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**Environmental, nutritional and welfare effects of introducing a Carbon Tax on  
food products in Spain**

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# **Environmental, nutritional and welfare effects of introducing a Carbon Tax on food products in Spain**

## **Abstract**

Current dietary habits contribute immensely to climate change as a result of the large amount of greenhouse gas production. Demand-side measures have been proved to be efficient to reduce greenhouse gas emissions. This study aims at assessing the impact of introducing a Pigovian CO<sub>2</sub> equivalent tax on food demand, welfare and diet quality in Spain. Alternative tax policy scenarios have been considered, which, in essence, reflect alternative social cost of emission or alternative tax magnitudes. The methodological framework has been based on expenditure as well as own and cross price elasticities calculated from estimating a complete EASI food demand system. Results suggest that the price increase as a consequence of the tax, reduces the consumption of the food products associated with higher CO<sub>2</sub> equivalent emissions, has a positive impact on human health as the quality of diet approximates to the WHO recommendations. On the negative side, the tax affects more lower income groups. Governments should be aware about the trade-off between the reduction of CO<sub>2</sub> equivalent emissions and the negative consequences on citizen's welfare.

## **Keywords**

Carbon tax; social cost of emissions, EASI demand model; welfare analysis, diet quality, Spain

## **Introduction**

Current dietary habits contribute immensely to climate change as a result of the large amount of greenhouse gas production (Castellón, Boonsaeng, & Carpio, 2015). The food chain contributes to about 30% of greenhouse gases produced in Europe comparable to 20% from total fossil fuel production (Audsley et al., 2010). In Spain the agricultural sector contributes to the 14% of the total Spanish greenhouse emissions (Bourne, Childs, Philippidis, & Feijoo, 2012).

Hedenus, Wirsenius, & Johansson (2014) showed that emission reduction in the agro-food sector can be achieved by: 1) productivity improvements; 2) technological changes (supply-side measures); and 3) changes in consumption behavior (demand-side measures). Command-and-control regulations, cap-and-trade systems or Pigovian (corrective) taxes which are supply side measures have been already used in the European Union (EU) to correct for the massive GHG emissions arising from the production of consumer goods (Chen et al., 2015). However, the use of command and control measures have been found to be economically

inefficient and does not lead to optimal production compared to cap-and-trade measures or Pigovian taxes (Burchell & Lightfoot, 2001).

Pigou (1957) proposed that Governments should influence the behavior of economic agents causing negative (positive) externalities through taxes (subsidies) (Endres, 2010). The Pigovian tax (subsidy) is aimed at correcting externalities generated by economic activities and it is set equal to the social cost (benefit) of the negative (positive) externality. The relevance of a Pigovian tax on unhealthy/high carbon footprint foods is justified under the assumption that of close to perfect competition food industry. Under such assumption, the burden of a Pigovian tax is irrelevant whether applied to the supply side or the demand end. For this reason, several studies have shown that imposing Pigovian taxes on food demand rather than on food supply constitute a cost efficient emission reduction strategy. This is because consumers are able to adjust to the tax according to their efficient level of consumption (Edjabou & Smed, 2013). (Aiking, de Boer, & Vereijken, 2006) and (McMichael, Powles, Butler, & Uauy, 2007) found that dietary changes provided a better alternative to reductions in GHG emissions, particularly towards Mediterranean diets with lower carbon emissions (Vidal, Moliner, Pikula, Mena-Nieto, & Ortega, 2014). Similarly, (Mytton, Clarke, & Rayner, 2012) showed that positively changing consumption patterns through food taxes could be attractive from the climate perspective. Contrary to taxing production which has always been a delicate issue because of “carbon leakage” (Wirsenius, Hedenus, & Mohlin, 2011) and high monitoring cost (Schmutzler & Goulder, 1997).

Influencing consumer behavior through taxes is not new. Several countries have introduced taxes on food consumption as a way of internalizing negative externalities associated with the intake of unhealthy products (Springmann et al., 2016). Denmark introduced health taxes targeted at sugar products, soft drinks and cigarettes as well as a fat tax which only lasted for one year (Smed, 2012). In Hungary and Mexico, taxes have been imposed on foods with high content in salt, sugar or fat. Similarly, Finland introduced a tax on sweets, ice-creams and soft drinks whilst France and Berkley (California, USA) have taxed only soft drinks (Cornelsen & Carreido, 2015).

The objective of this paper is to evaluate the potential effects of imposing a Pigovian CO<sub>2</sub> equivalent tax on food products in Spain. From food demand elasticities, we show that levying a CO<sub>2</sub> equivalent tax has two effects: 1) a reduction in greenhouse gas emission and improved nutrient intake ratios; and 2) a welfare effect. In spite of the increasing importance

of this topic in the policy arena as well as among researchers, up to our knowledge only a very few papers have been published. We highlight the seminal paper by (Säll & Gren, 2015), for Sweden, and that by (Garcia-Muros, Markandya, Romero-Jordán, & González-Eguino, 2016) who also focused in Spain. The former was limited to the meat and dairy sectors and the distributional impact of the Pigovian tax was ignored. Even though, the latter considered 10 food groups and assessed the distributional impact of the taxes. From a methodological point of view, both studies applied the Almost Ideal Demand System (AIDS) model ignoring the impact of household heterogeneity in their demand estimation. Moreover, both failed to account for substitution effects in food demand and for the impact of consumption discount rates on emission reduction strategies. In this paper we have tried to overcome such limitations by: 1) estimating a complete demand system; 2) calculating demand elasticities by estimating an approximate Exact Affine Stone Index (EASI) demand model which takes into account household heterogeneity; 3) simulating carbon tax policy scenarios based on current EU medium- and long-term emission reduction objectives; and 4) explicitly considering nutritional as well as welfare effects.

The remainder of the article is structured as follows. Section 2 describes the model and data used in this study. Section 3 shows main results and brief discussions. The paper ends with some concluding remarks and limitations.

## **Data and model**

### *Data*

This study uses microdata, homescan panel data from a representative sample of 1146 households in Catalonia (North-East Spain). Data have been collated by Kantar Worldpanel. The data set contains all day-to-day food purchases of Catalonian households in 2012 as well as some relevant household socio-demographic characteristics. From the total of 1146 households, only those who have remained in the sample for at least 45 weeks were considered. Purchased quantities and expenditures for each single food product have been aggregated to the annual level for each household. All food products have been aggregated into 16 food categories (alcoholic drinks are not included while non-alcoholic drinks are

included in the residual category for the purpose of this paper). Unit values were obtained by dividing expenditures by the purchasing quantities<sup>1</sup>.

