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Improving vitamin D intake through carbon consumption taxes

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Abstract

Salmon is an oily fish which contains vitamin D which cannot be obtained from the sun during the winter months in Scotland. Yet, farmed salmon often has a higher carbon footprint relative to chicken which conflicts with the Scottish government's aims of reducing carbon emissions while improving vitamin D intake. This paper investigates how the application of carbon consumption taxes on meat and fish products may affect these aims. Carbon and nutrient elasticities are calculated from Marshallian price elasticities of demand which are obtained from a linear version of an almost ideal demand system (LA-AIDS). The household purchasing data used in the analysis were obtained from Kantar Worldpanel for the years 2006-2011 with nutrient data provided by Defra and the Food Standards agency. The results suggest that taxing only meat products would have the positive effect of reducing carbon emissions associated with Scottish household food consumption by 46,304.02 t/CO_2e/y. Also, the intake of vitamin D per person would increase by 0.08 µg/day which represents 3.81% of the government's recommended daily vitamin D intake. Taxing both fish and meat products is likely to result in a reduction of vitamin D intake. Total fat intake is likely to reduce for either scenario.

Keywords: An Almost Ideal Demand System; Carbon consumption taxes; Carbon footprints; Vitamin D.

JEL code: D120

I. Introduction

During the winter months in Scotland the population cannot obtain vitamin D from the sun and vitamin D can be obtained from “ dietary vitamin D” (Food Standards Agency Scotland, 2013). The chief medical officer in Scotland has suggested increased consumption of oily fish (e.g. salmon) (Food Standards Agency Scotland, 2010). However, the Scottish Government have set legislative targets for reducing greenhouse gas emissions by 42% for the year 2020 (Scottish Government, 2012b). Yet, salmon has a greater carbon footprint relative to some meat products such as chicken which demonstrates the challenges of improving vitamin D intake and reducing greenhouse gas emission.

This study aims to understand how the application of carbon consumption taxes to fish and meat products, could potentially affect the vitamin D intake of Scottish households. Whilst also understanding the likely effect on the carbon footprint of these households. Therefore, this paper aims to understand if trade-offs exist between health and environmental sustainability which is relevant to policy. This will be done through comparing the results of scenario 1 which only taxes meat products with scenario 2 which taxes both fish and meat products.

The structure plan of the paper is as follows: it starts with a literature review that highlights the importance of vitamin D and weak separability in demand modelling. It is followed by a section describing the data used in the study. The next section presents the methods used in the paper. The penultimate section discusses the results. Finally, some conclusions are presented.

II. Literature review

The purpose of this literature review is to cover two points: the need for vitamin D and secondly demand separability between fish and meat products.

II.1 Vitamin D in Scotland

Vitamin D is found in relatively large quantities in only a few food products (e.g. oily fish (salmon), eggs and fortified breakfast cereal) and deficiency of this nutrient can cause bone development problems such as osteomalacia (NHS, 2012).

The chief medical officer in Scotland highlighted in his 2011 annual report, concerns regarding poor vitamin D intake amongst sections of the Scottish population (Scottish

Government, 2012a). The recommended daily average intake of vitamin D in Scotland is 2-4 µg/day, however, some at risk groups such as pregnant woman would require 10 µg/day of vitamin D (NHS Health Scotland, 2011). This does highlight the problem of using the average recommended vitamin D intake.

The Scottish Health Survey 2010-2011, found that 17% of the sample had suboptimal levels of vitamin D and during the winter months (October – March) the level of sunshine in Scotland is too low for the body to develop vitamin D naturally from the sun (Food Standards Agency Scotland, 2013). Therefore, the significance of foods such as salmon would appear to be important especially during the winter months.

In contrast to vitamin D, the consumption of total fat in 2012 represented 39% of household food energy which is higher than the recommended food energy share of 35% (Government, 2014). For this reason total fat will also be considered in the analysis.

II.2 Demand separability between fish and meat

Testing weak separability[1] using the log likelihood test (LR) found that fish products and meat products for Canadian households could be estimated together in a demand system since weak separability was rejected (Salvanes & DeVoretz, 1997). For the purposes of this paper the model's likelihood tests will be applied to the fish type and will not differentiate between fresh or processed as was the case in Salvanes & DeVoretz (1997). Salvanes & DeVoretz (1997) found that that when the fish products were aggregated then the likelihood tests favoured weak separability. It seems logical that fish and meat products are not weakly separable and can be grouped together in a demand system.

