Measuring the trade-off between greenhouse gas emissions and nutrition due to carbon consumption taxes in the UK

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Abstract:

Reducing greenhouse gas emissions (GHG) associated with food consumption is a particularly important issue given the recent concerns regarding climate change and diet. This paper modelled the effects of ad-valorem and carbon consumption taxes on different food products and found that taxing high carbon food products will likely result in a decrease in carbon emissions and intake of less beneficial nutrients (such as saturated fats and sugars). However, the taxes will also likely result in small reductions of beneficial nutrients which are currently under consumed in the UK. This may cause concern to policymakers and suggests the importance of monitoring nutrient intakes with regards to a potential introduction of carbon taxes.

Key Words: Carbon consumption taxes, Demand systems, Carbon emissions, Nutrition

D120, I120, Q180

1 Introduction

Reducing greenhouse gas emissions (GHG) associated with food consumption is a particularly important issue given the widespread consensus that humans are responsible for recent global warming (Cook et al. 2016). Also the World Meteorological Organization (World Meteorological Organization 2017) findings of 2016 being likely the hottest year since records began highlights the need for more action to reduce GHG. Changing the types of food consumed may have potential to reduce GHG. The emissions associated with British food consumption represent approximately 20 to 30 per cent (including land use change) of the UK's total consumption emissions (Audsley et al, 2009).

Public Health England have raised concerns that UK individuals consumed too much saturated fat, sugars, salt and lack the required consumption of fruit, vegetables, oily fish and fibre (Public Health England 2014). Therefore the UK diet on the whole is not as nutritious as it potentially could be given government dietary reference values (DRVs). The World Health Organization (2009) state that the "most prominent non-communicable diseases are linked to common risk factors, namely, tobacco use, alcohol abuse, unhealthy diet, physical inactivity, environmental carcinogens". This highlights the problem that poor dietary intake can cause and why a carbon consumption tax should consider the nutritional intakes in addition to GHG emissions.

The purpose of this paper is to model the effects of different taxes (Ad-Valorem and Carbon consumption taxes) on UK households in order to understand the likely changes in GHG emissions, nutrient intake and the trade-offs between these two metrics.

The structure of the paper is as follows: it starts with a background section and then describes the data used in the analysis. This is followed by the methodology in addition to a discussion of the results. The final section presents the conclusions.

2 Background

To influence consumer demand decisions for purchasing lower carbon emission food products there are three instruments are available: command and control, information provision and taxation. Command and control could take the form of banning certain high emission products

(Panzone et al. 2011). Information provision can take the form of providing information to the consumer on the harm of certain food products though Mazzocchi et al found that support for such campaigns from UK based respondents was lower relative to Belgium, Denmark, Italy and Poland (Mazzocchi et al. 2014). Taxation is not a new concept given its use in discouraging consumption of products which are considered unhealthy in certain quantities such as alcohol (Mytton, Clarke and Rayner 2012). There are recent examples of countries applying taxes to specific nutrients such as the fat taxes of Denmark (since repealed) and Hungary (Mytton et al. 2012). However, no country has yet applied a carbon consumption tax to food products.

Recent studies have modelled carbon consumption taxes with Edjabou and Smed (2013) studying the impact on Danish households, Briggs et al (2013) studying the impact on UK households and more recently García-Muros et al (2016) studied the effects on Spanish households of a carbon consumption tax. Caillavet et al (2016) took the innovative approach of applying a 20 per cent Ad-Valorem tax to high carbon products.

The results of the three carbon consumption tax studies showed similar changes in terms of the reduction in GHG emissions. Edjabou and Smed (2013) found that emissions could be reduced by 4 to 19.4 per cent (two different carbon prices were used along with different scenarios). The authors also found that consumption of saturated fat would decrease (ranged from 4 per cent to 10.5 per cent depending on carbon price) but consumption of sugars would likely increase (0.3 to 0.9 per cent depending on carbon price) (Edjabou and Smed 2013).

Briggs et al (2013) modelled a carbon consumption tax at UK level and found a likely 7.5 per cent reduction in emissions. The authors also studied the effects on 15 nutrients and reported that saturated fat consumption would decrease by more than 2 per cent and sugar consumption would decrease by less than 2 per cent[1]. García-Muros et al (2016) found that the emission reduction range was between 3.8 per cent (lowest tax rate) and 7.6 per cent (highest tax rate). García-Muros et al (2016) found that irrespective of scenario, the consumption of both saturated fat (approximate ranges provided of – 3 to -6 per cent) and sugar (approximate ranges provided of – 0.5 to -5 per cent) would likely decrease.

[1] Authors provide "nutrient composition of baseline diet and diets following tax scenarios", however the per centage change in nutrients is not provided and the author describes for scenario A either nutrients increasing by slightly more than 2 per cent or less than 2 per cent.

Caillavet et al (2016) found that the a 20 per cent Ad-Valorem tax applied to high carbon animal based products would likely reduce emissions by 7.5 per cent. The authors also studied the resulting likely consumption of ten nutrients and found that consumption decreases for both saturate fat (-15.02 per cent) and sugar (-3.24 per cent).

This study accepts that carbon consumption taxes are unlikely to result in an optimum quantity of carbon emissions reductions. This is because sourcing a suitable price of carbon emissions which reflects the true cost to society is very difficult. Baumol (1972) notes that even if such a tax does not produce the outcome of optimal reallocation (because of "complexities" of reality) then it can still be useful to have a tax which helps "controls" an externality. Baumol (1972) explain that taxes can still form an acceptable reduction in certain externalities without being a Pigouvian tax.