Table 1 shows some descriptive statistics of the data used. As can be observed, Spanish consumers allocate a significant share of the food budget to meat (fresh and processed) (26%) followed by fish and seafood (14%), milk and dairy products (including cheese) (14%), fruits (10%) and vegetables (8%). Differences among socioeconomic groups are found in Figure 1. In the high social class, the consumption of fruits, vegetables and beef and lamb are significantly more important than the other social classes, while in the case of poultry, pork and grains, differences are not significant. On the opposite side, in lower social class households, the consumption of grains, starchy roots, processed meat and composite dishes are slightly more important (although not significant) relative to the other social classes.

**Model**

*Estimating Food Price Elasticities*

Food price elasticities have been calculated by estimating an approximate Exact Affine Stone Index (EASI) demand model (Lewbel & Pendakur, 2009) which incorporates household characteristics. The EASI demand model has several advantages over the traditional Almost Ideal demand System (AIDS) as it derives the Implicit Marshallian demand function which combine desirable properties of both Hicksian and Marshallian demand functions. Moreover, the error terms can be interpreted as unobserved preference heterogeneity among individuals and Engle curves can adopt any shape over real expenditures. Finally, similar to the AIDS model, we can estimate a linear approximation which generates similar results than the full model.

The approximate EASI demand equation expresses budget shares,  $w^i$ , as a function of food prices  $p$ , total household expenditure  $y$ , and socio-demographic characteristics  $z$ , as follows:

$$w^i = \sum_{r=0}^5 b_r \bar{y}^r + Cz + Dz\bar{y} + \sum_{p=1}^k Ap + Bp\bar{y} + \varepsilon \dots\dots\dots$$

Equation 1

where  $b_r$ ,  $r= 0,1,2,\dots, 5$  are the parameters that control the shape of the Engel curve (up to a fifth-order polynomial);  $\bar{y} = x - p\bar{w}$  is the log of the Stone index-deflated nominal

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<sup>1</sup> Zero purchases is not an issue in this study. The highest percentages of zero purchases have been found in Beef, veal and lamb (3.1%) and Snacks and other food (2.7%).

expenditure (being  $\bar{w}$  the mean budget shares);  $C$  is a matrix of parameters corresponding to socio-demographic variables excluding the intercept;  $D$  is the matrix of coefficients from interaction between income and socio-demographic variables,  $A$  is a matrix of prices coefficients,  $B$  is a matrix of coefficients from interaction between income and prices, and  $\varepsilon$  is the error term. For the model to be consistent with theory, the budget share equations  $w^j$  are required to satisfy the properties of adding-up, linear homogeneity and Slutsky symmetry.

Taking into account the characteristics of our data set, quality adjusted prices were calculated from unit values (*total expenditure/total quantity*). The EASI demand system in (1) was estimated using derived quality adjusted prices following (Cox & Wohlgenant, 1986). Moreover, to preserve household heterogeneity, the actual log of the Stone index  $y = x - \bar{p}w$  was used in the estimation of system (1) with  $\bar{y}$  as an instrument because of income endogeneity. Finally, for parsimony (Castellón et al. (2015), the interaction effects between prices and social demographics were not included for parsimony. Linear 3-Stage least Squares has been used to estimate demand parameters.

By deriving (1) with respect to expenditure and log prices, we get the Marshallian demand semi-elasticities. The Hicksian and Marshallian price elasticities (at sample means) as well as the expenditure elasticities can be obtained using the following expressions (Lewbel & Pendakur, 2008)

- Hicksian price elasticities:

$$\frac{\partial q^i}{\partial p^j} = \frac{(A_j + By)}{w^i} + \bar{w}^j - \delta \dots\dots\dots \text{Equation 2}$$

- Marshallian price elasticities:

$$\frac{\partial q^{iM}}{\partial p^j} = \frac{(A_j + By)}{w^i} + \bar{w}^j - \delta - \bar{w}^j \left( \left[ \sum_{r=1}^5 b_r r y^{r-1} + Dz + Bp \right] \frac{1}{w^i} + 1 \right) \dots\dots\dots$$

Equation 3

simplified as

$$\frac{\partial q^{iM}}{\partial p^j} = \frac{(A_j + By)}{w^i} - \delta - \frac{\bar{w}^j}{w^i} \left( \left[ \sum_{r=1}^5 b_r r y^{r-1} + Dz + Bp \right] \right) \dots\dots\dots \text{Equation 4}$$

$\delta = 1$  where  $i=j$  and zero if otherwise

- Expenditure elasticity (the total expenditure is assumed to be constant):

$$\frac{\partial q^i}{\partial x} = \frac{[\sum_{r=1}^5 b_r r y^{r-1} + Dz + Bp]}{\bar{w}} + 1 \dots\dots\dots \text{Equation 5}$$

*Measuring the impact of CO<sub>2</sub> equivalent (CO<sub>2</sub>-Eq) tax on food demand*

To measure the impact of CO<sub>2</sub>-eq tax on food demand, we need data on CO<sub>2</sub> emissions per kg of food products. Although several studies have provided some figures, there isn't any single study that covers all food categories considered in this study for Spain (Macdiarmid et al, 2012). CO<sub>2</sub> equivalent emissions for major food products consumed in the European Union (EU) were taken from Hartikainen & Pulkkinen (2016)(unpublished). These estimates are based on the following assumptions: 1) they are restricted to the food chain (from primary production to final consumption encompassing processing, packaging (including recycling of packaging material), storing and cooking); 2) transport activities (including consumers' displacement to retail outlets) are not included; 3) GHG emissions due to food waste were not accounted for; and 4) direct land use changes were not considered due to lack of data. The work also take into account changes in the weight food products as a result of evaporation, addition of water for cooking and exclusion of inedible parts. In spite of the limitation to use this data due to differences in food production systems in Spain and other EU countries, we consider that the data set will serve the purposes of this study as it uses a common framework to estimate GHG emissions for a large list of food products. Average values for the 16 food groups considered in this study are shown in Table 2.

The impact of imposing a carbon/green tax on demand for food has been analyzed taking into account the price/kg of CO<sub>2</sub> equivalent emissions for each of the 16 food categories. Previous studies have used a wide range of values running from 0 USD up to 400 USD (Stern, 2007). To cite only two examples, (Edjabou & Smed, 2013)), based on the Stern Report (2006) , assumed a social cost of carbon of 85 USD per ton CO<sub>2</sub> equivalent, while Irz, Leroy, Réquillart, Soler, & others (2015) assumed a value of 32 Euro (35 USD), based on the meta analyses carried out by Tol (2012).

This study has considered four tax scenarios taking into account two different sources to calculate the price of CO<sub>2</sub> equivalent emissions: 1) The US Environmental Protection Agency (EPA) which uses a comprehensive procedure for calculating the social cost of emission based on three consumption discount rates (low consumption discount rates means greater emphasis on inter- and intra- generational equity and vice versa). We have chosen two discount rates of 5% and 2.5% which generate a social cost of CO<sub>2</sub>/t of \$57 and \$11, respectively; and 2) The European Union's (EU) medium- and long- term carbon emission



reduction objectives: the EU proposes a social cost of CO<sub>2</sub>/t equivalent emission of 56 Euros and 200 Euros to reduce carbon emissions by 20% and 60% by 2020 and 2050 across the EU.

