Assessing the distributional effects of carbon taxes on food: inequalities and nutritional insights

France Caillavet, Adélaïde Fadhuile, Veronique Nichèle

Working paper GAEL n° 12/2018

GAEL

Grenoble Applied Economic Laboratory

Consumption – Energy - Innovation

Assessing the distributional effects of carbon taxes on food: inequalities and nutritional insights

Caillavet, France
Fadhuile, Adélaïde
Nichèle, Véronique

November, 2018

https://gael.univ-grenoble-alpes.fr/accueil-gael

contact : agnes.vertier@inra.fr

Assessing the distributional effects of carbon taxes on food: inequalities and nutritional insights

France Caillavet[1], Adélaïde Fadhuile[2], Véronique Nichèle[3]

Abstract

A carbon tax on food could contribute to emissions mitigation and act as a strong signal to economic actors. However, tax regressivity is a major disadvantage. This article addresses equity issues by several means. First, this article includes reallocation proposals in a revenue-neutral approach of several emission-based carbon taxation scenarios at the consumption level on food. Second, this article develops these proposals' distributional incidence, and it evaluates the role of carbon pricing in policy impacts. With a carbon-based approach, the differing emission potentials of food groups highlight the relevance of using proteins as a tax base to redirect animal to plant sources in the diet. Thus, a scenario taxing foods rich in animal proteins and subsidizing plant proteins ones is built. Scanner data on French households in 2010 are analyzed. Several GHG emissions indicators and related nutritional impacts, such as diet quality scores and the shift from animal to plant proteins, are evaluated. Using individual changes in food expenditure, distributional effects based on continuous distribution and inequality indexes are measured, allowing the discussion of the policy options of a targeted vs nontargeted tax and a revenue-neutral approach in the food sector.

Keywords: carbon fiscal policy; revenue-neutral; food consumption; regressivity; inequalities.

Funding: This work was supported by INRA DIDIT Metaprogramme and IDEX Univ Grenoble Alpes. None of these sources had any involvement in any stage of this research.

---

[1] ALISS UR1303, INRA, Université Paris-Saclay, F-94200 Ivry-sur-Seine, France, france.caillavet@inra.fr
[2] UMR GAEL, Univ. Grenoble-Alpes, INRA, CNRS, Grenoble INP, France, adelaide.fadhuile@univ-grenoble-alpes.fr
[3] ALISS UR1303, INRA, Université Paris-Saclay, F-94200 Ivry-sur-Seine, France, veronique.nichele@inra.fr

Assessing the distributional effects of carbon taxes on food: inequalities and nutritional insights

1. Introduction

The recent IPCC report (2018) emphasizes the need for urgent action to preserve the planet from further adverse effects of climate change. At its current rate of change, the temperature is expected to increase by 2.7°C before the end of this century, far exceeding the temperature specified in the 2015 Paris Agreement. The Agriculture, Forestry and Other Land Use (AFOLU) sector is the second-highest greenhouse gas (GHG) emitter after energy (FAO, 2017). This sector is estimated to contribute 30% of total GHG emissions, with the livestock sector responsible for 14.5% of total emissions (Wellesley et al., 2015). Because world demand for proteins and meat is expected to grow steadily due to population increase and the preference for animal protein, the unsustainability of this demand is threatening global environmental resources. If meat and dairy consumption continues to rise at their current rates, by 2050, the agricultural sector alone will produce 20 GtCOeq of the 23 GtCOeq yearly limit, leaving only 3 GtCOeq for the rest of the global economy (Wellesley et al., 2015). Restrictions on meat consumption in developed countries are also supported by nutritional recommendations that encourage lower levels of protein and meat consumption than currently observed (World Cancer Fund, French Nutritional and Health Plan). Therefore, protein consumption is a key issue for GHG mitigation and health. At the European level, the 7th Environment Action Program provides a strategic direction for environment and climate policy planning to 2020 (EEA, 2017). Among the 29 indicators monitored, consumption of animal products and animal protein and the proportion of environmental taxes in total taxes have been identified. Indeed, a carbon tax on food could provide an incentive for consumers to modify their diets to be more climate-friendly, which would provide health benefits by reducing calorie consumption from proteins and/or increasing the importance of plant protein relative to animal protein.

Therefore, environmental taxation on food consumption has been considered in the recent literature; however, it raises several specific issues. First, taking into account the substitutions among all food groups and addressing compatibility between environment and nutritional outcomes are important issues. Indeed, the possibility that households could respond to the internalization of environmental costs in food prices through virtuous substitutions implying all foods, and changes to consumption patterns which would reduce GHGs, is not guaranteed (Wirsenius et al., 2011; Briggs et al., 2013; Edjabou and Smed, 2013; Caillavet et al., 2016; Revoredo-Giha et al., 2018; Bonnet et al., 2018). Second, distributional issues are critical. A major disadvantage to food taxation policies is their regressivity, since lower-income households spend a higher proportion of their budget on food. At the same time, differences in the composition of diets and purchasing patterns according to socioeconomic status are known to matter. In France, meat products in particular have been shown to be recently consumed more by lower status populations (Laisney, 2013; ANSES, 2017). Addressing the equity impact of the carbon tax enhances its social acceptability. In that perspective, since food taxation could result in substantial revenue to enable the implementation of compensation policies, the allocation of revenue through a combination of taxes and subsidies becomes a strategic issue, which is seldom studied in the food sector (García-Muros et al., 2017). Finally, on a methodological basis, carbon pricing is key for the establishment of emission-based taxes and is one of the policy tools for meeting distributional challenges (IPCC 2018), although the evaluation of carbon pricing is very much subject to debate (Stiglitz and Stern, 2017).

This paper contributes to the carbon tax debate by considering a revenue-neutral fiscal policy on food consumption and measuring its effects at a very disaggregated level, thus highlighting its distributional aspects. Applied to food consumption, a taxation policy may have important distributional and nutritional disadvantages, which can be addressed through specific scenario designs. The reallocation of revenues can modify distributional outcomes and diet quality. Furthermore, the importance of carbon pricing can be questioned to obtain not only substantial emissions mitigation but also co-benefits. This paper provides two main contributions. First a revenue-neutral scenario is implemented through subsidies on plant protein rich foods. Second, distributional effects are assessed at the individual level, thus allowing the derivation of inequality indexes. The lesser contributions of this paper consist in evaluating the impact of this fiscal policy with two levels of carbon price on several indicators. The revenue-neutral scenario is also compared to taxes-only scenarios, a carbon tax on all food products, and a tax on all animal-based protein products.

This paper retains an *Exact Affine Stone Index* (EASI) demand system (Lewbel and Pendakur, 2009) to simulate the effects of these fiscal policies on environmental, inequality and nutritional indexes based on French scanner data. The environmental effects are computed based on 3 different indicators capturing climate change, air acidification, and eutrophication. Inequality measures are evaluated through consumer surplus as well as the change in income due to each fiscal policy at the household level. Finally, the nutritional effects include separate nutrients results and a focus on proteins through total protein intake and plant protein proportion as well as an overall assessment of diet quality through a global score.

The remainder of the article is organized as follows. Section 2 provides the literature review. Section 3 describes the empirical method and the data on French households' food consumption. Section 4 presents the outcomes of the simulated tax scenarios with different carbon prices. Section 5 discusses the results, and section 6 concludes the paper.

2. Literature review

The regressive content of environmental taxes has been a topic of concern in recent decades, after the introduction of energy taxes in several countries or in simulation scenarios targeting reducing GHG emissions from the seminal OECD report (1994). Wier et al. (2005) evaluate the incidence of a tax on household consumption in Denmark and find a worsened marginal Gini index of +0.021% on disposable income and +0.007% on expenditure. Kerkhof et al. (2008) present 2 tax scenarios (concerning CO2 or more GHG) and study the distribution of the tax burden across income groups in the Netherlands. The researchers show a worsening of the Gini coefficient by + 0.4 points for a co2 tax and by + 0.11 points for a GHG tax. Feng et al. (2010) evaluates the incidence of a CO2 tax on UK households as a tax burden relative to income of 6.0% in the lower decile compared to only 2.4% in the highest decile; this is 4.3% and 1.7%, respectively, in the case of a GHG tax. Addressing regressivity, revenue-neutral approaches are key strategies to target distributional neutrality. In Metcalf (2008), the regressivity of the carbon tax in the US case is offset by using the revenue to fund a reduction in the income tax.