3 Data

3.1 Expenditure and food survey data

This paper used the 2012 Kantar Worldpanel database for Scotland to compute the UK elasticities. The reasoning behind using the Scottish data as a representation for the UK, is based on comparisons with data from "Family Food Module of the Living Costs and Food Survey (LCF)" (Defra 2016). The LCF indicated that Scottish data were a good approximation of UK purchases. The categories of food products were aggregated into 20 food groups consumed in the home.

3.2 Nutritional data

Data on British nutrient consumption were obtained from the European Food Safety Authority (EFSA) which were in turn supplied by the National Diet and Nutrition Survey (NDNS) years 1 to 3 (2008-2011) (EFSA 2017). This NDNS data sampled 3,073 individuals and the corresponding mean intake of nutrients associated with the food groups (Public Health England 2012).

3.3 Carbon emissions data

The carbon content of the food products is measured in terms of kilogram of carbon dioxide equivalent (Kg CO_2e) through the use of Life Cycle Assessments (commonly referred to as carbon footprints). The data were provided by the SUSDIET project (Hartikaiinen and Pulkkinen 2016).

4 Methodology

4.1 Estimation of the EASI demand system

The linearized Exact Affine Stone Index (referred to throughout this study as EASI) demand system Lewbel and Pendakur (Lewbel and Pendakur 2009) were derived from cost functions which are manipulated through the use of observable variables (these being: prices (p), expenditure (x) and budget shares (w) to form an expression for utility (Pendakur 2009).

The price index used in the EASI is that of the Stone Price Index (shown in equation 1) and is similar to the LA-AIDS whereby the real expenditure is estimated from this approximate index (Lewbel and Pendakur, 2009). The stone price index is equal to the following variables: x = log nominal expenditure, P'= log prices and $\overline{w}$ are the budget shares.

$$\tilde{y} = x - P'\overline{w} \tag{1}$$

Equation 2 shows the "approximate" model of the linear approximate EASI demand which is derived from Lewbel and Pendakur (Lewbel and Pendakur 2009) whereby w = budget shares, b = represents the Engel curve, $\tilde{y}$ = the stone price index, A = compensated price effects, p = log prices and the error term ε represented random utility parameter (Lewbel and Pendakur, 2009). The systems were estimated with no interactions between price, implicit utility and the demographic variables.

$$w = \sum_{r=0}^{r} b_r \tilde{y}_r + Cz + Dz\tilde{y} + \sum_{l=0}^{L} z_l A_l p + Bp\tilde{y} + \tilde{\varepsilon} \tag{2}$$

The price elasticities and income elasticities were then estimated from the estimated implicit Marshallian demand system. As the EASI demand system was estimated using aggregated categories, adjustment of unit values by quality changes were required. Cox and Wohlgenant (1986) methodology was used to account for quality effects.

4.2 Application of ad valorem tax and carbon consumption taxes

The ad-valorem tax had four tax rate rates depending on the carbon footprint of the food product. The tax rate and carbon threshold bands are shown in
Table 1.

Table 1 Ad-Valorem tax rates

Tax rate (%)	Carbon footprint criteria of food product
30	10 $KgCO_2$ equivalent emissions (per kg product)
20	5-9.9 $KgCO_2$ equivalent emissions (per kg product)
10	1-4.9 $KgCO_2$ equivalent emissions (per kg product)
5	0-0.9 $KgCO_2$ equivalent emissions (per kg product)

The carbon consumption tax rates were differentiated based on the carbon footprint of the food product. Equation 3 is based on Edjabou and Smed (2013) and estimates the tax rates (tax_i) which are equal to the carbon footprint of the food group (E_i) multiplied by the price of emissions (pe).

$$tax_i = E_i \, .pe \qquad \mathbf{3}$$

Three different prices of carbon were used for the estimation of the taxes. The first carbon price has been estimated using the European Commission's mean social cost of carbon which equates to £0.0427/kg. The second price used the recent European Emissions Trading Scheme (ETS) value of £0.0128/kg. The UK department of Energy and Climate change (DECC) refer to the issue of only some sectors being covered by the ETS, thus the ETS price will not equal the social cost (DECC 2009). The final value is based on the long term EU projection of carbon price of £0.1709/kg.

4.3 Simulations of the tax on household carbon footprint and nutrient intake

The simulations of the tax on household carbon footprints and the nutrient intakes were estimated using equation 4 to equation 6. Equation 4 estimated the change in quantity of food i (ΔQ_i) through multiplying the price elasticities (ε) obtained from Exact Affine Stone Index (EASI) by a vector of respective taxes for food i (t_i) and quantity of food i consumed (Q_i). The change in quantity of food i then formed the basis of the estimated change in GHG emissions and nutrition. Equation 5 estimated the change in GHG emissions (ΔGHG) through aggregating Q_i and multiplying by the GHG conversion coefficient for food i (α_i). Equation 6 used a similar approach as equation 5 but instead used nutrient conversion coefficients for food i with respect to nutrient j (β_{ij}) in order to estimate the change in nutrient j ($\Delta Nutrition_j$).