The use of separability tests in demand modelling with regards to meat and fish is not always used as in the case of Mangen et al (2001) which studied Dutch demand for meat and fish from 1994-1998. While structural change is considered when explaining the possible variables behind demand for these food products, there is no mention of separability tests. Yet the paper does make reference to grouping products by animal type (Mangen et al., 2001). The justification is given in the conclusion that health concerns may be a reason behind the increased demand for white meat and fish (Mangen et al., 2001). Therefore, this provides further reasoning to include fish and meat products in a demand system study. Eales et al (1999) study on Japanese demand for fish and meats found that prior to 1990 fish and

[1] Is essentially whereby a vector of goods can be divided into smaller groups (which are not substitutes), dependent on consumer preference ordering (Deaton & Muellbauer, 1980b)

meats were separable. This is an interesting result since post 1990, meat and fish products in an Asian country where fish has long dominated diets is not found to be weakly separable.

II.3 Consumption taxes

The concept of taxing food products is practised in the UK with VAT being applied to a few food products such as smoothies and biscuits (HMRC, 2013). With regards to Denmark all food products are taxed at 25% rate of VAT and for a brief time, the fat tax in the country was charged in addition to VAT (Jensen and Smed, 2013). The main concern regarding consumption taxes are the possible regressive effects on low income groups which spend a greater share of their income on food products relative to wealthier groups (Mytton et al, 2012). Yet, Mytton et al (2012) suggest that the health implications could be potentially progressive if public health is improved.

The Danish fat tax is an interesting example of a government wishing to restrict the demand of a good that it considers harmful in excess quantities. The tax was present in Denmark from October 2011 until January 2013, and research suggests that the tax reduced purchasing of foods products (Toft et al, 2014). Jensen and Smed (2013)'s early research suggests that for data covering a period from January 2008 until July 2012, consumption for high fat food products reduced 10-15% relative to the time period before the introduction of the tax. This suggests that the tax may have been quite successful in changing consumer behaviour.

The idea of applying a consumption tax to foods associated with high carbon footprints (studying all the major food groups) have been modelled for Denmark by Edjabou and Smed (2013) and for the UK by Briggs et al (2013). However, there have been no such studies for Scotland and more pertinently no government has yet applied such a tax. Edjabou and Smed (2013) found that after taking into account the existing VAT, that GHG emissions associated with food consumption (i.e. carbon footprint) could be reduced by 2.3 – 8.8%. This is similar to Briggs et al (2013) non subsidy scenario of a 7.5% decrease. Recent climate change modelling suggests that reduced consumption of meat products will be very important for maintaining a 2 C average temperature target. For this reason, meat is included in the paper's modelling.

III. Data

The carbon footprint data is obtained from a life cycle analysis which (represented per kilogram) is shown in table 1. The reason that minced beef and beef is included is to try and give an idea of how individual cuts can distort the overall footprint value. Minced beef which was provided by the Cooperative group and follows PAS 2050 (Lewis, 2013) will not be used as mince is not the only "cut" available from the animal.

Table 1 Meat and Fish carbon footprints

Fish	Carbon Footprint (kg CO_2e Kg)	Source
Salmon	8.33	The Co-operative Group (2012)
Haddock	5.60	The Co-operative Group (2012)
Beef (minced)	22.47	The Co-operative Group (2012)
Beef	12.65	Houses of Parliament (2013)
Chicken	2.90	Defra (2010)
Pork	3.58	Aarhus university (2014)
NZ Lamb	19.00	Ledgard et al (2011)

As carbon footprint data which exists on PAS 2050 meat is fairly limited, finding a value for pork was challenging. With regards to pork, this meat is mainly exported from both Denmark and the Netherlands (Committee on Climate Change, 2013). Hence the need to account for Denmark's PAS 2050 carbon footprint value. A Danish PAS 2050 study found that including transportation of pork products by chilled container (in ships for distances of 21,000 km) would provide a carbon footprint of 3.58 kg CO2e (Aarhus University, 2014). The only UK comprehensive food LCA study is Audsley et al (2009) whereby the pork value is 4.45 kg CO2e. All the other products are either PAS 2050 cradle to grave compliant or use similar methodologies as PAS 2050 hence the issue that pork may have a slightly unrepresentative carbon footprint since it does not take account of the post regional distribution centre.