All these works highlight that any policy raising the price of energy will disproportionately impact poor households, making equity a major concern when taxes are discussed. On this latter aspect, food can be directly compared to energy, although very few papers addressed the distributional issue of a carbon tax on food and skipped social issues, welfare and acceptability. The key issue of introducing compensating mechanisms with a combination of taxes and subsidies was used in certain carbon scenarios designed on food consumption (Briggs et al., 2013; Edjabou and Smed, 2013); however, they did not target distributional neutrality or frequently measure its effect. Evaluating whether the tax burden disproportionately affects households in the lower socioeconomic groups, making carbon taxes on food regressive can be done primarily by comparing the incidence of taxation in different income classes at the mean point. Kehlbacher et al. (2016), in the case of a carbon food tax, report a higher tax burden on poorer households in the UK. However, the finding may depend on the income classes chosen, and some effects may be discontinuous. In the case of the taxation of animal-based foods, Caillavet et al. (2016) find an incidence varying by -9.25% to -5.84% (according to age groups) in 2 lower income classes vs a variation of -7.74% to -4.53% in 2 higher income classes in the French case. In particular, the lowest income class does not bear the highest burden but the lower-average one. This discontinuity is confirmed by Sall‘s work (2018), computing the compensating variations for various income groups after a meat tax in Sweden. In both cases, the lowest income group may not expect the major change.

However, to *fully* assess the inequality impact, individual effects must be observed, and this is not the case of most works. The incidence of a food carbon tax at the level of the individual distribution is analyzed in a Spanish work by Garcia-Muros et al. (2017). By using several inequality measures, the researchers assess the regressive impact of different scenarios. With a carbon tax on all food (25 and 50€/t), the average tax rate varies from 0.83% to 0.40% between the lowest and highest food groups, and they decrease with the income level. At the individual level, very weak regressivity effects of the carbon tax are found; however, they are stronger with a higher carbon price.

Carbon pricing is a related issue, both for emission-based taxes and for redistribution of tax revenue. Guivarch and Rogelj (2017) review scenarios that limit warming to below 2°C with a greater than 66% probability. The latest carbon price trajectory quantifications show short-term prices varying from 15 USD to 360 USD_{2005}/tCO2e in 2030. Compared to the above range of estimations, studies of carbon tax on food consumption set carbon prices at moderate levels. For the world, Revell (2015) applies a level of USD 80/tCO2eq/t meat (0.06 €/tCO2eq/kg meat at 2010 rates). In the UK case, Briggs et al. (2013) assume 2.86 £/tCO2eq/100 g food (0.32 €/tCO2eq/kg food at 2010 rates). Edjabou and Smed (2013) test two prices: 0.26 DKK/kgCO2/kg and 0.76 DKK/kgCO2/kg food (respectively, 35 €/t and 102 €/tCO2eq/kg food at 2010 rates). The range of rates varies greatly; however, it could be floor values. The Stern-Stiglitz Commission (2017) suggests that carbon values computed using older models tend to be underestimated, since they do not consider the many risks and costs associated with climate change.

3. Material and methods

3.1. Empirical strategy

To evaluate the effects of a carbon tax, we use an ex ante framework modeling food-at-home purchases. The *Exact Affine Stone Index* (EASI) demand system (Lewbel and Pendakur, 2009) is retained to model a complete food demand system. The demand for each food group is defined under a weak separability assumption as a function of prices, food expenditure, and socioeconomic characteristics. First, this theoretical demand system is linear in prices and nonlinear in food expenditure, providing a very flexible demand function. This system enables aggregation over preferences as well as considers complementarities and substitutions by defining implicit Marshallian demand functions. The flexibility is also given by Engel curves, which depend on each food group in the entire food purchase bundle. In this specification, the implicit utility is expressed as the log of expenditure on food deflated by the log of the Stone price index, i.e., an exact deflator instead of an approximate expenditure. Second, the EASI demand system is dual to cost functions; therefore, the cost change can easily be derived from the demand parameters. Generally, any price change can be measured given the implicit utility level compared to the baseline situation. Hence, consumer surplus variations are computed here from food cost and its corresponding implicit utility level at the individual level. This last measure enables the calculation of the total revenue generated by a fiscal policy that is used to subsidize selected goods. The subsidy rate is deduced such that the whole revenue is allocated to the households consuming these foods. Distributional effects are computed first through the consumer surplus loss concerning food, i.e., the loss in purchasing power induced by a change in prices. At the global level, this methodology allows comparison of the social impact of different scenarios. However, this measure does not inform on the distributive pattern of the loss or, in particular, on whether the tax burden disproportionately affects poorer households. Thus, we compute inequality measures based on food expenditure and income changes by exploiting the individual heterogeneity captured by our individual evaluations. Using the Gini inequality index, we measure the change between the distribution of expenditures pre- and post-scenario. We also compute the distribution of the share of food expenditure to income pre- and post-scenario with an Engel curve. Furthermore, assuming that a fiscal policy is directly set on consumer prices, we evaluate the impact of this price change on consumer behavior[1]. Using the demand parameters, we compute Hicksian elasticities and food expenditure elasticities. Then, Marshallian elasticities are computed at the individual level of households' purchases. Finally, for several environmental and nutritional indicators, we deduce the change implied by the fiscal policy, deriving indicators elasticities at the individual level. Therefore, for each food group j ($j \in \mathbb{N}$), let ϑ_j represent the emission level and υ represent the extracost corresponding to the value of the carbon tax. We define a subset c of the taxed food groups proportional to the emission level. Let $\tau_{c(j)} = \vartheta_j \tau_j$ if j is taxed in subset c, and 0 if j is not taxed. This designation enables computation of the quantity, denoted $q_{k,j}$, for each indicator k of the post-taxation situation:

$$q_{k,j} = \left(1 + \varepsilon_{k,j} \tau_{c(j)}\right) q_j / 100,$$

where $\varepsilon_{k,j}$ is the indicator elasticity (computed in the first step),

q_j is the initial quantity of food group j,

and $\tau_{c(j)} = \vartheta_{c(j)} / \mathrm{exp}_j$, where exp_j is the household expenditure.

To evaluate the precise impact of the fiscal policy described later, we use individual purchases, i.e., individual prices and quantities for each food group, and total expenditures on food-at-home. These individual values enable evaluation of the statistical distributional effects by comparing the distribution of each indicator before and after the taxation scenario effects. Then, the confidence interval can be computed. The elasticities used to predict changes to consumer behavior are based mainly on the elasticities estimated in Caillavet et al. (2016). The demand parameters are used to compute demand elasticities for 21 food groups. The model takes into account the substitutions between food groups and the household's budget constraints. Here, we used the Hicksian and food expenditure elasticities from that

[1] Modeling firm strategies is outside the scope of this paper. Here the price paid by consumer is directly targeted by the tax. Hence the revenue generated can directly be redistributed to subsidies to other goods.

paper to compute Marshallian elasticities based on individual observations. We then compute environmental and nutrient elasticities at the individual level. We address the distribution of all the indicators described in the section 3.2. The measures are individual and allow the derivation of the distribution of all the changes of these measures.

3.2. The Data

The dataset is based on the merging of several sources. First, purchases are computed from scanner data from the 2010 Kantar Worldpanel. This survey registers households' food purchases, i.e., quantities and expenditure. Households with complete purchase data were selected, resulting in a sample of 7,134 households.