$$\Delta Q_i = \{\varepsilon \,.\, t_i\}\, Q_i \qquad (4)$$

$$\Delta GHG = \sum_i \Delta Q_i . \alpha_i \qquad (5)$$

$$\Delta Nutrition_j = \sum_i \Delta Q_i . \beta_{ij} \qquad (6)$$

4.4 Mean Adequacy Ratio (MAR) and Mean Excess Ratio (MER)

In order to assess the nutritional change as a result of the taxes it is necessary to use two metrics which are the Mean Adequacy Ratio (MAR) and Mean Excess Ratio (MER) developed by Vieux et al (Vieux et al. 2013). The MAR estimates the percentage of mean daily intake of 20 beneficial nutrients[2] with 100 per cent representing a diet which meets all of the nutritional requirements and a value less than 100 representing a diet which does not meet all the nutrient requirements (as represented through the Dietary Reference Values) (Vieux et al. 2013). Equation 7 represents the estimation of the MAR whereby the intake of beneficial nutrients (bn) is weighted by the Dietary Reference Values (DRV) and is scaled by the number of nutrients used (in this case 20).

$$MAR = \frac{1}{20} * \sum_{bn=1}^{20} \frac{intake_{bn}}{DRV_{bn}} * 100 \qquad (7)$$

The MER estimates the per centage mean daily maximum recommended intake of three nutrients (shown in equation 8 as harmful nutrients- hn) which are consumed in excess quantities: saturated fats, sugars. A value greater than 100 suggests excess consumption of these nutrients (Vieux et al. 2013).

$$MER = \left[\frac{1}{3} * \left(\sum_{hn=1}^{3} \frac{intake_{hn}}{DRV_{hn}} * 100\right)\right] - 100 \qquad (8)$$

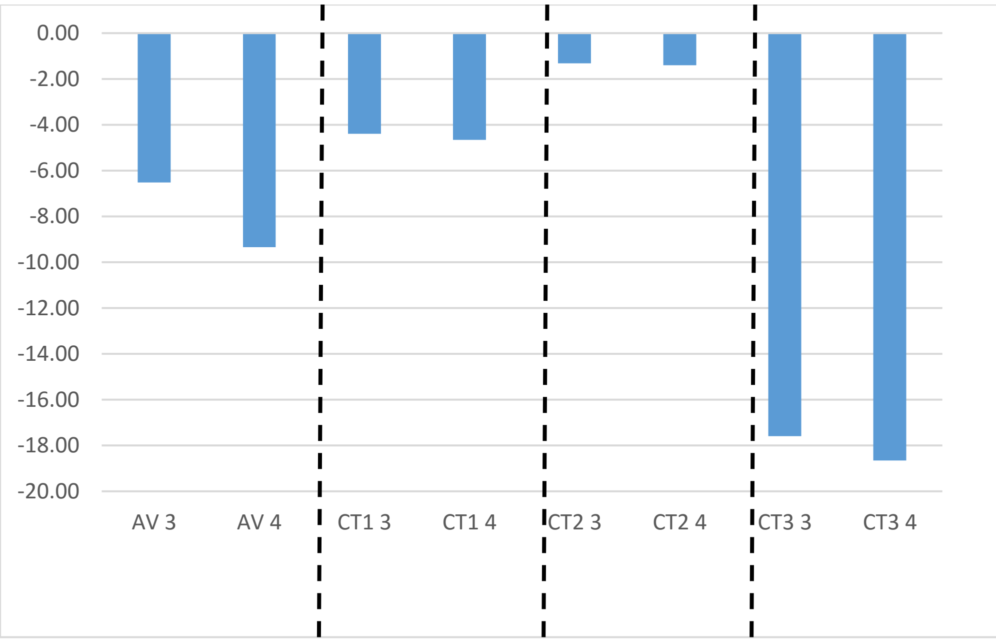
[2] Proteins, Fibre, Retinol Equivalents, Thiamine, Riboflavin, Niacin, Vitamin B-6, Folates, Vitamin B-12, Ascorbic Acid, Vitamin E, Vitamin D, Calcium, Potassium, Iron, Magnesium and Zinc

5 Results and discussions

This section presents the results of the uncompensated simulations as these were considered more realistic for policy than compensated simulations. The compensated simulations would likely require costly administration from a tax authority in order to ensure that the carbon consumption taxes were distributed amongst food products[3].

The largest reduction in GHG emissions (relative to the baseline of 4.02 $KgCO_2e/g$) ranges from 1 per cent (3.98 $KgCO_2e/g$) for carbon tax two, simulation one to approximately 19 per cent (3.31 $KgCO_2e/g$) for simulation three, carbon price three. These results are largely consistent with the result of Edjabou and Smed (2013) in the sense that higher prices will prevail in the uncompensated scenario, thus the reduction in demand is greater. A particularly interesting result is how there is little difference in change between GHG reductions of taxing animal-based products relative to taxing all products with regards to each of the three carbon taxes which is shown in Figure 1.

Figure 1 Per cent changes between simulation 3 and 4 (Greenhouse gas emissions)



Notes: "AV" means Ad-valorem tax and "CT" means carbon tax.

The food group associated with largest GHG emissions are the meat groups with beef being one of the highest emitters. It is therefore, of little surprise that this food group experiences a decrease in consumption for all the different tax scenarios.

