from 13 periods per years of 4-weeks purchases. Therefore, we introduce 13 years and 12 periods of 4-weeks dummies.

[6] Note that these variables are not included into the demand system.

[7] This level is retained for all the comments in this article.

[8] These results are available upon request.

drinks, soft drinks and bottled water elasticities show some variation with income and life-cycle classes. For example, an increasing budget means a higher increase of soft drinks for older households (reference person over 60 years) and richer ones. Juices elasticities are higher for modest households, in particular over 60 years. Among other foods, plant-based fats and fish elasticities are higher with increasing age. Conversely, starchy foods, processed fruits and vegetables elasticities decrease for all age groups above 30 years.

Second, we compute two kinds of *price elasticities*. Indeed, the EASI is directly derived from a cost function, therefore, it estimates Hicksian demand functions. These latter enables to compute compensated price elasticities (e_{ij}^{EPC}) (or Hicksian price elasticities). They are given by:

$$e_{ij}^{EPC} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} + w_j, \text{where } \delta_{ij} = 1 \text{ if } i = j.$$

These elasticities give the impact of 1% price increase at a constant utility level. However, to design policy issues, uncompensated price elasticities are commonly used because they enable to consider a constant food expenditure in consumer choices. Hence these elasticities are computed with e_i^{EX} and e_{ij}^{EPC} by:

$$e_{ij}^{EPNC} = e_{ij}^{EPC} - w_j e_i^{EX}.$$

As expected, *compensated own-price elasticities* are negative and all significant, see Table 4. Their values are in the same range than Allais, Bertail, and Nichèle (2010)'s results, which were obtained with an AIDS estimation.

Table 4: Food Expenditure, Compensated Own and Cross-Price Elasticities

	Juic	Alc	Soda	Wat	Cof	FF&V	Grains	VHF	VD	VHS	Starch	PF&V	Beef	OM	CM	AHF	Cheese	Fish	Yogurt	PrepM
Juic	-1.295	0.176	0.173	0.061	0.090	0.006	0.028	0.099	0.051	-0.001	0.032	0.039	0.155	0.129	0.087	0.085	-0.153	0.022	0.141	0.005
Alc	0.091	-1.206	0.117	0.041	0.071	0.007	0.016	0.032	0.024	0.102	0.020	0.039	0.044	0.069	0.071	0.033	0.122	0.124	0.071	0.050
Soda	0.229	0.300	-1.518	0.041	0.098	0.018	0.010	0.032	-0.055	0.013	0.020	0.023	0.076	0.059	0.043	0.051	0.252	0.007	0.087	0.107
Wat	0.056	0.072	0.029	-1.389	0.025	0.071	0.007	0.036	0.060	0.011	0.062	0.030	0.122	0.016	0.090	0.056	0.313	0.012	0.117	0.080
Cof	0.098	0.149	0.080	0.030	-0.942	-0.022	0.025	0.023	0.030	0.021	0.012	0.014	0.078	0.022	0.039	0.052	0.005	0.116	0.094	0.056
FF&V	0.011	0.025	0.026	0.151	-0.040	-1.086	0.006	-0.013	0.032	0.001	0.074	0.027	0.111	0.182	0.075	0.091	0.186	-0.056	0.025	0.130
Grains	0.093	0.104	0.026	0.027	0.079	0.011	-0.999	0.031	0.033	0.189	-0.006	0.018	0.131	0.099	0.056	-0.010	-0.051	0.101	0.083	-0.097
VHF	0.185	0.116	0.045	0.073	0.039	-0.012	0.017	-1.171	0.068	0.039	0.108	0.111	0.109	0.089	0.066	0.052	-0.249	0.036	0.211	0.002
VD	0.067	0.060	-0.054	0.087	0.036	0.021	0.013	0.048	-1.018	0.045	0.027	0.032	0.173	0.051	0.073	0.037	-0.153	0.191	0.097	0.100
VHS	-0.002	0.274	0.013	0.017	0.027	0.000	0.078	0.029	0.048	-1.078	0.032	0.015	0.188	0.070	-0.042	-0.003	-0.074	0.264	-0.030	0.135
Starch	0.068	0.081	0.031	0.146	0.023	0.081	-0.004	0.124	0.044	0.049	-1.234	0.061	0.095	0.157	0.106	-0.008	-0.038	-0.010	0.098	0.007
PF&V	0.087	0.166	0.038	0.073	0.030	0.031	0.012	0.132	0.055	0.024	0.064	-1.242	0.099	0.118	0.083	0.031	-0.083	0.097	0.094	0.002
Beef	0.091	0.050	0.033	0.078	0.042	0.033	0.023	0.034	0.077	0.079	0.026	0.026	-1.113	0.099	0.100	0.025	0.016	0.069	0.099	0.014
OM	0.110	0.114	0.038	0.015	0.017	0.080	0.025	0.040	0.033	0.043	0.063	0.045	0.145	-1.340	0.056	0.047	0.114	0.083	0.072	0.100
CM	0.093	0.146	0.035	0.105	0.039	0.041	0.018	0.038	0.060	-0.033	0.053	0.040	0.183	0.070	-1.199	0.069	0.039	0.001	0.096	0.040
AHF	0.161	0.120	0.073	0.117	0.091	0.088	-0.006	0.053	0.054	-0.004	-0.007	0.026	0.082	0.105	0.123	-1.402	0.019	0.067	0.056	0.025
Cheese	-0.102	0.156	0.126	0.227	0.003	0.063	-0.010	-0.088	-0.077	-0.035	-0.012	-0.025	0.018	0.088	0.024	0.007	-0.774	-0.005	0.028	0.106
Fish	0.020	0.221	0.005	0.012	0.098	-0.027	0.028	0.018	0.134	0.176	-0.004	0.040	0.108	0.090	0.001	0.032	-0.007	-1.148	0.093	0.051
Yogurt	0.119	0.116	0.056	0.108	0.073	0.011	0.021	0.095	0.062	-0.018	0.039	0.036	0.143	0.071	0.076	0.025	0.036	0.085	-1.347	0.028
PrepM	0.005	0.102	0.084	0.092	0.054	0.070	-0.030	0.001	0.080	0.103	0.003	0.001	0.025	0.123	0.039	0.014	0.169	0.058	0.035	-1.173
Food X	0.988	0.957	1.050	0.918	1.014	0.944	0.959	1.008	0.837	0.988	0.848	0.853	0.960	0.957	0.976	0.900	0.374	0.862	0.958	0.919