Environmental data are collected by Greenext, an environment consultancy that assesses the environmental impact of 311 food products in France based on life-cycle analysis (Goedkoop et al., 2009). The final values are represented by three different indicators: GHG emissions (gCO2eq/100 g), air acidification (gSO2eq/100 g), and marine water eutrophication (gNeq/100 g), which are denoted CO2, SO2 and N, respectively. These estimations are the only ones available in France of the environmental impact of foods.

The calories and nutrient equivalences of food purchases are based on food composition CIQUAL data[2] provided by the French Agency for Food and Environmental, Occupational, and Health and Safety. CIQUAL data provide information on the number of calories per 100 g of the edible portion of each food item and a set of 18 nutrients. The data are used to assess the mean adequacy ratio (MAR) nutritional score (see Madden et al., 1976). Computed on the basis of a 2,000 kcal per day intake, this score shows the suitability of a diet to the nutritional recommendations. The closer this score is to 100, the better the household diet is.

Finally, foods are allocated to 21 groups that consider their environmental emissions and nutritional content, consumer preferences and the willingness to substitute products within food categories, as in Caillavet et al. (2016). Table 1 summarizes the characteristics of our sample by food groups, in terms of budget proportion, emissions, and nutrients. This table provides daily emission quantities, food expenditure, and purchased quantities per household.

[Table 1 near here]

---

[2] Available at http://www.ansespro.fr/tableciqual.

3.3. Simulation set up

Carbon pricing is based on the French estimations that are compatible with the European Commission's commitment (Quinet, 2009). To evaluate the comparative benefits of different tax rates, and particularly in a revenue-neutral approach, we chose 2 different carbon prices. As a floor price, we used the minimum value set by the Quinet report (56€/t) and a higher value (140€/t), multiplier from the basic one (times 2.5). This ratio eases comparison among our proposed scenarios.

All food groups have different GHG emitting potentials. Table 1 presents the average CO2eq values, expressed per 100 g, for each food group (column A) on which the targeted group choices are made. As steps to the revenue-neutral approach (TAX_SUB), we construct the 3 following scenarios based on GHG levels for each food group (see Table 2).

- **TAX_ALL** concerns all food. With a purely environmental focus, this scenario measures the incorporation of the environmental cost to the entire food sector by applying taxes to all food groups with emission-based rates.
- **TAX_ANI** taxes only the four highest-emitting food groups that are rich in animal proteins. Sustainability is linked to nutrition goals by targeting the set of products most unfavorable to the environment and health, i.e., foods rich in animal proteins, and by highlighting the desired shift to plant protein rich foods. The highest-emitting food groups are primarily animal-based and include "beef", "other meats", "cooked meats", and "cheese". Taxing other animal-based products appears to be less relevant; "fish and seafood" is close to the emissions average and, according to French nutritional guidelines, has suitable nutritional properties. Similarly, "prepared mixed dishes" is close to the emissions average, while "animal-based fats" have a low protein content.
- **TAX_SUB** is the revenue-neutral scenario. This scenario uses TAX_ANI revenue to subsidize two food groups rich in plant protein, "fresh fruits and vegetables" and "starchy foods" (including pulses). This scenario subsidizes healthier and more environmentally friendly foods, which includes foods rich in plant protein. There is a consensus on the role in diets of fruits, vegetables, and pulses (PNNS, 2017; EFSA, 2012). We consider fresh fruits and vegetables whose protein content is higher (4.10%) than processed fruits and vegetables (2.56%). In addition, consumption of fresh compared to processed fruits and vegetables is socially differentiated. In France, dietary intake surveys (ANSES, 2017; Plessz and Gojard, 2013) show that low-income households consume fewer fresh fruits and vegetables. In the case of pulses, for data reasons, we consider the whole

“starchy foods” group. Therefore, two food groups are candidates for subsidies. The food groups targeted for subsidies are consumed less by lower-income households and meet explicit nutritional goals (PNNS, 2017), as improvements are more necessary for disadvantaged households. In addition, subsidizing a restricted set of foods is advantageous to the finances available in the revenue-neutral approach and should have a greater impact on environmental and nutritional outcomes.

4. Results

The scenarios implemented represent different shares among household food consumption. Compared to TAX_ALL, which includes all food groups (100% of household food budget) and related emissions, TAX_ANI concerns 28.2% of the food budget, 52.4% of the SO2 emissions, 30.7% of the CO2 emissions, 39.1% of the N emissions, and 19.7% of the calories of food-at-home purchases. This scenario also taxes 64.3% of the animal proteins (Table 2). TAX_SUB focuses 42.9% of the food budget, 48.8% of the CO2 emissions, 60.8% of the SO2 emissions, 53.0% of the N emissions, and 34.9% of the calories. This scenario taxes 64.3% of the animal proteins and subsidizes 44.2% of the plant proteins.

[Table 2 near here]

The effects of each scenario are evaluated for the two carbon price levels described above (56 €/tCO2eq and 140 €/tCO2eq); see Table 2. When applied to all food groups (TAX_ALL), average tax rates vary from 0.37% to 0.93% (for “coffee and tea” at 56 € and 140 €/t, respectively) to 9.28% to 23.20% (for “animal-based foods high in fats”). For the food groups in TAX_ANI, tax rates are 7.77% to 19.41% for “beef”, 7.74% to 19.35% for “other meats”, 3.67% to 9.18% for “cooked meats,” and 4.29% to 10.73% for “cheese”. TAX_SUB rates are the same as TAX_ANI rates, and the subsidy rates are 4.93% to 14.92% for “fresh fruits and vegetables” and 1.47% to 4.53% for “starchy foods”, including pulses.

In relation to *environmental changes*, all the scenarios predict a significant decrease in emissions (Table 3 and Figure 1). In the case of TAX_ALL, which taxes all foods, the variations in the environmental indicators are noticeable, with emission changes of -6.19% to -15.48% for CO2, -6.97% to -17.43% for SO2 and -6.11% to -15.24% for N. In TAX_ANI, which targets 4 animal protein-based food groups, a lower emissions reduction was induced, with changes of -2.20% to -5.50% for CO2, -3.92% to -9.80% for SO2, and -2.76% to -6.88%

for N. TAX_SUB demonstrates further nuances to the effects on the environment with changes of -0.97% to -1.78% for CO_2, -3.41% to -8.24% for SO_2, and -1.92% to -4.31% for N. Figure 1, for 140 €/tCO_2eq, illustrates that some scenarios are not always different; for example, SO_2 emissions at the 95% confidence intervals are overlapping TAX_ANI and TAX_SUB.

[Table 3 near here]

[Figure 1 near here]

If we examine *equity* first, in terms of loss of purchasing power relative to the food budget, incorporating the cost of carbon into all components of household food has the stronger impact in the TAX_ALL scenario, as expected, compared to the scenarios that involve fewer food groups. TAX_ALL induces a supplementary daily expenditure on food per household of 4.49% to 11.22%, while TAX_ANI increases expenditure of 1.59% to 3.98%, respectively, for 56 €/tCO_2eq and 140 €/tCO_2eq. TAX_SUB induces no increase in food expenditure, on average (Table 1). Then, investigating further the impact of taxation on equity among households, the Gini pre- and post-scenario shows a different range of variations. Based on the distribution of food expenditure, it decreases very slightly with TAX_ALL (-0.001/-0.002 points) and slightly more after taxing and subsidizing the protein food groups (-0.004/-0.010 points) with TAX_SUB. This small effect barely affects the Gini index of the income distribution, which remains unchanged except at the 4th decimal. Finally, considering the change in the share of food expenditure according to income depicts the upward shift for TAX_ALL and TAX_ANI compared to the baseline, Figure 2. Interestingly, the TAX_SUB curve rotates around an approximate average daily income of 100 €. This curve shows that, post-TAX_SUB, lower-income households have a higher food burden, while richer households have a decreased food burden.