[3] The results of the compensated scenarios are available from the authors on request

There are other nutrients to which a decrease in consumption with regards to simulation three and four (irrespective of tax) is estimated and likely to be beneficial given the current overconsumption at UK population level (Public Health England 2014). These nutrients are sugar, saturated fat and salt and energy (will also be discussed given the relation to the aforementioned nutrients). The results of the changes in nutrients consumed associated with the different simulations are shown in Table 3 of the appendix (due to space constraints). With regards to sugar, the results suggest an overall decrease in consumption irrespective of type of tax or simulation. However, the decreases are less for all the simulations of carbon tax price two (ranging from a decrease of approximately 1 per cent for simulation one for simulation two). Whilst the highest reduction is experienced for carbon price three and ranges from approximately 9 per cent for simulation one to approximately 14 per cent for simulation four. However, comparing the relative decreases within both carbon prices shows that the difference for both simulation three and four is similar.

With regards to saturated fats, a similar result occurs where there is little difference between the reduction in simulation three and four in terms of all the carbon tax simulations and ad valorem taxes. The same relationship is also apparent for sodium. Other nutrients which are shown in table 3, also experience a similar pattern whereby taxing all animal-based products relative to taxing all products would have little difference in terms of nutrients consumed.

As the effect of the different tax simulations suggest consumption of all nutrients would decrease, then some attention should be focussed on nutrients where average consumption for adults (irrespective of gender from aged 19 onwards) is currently less than government recommendations. According to the latest National Diet and Nutrition (NDNS) report, the nutrients which are currently under consumed are: Magnesium and Potassium[4] (Food Standards Agency and Public Health England 2016). The scenario with the greatest decrease occurred for carbon tax three, simulations three and four. Magnesium consumption decreased respectively by approximately 15 per cent and approximately 19 per cent. Potassium consumption reduced by approximately 13 per cent and 17 per cent. This may cause concern to policymakers but it should be emphasised that the NDNS report found that for the UK, most

[4] Selenium is also under-consumed but was not modelled in this study

nutrients were overconsumed rather than under-consumed (Food Standards Agency and Public Health England 2016).

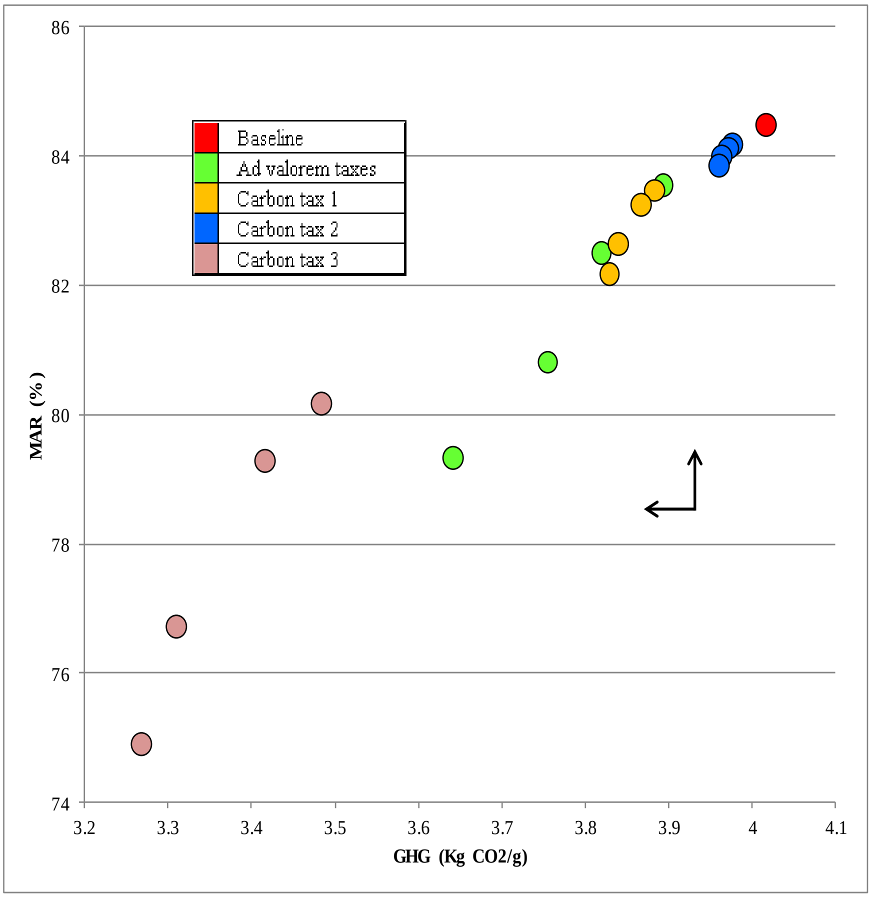
The quantity demanded as a result of different food products does vary depending on the tax and simulations. However, “Grains and grain-based products”, “Vegetables and vegetable products”, “Starchy roots, tubers, legumes, nuts and oilseeds”, “Fruit, fruit products and fruit and vegetable juices” and “Beef, veal and lamb” were product groups which experienced a decline in demand (relative to the baseline), irrespective of tax and simulation. Considering the recent concern that only 30 per cent of UK adults consume the recommended “5-a-day” of fruit and vegetables (Public Health England 2014), it is therefore of some concern that these two groups would likely experience a decline in demand. This result is in contrast to Briggs et al (2013) whereby a reduction in demand for vegetables and a small increase in demand for fresh fruit was found (for the uncompensated scenario). Direct comparisons with Briggs et al (2013) are difficult given the data and tax rates differ relative to this study.