Following Baumol & Oates (1975), the taxes imposed on each food category have been calculated in the following way. We have first calculated the average CO<sub>2</sub> equivalent emissions generated by each food category using the data from Hartikainen & Pulkkinen (2016)(unpublished). The tax on the i-th food category, ( $Tax_i$ ) has been calculated as the product of the average CO<sub>2</sub> equivalent emissions per kg of each food category ( $e_i$ ) and the social cost ( $SC_m$ ) associated with each of the four scenarios mentioned above (based on EPA and EPA and EU objectives):

$$Tax_i = e_i * SC_m \dots\dots\dots\text{Equation 6}$$

From (5), the tax rate for the i-th food category  $i$ , has been calculated as:

$$Tax_{rate.i} = \frac{p_1 - p_0}{p_0} * 100 \dots\dots\dots\text{Equation 7}$$

where  $p_1 = Tax_i + p_0$ , being  $p_0$  the average price before the tax.

Results are shown in Table 3. We have found tax levels ranging from 0.07% for Starchy roots, legumes, and pulse category to 55.07% for composite dishes, which contained a large extent of meat-based prepared meals. The percentage reduction in the quantities consumed after imposing the tax has been calculated taking into account the demand elasticities:

$$\frac{\Delta Q^j}{Q_j} = \sum_k^n \epsilon_{jk} * \frac{\Delta P^k}{P_j} \dots\dots\dots\text{Equation 8}$$

where  $\frac{\Delta P^k}{P_j} = \frac{p_1 - p_0}{p_0}$  and  $\frac{\Delta Q^j}{Q_j}$  represent the percentage change in prices and quantities of each food group, respectively (Säll & Gren, 2015)

Finally, the post-tax change in CO<sub>2</sub> equivalent emission is defined as

$$\Delta E_i = \sum_j^n e_i * \Delta Q_j \dots\dots\dots\text{Equation 9}$$

where  $e_i$ , is the average CO<sub>2</sub> equivalent emission in each of the food group.

*Estimating the impact of CO<sub>2</sub>-eq tax on household's welfare*

In order to calculate the impact of the above mentioned tax on household's welfare, being consistent with previous literature, we have assumed, that the food supply is perfectly inelastic and is not influenced by the CO<sub>2</sub>-eq tax. In other words, the burden of the tax is borne solely by the consumer. Deaton (1989, 1997) defined the welfare effects of a price

change as the compensating variation expressed as a share of the total household expenditure. Tax effects have been estimated taking into account both first-order and second-order effects. The first order-effect assesses the distributional impact of the tax imposition on each food category as the product of its corresponding budget share by the price change in that food category, while the second order-effect considers how consumers react to price changes.

Welfares effects are based (Lewbel & Pendakur, 2009) log of living cost index which takes into account both first and second order effects:

$$C(p_1, u, z, \epsilon) - C(p_0, u, z, \epsilon) = (p_1 - p_0)'w_0 + 0.5(p_1 - p_0)'(\sum_{k=1}^K A + By)(p_1 - p_0) \dots\dots\dots\text{Equation 10}$$

The term  $(p_1 - p_0)'w_0$  in (10) is the Stone index for the price change while  $0.5(p_1 - p_0)'(\sum_{k=1}^K A + By)(p_1 - p_0)$  models substitution effects resulting from price changes.

**Results and Discussion**

*Price and expenditure elasticities*

Table 4 shows the calculated expenditure as well as Marshallian own price elasticities. Expenditure elasticity estimates are statistically significant at the one percent level and positive. Nine food groups out of the 16 are expenditure elastic, including grains and grain products, vegetables and vegetable products or plant based fats as well as all categories related to animal sources of protein. Again, in this case, results do not significantly differ from previous studies, taking into account again that sample periods are different as well as food categories. Dhehibi, Gil, & Angulo, (2007) and (Garcia-Muros et al., 2016) also found that the food expenditure elasticity for beef to be greater than one (in the latter case also the demand for fish was also elastic with respect to income).

Table 5 shows the own- and cross- price elasticities at the mean values. All own price elasticities estimates are statistically significant and negative except for plant based fats and residual categories which are insignificant but negative. All food categories have absolute price elasticities less than unity except for vegetables and vegetable products, which is consistent with (Garcia-Muros et al., 2016). On the contrary, the elasticities for the category of beef, veal and lamb, and fruits and fruit products are a bit lower, which can be attributed to differences on the data sets used and on how food categories have been defined and aggregated. Finally, As can be observed, results are quite consistent with literature, for

instance Zhen et al. (2013). Most of the cross price elasticities are significant and exhibit complementary relationships, which is quite plausible even though we expect more substitution effects between food categories. It is noticeable that meat and fish categories are complementary. This is not surprising as the data set provides empirical evidence that households use to buy different types of meat and fish products at the same purchasing occasion.

#### *Impact of a CO<sub>2</sub> tax on household CO<sub>2</sub>-eq emissions*

Table 6 (first row) shows the total marginal change (decrease) in households' CO<sub>2</sub> equivalent emissions after the tax imposition under the four tax scenarios mentioned in the previous section while Figure 2 shows the impact on each food category. As can be observed, under all policy scenarios, the imposition of the tax has a more significant effect on those food categories which generate higher CO<sub>2</sub> equivalent emissions: composite dishes; beef, veal and lamb; and milk and dairy products despite their relatively lower share in food expenditure. Our results are consistent with most of the previous literature (Henchion, McCarthy, Resconi, & Troy, 2014; Säll & Gren, 2015) but highlight the importance of composite dishes which has been neglected in previous studies. Secondly, the vegetables and vegetable products category has a relatively low impact on the decline in CO<sub>2</sub>-eq emissions despite their relatively large expenditure share as it generates a quite low CO<sub>2</sub> equivalent emission per kg. Thirdly, although there is a high correlation between consumption decrease and the tax level on each food category, this is not always the case as, when calculating the impact, we have taken into account not only own-price elasticities but also substitution effects. Results from this study suggest that a reduction in the consumption of red meat and dairy products would contribute to a significant decline in CO<sub>2</sub>-eq emissions (Hedenus et al., 2014; Säll & Gren, 2015).