[Figure 2 near here]

In relation to *nutritional effects*, three indicators are summarized for the different scenarios (Table 3 and Figure 3). First, MAR indicates the suitability of food purchases in relation to nutritional recommendations. MAR improves slightly in TAX_ALL (+0.16 to +0.38 percentage points), more in TAX_SUB (+0.12 to +0.33 percentage points) but decreases in TAX_ANI (-0.08 to -0.21 percentage points). Second, the proportion of protein in total calories measures the impact of protein substitutions following taxation. Regardless of the carbon price used, all the scenarios show a decrease in the protein proportion, with the greatest being in TAX_SUB (-0.28 to -0.71 percentage points), inducing a protein content of less than 14% for 140 €/tCO2eq pricing. Third, the share of plant protein in total proteins measures the desired substitution from animal to plant proteins. In all the scenarios, the plant protein share increases with the highest rate, 27.59%, in TAX_SUB (+0.92 to +2.54 percentage points). Note that the reduction in total calories purchased reaches -14.85% in TAX_ALL, -2.68% in TAX_ANI and is nearly neutral in TAX_SUB (-0.73%).

[Figure 3 near here]

Representing the distribution of individual effects shows further differences between scenarios. Beyond the difference in levels between scenarios, taxation does not modify the distributional profile of the protein content, with a protein share increasing with income (Figure 4). Conversely, the balance between plant and animal proteins is greatly modified by the different policies. As the plant protein distribution shows a basic U-curve at the baseline, the Figure 5 shows that taxing animal-based foods (TAX_ANI) introduces a disruptive pattern; the plant protein share post-taxation at lower income is at a larger distance from the baseline than at higher income. This finding shows more virtuous substitutions in the purchases of low-income households; one element of explanation is more sensitivity to price increases. Conversely, the new pattern post subsidies (TAX_SUB) shows a greater distance from the baseline for the richer households, which show the highest potential for improvement.

[Figure 4 and Figure 5 near here]

A comparison of the impact of the two *carbon prices* shows a difference in the magnitude of the effects that does not always correspond to the gap between the 56 € and 140 € values (2.5 times), refer to Table 3. In pure taxation scenarios (TAX_ALL and TAX_ANI), tax rates are exactly proportional (Table 2), as are the environmental, nutritional and consumer loss effects. In TAX_SUB, tax rates obtained remain proportional; however, the subsidy rates, which are higher (3.02 times for "fruits and vegetables", 3.09 times for "starchy foods") than the carbon price gap, do not.

Note that our data induce certain limits. Kantar scanner data cover only food. Therefore, we assume that food consumption is separable from other consumer goods, as with other works encountering such constraints (among others, Zhen et al. 2014). However, the results presented here are related to household income, assuming relevant substitutions within food expenditure. Concerning at-home purchases, these estimates can be considered to be lower bound. Considering the whole diet would lead to higher GHG reductions. However, in France, food consumed at home represents 80% of the calories (ANSES, 2017), a higher proportion than in other developed countries. Finally, another limit consists in assuming here that the price increase directly concerns consumer prices. Since we do not include in our analysis the strategies of firms, consumers are assumed to pay the whole carbon tax directly. In this context, our estimations provide a comprehensive assessment of the carbon tax incidence on food-at-home patterns, since they include three dimensions: environment, inequality and nutrition, which are the terms of policy trade-offs.

5. Discussion

The fiscal policies presented here target virtuous substitutions between food groups on an environmental basis. Our first issue is measuring the policies expected regressive content. Our second issue states the potential of a revenue-neutral approach to control for this regressivity, using the redirection of proteins as an allocation tool. Uncertainty remains since certain meat products may be consumed more by lower-income households. The distribution of individual effects on the equity and nutrition aspects remain unknown.

5.1. The respective benefits of scenarios implementing taxes-only: a generalized tax vs a targeted tax

TAX_ALL provide the first ex ante evaluation of the incorporation of carbon costs to all foods for France, distinguishing the emission potential within animal-based and plant-based categories. A similar analysis was conducted in several European countries, the range of emissions reductions depending on the carbon cost applied. For instance, estimated reductions vary in UK by 7.5% (Briggs et al., 2013) or 6.3% (Kehlbacher et al. 2016) and, in Denmark, by 7.9% to 19.4% (Edjabou and Smed, 2013). While at a close rate in Spain (50 €/t, Garcia-Muros et al., 2017), the emissions reduction of 7.5% is in accordance with our results at the mid-range price (56 €/t). In comparison, only a high carbon price (140 €/t) allows substantial environmental impacts (15% or more decrease in emissions) based on the resulting tax rates (0.9% to 19.4% depending on the food group). The nutrition tax literature argues that a minimum 20% tax rate is necessary to achieve dietary change (Mytton et al., 2012). At a 140 €/t, TAX_ALL reduces annual emissions by 318 kgCO2eq per household.

Note that GHG emissions expressed in CO2eq do not register the highest variations. SO2eq emissions are more sensitive to food carbon tax policies and show a change of -17.43%.

TAX_ALL rates induce the highest emissions reductions among the three scenarios considered, since it includes all food groups. Interestingly, this scenario also provides nutritional co-benefits, although moderate (MAR and the shift from animal to plant protein are improved). Therefore, substitution and complementary patterns have favorable environmental and nutritional impacts, providing compatibility between those 2 aspects.

However, the real disadvantage of this scenario concerns equity, since there are both an important negative effect on food budgets observed on average and a regressive impact with an increasing proportion of food relative to income for all households, particularly at the lower end of the income distribution (Figure 2). This finding confirms the worsening of the Gini index + 0.001 at 56 € and + 0.002 at 140 €. This regressive effect of environmental taxes on all foods is found for Spain with a worsening Gini of +0.004 points at a carbon cost of 50 €/t (Garcia-Muros et al., 2017).

TAX_ANI, targeting foods rich in animal proteins, shows a moderate reduction in emissions, nutritional degradation, an extra cost, and a very slight difference related to increased food proportion at both ends of income distribution (Figure 2). Among food groups, meat and cheese are indeed the main contributors to emissions and to vitamin B12 or iron. This finding may explain a lower MAR, which includes, in particular, adequacy of nutrients found in animal foods. The higher consumption of meat products by lower socioeconomic households in France, as in Denmark (Smed et al., 2007) and Spain (Garcia-Muros et al., 2018), confirms the small regressive effect also found in these countries. However, the distributional effects are not directly comparable in the Danish case, where taxes are applied to products other than meat in a nutrition-based scenario targeting foods with high saturated fat content. A study on Sweden finds meat taxes to be nearly neutral in the context of expenditure and regressive in the context of income, although lower-income households spend a lower proportion of their budget on meat (Säll, 2018).

Compared with other French works, the reduction obtained with the 140 €/t in TAX_ANI remains slightly lower than the decrease with a 20% tax imposed on animal-based foods (Caillavet et al. 2016), providing a CO2 reduction of 7.5%. Compared with Bonnet et al. (2018), the maximum emission reduction they found at a 56 € rate is 1.90%. This finding is lower than our results, regardless of the scenarios targeting different sets of products (most foods, fruits, fats and sugar excluded; only beef; only ruminants). The authors use a different approach: a random utility framework to model the demand for animal products and an outside option (certain plant-based products) and a different disaggregation of animal-based products. Here, we use a complete food demand model to analyze the possible substitutions among all food purchases for a higher level of aggregation and considering the entire food purchase.

On a nutritional basis, our approach enables the measurement of the effects on several nutrients (appendix online) and compile them to obtain an overall impact on a diet quality score. Here, we find a deterioration of the MAR. Therefore, such a fiscal policy cannot be recommended on a nutritional basis. Furthermore, our results show a regressive effect at both food expenditure and income distributions.

5.2. A revenue-neutral approach: taxes/subsidies using source of proteins as tool

Concerning *emissions* mitigation, the implementation of subsidies results in an additional emissions effect known as the rebound effect (Greene and Braathen, 2014), compared to the pure tax scenario. This effect may be related to a quantity effect since subsidized products benefit from higher purchases. Indeed, the decrease in total calories purchased remains nonsubstantial in TAX_SUB. These results are consistent with findings highlighting the relationship between emissions and calorie intake (Vieux et al., 2012).