New Zealand lamb has been chosen as a representative carbon footprint of lamb as data could not be found regarding purchasing of NZ lamb in Scotland. NZ lamb has a lower carbon footprint relative to British lamb (Webb et al, 2013). Therefore, this may underestimate the true damage in terms of GHG emissions associated with consumption of lamb and sheep products.

With regards to salmon it can be seen from table 1, that the carbon footprint is greater relative to chicken. This is despite the carbon footprint for salmon being based on farmed fish and not line caught salmon. The main hotspot identified with farmed salmon is the production of feed (The Co-operative Group, 2012). This is also highlighted for line caught Norwegian salmon whereby marine based feed is what creates a higher carbon footprint relative to chicken and if salmon were fed on a “vegetarian diet” then it is likely that the carbon footprint would be lower as salmon has a greater feed conversions ratio relative to chicken (Ellingsen et al., 2006).

Audsley et al (2009) paper provided data on pre regional distribution centre emissions (RDC) for Scotland. While the authors acknowledge there are uncertainties with this data, it does allow for an approximate idea of the total emissions of fish and meat products. Whilst most of the obtained carbon footprints include the post emissions stages (i.e. such as processing) it would have given a more realistic impression if post RDC data were available. However, this data could not be obtained.

Table 2 shows that the meat products of beef, chicken and pork are purchased the most relative to the other meat and fish products. Turkey meat products have not been included in this analysis due to the expenditure share of the product being relatively high only around December (i.e. Christmas time). The Kantar data was adjusted to include unit prices (which include discounts by the retailer) and a weighting variable (provided by Kantar) was used due to the variation in populations in Scotland. The data has also been adjusted using the Scottish population to create per capita data which is important for the demand model.

Table 2 Population sample data

Product	Number of purchasing households
Haddock	992
Salmon	2,356
Beef	3,938
Chicken	4,102
Pork	4,176
Sheep	2,930

Source: Own elaboration based on Kantar Worldpanel data

The cost (sometimes referred to as price) of carbon emissions is required in order to calculate the carbon consumption tax rate. The shadow price cost (SPC) differs from just the social cost which only considers the damage caused, whilst the SPC can take into account the marginal abatement costs of a particular climate stabilisation range (Defra, 2007). The SPC for 2011 can be calculated by applying HM Treasury's inflating figures[2] which this paper found would be £27.33 t/CO_2e for 2011. However, it must be emphasized that this figure could change in the future based on evidence from climate change science.

The most recent nutritional data for the UK is the "National Diet and Nutrition Survey" (NDNS) which used data obtained in 2000-01 to calculate dietary behaviour of adults (aged 19-64) living in the UK (Office of National Statistics, 2005). This data were useful as it allowed for an idea of the nutritional value (share of vitamin D) which the different fish and meat products provided. Each food category within the dataset provided by the UK Data Service[3] was matched with the fish or meat groups of table 2. For the meat group only meats were selected which did not contain sauces or other condiments in order for each meat products to be aggregated into the corresponding meat category which allows for matching with the Kantar data. Offal products have been excluded as few observations were found with the kantar dataset and offal products contain different nutrients[4] relative to cuts of meat from the same animal type.

Data on Scottish household intake of vitamin D is available from either the Food Standards Agency (2014a) Scottish National Diet and Nutrition Survey or from Defra (2014)'s Family Food report. The Scottish National Diet and Nutrition Survey data covers the year 2008-2012 from a sample of Scottish households (Food Standards Agency, 2014b). This dataset allows for an understanding of the average daily intake of vitamin D across the households and contains the very useful data regarding the contribution of fish and meat to overall mean daily vitamin D intake. However, this data is represented by the mean vitamin D per person of different demographic groups (age and sex). This could be problematic since the Kantar data cannot be broken down by age hence the reason that Defra (2014)'s Family Food report is used for obtaining the 2011 average vitamin D intake per person. This data is then adjusted to account for just fish and meat vitamin D intake using the Scottish National Diet and Nutrition Survey.