The second noticeable result is the level of the tax has to be large enough to generate a significant reduction of CO<sub>2</sub> equivalent emissions or, alternatively, to assume a lower consumption discount rate. Choosing a low consumption discount rate indicate how important inter- and intra-generational equity is to policy makers. If policy makers aim at a significant reduction in CO<sub>2</sub>-eq emission then the discount rate at which economic decisions are arrived at should be given keen consideration. Choosing a high consumption discount rate reduces CO<sub>2</sub>-eq emission but marginally as shown in Table 6. In this context, Stern (2007) proposed a consumption discount rate as low as 1.4 percent on consumption to achieve a higher reduction in Green House gas emissions, although this study has been criticized by researchers like Mendelsohn, (2008) and Nordhaus, (2007) . From an EU perspective, the objective for 2050 is

more restrictive than that for 2020 and it implies imposing a higher tax level (the kilogram of CO<sub>2</sub>-eq emission should be priced at 0.2 Euros). This result is consistent with Bonnet, Bouamra-Mechemache, Corre et al. (2016).

The last three rows in Table 6 simulate the impact of three alternative policy scenarios. Instead of imposing a CO<sub>2</sub>-eq tax on all food categories, we simulate the impact of restricted the imposition of the tax on selected food categories. Although the number of combination is large enough, we have concentrated the analysis in those food categories that generate larger CO<sub>2</sub>-eq emissions (meat and dairy products). The following three alternative policy scenarios have been considered: 1) the tax is restricted only to beef, veal and lamb as well as to composite dishes; 2) the tax is restricted to all meat products; and 3) the tax is restricted to beef, veal and lamb, as well as to dairy products as this has been the direction of most studies dealing with environmental taxes.

The results from Table 6 indicate that restricting the imposition of the tax only to beef and dairy products (fourth row) would have the lowest impact in CO<sub>2</sub>-eq emission reduction among the four policy scenarios ranging from 0.41% to 8.51%, depending on the four social cost scenarios that we have considered in this study. If all meats are considered, the impact is larger (50% increase in CO<sub>2</sub>-eq emissions) but still is far from the impact that would be generated by taxing all food categories. This result would imply that studies like Bailey, Froggatt, & Wellesley (2010) and Säll & Gren (2015) would underestimate the potential impact of the tax as in both studies the tax is restricted to meat and dairy products. Finally, results from this study also indicate that a tax policy targeted to beef and composite dishes would have a similar impact like that restricted to all meat and dairy products.

#### *Welfare impacts of CO<sub>2</sub> equivalent taxes*

Welfare effects have been calculated using compensated variation, approximate values are presented for the individual food groups and Log of the Living Cost Index of (Lewbel & Pendakur, 2009) for all food groups and social classes. Table 7 shows that the level of compensation is quite heterogeneous across food categories being highly correlated with both their associated CO<sub>2</sub> equivalent emissions and food expenditure elasticities. The needed compensation is higher in the case of composite dishes, followed by beef, veal and lamb and poultry, eggs and other fresh meat categories. The last row on Table 8 shows that on average, the compensation is higher as the associated social cost (discount rate) of emissions also

increases (decreases). If we take the EPA scenarios, reducing the discount rate from 5% to 2.5% would require an increase in food expenditure from 0.85% to 4.24%. In the case of the EU, reducing the emissions by 20% in 2020 via taxes would generate a food budget increase of 4.84% to compensate price increases. If the objective is to reduce the emissions by 60% in 2050, the CV would increase up to a 16.00%

We further sub-grouped the sample into social classes to analyze the distributional impact of the tax on consumer welfare. Table 8 shows that the impact of the tax is heterogeneous across social classes. The welfare losses are higher for the lowest social class due to the higher consumption of meat and milk and dairy products and the lower consumption of fish, fruits and vegetables. Nugraha & Lewis (2013) showed that the impact of a tax on consumption or production is more regressive for lower and middle income social groups. However, this study shows some differences: the impact decreases as the income level increases. However, for the higher income group the situation worsens in relation to the middle income group. This is due to the fact of the high consumption of ready-to-eat meals (composite dishes) and beef, veal and lamb. Again, as the tax is linear and proportional to the CO<sub>2</sub>-equivalent emission, the effect is higher at low consumption discount rates and higher social cost of emission scenarios.

#### *Impact of CO<sub>2</sub>-eq tax on diet quality*

To end with the impact assessment, we have included this section to report the impact of the alternative tax policy scenarios on the diet quality. Although there is a vast literature about alternative measures for diet quality, we have used here a very simplistic approach (the definition of diet quality is out of the scope of this paper). We have considered the World Health Organization (WHO) recommendations which suggest that the daily proportion of proteins, lipids and carbohydrates on total energy intake should be 10%-15%, 30%-35% and 50-55%, respectively. In this study we have calculated average per capita adult equivalent values. Figure 3 shows the main results. The first line of the graph corresponds to the current situation while the rest correspond to each of the tax policy scenarios. It is evident that price increases would contribute to lower consumption but, a priori, it was not clear if this reduction would affect or not the diet quality.

Our result indicates that the current macronutrient intake significantly exceeds the recommended values in the case of lipids (42.71%) and very slightly, in the case of proteins (15.61%). As a consequence, the intake of carbohydrates is lower than the recommended

values (41.64%). These results are consistent with previous studies in Spain suggesting an overconsumption of lipids and fats (Moreno, Sarría, & Popkin, 2002), which is one of the main reasons for the rapid increase of the prevalence of obesity and health related diseases compared to other EU countries (García-Goñi & Hernández-Quevedo, 2012).

Any tax policy to reduce CO<sub>2</sub> equivalent emissions would reduce the consumption of the most contaminating products, which will generate a more equilibrated diet. We have not found significant differences here in relation to the magnitude of the tax corresponding to each scenario. In general terms, the consequences on diet are two: a reduction in the intake of lipids and proteins towards an increase in that of carbohydrates. Let us take an example the tax scenario addressed to reduce emissions by 60% in 20250. As can be observed, proteins and lipids intake would decrease by 1.96% and 3.71%, respectively, while that of carbohydrates would increase by 4.55%. Summing up, our results suggest that imposing a carbon tax on all food categories would lead to a decline not only in CO<sub>2</sub>-eq emissions but also to a more equilibrated diet. We have also carried out some analyses by social income groups and we have not found any significant difference in relation to the average behavior.

### **Concluding remarks**

The study aimed at assessing the impact of introducing a Pigovian or CO<sub>2</sub> equivalent tax on food demand, welfare and diet quality in Spain. Alternative tax policy scenarios have been considered, which, in essence, reflect alternative social cost of emission or alternative tax magnitudes. In any case, the scenarios have been chosen taking into account real scenarios discussed at the US Environmental Protection Agency or at the EU. The methodological framework has been based on expenditure as well as own and cross price elasticities calculated from estimating a complete EASI food demand system. From elasticities estimates, the paper has assessed the impact of the tax on household's welfare and diet quality.