The reallocation of the food budget through subsidies is expected to have a favorable impact on poorer households. Accordingly, the *equity* effects are very different from the other scenarios. The revenue-neutral scenario is the only policy that is not regressive, on average, since the food budget remains unchanged. However, disaggregating over household income suggests that regressivity continues to be observed since the proportion of food expenditure in income increases for lower-income households and decreases for higher-income households. These results are explained by socially differentiated consumption patterns. Although lower socioeconomic status households consume more meat products, this regressivity result is not induced by meat taxation since this crossover effect is not observed in TAX_ANI. The other patterns of consumption specific to lower income households consist in smaller quantities of fruits and vegetables, particularly fresh ones. Indeed, the regressivity of the TAX_SUB scenario can be explained by the impact of subsidies on fresh fruits and vegetables. Comparing the variations in quantities for households below the poverty line (Burricand et al., 2012) to those for the average population shows that the baseline quantities are lower in poorer households (180 g vs 354 g/capita/day), and the rate of increase post-TAX_SUB is lower (17.2% vs 23.2%). As Marshallian elasticities are very similar for the two sample populations (appendix online), total and households below the poverty line, this finding can be interpreted as a pure quantity effect.

Therefore, subsidizing healthier foods will provide greater benefits for those consumers who currently consume more of these foods, i.e., higher income households (Figure 2). This finding may not be always the case, as Garcia-Muros et al. find that, in Spain, a combination of taxes and exemptions yields better results in terms of distribution regressivity, as the exempted goods (cereals, milk, fruits and vegetables) are consumed in greater proportions by lower-income households. The choice of targeted foods for redistribution purposes may be very different on nutritional or social bases.

TAX_SUB shows the efficiency of a reallocation of tax revenue to combine environmental and nutritional benefits, by allowing a reduction of GHGE and an increase of the balance of consumption with more plant-based foods. As shown by Briggs et al. (2013) for Britain, a revenue-neutral approach cannot build a reallocation rule on a pure emissions criterion. The authors showed that taxing the highest emitting food groups (above the average level of emission) to subsidize the lowest-emission food groups would have adverse health effects. Our results confirm this finding. Indeed, average emissions are 360 kgCO2eq per kg of food for French households. Using the approach in Briggs et al. (2013), seven food groups would exceed this threshold and would be candidates for taxation (Table 1). At the same time, in a revenue-neutral approach focused on a pure environmental basis, subsidies would be allocated to the food groups below this threshold. This allocation would favor nutritionally undesirable products such as “alcohol”, “soft drinks,” and “foods high in sugar”. In contrast, promoting a shift from animal to plant-based protein on an environmental basis improves the nutritional indicators. In this case, the MAR degradation of TAX_ANI is overtaken by the beneficial effect of subsidies in TAX_SUB, which target the main contributors of fiber and vitamin C intakes, mainly through fruits and vegetables. The highest carbon price allows a 14% reduction in calories from protein and an increase in fresh fruit and vegetable purchases consistent with nutritional guidelines (400 g/capita/day for fruits and vegetables in PNNS). Averaging household per capita quantities, we obtain an average of 404 g at 56 € *versus* 502 g at 140 €. However, since fruit and vegetable consumption is known to be heterogeneous, and since increasing this consumption for disadvantaged populations is a national priority, it is necessary to check whether the TAX_SUB impact holds for lower-income households. For households below the poverty threshold, quantities purchased were found to remain well under the nutritional recommendations (232 g/capita/day including at a carbon price of 140 €/t). In this perspective, a high carbon price is more than adequate. Then, using the source of protein as a reallocation rule is much better than a pure environmental criterion based on emissions.

Finally, the revenue-neutral scenario shows strategic cobenefits compared to the two other scenarios and shows that a high carbon price is a necessary condition for its impact. The resulting nutritional indicators of TAX_SUB are all favorable, with an improving diet quality score, a decreasing total protein content, and an increasing proportion of plant proteins. As in other works that do not impose an isocaloric constraint, our scenarios based on taxation alone induce calorie reductions, which raises doubts regarding the feasibility of the consumer behavior change. In contrast, TAX_SUB is more reasonable by showing calorie stability (under 1% decrease). Compared to other articles, the scenarios including subsidies induce calories changes, increases in Edjabou and Smed, respectively (2013), and a decrease in Garcia-Muros et al. (2017).

A high carbon price logically induces a larger decrease in emissions (in TAX_SUB: 20 kgCO2eq per household) than the intermediate price. However, the high carbon price is also crucial for achieving better compliance with nutritional guidelines. Indeed, the higher the carbon price is, the higher the revenue available for public action at a nonproportional rate (here, a factor of 2.7). Since the revenue amount in a revenue-neutral scenario determines subsidies, the gap between subsidy rates at different carbon prices is observed to be higher than the carbon price gap. Although regressivity is also stronger when the carbon price is higher (as also noted in Garcia-Muros et al.), the decision over the use of revenue makes the difference. The social acceptability of the carbon tax relies on the political choices of redistribution. While a distributionally neutral scenario for a carbon tax appears to be difficult to build, considering nutritional constraints, another perspective is to study income compensation in another field, in the manner of Metcalf (2008), combining energy carbon taxes with labor taxes. To match with nutritional priorities, the use of food stamps for lower-income populations appears more adequate than global subsidies.

6. Conclusions and perspectives

This paper analyzed the impacts of several taxation scenarios targeting GHG mitigation. Carbon taxation represents an efficient tool for discouraging carbon-intensive patterns of food consumption but bears regressive content. Therefore, a revenue-neutral scenario has been implemented for France. Proportional emission-based tax rates allowing discrimination among foods according to their environmental impacts were designed. The investigation was based on two carbon prices in the mid- and high-ranges (56 €/tCO2eq to 140 €/tCO2eq). The key environmental food tax issues are discussed with a specific focus on the distributional impacts and nutritional cobenefits.

The results show that carbon pricing needs to be high to obtain substantial impacts. A carbon tax policy could reduce GHGs by more than 15% if all food groups are targeted. We show that the reallocation scenario improves the nutritional quality of food purchases, related particularly to the desired substitution of animal with plant proteins. However, although neutral on average, this scenario induces overall unfavorable distributional effects between households and subsidies. The literature shows (Briggs et al., 2013; Caillavet et al., 2016) that compatibility among environmental objectives, health, and social equity is difficult and leads to trade-offs.

Regarding the direction set by the 7th Environment Action Program, our results show that it is possible to reduce consumption of animal protein and increase the proportion of environmental taxes in total tax revenues at the French level. We also show that the magnitude of the carbon price matters. Indeed, a high carbon price could have several benefits for food environmental taxation. This price provides a stronger signal to consumers, is more efficient at changing consumption patterns, and induces higher emissions reductions. Interestingly, the induced impacts are nonproportional to the price gap and are higher for tax revenues, accelerating nutritional improvements and providing more means to improve equity. Further research could, at the least, consider a policy of targeted subsidies on fresh fruits and vegetables, perhaps via stamps issued to lower-income households, to take care of the regressivity effects, although nonfood compensation could be more efficient as the other literature on energy taxes suggest (Metcalf 2008). In all cases, higher carbon pricing would provide large cobenefits, which should encourage policy-makers to prioritize this option to achieve European and world environmental goals.

Disclosure statement: no potential conflict of interest is reported by the authors.