The reduction in red meats is potentially a welcome outcome given health warnings which advise reducing consumption of these products (NHS Choices 2017). The food group associated with the largest GHG emissions are the meat groups with beef being one of the highest emitters. It is therefore, of little surprise that this food group experiences a decrease in consumption for all the different tax scenarios given the overall decline in GHG emissions.

The largest decrease (approximately 40 per cent) in demand is as a result of the taxes for “Milk, dairy products and milk product imitates” with regards to carbon price three, simulation three. A small reduction in demand for the other carbon taxes and ad-valorem tax were also estimated. The main reason behind the 40 per cent reduction is due to many of the animal based products being complements of milk products. It should also be highlighted that the largest decrease in calcium consumption would be for carbon price three simulation three and four. This may be of concern to policymakers yet the largest reduction in saturated fats is also associated with these simulations. Thus a clear example of the trade-off in nutrients.

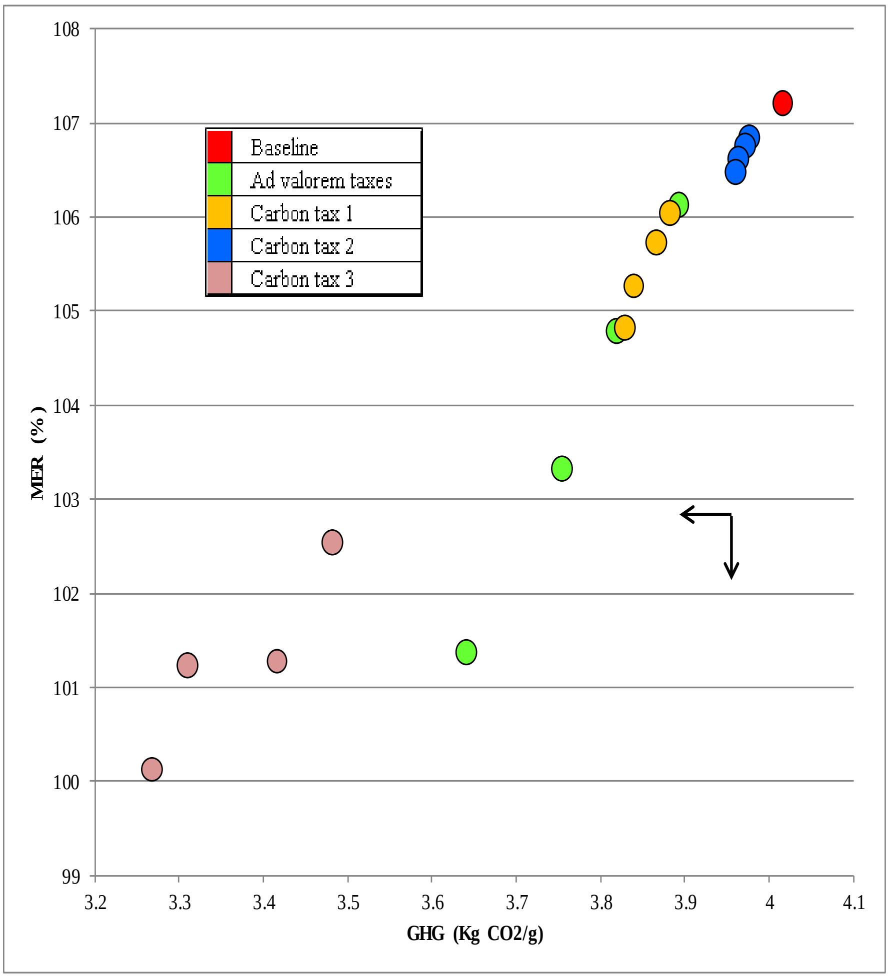
The previous discussion focussed on selected individual nutrients but the discussion will now focus on the trade-off between the beneficial and less beneficial nutrients. The MAR as shown in Figure 2 indicated that for every tax simulation there was a slight decrease in the MAR ratio which suggests the simulations will result in slightly less intake of beneficial nutrients. The reduction is small considering that the baseline is approximately 85 per cent and the lowest value is approximately 75 per cent for carbon tax price three (simulation four) and the highest value is approximately 84 per cent for carbon tax price two (simulations one and two). The reduction in beneficial nutrients for carbon tax price three, simulation appears to be small but given the low initial baseline, this could be an area of concern for policymakers.

Figure 2 Mean Adequacy Ratio (MAR)



The MER as shown in Figure 3 indicated a small decrease for all scenarios relative to the baseline of approximately 107 per cent. The lowest MER is experienced for carbon tax price three (simulation four) of approximately 100 per cent to approximately 106 per cent for carbon tax price two (irrespective of simulation). Therefore, the likely effect of the taxes will slightly decrease intake of harmful nutrients for both the ad-valorem and carbon taxes.

Figure 3 Mean Excess Ratio (MER)



The impacts of either the Ad-Valorem or carbon consumption taxes are unlikely to have a particularly negative effect on nutrient consumption, the effect on consumer welfare is also very small. The compensating variation (CV) as a percentage of food expenditure is approximately one per cent for the uncompensated carbon tax scenarios. As the CV is essentially the compensation required for a consumer given a price rise, then these values are small and suggest the household would require little compensation to accept the taxes (irrespective of scenario). However, it should be emphasised that lower income households may require a higher CV and the regressive element of such taxes is therefore a possibility. Socio-economic classes have not been incorporated into this study.