Results obtained in this study suggest that that the price increase as a consequence of the tax, reduces the consumption of the food products associated with higher CO<sub>2</sub> equivalent emissions. However, the impact on human health is positive as the quality of diet approximates to the WHO recommendations. However, the tax will affect more to lower income groups. It is also evident that the impact increases as the level of the tax also increases, suggesting that the tax level should be large enough to generate significant reduction in CO<sub>2</sub> equivalent emissions. Finally, our results suggest that the impact on the

reduction of greenhouse gas emissions will be significant only if the tax is imposed on all food products according to their contamination rate. Governments should be aware about the trade-off between the reduction of CO<sub>2</sub> equivalent emissions and the negative consequences on the citizen's welfare and set up their goals finding out a compromise between these two contradictory goals.

In any case, results from this study only apply to Spain and similar analyses should be conducted in other countries considering all food categories. In spite of the contribution of this study to the policy discussion, we have to recognize that our results should be interpreted with caution for several reasons. The most important is the lack of data. Although there is a lot of studies on life-cycle analysis, most of them are product specific and does not exist any study covering a wide range of products in Spain using a common methodological approach. Second, we have assumed that food supply is perfectly inelastic ignoring potential strategic decisions of firms. Further research could be focused on relaxing this assumption. Finally, authors have assumed, due to data unavailability, strong separability between food and other durable and non-durable goods. On the other hand, this limitation is difficult to overcome as we would need, at least, a composite indicator of greenhouse emission of other non-durable and durable goods. In spite of these limitations, this study provides some evidences about the potential impacts of imposing a CO<sub>2</sub> equivalent tax on food products.

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**Table 1. Data descriptive characteristics**

Food Category	Bud get Shar e (%)	Quantities (kg/capita)		Unit Values (€/kg)		Expenditures (€/capita)	
		Mean	SD*	Mean	SD*	Mean	SD*
Grains and grain-based products	5.47	54.13	44.8	2.69	0.95	136.95	113.55
Vegetables and vegetable products	8.03	124.04	109.51	1.77	0.6	201.06	168.22
Starchy roots, tubers, legumes, nuts and oilseeds	1.86	13.51	13.03	4.45	3.31	46.89	45.30
Fruit and fruit products	10.3	191.75	139.38	1.38	0.33	258.06	191.86
Beef, veal and lamb	5.52	16.14	15.77	8.65	3.27	142.73	165.25
Pork	4.71	17.41	15.28	7.48	3.14	119.17	99.79
Poultry, eggs, other fresh meat	5.62	39.99	28.63	3.61	1.00	141.23	103.37
Processed meat products	10.2	32.76	24.62	7.95	2.63	255.98	214.33
Fish and seafood	13.55	42.63	32.29	8.09	2.26	339.69	271.10
Milk and dairy products	8.14	183.41	128.01	1.27	0.72	203.93	140.44
Cheese	5.84	20.79	15.61	7.33	1.96	146.73	107.14
Sugar and confectionary and prepared desserts	7.71	47.45	36.73	4.44	1.66	193.18	144.43
Plant based fats	2.07	23.29	19.53	2.42	1.24	53.52	44.44
Composite dishes	5.10	31.14	29.99	4.58	1.88	129.27	121.87
Snacks and other foods	1.49	6.22	5.85	6.21	2.19	38.28	37.18
Residual category	4.39	39.78	38	3.87	4.09	110.21	109.64

\*SD= standard deviation

**Table 2. Average CO2 equivalent emissions per kg for each food category**

Food Category	kg CO2-eq/kg food	Standard Deviation
Grains and grain-based products	1.1	0.3
Vegetables and vegetable products	1.2	0.7
Starchy roots, tubers, legumes, nuts and oilseeds	0.4	0.5
Fruit and fruit products	0.9	0.7
Beef, veal and lamb	18.9	11.7
Pork	5.8	0.2
Poultry, eggs, other fresh meat	5.9	1.7
Processed meat products	5.4	0.4
Fish and seafood	5.3	2.3
Milk and dairy products	1.5	0.1
Cheese	8.2	0.05
Sugar and confectionary and prepared desserts	1.2	0.5
Plant based fats	2.6	1.0
Composite dishes	12.5	8.6
Snacks and other foods	1.9	0.2
Residual category	1.3	0.3

Source: Own elaboration from Hartikainen & Pulkkinen (2016)

**Table 3. Tax simulation scenarios (%)**

	EPA Discount rate 5%	EPA Discount Rate 2.5%	EU objective: reducing emissions by 20% in 2020	EU objective: reducing emissions by 60% in 2050
Social Cost of Emission	9.62 Euros	48.98 Euros	56 Euros	200 Euros
Grains and grain-based products	0.37	1.88	2.46	7.69
Vegetables and vegetable products	0.61	3.13	3.58	12.78
Starchy roots, tubers, legumes, nuts and oilseeds	0.07	0.37	0.43	1.53
Fruit and fruit products	0.61	3.11	3.56	12.71
Beef, veal and lamb	2.14	10.88	12.43	44.41
Pork	0.67	3.40	3.89	13.89
Poultry, eggs, other fresh meat	1.58	8.06	9.22	32.92
Processed meat products	0.64	3.27	3.74	13.36
Fish and seafood	0.59	3.02	3.45	12.34
Milk and dairy products	1.05	5.35	6.11	21.83
Cheese	1.05	5.37	6.14	21.92
Sugar and confectionary and prepared desserts	0.24	1.21	1.38	4.92
Plant based fats	0.97	4.93	5.64	20.13
Composite dishes	2.65	13.49	15.42	55.07
Snacks and other foods	0.31	1.58	1.81	6.45
Residual category	0.27	1.35	1.55	5.52

EPA: Environmental Protection Agency (USA)

**Table 4. Expenditure and Marshallian own-price elasticities (t-values in brackets)**

<b>Food Category</b>	<b>Own-price Elasticity</b>	<b>Expenditure Elasticity</b>
Grains and grain-based products	-0.50 (-4.25)	1.35 (28.06)
Vegetables and vegetable products	-1.03 (-16.31)	1.17 (24.99)
Starchy roots, tubers, legumes, nuts and oilseeds	-0.65 (-12.26)	0.49 (6.85)
Fruit and fruit products	-0.87 (-10.89)	0.99 (23.11)
Beef, veal and lamb	-0.65 (-14.60)	1.20 (18.75)
Pork	-0.65 (-9.12)	1.55 (26.99)
Poultry, eggs, other fresh meat	-0.53 (-9.26)	1.16 (26.82)
Processed meat products	-0.39 (-5.71)	1.02 (23.61)
Fish and seafood	-0.72 (-8.39)	1.04 (24.89)
Milk and dairy products	-0.69 (-15.02)	1.32 (28.84)
Cheese	-0.74 (-11.1)	0.89 (18.82)
Sugar and confectionary and prepared desserts	-0.85 (-14.91)	0.80 (17.55)
Plant based fats	-0.72 (-0.87)	1.06 (16.33)
Composite dishes	-0.89 (-21.53)	0.84 (13.19)
Snacks and other foods	-0.72 (-15.49)	0.66 (8.65)
Residual category	-4.09 (-0.62)	0.45 (1.53)