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[2] Figures can be found from HM Treasury (2013)
[3] UK Data Services provided data for this survey
[4] According to the National Diet and Nutrition Survey data

IV. Methods

The likelihood ratio test for separability will be used with the unrestricted model excluding fish products. The null hypothesis of meat products and their respective shift variables (dummies and time trend) is equal to zero, with the alternative hypothesis not equal to zero:

$$\boldsymbol{H_0}: \boldsymbol{x_{meat}} = \mathbf{0}, \qquad \boldsymbol{H_{01}}: \boldsymbol{x_{meat}} \neq \mathbf{0}$$

$$\boldsymbol{x_{meat}} = \begin{bmatrix} \boldsymbol{Beef} \\ \boldsymbol{Chicken} \\ \boldsymbol{Pork} \\ \boldsymbol{Sheep} \\ \boldsymbol{Dummies} \\ \boldsymbol{Time\ trend} \end{bmatrix}$$

Should the test fail to reject the null hypothesis then it is likely that separability is present between meat and fish products. The assumption of weak separability is in order to understand if meat and fish products can be included in the same conditional demand system.

The static linear An Almost ideal demand system (LA-AIDS) originally developed by (Deaton & Muellbauer, 1980a) is shown in equation 1 has been calculated by seemingly unrelated regressions (SUR) using R package "erer" (Sun, 2014). The SUR method which was first proposed by Zellner (1962) allows for the disturbance terms of different equations to be correlated which is important since in demand modelling aggregated household data are likely to have this situation occurring in contrast to data on individual households. The other advantage over Ordinary Least Squares (OLS) is that many different regressions can be run within the SUR (Zellner, 1962), which for demand modelling is useful since the LA-AIDS runs many different equations. The LA-AIDS will model conditional demand for fish and meat products.

$$\boldsymbol{w_{it}} = \boldsymbol{\alpha_i} + \boldsymbol{\beta_i} \ln\left(\frac{\boldsymbol{m_t}}{\boldsymbol{P_t}}\right) + \sum_{j=1}^{N} \boldsymbol{\gamma_{ij}} \ln \boldsymbol{p_{jt}} + \sum_{k=1}^{K} \boldsymbol{D_{kt}} \boldsymbol{T} + \boldsymbol{u_{it}} \qquad (1)$$

w= budget shares, m = expenditure, Pt = price index, γ = relative prices and D = seasonal dummy variables. Subscripts: i and j= products and T = time trend. It should be highlighted that the demand shifter variables consist of the seasonal dummies and the time trend.

In order for the LA-AIDS model to produce plausible results it must meet the four restrictions of demand theory (Deaton & Muellbauer, 1980b):

Adding up $\quad \sum_k a_k = 1, \sum_k \beta_k = 0, \sum_k \gamma_{kj} = 0$

Homogeneity $\sum_k \gamma_{jk} = 0$

Symmetry $\gamma_{ij} = \gamma_{ji}$

Negativity[5] $c_{ij} = \gamma_{ij} + \beta_i \beta_j \log\left(\frac{x}{p}\right) - w_i \delta_{ij} + w_i w_j$

The calculation of the tax rates were based on similar methods as Edjabou and Smed (2013) which is show in equation 2. In the equation the change in price ($\Delta \boldsymbol{p_{ik}}$) which is essentially the tax is equal to the carbon footprint of the product ($\boldsymbol{k_i}$) multiplied by the carbon price. Subscript i represents food group while subscript k was used by Edjabou and Smed (2013) to highlight the two scenarios, 1 where the price of carbon (referred to as cost) was obtained from the Stern review and other obtained from a peer reviewed paper by Tol (2005). This paper uses average prices for each fish and meat category using the most complete year of 2011.

$$\Delta \mathbf{p_{ik}} = \mathbf{k_i} \text{ x } \mathbf{p_k} \quad (2)$$

This paper will have two scenarios: scenario 1 where the carbon consumption tax is only applied to meat products and scenario 2 whereby the tax is applied to both fish and meat products. Therefore, a carbon consumption tax will be calculated for both fish and meat products.

The calculations behind both the nutrient and carbon footprint elasticities have been obtained by using Huang (1996)'s methods seen in equation 3. S represents the share of either nutrients or carbon emissions within the product of interest. D represents the matrix of demand elasticities.

$$\mathbf{N} = \mathbf{S} \text{ x } \mathbf{D} \quad (3)$$

Huang (1996)'s paper used a complete demand system which covered all the main food groups. However, the paper only gives the nutrient elasticities and does not apply them to a total intake of nutrients for the population. Calculating the subsequent nutrient changes in international units would have been useful for policy makers. This highlights the importance of understanding what the carbon/nutrient share of the products of interest are for a conditional demand system.