References

1. ANSES. (2017). INCA3: Evolution des habitudes et modes de consommation. https://www.anses.fr/fr/content/inca-3-evolution-des-habitudes-et-modes-de-consommation-de-nouveaux-enjeux-en-mati%C3%A8re-de.
2. Briggs, A.D., Kehlbacher, A., Tiffin, R., Garnett, T., Rayner, M., Scarborough, P. (2013). Assessing the impact on chronic disease of incorporating the societal cost of greenhouse gases into the price of food: an econometric and comparative risk assessment modelling study. *BMJ open,* 3: e003543.
3. Bonnet, C., Bouamra-Mechemache, Z., Corre, T. (2018). An Environmental Tax Towards More Sustainable Food: Empirical Evidence of the Consumption of Animal Products in France. *Ecological Economics*, *147*, 48-61.
4. Burricand, C., Houdré, C., Seguin, E. (2012). Les niveaux de vie en 2010. *Insee Première,* 1412.
5. Caillavet, F., Fadhuile, A.,Nichèle, V. (2016). Taxing animal-based foods for sustainability: environmental, nutritional and social perspectives in France. *European Review of Agricultural Economics*, *43*(4), 537-560.
6. Edjabou, L.D., Smed, S. (2013). The effect of using consumption taxes on foods to promote climate friendly diets: the case of Denmark. *Food Policy,* 39:84-96.
7. EFSA, Panel on Dietetic Products, Nutrition and Allergies (2012). Scientific Opinion on Dietary Reference Values for Protein. *EFSA Journal*, 10(2), 2557.
8. European Environment Agency (EEA). (2017). *Environmental indicator report 2017 in support to the monitoring of the 7th Environment Action Programme*. Publications Office of the European Union, Luxembourg.
9. FAO. (2017). *The future of food and agriculture – Trends and challenges.* Rome.
10. Feng, K., Hubacek, K., Guan, D., Contestabile , M., Minx, J., Barrett, J. (2010). Effects of Climate Change Taxation: The Case of the UK. *Environmental Science and Technology***,** 44, 3670–3676.
11. García-Muros, X., Markandya, A., Romero-Jordán, D., González-Eguino, M. (2017). The distributional effects of carbon-based food taxes. *Journal of Cleaner Production*, *140*, 996-1006.
12. Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., Zelm, R. (2009). Recipe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level 1.
13. Greene, J., Braathen, N.A. (2014). Tax preferences for environmental goals: use, limitations and preferred practices. OECD Environment Working Papers n°71.
14. Guivarch, C., Rogelj, J. (2017). Carbon price variations in 2°C scenarios explored. Commission Stiglitz-Stern.
15. Intergovernmental Panel on Climate Change IPCC. (2018). Global warming of 1.5°C. First Joint Session of Working Groups I, II and III of the IPCC and accepted by the 48th Session of the IPCC, Incheon, Republic of Korea, 6 October 2018. http://www.ipcc.ch/report/sr15/
16. Kehlbacher, A., Tiffin, R., Briggs, A., Berners-Lee, M., Scarborough, P. (2016). The distributional and nutritional impacts and mitigation potential of emission-based food taxes in the UK. *Climatic Change* DOI 10.1007/s10584-016-1673-6.
17. Kerkhof, A.C., Moll, H.C., Drissen, E., Wilting, H.C. 2008. Taxation of multiple greenhouse gases and the effects on income distribution – A case study of the Netherlands. *Ecological Economics* 67 : 318-326.
18. Laisney, C. (2013). Les différences sociales en matière d'alimentation. Centre d'Etudes et de Prospective, *Analyse* n°64, octobre, Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt.
19. Lewbel, A., Pendakur, K. (2009). Tricks with Hicks: The EASI demand system. *The American Economic Review*, 99: 827–863.
20. Metcalf, G.E. (2008). Designing a carbon tax to reduce U.S. Greenhouse Gas Emissions. Working Paper 14375 http://www.nber.org/papers/w14375
21. Madden JP, Goodman SJ, Guthrie HA. Validity of the 24-hr. recall. Analysis of data obtained from elderly subjects. *J Am Diet Assoc* 1976; 68:143-7.
22. Mytton, O.T., Clarke, D., Rayner, M. (2012). Taxing unhealthy food and drinks to
23. improve health. *British Medical Journal* 344: e2931.
24. OECD. 1994.The Distributive Effects of Economic Instruments for Environmental Policy. OECD Publications and Information Center, Washington, DC. 139 pages. ISBN: 92-64-04026-9.

25. Plessz, M., Gojard S. (2013). Do processed vegetables reduce the socio-economic differences in vegetable purchases? A study in France. *European Journal of Public Health,* 23(5): 747-752.
26. PNNS. (2017). Plan National Nutrition Santé 2017-2021. https://quoidansmonassiette.fr/pnns-2017-2021-revision-des-reperes-nutritionnels-pour-les-adultes/
27. Quinet, A. (2009). La valeur tutélaire du carbone. Rapports et Documents n°16. La documentation française.
28. Revell, B. (2015). Meat and milk consumption 2050: the potential for demand-side solutions to GHGE reduction. *Eurochoices,* 14(3) DOI: 10.1111/1746-692X.12103
29. Revoredo-Giha, C., Chalmers, N., Akaichi, F. (2018). Simulating the Impact of Carbon Taxes on Greenhouse Gas Emission and Nutrition in the UK. *Sustainability*,10(1), 13.
30. Säll, S. (2018). Environmental food taxes and inequalities: Simulation of a meat tax in Sweden. *Food Policy* 74:147-153.
31. Smed, S., Jensen, J.D., Denver, S. (2007). Socio-economic characteristics and the effect of taxation as a health policy instrument, *Food Policy* 32: 624-639.
32. Stiglitz, J.E., Stern, N. (2017). Report of the High-Level Commission on Carbon Prices, CPLC/World Bank.
33. Vieux, F., Darmon, N., Touazi, D., Soler, L.G. (2012). Greenhouse gas emissions of self-selected individual diets in France: changing the diet structure or consuming less? *Ecological Economics,* 75: 91-101.
34. Wier M., Birr-Pedersen K., Jacobsen H.K., Klok J. 2005. Are CO2 taxes regressive ? Evidence from the Danish experience. *Ecological Economics* 52: 239-251.
35. Wirsenius, S., Hedenus, F., Mohlin, K. (2011). Greenhouse gas taxes on animal food products: rationale, tax scheme and climate mitigation effects. *Climatic Change,* 108: 159–184.
36. Wellesley, L., Happer, C., Froggatt, A. (2015). Changing climate, changing diets. Chatham House Report.
37. Zhen, C., Finkelstein, E. A., Nonnemaker, J. M., Karns, S. A., & Todd, J. E. (2013). Predicting the effects of sugar-sweetened beverage taxes on food and beverage demand in a large demand system. *American Journal of Agricultural Economics*, *96*(1), 1-25.

Table 1 Summary statistics by food group: Shares, emissions, household expenditure and quantity (daily basis per household), N=7134.

Food groups	Shares (in %)						(A) Emissions (gCO2eq/100 g food)	(B) Food expenditure (€)	(C) Quantity (kg)
	Food Budget	Environment			Nutrition				
		CO2	SO2	N	Calories	Proteins			
Plant-based food groups									
Beverages									
Juices	1.99	3.41	1.81	3.39	1.71	0.72	70.59	0.21	0.20
Alcohol	7.57	6.89	3.94	4.55	4.40	0.44	175.82	0.84	0.26
Soft drinks	1.98	2.38	1.10	1.86	2.73	0.02	62.74	0.21	0.27
Bottled water	1.72	3.46	1.17	1.50	0.00	0.00	26.09	0.19	0.79
Coffee and tea	2.53	0.25	0.15	0.24	0.31	1.51	36.14	0.26	0.04
Other plant-based products									
Fresh fruits and vegetables	11.16	14.22	6.39	10.08	5.90	4.10	129.23	1.27	0.75
Spices	0.46	0.71	0.40	0.46	0.39	0.36	245.26	0.05	0.02
Plant-based foods, high in fats	1.16	1.15	0.47	5.17	6.59	0.06	181.43	0.12	0.04
Plant-based dishes	1.10	0.75	0.30	0.67	0.88	0.36	141.74	0.11	0.02
Plant-based foods, high in sugar	5.67	2.51	1.89	2.81	10.06	2.85	194.22	0.61	0.12
Starchy foods	3.56	3.86	2.09	3.73	9.30	7.59	195.81	0.37	0.20
Processed fruits and vegetables	5.15	4.86	2.13	6.56	4.28	2.56	223.67	0.54	0.17
Animal-based food groups									
Animal-based products									
Beef	5.10	13.29	22.93	9.81	2.08	7.61	1387.10	0.60	0.05
Other meats	8.65	7.37	13.59	15.04	4.93	14.95	817.08	0.95	0.15
Cooked meats	6.31	7.32	11.88	13.15	3.27	8.41	562.92	0.67	0.08
Animal-based foods, high in fats	2.46	7.19	11.14	4.93	7.29	1.25	620.73	0.26	0.07
Cheese	8.14	2.71	3.95	1.15	9.42	17.07	454.48	0.87	0.14
Fish and Seafood	5.24	2.75	1.43	0.86	1.08	4.20	380.27	0.57	0.05
Dairy products	6.45	0.09	0.08	0.04	7.93	13.18	159.55	0.69	0.57
Mixed origin-based products									
Prepared mixed meals	6.11	4.11	4.24	4.60	5.89	6.25	390.23	0.64	0.11
Prepared desserts	7.48	10.73	8.93	9.42	11.57	6.49	273.37	0.79	0.20