**Table 5. Marshallian price elasticities at mean values (t-values in brackets)**

<b>Food category</b>	<b>Grains</b>	<b>Vegetables</b>	<b>Pulse, Legumes and Starchy roots</b>	<b>Fruit and vegetable juices</b>	<b>Beef, veal and lamb</b>	<b>Pork</b>	<b>Poultry, eggs, other fresh meat</b>	<b>Processed and other cooked meats</b>	<b>Fish and other seafood</b>	<b>Milk, dairy and milk product imitates</b>	<b>Cheese</b>	<b>Sugar and confectionary and prepared desserts</b>	<b>Plant based fats</b>	<b>Composite dishes</b>	<b>Snacks and other foods</b>	<b>Residual category</b>
<b>Grains and grain-based products</b>	<b>-0.5005</b>	-0.1575	-0.0075	-0.0387	-0.0319	-0.1206	-0.1065	-0.0352	-0.0014	-0.1109	-0.0587	0.0996	-0.1454	0.0855	-0.0441	0.1820
	(-7.92)	(-4.25)	(-0.11)	(-1.06)	(-0.99)	(-2.39)	(-2.56)	(-1.03)	(-0.04)	(-4.01)	(-1.35)	(2.89)	(-2.28)	(2.93)	(-0.62)	(0.11)
<b>Vegetables and vegetable products</b>	-0.2418	<b>-1.0329</b>	0.2444	-0.0092	-0.0859	-0.1498	0.0359	-0.0581	-0.0186	0.0262	0.0790	-0.0006	0.0767	0.1597	0.0191	-0.0297
	(-4.52)	(-16.31)	(2.96)	(-0.20)	(-2.06)	(-2.45)	(0.72)	(-1.39)	(-0.46)	(0.75)	(1.51)	(-0.01)	(1.00)	(4.15)	(0.23)	(-0.02)
<b>Starchy roots, tubers, legumes, nuts and oilseeds</b>	-0.0188	0.0456	<b>-0.6527</b>	0.0477	-0.0297	-0.0624	-0.1045	-0.0273	-0.0225	0.0086	0.0417	0.0177	-0.1233	-0.0019	0.0349	-0.0330
	(-0.78)	(2.31)	(-12.26)	(2.44)	(-1.76)	(-2.32)	(-4.70)	(-1.50)	(-1.27)	(0.59)	(1.78)	(0.97)	(-3.59)	(-0.12)	(0.91)	(-0.04)
<b>Fruit and fruit products</b>	-0.1106	-0.0307	0.3131	<b>-0.8689</b>	-0.1822	0.0091	-0.0515	-0.0099	-0.1964	0.2013	0.0517	0.0806	0.0785	0.0199	-0.0698	-0.1267
	(-1.60)	(-0.51)	(2.91)	(-10.89)	(-3.51)	(0.11)	(-0.79)	(-0.18)	(-3.77)	(4.64)	(0.77)	(1.51)	(0.79)	(0.42)	(-0.64)	(-0.05)
<b>Beef, veal and lamb</b>	-0.0378	-0.0547	-0.0446	-0.0802	<b>-0.6484</b>	0.0156	0.0508	-0.0060	0.0666	-0.0509	-0.0876	-0.0398	0.0464	-0.0475	-0.0907	-0.0177
	(-1.23)	(-1.99)	(-0.96)	(-3.09)	(-14.6)	(0.43)	(1.80)	(-0.23)	(2.62)	(-2.09)	(-2.89)	(-1.51)	(1.09)	(-1.67)	(-1.90)	(-0.02)
<b>Pork</b>	-0.0954	-0.0722	-0.1069	0.0303	0.0302	<b>-0.6474</b>	-0.0859	-0.2101	-0.0685	-0.0421	0.1355	0.0099	0.0269	-0.0114	0.1098	0.3835
	(-2.19)	(-1.97)	(-1.58)	(0.84)	(0.92)	(-9.12)	(-2.07)	(-6.29)	(-2.05)	(-1.54)	(3.14)	(0.30)	(0.42)	(-0.39)	(1.62)	(0.25)
<b>Poultry, eggs, other fresh meat</b>	-0.1197	0.0249	-0.2728	-0.0183	0.0523	-0.1230	<b>-0.5320</b>	-0.0004	-0.0595	-0.0498	-0.0358	-0.0751	-0.1055	0.0180	-0.1670	0.2302
	(-2.81)	(0.71)	(-4.13)	(-0.52)	(1.72)	(-2.50)	(-9.26)	(-0.01)	(-1.87)	(-1.97)	(-0.85)	(-2.37)	(-1.67)	(0.68)	(-2.54)	(0.16)
<b>Processed meats products</b>	-0.0962	-0.0876	-0.0910	-0.0066	-0.0297	-0.4896	-0.0147	<b>-0.3885</b>	0.0503	-0.2026	0.0608	-0.1045	-0.2001	-0.0487	-0.0520	-0.0317
	(-1.57)	(-1.68)	(-0.96)	(-0.13)	(-0.60)	(-7.04)	(-0.26)	(-5.71)	(1.06)	(-4.89)	(1.01)	(-2.12)	(-2.34)	(-1.08)	(-0.54)	(-0.01)
<b>Fish and seafood</b>	-0.0438	-0.0476	-0.0836	-0.2400	0.1451	-0.2532	-0.1537	0.0689	<b>-0.7217</b>	0.0243	-0.1539	0.1145	0.0422	0.0059	0.1407	-0.1922
	(-0.55)	(-0.71)	(-0.69)	(-3.67)	(2.29)	(-2.76)	(-2.08)	(1.10)	(-8.39)	(0.46)	(-1.96)	(1.81)	(0.37)	(0.10)	(1.14)	(-0.07)
<b>Milk and dairy products</b>	-0.1763	0.0412	0.1100	0.1947	-0.0742	-0.0952	-0.0625	-0.1500	0.0401	<b>-0.6879</b>	-0.1278	-0.1511	-0.1059	-0.0738	0.0575	0.0040
	(-4.07)	(1.08)	(1.67)	(5.43)	(-1.85)	(-1.93)	(-1.61)	(-4.17)	(1.16)	(-15.02)	(-3.06)	(-4.14)	(-1.79)	(-1.97)	(0.85)	(0.00)
<b>Cheese</b>	-0.0924	0.0430	0.1562	0.0238	-0.1205	0.1325	-0.0549	0.0290	-0.0804	-0.1157	<b>-0.7428</b>	-0.0349	0.0799	0.0079	-0.0933	0.4786
	(-1.93)	(1.08)	(2.10)	(0.61)	(-3.44)	(2.42)	(-1.21)	(0.79)	(-2.21)	(-3.94)	(-11.1)	(-0.96)	(1.14)	(0.26)	(-1.25)	(0.30)
<b>Sugar and confectionary and prepared desserts</b>	0.1017	-0.0300	0.0996	0.0472	-0.0935	-0.0425	-0.1358	-0.1020	0.0515	-0.1824	-0.0531	<b>-0.8463</b>	-0.0613	-0.0189	0.1665	-0.8483
	(2.02)	(-0.70)	(1.28)	(1.14)	(-2.30)	(-0.75)	(-3.01)	(-2.56)	(1.32)	(-5.35)	(-1.10)	(-14.91)	(-0.89)	(-0.50)	(2.08)	(-0.39)
<b>Plant based fats</b>	-0.0619	0.0181	-0.1253	0.0174	0.0158	0.0018	-0.0417	-0.0417	0.0073	-0.0314	0.0316	-0.0107	<b>-0.7166</b>	-0.0070	-0.0382	0.0814
	(-0.10)	(0.04)	(-0.13)	(0.03)	(0.04)	(0.00)	(-0.08)	(-0.10)	(0.02)	(-0.08)	(0.06)	(-0.02)	(-0.87)	(-0.02)	(-0.04)	(0.10)
<b>Composite dishes</b>	0.0568	0.0914	0.0132	0.0020	-0.0698	-0.0515	-0.0003	-0.0369	-0.0087	-0.0731	0.0043	-0.0111	-0.0305	<b>-0.8858</b>	0.0088	0.0342
	(1.96)	(3.46)	(0.30)	(0.08)	(-2.35)	(-1.55)	(-0.01)	(-1.49)	(-0.36)	(-3.08)	(0.15)	(-0.43)	(-0.78)	(-21.53)	(0.19)	(0.03)
<b>Snacks and other foods</b>	-0.0239	-0.0043	0.0320	-0.0160	-0.0365	0.0228	-0.0554	-0.0141	0.0111	0.0001	-0.0283	0.0308	-0.0354	-0.0002	<b>-0.7212</b>	-0.1446
	(-1.16)	(-0.26)	(0.99)	(-0.96)	(-2.49)	(1.00)	(-2.96)	(-0.91)	(0.74)	(0.01)	(-1.44)	(1.94)	(-1.24)	(-0.02)	(-15.49)	(-0.20)
<b>Residual category</b>	0.1068	-0.0484	-0.0789	-0.0778	-0.0484	0.3086	0.1497	-0.0393	-0.0912	-0.0364	0.3316	-0.4830	0.1437	0.0108	-0.4096	<b>-4.0891</b>
	(0.08)	(-0.05)	(-0.04)	(-0.07)	(-0.05)	(0.21)	(0.13)	(-0.04)	(-0.10)	(-0.04)	(0.29)	(-0.40)	(0.08)	(0.01)	(-0.21)	(-0.62)