Beverages show the highest price sensitivity, in particular soft drinks. Note that alcohol price elasticity decreases with age and income, while soft drinks price elasticity increase strongly in both dimensions (reaching -1.69 for well-off households whose head is over 60). Contrary to other age groups, juices show a higher elasticity than alcohol above 45 years. Soft drinks and juices are the products with more price sensitivity variations according to income classes at the extreme age groups (younger and older households).

Excluding beverages, higher values are observed for products of animal origin: animal fats, meats excluding beef (i.e.mainly poultry and pork), and yogurts. These foods groups are specially price sensitive. Cooked meats, fish and seafood, and beef price elasticities remain are around 1.2. Yogurts elasticities vary with income : they are lower for modest households and increasing over 45 years, in particular for well-off households. Animal fats and meats other than beef have a price sensitivity driven by income more than by age of the household head. Controlled by age groups, we observe a varying price sensitivity to income for yogurts, animal fats, and other meats (poultry, pork). Here, well-off households show higher elasticities compared to modest households. Among plant-based products, processed fruits and vegetables and starchy foods are the more price sensitive. Plant-based products show less varying elasticities: flat with income, except starchy foods which are more price sensitive for well-off households in the 45-60 age group. Plant-based fats elasticities are higher for modest households under the age of 45, and lower after 60. Note that fresh fruits and vegetables price sensitivity is the same among income classes (but increasing with age of the household head till 60 years). Consequently, when restricting to own-price effects, food groups more suitable for intervention in terms of price sensitivity, are firstly beverages: soft drinks, juices, and bottled water; then animal products: yogurts, animal fats and other meats; among plant-based products: processed fruits and vegetables, starchy foods, and plant-based fats.

However overall food purchases, energy intake and environmental impacts also depend on the signs and magnitude of *cross-price elasticities* between the 21 foods and beverages groups, and in particular between animal and plant-based products. They are presented in Table 4. They all have low values since 0.15 is the maximum. This result differs in particular from the high values obtained by Zhen et al. (2014) in an EASI setting, but based on individual data and not cohorts which have a smoothing effect due to loss of variability. In our estimation, compared to own-price elasticities values, cross-price elasticities could in most cases be considered as negligible. We comment in the following the relationships reaching at least 0.1. Those relationships are substitutions, since all complementarities have low values except in the case of mixed-origin prepared dishes.