Table 2: Average price variation (%) per food group by scenario and carbon price (tax and subsidy rates)

Scenario	TAX_ALL		TAX_ANI		TAX_SUB	
Carbon price in €/tCO2eq	**56**	**140**	**56**	**140**	**56**	**140**
Plant-based food groups						
Beverages						
Juices	3.95	9.87				
Alcohol	3.21	8.03				
Soft drinks	4.18	1.44				
Bottled water	6.20	15.50				
Coffee and tea	0.37	0.93				
Other plant-based products						
Fresh fruits and vegetables	4.63	11.57			-4.93	-14.92
Spices	7.41	18.54				
Plant foods, high in fats	3.69	9.23				
Plant dishes	1.87	4.67				
Plant foods, high in sugar	2.43	6.07				
Starchy foods	6.36	15.91			-1.47	-4.53
Processed fruits and vegetables	4.07	10.18				
Animal-based food groups						
Animal-based products						
Beef	7.77	19.41	7.77	19.41	7.77	19.41
Other meats	7.74	19.35	7.74	19.35	7.74	19.35
Cooked meats	3.67	9.18	3.67	9.18	3.67	9.18
Animal-based foods, high in fats	9.28	23.20				
Cheese	4.29	10.73	4.29	10.73	4.29	10.73
Fish and Seafood	1.92	4.80				
Dairy products	7.71	19.27				
Mixed origin-based products						
Prepared mixed meals	3.89	9.72				
Prepared desserts	3.89	9.73				

Table 3: Variations in environmental, inequality and nutritional indicators by scenario for each carbon price

Carbon price		**56 €/tCO2eq**						**140 €/tCO2eq**					
	Baseline	**TAX_ALL**	**(%)**	**TAX_ANI**	**(%)**	**TAX-SUB**	**(%)**	**TAX_ALL**	**(%)**	**TAX_ANI**	**(%)**	**TAX-SUB**	**(%)**
Environmental indicators													
Q_co2 (g/day/hh)	5,635.93	5,286.96	-6.19	5,511.92	-2.20	5,581.25	-0.97	4,763.50	-15.48	5,325.91	-5.50	5,535.75	-1.78
Q_so2 (g/day/hh)	65.05	60.51	-6.97	62.50	-3.92	62.83	-3.41	53.71	-17.43	58.68	-9.80	59.69	-8.24
Q_nitrates (g/day/hh)	22.10	20.75	-6.11	21.49	-2.76	21.68	-1.92	18.73	-15.24	20.58	-6.88	21.15	-4.31
Nutritional indicators													
MAR (%)	84.33	84.50	0.16 [a]	84.26	-0.08 [a]	84.45	0.12 [a]	84.72	0.38 [a]	84.12	-0.21 [a]	84.66	0.33 [a]
protein share (% calories)	14.69	14.66	-0.03 [a]	14.43	-0.26 [a]	14.41	-0.28 [a]	14.60	-0.09 [a]	14.03	-0.65 [a]	13.97	-0.71 [a]
plant proteins (% proteins)	25.05	25.23	0.18 [a]	25.71	0.66 [a]	25.97	0.92 [a]	25.55	0.50 [a]	26.79	1.74 [a]	27.59	2.54 [a]
calories (day/hh)	4,716.64	4,436.51	-5.94	4,666.16	-1.07	4,696.26	-0.43	4,016.31	-14.85	4,590.44	-2.68	4,682.12	-0.73
Equity effects													
Food expend (€/day/hh)	10.83	11.31	4.49	11.00	1.59	10.83	0.00	12.04	11.22	11.26	3.98	10.83	0.00
Gini of food expenditure	0.308	0.307	-0.001 [b]	0.308	-0.0002 [b]	0.304	-0.004 [b]	0.306	-0.002 [b]	0.308	-0.0005 [b]	0.298	-0.01 [b]

Notes: [a]Percentage point variation; [b]Absolute variation.

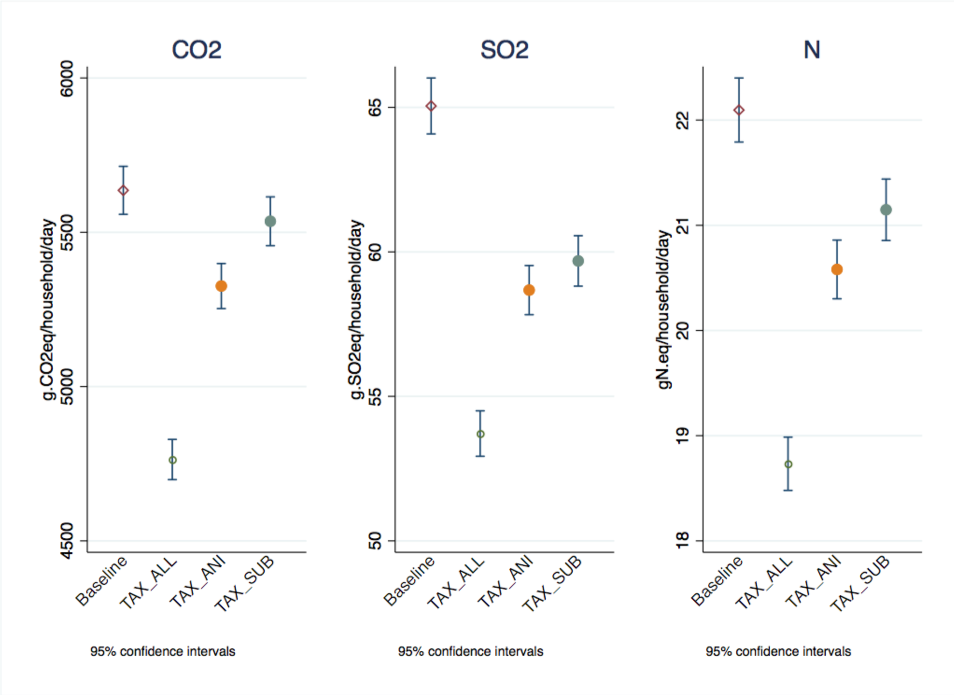

Figure 1: Environmental values for CO2, SO2 and N by scenario at 140 €/tCO2eq (average values and 95% confidence intervals).