[5] This matrix C must be negative semidefinite for the restriction of negativity to apply (Deaton et al., 1980b).

V. Results and Discussion

Table 3 displays the results for the likelihood ratio test for separability. The likelihood ratio test of the restricted model whereby only meat products and their associated shift variables have been included (with the exclusion of fish products). The null hypothesis of the restricted model has been rejected, thus, it seems likely that fish and meat are not separable in the demand system. This finding is similar to Eales et al (1999)'s post 1990 result for fish and meat not being separable. Mangen et al (2001) point regarding health concerns possibly shifting consumer attention to fish and white meats may be a potential reason behind the lack of separability found.

Table 3 Likelihood ratio test

		Degree of Freedom	LogLik	Df	Chisq	Pr(>Chisq)
Model 1	Meat restricted	114	1468.7			
Model 2	Unrestricted	115	1478.4	1	19.315	0.00001109

Notes:
LogLik represents the Log Likelihood
Df represents the degree of freedom
Chisq represents the Chi squared distribution
Source: Own elaboration based on data obtained from Kantar Worldpanel

The tax rates (shown in table 4) calculated based on equation 2 from the methods used the shadow price cost (SPC) and carbon footprints of the different fish and meat products. The highest taxes are applied to sheep and beef products which comes as little surprise as these have the highest carbon footprints within the group. Salmon attracts the third highest tax rate. The first scenario will not include the tax rates for either haddock or salmon.

Table 4 Tax rate

Product	Tax rate %
Haddock	15.3
Salmon	22.8
Beef	34.6
Chicken	7.9
Pork	9.8
Sheep	51.9

Source: Own elaborations

The elasticity results can be found in the appendix (tables 8 – 10) and table 5 displays the various diagnostic test results. Using the P-value from table 5, all equations except for chicken fail to reject their null hypothesises for the Breusch-Godfrey and it can be concluded that it is unlikely that autocorrelation or poor fit is causing bias in the elasticity results except for the chicken equation. The Breusch-Pagan (BP) test highlights no potential problem with heteroskedasticity. In order to avoid the singular covariance matrix problem the sheep equation is excluded.

A log likelihood test favoured the restriction of homogeneity and symmetry[6]. Tables 9 and 10 in the appendix demonstrate the likelihood that the negativity condition has been met.

Table 5 Diagnostic tests

Equation	Breusch-Godfrey (BG) test		Breusch-Pagan (BP) test		Ramsey's Regression Specification Error test (RESET)		Jarque-Bera (JB) test	
	Statistic	P-value	Statistic	P-value	Statistic	P-value	Statistic	P-value
Haddock	0.672	0.41	24.268	0.19	0.084	0.92	2.251	0.32
Salmon	0.08	0.77	20.11	0.39	0.734	0.48	2.05	0.36
Beef	1.77	0.18	19.77	0.41	0.593	0.56	1.155	0.56
Chicken	4.52	0.03	23.45	0.22	0.041	0.96	5.235	0.07
Pork	1.15	0.28	26.18	0.13	0.67	0.52	0.803	0.67

Note:
Results are returned from R package "Erer"

The second column of table 6 shows the carbon elasticity which is positive for only chicken and sheep. This is due to both products having substitutes which were high carbon footprints hence the positive elasticity. The total emission value used to calculate the implied reduction is for Scotland only Scenario 2 reduces household carbon footprints by the larger quantity of 224,592.98 t/CO_2e/y. This corresponds to 0.42% of the Scottish government's 2011 targeted reduction level of 53,404 kt CO_2e (Scottish Government, 2012b). This is in contrast to Scenario 1's reduction in carbon footprint which represents 0.09% of the Scottish government's 2011 reduction target levels. Though, it is worth emphasising that the emissions associated with food

[6] Results have not been included owing to space constraints, results are available from the author

products (i.e. carbon footprints) will take into account emissions from other countries which suggests that comparing the decline in household carbon footprints with government targets is not very useful.