6 Conclusions

Taxing high carbon food and drink products is likely to reduce greenhouse gas emissions irrespective of whether an ad-valorem or carbon consumption tax is used. Carbon tax three would likely induce the largest reduction in emissions. There is little difference in change between GHG reductions of taxing animal based products relative to taxing all products irrespective of tax used which is a particularly interesting finding. This suggests that policymakers in the UK could tax animal based products instead of taxing all food products which may be more desirable from a policy perspective. The ad-valorem tax may be the simplest of the taxes modelled in this study to administer and therefore may be of particular interest to policymakers.

With regards to nutrient intake, the likely outcome (irrespective of tax and subsequent scenario) is that all nutrients would experience a decrease in consumption. This naturally leads to a decrease in consumption of beneficial nutrients as measured by the mean adequacy ratio (MAR) though this decrease is relatively small when compared with the baseline. However, the mean excess ratio (MER) showed that intake of less beneficial nutrients (when consumed to excessive quantities) would decrease relative to the baseline. This provides two important outcomes, namely that greenhouse gas emissions and less beneficial nutrients can be reduced. However, a trade-off does seem to occur between reducing greenhouse gas emissions and improving the intake of beneficial nutrients.

Overall a carbon consumption tax is likely (given current British food preferences) to both reduce greenhouse gas emissions and mostly improve nutrient intake though a trade-off between beneficial and less beneficial nutrients is present and may cause concern to policymakers.

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Appendix

Table 2 Effect of taxes on quantities of selected food groups

Variables	Uncompensated case (without tax redistribution)															
	Ad-Valorem Tax				Carbon tax, Rate 1: 0.0427 £/kg				Carbon tax, Rate 2: 0.0128 £/kg				Carbon tax, Rate 3: 0.1709 £/kg			
	Simulations				Simulations				Simulations				Simulations			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Quantities																
Grains and grain-based products	-3.86	-4.55	-10.03	-17.71	-4.18	-4.29	-6.16	-8.49	-1.25	-1.29	-1.85	-2.55	-16.73	-17.17	-24.65	-33.96
Vegetables and vegetable products	-4.31	-12.20	-7.79	-14.99	-4.67	-6.29	-4.94	-7.44	-1.40	-1.89	-1.48	-2.23	-18.67	-25.17	-19.76	-29.77
Starchy roots, tubers, legumes, nuts and oilseeds	-1.08	0.19	-0.19	-4.78	-1.17	-0.75	-0.57	-2.08	-0.35	-0.22	-0.17	-0.62	-4.66	-3.00	-2.28	-8.30
Fruit, fruit products and fruit and vegetable juices	-3.01	-6.92	-7.26	-13.57	-3.26	-4.03	-3.74	-4.77	-0.98	-1.21	-1.12	-1.43	-13.05	-16.11	-14.96	-19.07
Beef, veal and lamb	-10.18	-8.32	-4.48	-10.80	-11.04	-10.69	-9.81	-9.85	-3.31	-3.21	-2.94	-2.96	-44.14	-42.76	-39.24	-39.42
Pork	0.39	-16.98	-17.62	-18.80	0.43	-4.05	-4.46	-4.99	0.13	-1.22	-1.34	-1.50	1.71	-16.22	-17.85	-19.95
Poultry, eggs, other fresh meat	1.54	-12.12	-18.68	-12.33	1.67	0.03	-1.65	-2.84	0.50	0.01	-0.49	-0.85	6.69	0.13	-6.59	-11.36
Processed and other cooked meats	-0.23	-10.49	-6.62	-8.60	-0.25	-2.95	-0.55	-0.72	-0.07	-0.89	-0.17	-0.22	-0.98	-11.82	-2.22	-2.88
Fish and other seafood	1.80	-0.44	-9.28	-9.02	1.95	1.51	0.76	0.39	0.59	0.45	0.23	0.12	7.82	6.03	3.06	1.58
Milk, dairy products and milk product imitates	-0.88	-2.94	-19.83	-10.62	-0.96	-1.39	-10.12	-9.79	-0.29	-0.42	-3.03	-2.94	-3.83	-5.57	-40.47	-39.18
Cheese	-0.52	-1.61	-23.20	-22.32	-0.56	-0.68	-5.30	-4.93	-0.17	-0.20	-1.59	-1.48	-2.24	-2.72	-21.20	-19.73
Sugar and confectionary and prepared desserts	-2.69	-8.59	-3.15	-13.75	-2.92	-4.43	-2.29	-3.87	-0.88	-1.33	-0.69	-1.16	-11.68	-17.72	-9.17	-15.50