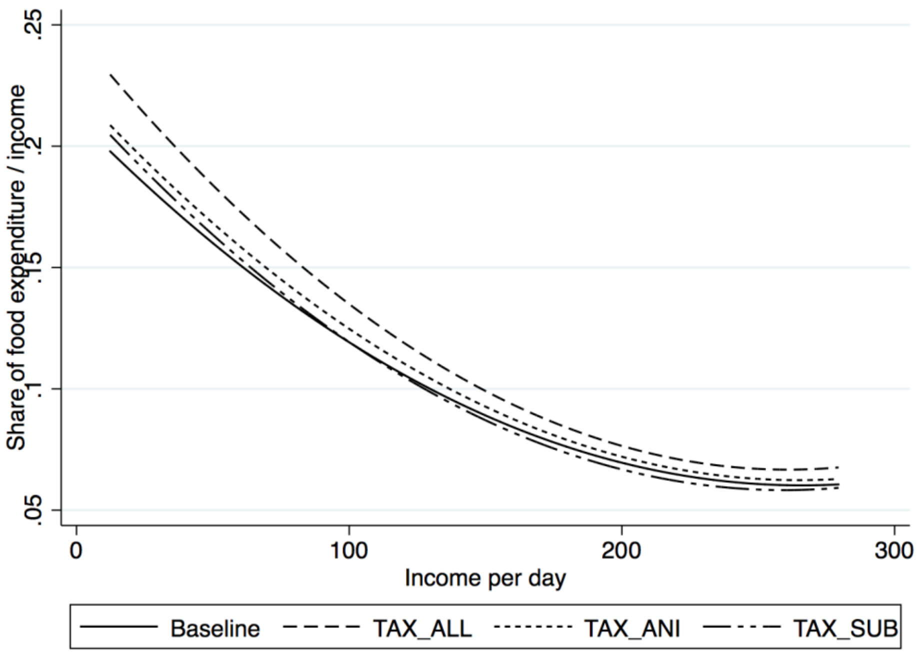

Figure 2: Income Share of Food Expenditure at the baseline and for each scenario: TAX_ALL, TAX_ANI and TAX_SUB.

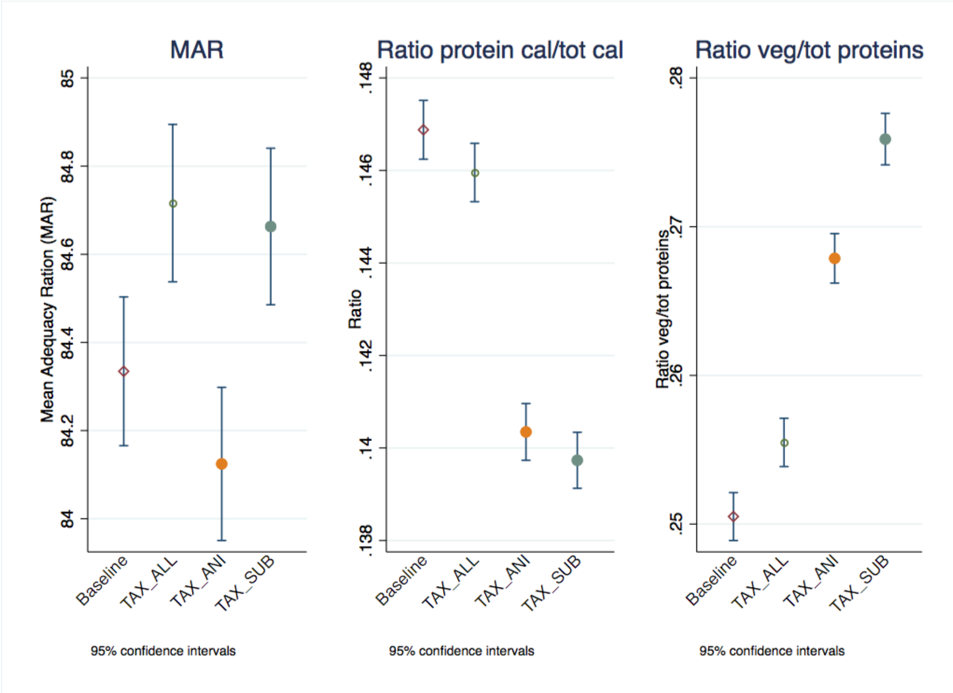

Figure 3: Nutritional values for MAR (2000kcal basis), proteins' share in total calories, and plant share in total proteins by scenario at 140 €/tCO2eq (average values and 95% confidence intervals).

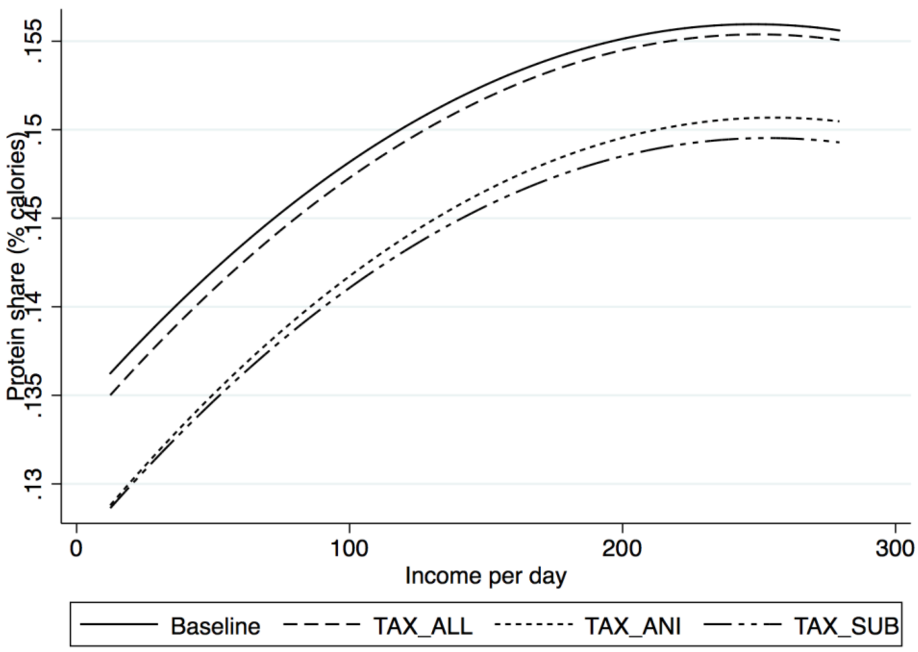

Figure 4: Protein share (% calories) at the baseline and for each scenario: TAX_ALL, TAX_ANI and TAX_SUB.

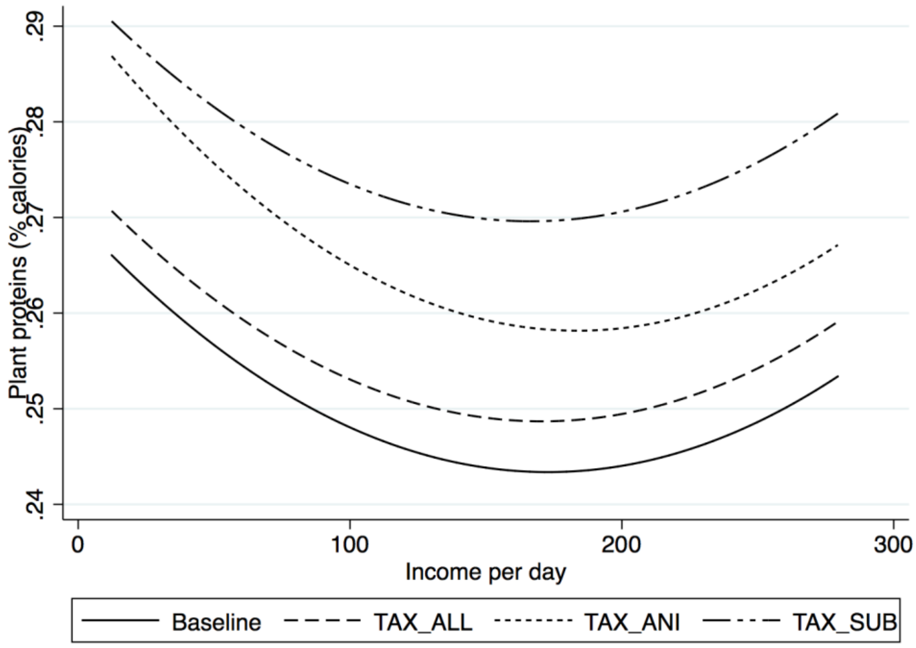

Figure 5: Plant proteins share (% proteins) at the baseline and for each scenario: TAX_ALL, TAX_ANI and TAX_SUB.