**Table 6. Average percentage reduction in CO2-eq emission under alternative tax scenarios (%)**

Tax simulation scenario	EPA Discount rate 5%	EPA Discount Rate 2.5%	EU objective: reducing emissions by 20% in 2020	EU objective: reducing emissions by 60% in 2050
All food categories	1.24	6.31	7.23	25.77
Beef and composite dish	0.62	3.18	3.63	12.96
Tax on all meat and dairy	0.60	3.05	3.49	12.47
Tax on beef and dairy	0.41	2.08	2.38	8.51

EPA: Environmental Protection Agency (USA)

**Table 7. Approximate compensating variation (CV) as a percentage of initial expenditure for 5 different policy scenarios and carbon tax based on CO2 equivalent emission**

Food Category	Tax Scenario			
	EPA Discount rate 5%	EPA Discount Rate 2.5%	EU objective: reducing emissions by 20% in 2020	EU objective: reducing emissions by 60% in 2050
Grains and grain-based products	0.02	0.10	0.13	0.40
Vegetables and vegetable products	0.05	0.24	0.27	0.90
Starchy roots, tubers, legumes, nuts and oilseeds	0.00	0.01	0.01	0.03
Fruit and fruit products	0.06	0.31	0.36	1.17
Beef, veal and lamb	0.11	0.52	0.58	1.68
Pork	0.03	0.16	0.18	0.59
Poultry, eggs, other fresh meat	0.09	0.42	0.48	1.47
Processed meat products	0.06	0.32	0.36	1.21
Fish and seafood	0.08	0.38	0.44	1.45
Milk and dairy products	0.09	0.44	0.50	1.57
Cheese	0.06	0.31	0.35	1.10
Sugar and confectionary and prepared desserts	0.02	0.10	0.11	0.38
Plant based fats	0.02	0.10	0.11	0.36
Composite dishes	0.14	0.65	0.73	1.92
Snacks and other foods	0.00	0.02	0.03	0.10
Residual category	0.01	0.06	0.07	0.23

EPA: Environmental Protection Agency (USA)