The cross-price elasticities observed (see Table 4), when significant, show us both kinds of substitutions: between animal and plant-based products, and within each same origin of products. They also implicate beverages with other food products, showing that liquid and solid part of the diet interfere strongly. Indeed, focusing on animal products, we find that beef purchases substitute mainly with cooked meats, but also with plant-based foods high in sugar and prepared dishes. We observe the same relationships with cooked meats but with a lesser magnitude. Conversely, the group of other meats (mainly pork and poultry) substitute with plant-based foods: fruits and vegetables products (fresh, processed, juices), starchy foods, mixed-origin prepared dishes. Fish and seafoods seem to be a special case: they show higher values for substitutions: with plant-based foods high in sugar (i.e. biscuits and confectionary) and with plant-based dishes. They substitute also with several beverages: alcohol and coffee and tea. Animal fats do not show substitutions nor complementarities with noticeable values. Concerning cheese purchases, we find substitutions with mixed-origin prepared dishes and more unexpectedly with fresh fruits and vegetables, bottled water and soft drinks. Note that Zhen et al. (2014) found also substitution between cheese and soft drinks. Yogurts purchases substitute with plant-based fats and juices. Finally, origin-mixed prepared dishes interact with a large number of other food groups. They substitute mainly with plant-based foods high in sugar, fresh fruits and vegetables, cheese, soft drinks, other meats.

Turning to income and life-cycle effects differences in price responsiveness, we find evidence of limited differentiation for some food groups. Beverages are driven by age more than income (older households showing more price sensitivity to juices and lower for soft drinks, bottled water and alcohol). Conversely to previous estimations on French data (Bertail and Caillavet (2008), Allais, Bertail, and Nichèle (2010)), fruits and vegetables -processed or fresh- have stable price sensitivity according to the income class, but older households have a higher price sensitivity to processed ones. We find as well that disparities in animal or plant-based foods are more driven by age than by income at this stage (for example animal fats and other meats while cooked meats and beef are neutral). Several reasons may explain the weakness of these results. First, it is known that the level of aggregation of data in food groups (21 in our case) does not allow to detect differentiation of purchases through brands and quality within a same food group, which is probably at this level the main strategy of low income households (Beatty (2010)). Second, the aggregation of data through cohorts, implied by the structure of Kantar data, induces mechanically a loss of variability. Finally, we deal with purchases at the level of the household. Therefore the variable of age of the household head becomes a proxy for household structure (determined by the position in the life-cycle : number of members, presence of children) which is a major determinant of the composition of food purchases. Indeed, the two medium age groups (30-45 and 46-60 years), corresponding to working-age adults, show very similar elasticities. The age variable probably captures most part of the remaining variability left by the cohort structure of the sample.

Nutrients and environmental elasticities Finally, with e_{ij}^{EPNC}, we compute environmental and nutrients elasticities (Huang (1996); Huang and Lin (2000); Allais, Bertail, and Nichèle (2010)). For each indicator ℓ, they are given by:

$$Ind_\ell = S_\ell \times D_\ell, \tag{3}$$

where Ind_ℓ denotes the matrix of nutrient and environmental price elasticities, S_ℓ is a matrix including the food share of indicator ℓ, and D_ℓ is a matrix of price elasticities. Hence, we measure the impact of 1% increase of prices on the amount of environmental emissions and nutrient intakes. Such elasticities enable to compute the impact of a price increase on some targeted food products on environmental emissions and nutrient intakes. Nutrient response to price changes are have very low values [9]. This result confirms previous literature (Huang and Lin (2000); Beatty and LaFrance (2005) ; Allais, Bertail, and Nichèle (2010)).

5 Impact of taxation : alternative scenarios

Finally, we implement two scenarios of tax, which are equivalent to a VAT increase:

- In the environment-friendly scenario, namely ENV, we increase by 20% the prices of all products with animal contents. The tax concerns beef, other meats, cooked meats, fats from animal production, cheese, fish and seafoods, yogurts, and prepared mixed meals. These goods have a high environmental impact, see Masset et al. (2014).
- In the environment and nutrition-friendly scenario, namely ENV-NUT, we increase by 20% the prices of food categories most adverse to both environment and health. The tax is implemented on beef, cooked meats, fats from animal production, cheese, and prepared mixed-origin dishes.

The results are presented in columns (b) of Table 3. To assess the attractiveness of our two scenarios, our focus is primarily on the reductions obtained in the environmental impacts through SO_2, CO_2 and N emissions. Then we consider the induced changes in dietary health indicators, such as the changes in total calories and in related animal sources of nutrients, which can be positive or negative for health.