Source: Authors' own elaboration

Table 3 Effect of taxes on selected nutrients and greenhouse gas emissions

Variables	Uncompensated case (without tax redistribution)															
	Ad-Valorem Tax				Carbon tax, Rate 1: 0.0427 £/kg				Carbon tax, Rate 2: 0.0128 £/kg				Carbon tax, Rate 3: 0.1709 £/kg			
	Simulations				Simulations				Simulations				Simulations			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Nutritional and environmental indicators																
Energy	-1.98	-3.87	-7.09	-10.87	-2.15	-2.56	-3.63	-4.58	-0.64	-0.77	-1.09	-1.37	-8.59	-10.22	-14.52	-18.33
Proteins	-1.86	-5.39	-9.72	-11.03	-2.02	-2.70	-4.08	-4.67	-0.60	-0.81	-1.22	-1.40	-8.06	-10.79	-16.33	-18.67
Fibre	-2.73	-4.32	-5.93	-11.33	-2.96	-3.28	-3.81	-5.24	-0.89	-0.98	-1.14	-1.57	-11.84	-13.13	-15.23	-20.96
Carbohydrates	-2.60	-3.91	-6.40	-11.61	-2.82	-3.11	-4.02	-5.28	-0.85	-0.93	-1.21	-1.58	-11.27	-12.43	-16.08	-21.10
Sugar	-2.27	-4.92	-6.02	-10.76	-2.46	-3.06	-3.57	-4.50	-0.74	-0.92	-1.07	-1.35	-9.85	-12.25	-14.29	-18.01
Fats - Saturates	-1.34	-3.44	-6.45	-8.87	-1.45	-1.93	-2.87	-3.64	-0.43	-0.58	-0.86	-1.09	-5.80	-7.70	-11.47	-14.55
Free sugar	-2.18	-4.70	-4.10	-10.15	-2.36	-2.96	-2.65	-3.60	-0.71	-0.89	-0.80	-1.08	-9.43	-11.83	-10.62	-14.39
Minerals - Sodium	-1.51	-3.66	-6.55	-8.94	-1.64	-2.18	-3.00	-3.53	-0.49	-0.65	-0.90	-1.06	-6.56	-8.71	-11.99	-14.11
Minerals - Magnesium	-1.99	-3.86	-7.03	-10.64	-2.16	-2.53	-3.65	-4.61	-0.65	-0.76	-1.09	-1.38	-8.64	-10.10	-14.59	-18.45
Minerals - Phosphorus	-1.73	-4.36	-9.61	-11.00	-1.88	-2.40	-4.28	-4.91	-0.56	-0.72	-1.28	-1.47	-7.51	-9.58	-17.11	-19.65
Minerals - Potassium	-1.80	-4.07	-6.51	-9.28	-1.95	-2.39	-3.36	-4.17	-0.59	-0.72	-1.01	-1.25	-7.81	-9.57	-13.42	-16.69
Minerals - Calcium	-1.80	-3.52	-12.28	-12.81	-1.95	-2.32	-5.68	-6.27	-0.58	-0.69	-1.70	-1.88	-7.80	-9.26	-22.72	-25.07
Minerals - Iron	-2.68	-4.32	-6.30	-11.08	-2.90	-3.25	-3.90	-5.02	-0.87	-0.98	-1.17	-1.51	-11.61	-13.00	-15.60	-20.08
Minerals - Zinc	-2.83	-5.10	-8.77	-11.21	-3.07	-3.57	-4.87	-5.44	-0.92	-1.07	-1.46	-1.63	-12.28	-14.27	-19.47	-21.77
Vitamins - A	-2.97	-6.94	-7.96	-11.82	-3.22	-4.07	-4.54	-5.80	-0.97	-1.22	-1.36	-1.74	-12.87	-16.28	-18.14	-23.18
Vitamins - C	-2.80	-6.48	-6.22	-11.25	-3.03	-3.77	-3.62	-4.80	-0.91	-1.13	-1.09	-1.44	-12.12	-15.08	-14.47	-19.20
Vitamins - B6	-1.69	-4.24	-6.62	-9.70	-1.83	-2.32	-3.13	-4.14	-0.55	-0.70	-0.94	-1.24	-7.31	-9.27	-12.51	-16.54
Vitamins - B9	-2.19	-4.00	-6.32	-10.75	-2.37	-2.73	-3.56	-4.83	-0.71	-0.82	-1.07	-1.45	-9.48	-10.91	-14.22	-19.31
Vitamins - B12	-1.92	-3.96	-10.58	-9.88	-2.09	-2.56	-4.97	-4.98	-0.63	-0.77	-1.49	-1.49	-8.34	-10.22	-19.86	-19.93
Greenhouse gas equivalent	-3.07	-4.90	-6.52	-9.34	-3.32	-3.74	-4.40	-4.66	-1.00	-1.12	-1.32	-1.40	-13.30	-14.94	-17.60	-18.65

Source: Authors' own elaboration

Table 4 Ad-Valorem tax simulations

Variables	Baseline	Uncompensated case (without tax redistribution)			
		Ad-Valorem Tax			
		Simulations			
		1	2	3	4
Tax revenues and welfare indicator					
Tax revenues (£/day)	0.00	32.27	115.21	206.42	487.73
As percentage of food expenditure/or reduction in tax (%)	0.00	0.34	1.20	2.16	5.10
Compensating variation (CV) (£/day)	0.00	1.00	1.01	1.02	1.05
CV as percentage of food expenditure (%)	0.00	0.01	0.01	0.01	0.01
Mean adequacy ratio (MAR) (%)	84.47	83.55	82.49	80.81	79.32
Mean excess ratio (MER) (%)	107.21	106.13	104.79	103.33	101.38
Greenhouse gas equivalent (Kg CO2/g)	4.02	3.89	3.82	3.75	3.64
Greenhouse gas equivalent (%)		-3.07	-4.90	-6.52	-9.34
Free sugar (g/g)	58.71	57.44	55.96	56.30	52.76
Free Sugar (%)		-2.18	-4.70	-4.10	-10.15
Minerals - Iron (mg/g)	10.36	10.08	9.91	9.71	9.21
Minerals - Iron (%)		-2.68	-4.32	-6.30	-11.08
Minerals - Zinc (mg/g)	8.40	8.16	7.97	7.67	7.46
Minerals - Zinc (%)		-2.83	-5.10	-8.77	-11.21
Fruit, fruit products and fruit and vegetable juices (g/day)	160.73	155.89	149.60	149.06	138.91
Fruit, fruit products and fruit and vegetable juices (%)		-3.01	-6.92	-7.26	-13.57
Beef, veal and lamb (g/day)	22.78	20.46	20.88	21.76	20.32
Beef, veal and lamb (%)		-10.18	-8.32	-4.48	-10.80
Pork (g/day)	7.59	7.62	6.30	6.25	6.16
Pork (%)		0.39	-16.98	-17.62	-18.80
Poultry, eggs, other fresh meat (g/day)	36.16	36.72	31.78	29.41	31.70
Poultry, eggs, other fresh meat (%)		1.54	-12.12	-18.68	-12.33
Processed and other cooked meats (g/day)	30.17	30.10	27.00	28.17	27.57
Processed and other cooked meats (%)		-0.23	-10.49	-6.62	-8.60