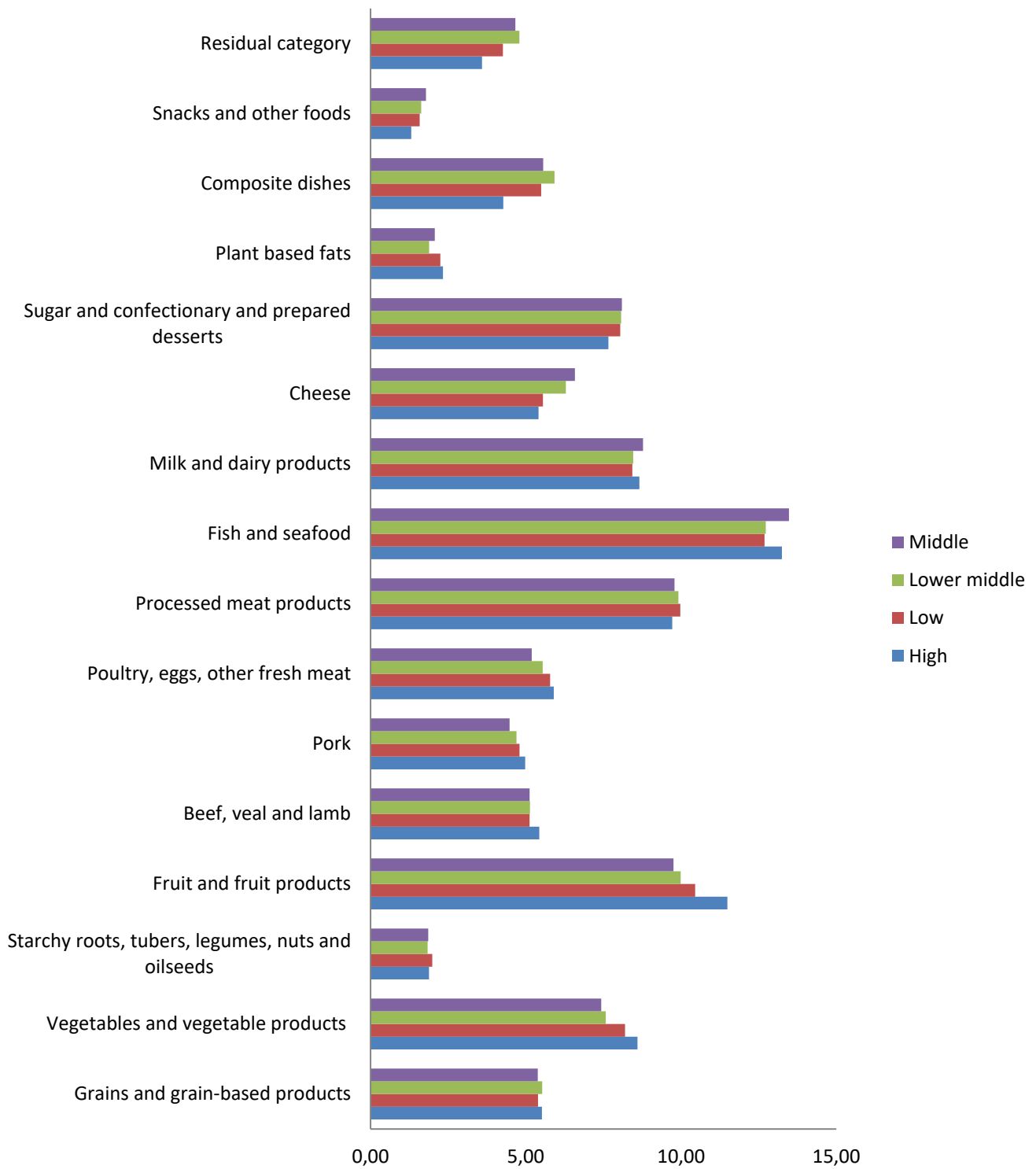


**Table 8. Log of cost living index for different income groups and different policy options**

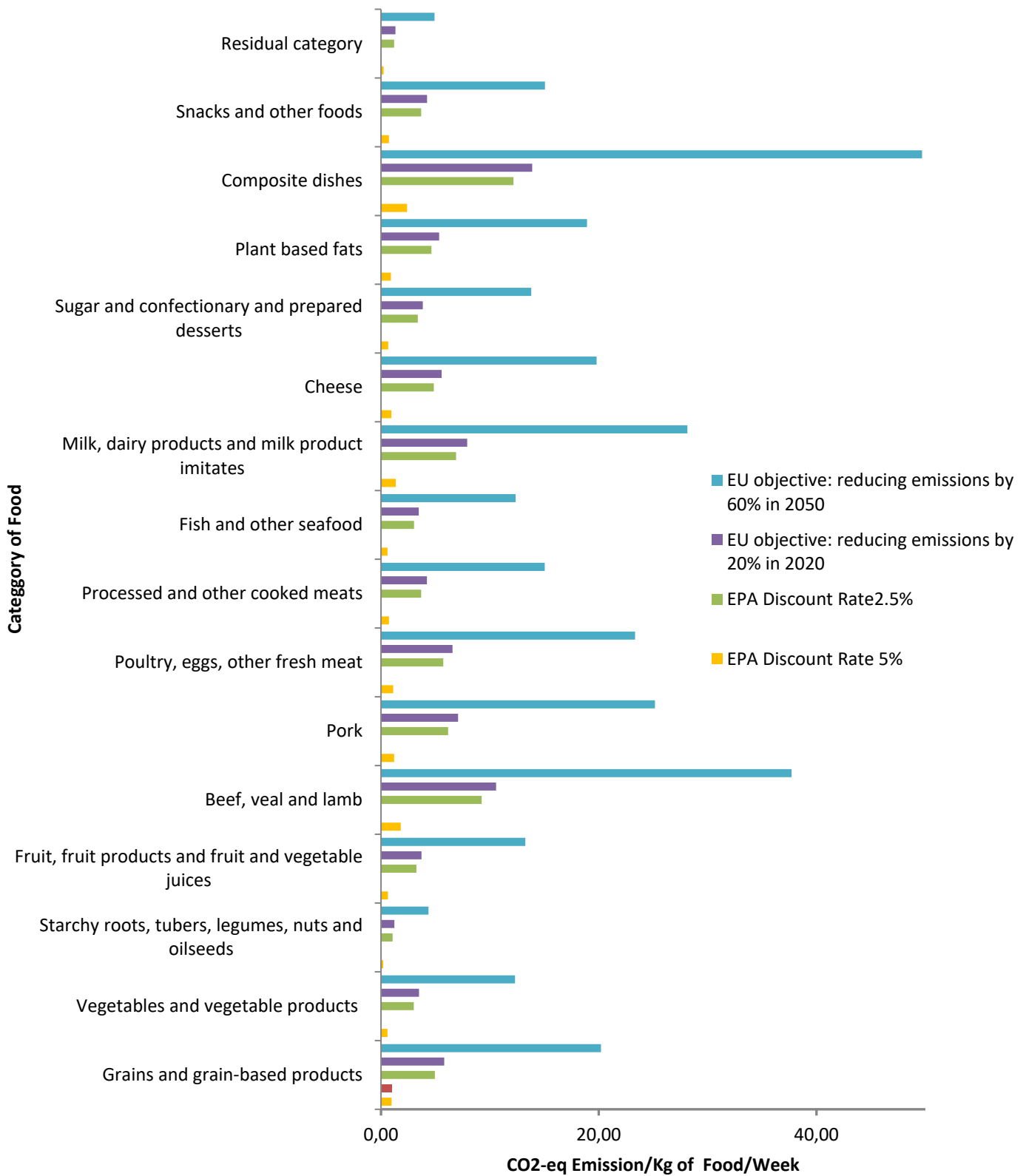
Income Class	Tax Scenario			
	EPA Discount rate 5%	EPA Discount Rate 2.5%	EU objective: reducing emissions by 20% in 2020	EU objective: reducing emissions by 60% in 2050
Low	0,93	4,56	5,20	17,11
Lower middle	0,89	4,43	5,06	16,70
Middle	0,85	4,22	4,82	15,95
High	0,88	4,38	5,01	16,58
All social classes	0,85	4,24	4,84	16,00

EPA: Environmental Protection Agency (USA)

**Figure 1. Food Expenditure shares by different social classes in Spain**



**Figure 2. Percentage decrease in CO2-eq emission/year/household for all food categories after the introduction of CO2-eq emission tax**



**Figure 3. Impact of CO2-eq tax on diet quality**