At the environmental level, columns (b) of Table 3, the scenario of taxing all animal products with a 20% rate, ENV, has logically more impact than the mixed scenario, ENV-NUT. ENV decreases emissions from 10% (CO_2 and N) to 16.6% (SO_2). Compared to ENV, ENV-NUT displays inferior reductions in emissions, in particular for N (-30%). Concerning CO_2, total yearly reduction would reach 117kg (ENV-NUT) to 142kg (ENV) CO_2 equivalent per person[10]. This is comparable to the Danish estimates using consumer data which finds a 112kg to 277kg reduction when taxing all foods according to their polluting potential (Edjabou and Smed (2013)). No other literature were found to compare interventions on levels of SO_2 and N emissions.

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[9] They are available upon request.

[10] Computations are based on daily emissions of food purchases. Details are available upon request.

At the nutritional level, reductions in total energy content from purchases vary from -8.8% in ENV to -5.4% in ENV-NUT. In ENV, interesting reductions concern animal proteins (-21.5%) and total proteins (-17%). Vegetal proteins also decrease slightly due to the taxation of products mixing animal and vegetal contents (prepared mixed meals and prepared desserts). Health favorable effects include decreases in saturated fats (-15.6%), cholesterol (-18.7%) or sodium (-12.5%). However, we observe undesirable effects such as a strong decrease in key nutrients: vitamin B12 (-20.6%), vitamin D (-18.8%) and iron (-6.4%). In ENV-NUT, total and animal proteins reductions are only half of those observed in ENV. This leads to lower effects on unhealthy nutrients such as sodium or saturated fats, but also on losses of good nutrients.

In terms of environmental/nutritional compatibility, ENV-NUT appears more balanced: the environmental impact on CO_2 is not so different from ENV, saturated fats and sodium reductions are still consistent, and good nutrients (here vitamins B12 and D, and iron) losses are more limited than in ENV. We find that taking into account health constraints is not so costly since it reduces CO_2 by 17.7%.

Income and life-cycle effects For a given income class, we can observe life-cycle effects, see Table 5. In both scenarios, regarding emissions, age introduces more variations in the well-off income class, especially in N emissions, but this effect remains very moderate. From a nutritional perspective, there are more differentiated effects: reductions in proteins are observed mainly among the 30-45 years, while reductions in saturated fats are more important among the 60 years and over.

For a given age group, we observe income class effects. Here, variations in emissions are a little higher since the rate of change induced by taxation emissions decline from modest to well-off households. However, the nutritional content of the food basket does not appear to vary much with income class. Though moderate, these effects suggest that taxation would induce more differentiated impacts on emissions according to income class, while nutritional changes would induce more disparities among age groups.

Combining income and age effects, in both scenarios the highest rate of reduction in environmental impacts is observed for the young (less than 30 years) and lower-average income households (in ENV, -17% for SO_2 and -10% for CO_2 and N). However in levels, higher total yearly impacts are obtained for households which are in the middle of the life-cycle. Among the various environmental indicators we use, the greatest impact is on SO_2 emissions, which decrease (around -16%), corresponding to the highest reduction in animal proteins (approximately -22%).

More precisely focusing on CO_2 in the ENV scenario, the highest rate of CO_2 reduction is observed for modest or lower-average income households whose head is under 30. In that case, yearly reductions amount to 160kg[11]. However, with a smallest impact rate, total yearly reductions reaches 179kg for the modest households which are in the middle of the life-cycle (household head between 45 and 60 years). The smallest effect accounts for the young and well-off households which has a lower CO_2 content of purchases and therefore reaches only 100kg reduction. Similar impacts can be calculated concerning SO_2 and N emissions. These disparities are partly explained by different patterns of food-at-home consumption, probably more than by variations in price responsiveness as shown by the elasticities. Trade-offs between the two scenarios are however larger for the older households, be they well-off or modest (-18.1% loss in CO_2 reduction) than for the younger ones (-16.8%).

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[11] Computations are based on daily emissions for each income and life-cycle classes of food purchases. Details are available upon request.