Source: Authors' own elaboration. Notes: Unit of measurement is indicated in brackets within the variables column.

Table 5 Uncompensated carbon tax simulations

Variables	Carbon tax, Price 1: 0.0427 £/kg				Carbon tax, Price 2: 0.0128 £/kg				Carbon tax, Price 3: 0.1709 £/kg			
	Simulations				Simulations				Simulations			
	1	2	3	4	1	2	3	4	1	2	3	4
Tax revenues and welfare indicator												
Tax revenues (£/day)	34.64	52.51	80.34	137.12	11.29	16.70	25.39	42.88	86.99	155.77	248.09	448.88
As percentage of food expenditure/or reduction in tax (%)	0.73	1.11	1.69	2.89	0.14	0.21	0.32	0.53	1.07	1.92	3.06	5.54
Compensating variation (CV) (£/day)	1.00	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.02	1.03	1.05
CV as percentage of food expenditure (%)	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mean adequacy ratio (MAR) (%)	83.47	83.25	82.63	82.18	84.18	84.12	83.98	83.85	80.18	79.31	76.74	74.91
Mean excess ratio (MER) (%)	106.04	105.73	105.27	104.82	106.86	106.77	106.63	106.49	102.54	101.28	101.24	100.13
Greenhouse gas equivalent (Kg CO2/g)	3.88	3.87	3.84	3.83	3.98	3.97	3.96	3.96	3.48	3.42	3.31	3.27
Greenhouse gas equivalent (%)	-3.32	-3.74	-4.40	-4.66	-1.00	-1.12	-1.32	-1.40	-13.30	-14.94	-17.60	-18.65
Free sugar (g/g)	57.33	56.98	57.15	56.60	58.30	58.19	58.25	58.08	53.18	51.76	52.48	50.26
Free sugar (%)	-2.36	-2.96	-2.65	-3.60	-0.71	-0.89	-0.80	-1.08	-9.43	-11.83	-10.62	-14.39
Minerals - Iron (mg/g)	10.06	10.02	9.96	9.84	10.27	10.26	10.24	10.20	9.16	9.01	8.74	8.28
Minerals - Iron (%)	-2.90	-3.25	-3.90	-5.02	-0.87	-0.98	-1.17	-1.51	-11.61	-13.00	-15.60	-20.08
Minerals - Zinc (mg/g)	8.14	8.10	7.99	7.94	8.32	8.31	8.28	8.26	7.37	7.20	6.77	6.57
Minerals - Zinc (%)	-3.07	-3.57	-4.87	-5.44	-0.92	-1.07	-1.46	-1.63	-12.28	-14.27	-19.47	-21.77
Fruit, fruit products and fruit and vegetable juices (g/day)	155.48	154.25	154.71	153.07	159.15	158.78	158.92	158.43	139.75	134.83	136.68	130.08
Fruit, fruit products and fruit and vegetable juices (%)	-3.26	-4.03	-3.74	-4.77	-0.98	-1.21	-1.12	-1.43	-13.05	-16.11	-14.96	-19.07
Beef, veal and lamb (g/day)	20.26	20.34	20.54	20.53	22.02	22.05	22.11	22.10	12.72	13.04	13.84	13.80
Beef, veal and lamb (%)	-11.04	-10.69	-9.81	-9.85	-3.31	-3.21	-2.94	-2.96	-44.14	-42.76	-39.24	-39.42
Pork (g/day)	7.62	7.28	7.25	7.21	7.60	7.50	7.49	7.48	7.72	6.36	6.24	6.08
Pork (%)	0.43	-4.05	-4.46	-4.99	0.13	-1.22	-1.34	-1.50	1.71	-16.22	-17.85	-19.95
Poultry, eggs, other fresh meat (g/day)	36.77	36.17	35.57	35.13	36.34	36.17	35.98	35.85	38.58	36.21	33.78	32.05
Poultry, eggs, other fresh meat (%)	1.67	0.03	-1.65	-2.84	0.50	0.01	-0.49	-0.85	6.69	0.13	-6.59	-11.36
Processed and other cooked meats (g/day)	30.09	29.27	30.00	29.95	30.14	29.90	30.12	30.10	29.87	26.60	29.50	29.30
Processed and other cooked meats (%)	-0.25	-2.95	-0.55	-0.72	-0.07	-0.89	-0.17	-0.22	-0.98	-11.82	-2.22	-2.88

Source: Authors' own elaboration. Notes: Unit of measurement is indicated in brackets within the variables column