Table 5: Percentage of Quantity Change in Total Purchased with 20 % Targeted Taxes

	ENV	ENV-NUT	ENV	ENV-NUT	ENV	ENV-NUT	ENV	ENV-NUT
	Well-Off		**Upper-Average**		**Lower-Average**		**Modest**	
Age less than 30								
CO_2	-9.085	-7.565	-9.848	-8.225	-10.318	-8.612	-10.316	-8.581
SO_2	-15.791	-13.377	-16.532	-14.059	-16.959	-14.386	-16.842	-14.231
N	-9.594	-6.970	-10.173	-7.390	-10.470	-7.493	-10.276	-7.344
Energy	-8.365	-5.067	-9.142	-5.269	-9.506	-5.271	-9.169	-5.220
Proteins	-16.198	-7.884	-17.710	-7.863	-18.074	-7.487	-17.646	-7.651
Vegetal Proteins	-2.075	-2.019	-2.346	-2.291	-2.488	-2.436	-2.744	-2.701
Animal Proteins	-20.745	-9.509	-22.127	-9.320	-22.490	-8.811	-22.135	-8.973
Saturated Fats	-14.536	-11.606	-15.054	-11.843	-15.374	-11.827	-15.366	-11.633
Cholesterol	-18.305	-8.979	-18.532	-9.235	-18.802	-9.272	-19.002	-9.042
Vitamin B12	-19.582	-7.553	-21.233	-7.484	-21.530	-7.100	-21.289	-7.202
Vitamin D	-17.802	-4.452	-18.357	-4.671	-18.553	-4.951	-18.386	-4.667
Iron	-6.492	-3.854	-6.802	-4.038	-7.023	-4.119	-7.191	-4.271
Sodium	-12.250	-8.576	-13.073	-8.594	-13.822	-8.431	-13.299	-8.659
Age between 30 and 45								
CO_2	-10.003	-8.256	-10.001	-8.199	-10.290	-8.472	-10.308	-8.501
SO_2	-16.608	-13.957	-16.670	-13.879	-16.952	-14.162	-16.907	-14.101
N	-10.629	-7.648	-10.496	-7.397	-10.601	-7.454	-10.391	-7.280
Energy	-9.035	-5.576	-9.325	-5.488	-9.489	-5.551	-9.399	-5.405
Proteins	-17.034	-8.528	-17.530	-7.981	-17.788	-8.018	-17.938	-7.787
Vegetal Proteins	-2.039	-1.978	-2.135	-2.080	-2.327	-2.273	-2.612	-2.565
Animal Proteins	-21.472	-10.227	-22.005	-9.564	-22.283	-9.553	-22.470	-9.238
Saturated Fats	-15.463	-12.463	-15.467	-12.180	-15.762	-12.241	-15.732	-11.950
Cholesterol	-18.711	-9.741	-18.602	-9.460	-18.764	-9.443	-19.062	-9.236
Vitamin B12	-20.751	-8.640	-21.178	-8.024	-21.482	-8.075	-21.496	-7.735
Vitamin D	-18.372	-4.938	-18.227	-5.077	-18.440	-5.278	-18.678	-5.173
Iron	-6.557	-3.949	-6.627	-3.943	-6.796	-4.042	-6.925	-4.101
Sodium	-12.513	-8.948	-13.269	-8.849	-13.542	-8.969	-13.573	-8.935
Age between 45 and 60								
CO_2	-9.828	-7.976	-9.885	-8.084	-9.804	-8.048	-9.713	-8.065
SO_2	-16.429	-13.524	-16.550	-13.732	-16.524	-13.733	-16.442	-13.795
N	-10.308	-7.310	-10.364	-7.303	-10.197	-7.142	-9.812	-6.885
Energy	-8.793	-5.757	-8.918	-5.712	-8.889	-5.619	-8.730	-5.485
Proteins	-17.010	-8.980	-17.196	-8.779	-17.316	-8.513	-17.286	-8.199
Vegetal Proteins	-2.034	-1.972	-2.190	-2.132	-2.241	-2.188	-2.348	-2.306
Animal Proteins	-21.328	-10.822	-21.669	-10.576	-21.949	-10.227	-22.043	-9.917
Saturated Fats	-15.772	-13.042	-15.779	-12.846	-16.109	-13.013	-16.188	-12.969
Cholesterol	-18.936	-10.479	-18.776	-10.242	-19.091	-10.201	-19.135	-10.189
Vitamin B12	-20.702	-9.578	-20.914	-9.451	-20.990	-9.133	-21.118	-8.746
Vitamin D	-19.141	-5.630	-18.873	-5.612	-19.009	-5.689	-18.905	-5.897
Iron	-6.195	-3.843	-6.350	-3.919	-6.317	-3.879	-6.220	-3.821
Sodium	-12.901	-9.732	-13.132	-9.628	-13.324	-9.599	-13.006	-9.297
Age more than 60								
CO_2	-10.066	-8.242	-10.044	-8.215	-10.174	-8.399	-10.059	-8.241
SO_2	-16.579	-13.721	-16.668	-13.795	-16.857	-14.061	-16.698	-13.857
N	-10.377	-7.531	-10.315	-7.355	-10.260	-7.327	-10.053	-7.029
Energy	-8.978	-5.978	-8.833	-5.810	-8.729	-5.712	-8.600	-5.487
Proteins	-17.092	-9.166	-17.091	-8.923	-17.180	-8.765	-17.285	-8.339
Vegetal Proteins	-2.055	-1.996	-2.068	-2.011	-2.220	-2.171	-2.277	-2.236
Animal Proteins	-21.277	-10.991	-21.570	-10.744	-21.679	-10.535	-21.811	-9.960
Saturated Fats	-16.424	-13.742	-16.261	-13.528	-16.426	-13.636	-16.399	-13.374
Cholesterol	-19.116	-11.489	-19.183	-11.207	-19.417	-11.524	-19.345	-11.009
Vitamin B12	-20.905	-9.997	-21.073	-9.963	-21.178	-10.079	-21.078	-9.353
Vitamin D	-19.585	-6.410	-19.730	-6.315	-19.907	-6.605	-19.784	-6.409
Iron	-5.793	-3.690	-5.820	-3.684	-5.862	-3.743	-6.074	-3.777
Sodium	-12.939	-9.890	-13.236	-9.928	-13.155	-9.716	-13.114	-9.715

6 Conclusions

In a sustainability perspective, this article examined the impact of French food-at-home purchases on both environmental emissions and nutritional intakes. Furthermore, two alternative price policy scenarios are explored in an attempt to combine environmental and health objectives. For this, we built 21 food groups distinguishing plant-based and animal-based products. We computed food demand elasticities from the EASI demand system estimated on a sample covering 13 years (1998-2010). This demand system allows for flexible Engel curves for each food group. We found evidence of the relevance of this model since the best fit of our estimation was obtained for a polynomial specification of range 4.

On this basis, we computed the mostly used CO_2 emissions elasticities, and also SO_2 and nitrate ones. This is an attempt to widen the range of indicators to take into account different aspects of pollution. To assess possible health effects, we ran as well nutrient elasticities. Finally, we computed disaggregated elasticities over income and life cycle-effect classes in order to take into account the social differentiation of food patterns and price responsiveness. At this point of research, the price elasticities of emissions and nutrients do not induce very important income disparities, but our results on life-cycle effects are noticeable. We are thus able to address key issues in food policy design.

Are animal products sensitive to a price policy and possible to target ? Among food groups, soft drinks, animal fats, yogurts and meats other than beef show the highest responsiveness to prices. At the same time, we find high values of environmental and nutrient elasticities for meats and soft drinks. Our results suggest that taxing these food groups may be a tool for an environmental-friendly policy. This is supported by the fact that we find many interactions in terms of substitutions between all types of foods, be they liquid, solid, plant-based or animal-based. However, their range remains quite limited compared to own-price values.

Is the environmental impact very sensitive to the use of different indicators ? Our results evidence that the CO_2 emissions, which is the indicator most used in the literature, does not show the strongest results. We find that the price sensitivity of SO_2 emissions is higher. Therefore, widening the range of indicators studied could be crucial for the conclusions and is a useful input of our study.

What would be the health implications of an environmental tax designed on animal products? Focusing on eight groups of animal products, which appeared the best candidates to tax on environment grounds, we could appreciate that the nutritional impact is far from neutral. Strong favourable effects on fats or cholesterol decreases coincide with undesirable ones, in particular reduced intakes of key micronutrients such as vitamins and iron. A second scenario which takes into account also health considerations and applies a price increase to five animal products groups only, does not yield the same reduction in emissions but limits the unfavourable nutritional effects. Indeed, in the scenarios presented here, an improvement in health impact would lead to 18% loss of CO_2 reduction.

In conclusion, our study illustrates in the French case the complexity of food demand through the multiple relationships observed between animal and plant-based food groups. It also shows the ambiguities of combining environment with nutrition objectives, through the choice of the food groups on which a price increase should be applied. Obviously, a trade-off cannot be avoided between both constraints. Our analysis shows that it may be not so costly. Of course, more economic scenarios should be implemented. For this, a combined set of healthy and environmental-friendly guidelines from nutritional experts is certainly one issue deserving other developments in the future. Moreover, this perspective may be improved by computations of Consumer Surplus to measure these different public policies.

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