Table 6 Carbon footprint elasticity results

Products	Carbon elasticity	1% Price increase Implied reduction t/CO_2e/y **1/**	Scenario 1 Implied reduction t/CO_2e/y **1/**	Scenario 2 Implied reduction t/CO_2e/y **1/**
Haddock	-0.112	- 2,935.40	0.00	- 44,924.09
Salmon	-0.223	- 5,855.98	0.00	- 133,364.87
Beef	-0.029	- 766.64	- 26,503.76	- 26,503.76
Chicken	0.043	1,129.65	8,952.94	8,952.94
Pork	-0.064	- 1,688.73	- 16,522.11	- 16,522.11
Sheep	-0.009	- 235.55	- 12,231.09	- 12,231.09
	Total	-10,352.65	- 46,304.02	- 224,592.98

Notes:
1/ Value is positive
Source: Own elaboration based on Kantar Worldpanel data

While Scenario 2 may be the most effective scenario for reducing household carbon footprints it seems that from table 7 it would reduce vitamin D intake to households. However, applying a tax to just meat products as in Scenario 1 would have the benefit of increasing average vitamin D intake for Scottish households. The average daily intake of vitamin D per person would likely increase by 0.076 µg which represents approximately 3.81% of the recommended daily intake, therefore, this scenario is superior to scenario 2. Different age groups and pregnant mothers require different levels of vitamin D intake. However, for the reasons discussed in the data section with regards to the difficulty of matching age with Kantar data, it seems that this is a limitation. Therefore this paper will draw the conclusion that any tax scenario which leads to a reduction in daily intake for a population which is unable to obtain vitamin D from the sun in winter is likely to be problematic from a health perspective.

Table 7 Vitamin D nutrient elasticity results

Products	Nutrient elasticity	1% Price increase Implied reduction µg/Vitamin D/day /person **1/**	Scenario 1 Implied reduction µg/Vitamin D/day /person **1/**	Scenario 2 Implied Reduction µg/Vitamin D/day /person **1/**
Haddock	0.00	0.000	0.000	0.000
Salmon	-1.10	-0.011	0.000	-0.257
Beef	-0.02	-0.000	-0.006	-0.006
Chicken	1.11	0.011	0.090	0.090
Pork	-0.06	-0.001	-0.006	-0.006
Sheep	-0.00	-0.000	-0.003	-0.003
	Total	-0.001	0.076	-0.181

Notes:
Source: Own elaboration based on Kantar Worldpanel data

While the focus of this paper is on the effects of carbon consumption taxes on vitamin D intake, it is worth looking into likely fat intake. This paper found that the fish and meat groups contributed to 21% of average Scottish household fat consumption (Food Standards Agency, 2014a). There were variations for different demographic groups as was the case for vitamin D. Table 8 shows that either scenario is likely to result in a decrease in nutrient intake of approximately one gram of fat for scenario 1 and 2.07 grams for scenario 2. This decrease in fat intake may from a public health perspective have a positive effect on households.

Table 8 Fat nutrient elasticity results

Products	Nutrient elasticity	1% Price Change Implied reduction g/Fat/day /person **1/**	Scenario 1 Implied reduction g/Fat/day /person **1/**	Scenario 2 Implied reduction g/Fat/day /person **1/**
Haddock	-0.02	-0.003	0.000	-0.047
Salmon	-0.23	-0.045	0.000	-1.020
Beef	-0.08	-0.015	-0.516	-0.516
Chicken	0.05	0.009	0.073	0.073
Pork	-0.17	-0.033	-0.323	-0.323
Sheep	-0.02	-0.005	-0.238	-0.238
	Total	-0.091	-1.004	-2.071

Notes:
Source: Own elaboration based on Kantar Worldpanel data

VI. Conclusions

The purpose of this paper was to understand the potential effect of carbon consumption taxes on fish and meat products on Scottish household carbon footprints and vitamin D intake. The demand analysis provided evidence to suggest that fish and meat products are not weakly separable for Scottish household demand.

With regards to taxation, it was found that there is a likely conflict between taxing both fish and meat products, due to the likely outcome of a decline in vitamin D intake. With the issue of sustainability in terms of both the natural environment and human health it seems a policy which potentially jeopardises human health is not one which policy makers should take.

Scenario 1 offers the pragmatic approach whereby only meat products are taxed and not fish products which would likely reduce Scottish household carbon footprints by 46,304.02 t/CO_2e/y. While simultaneously increasing the average daily intake of vitamin D per person by 0.076 µg. A limitation of this paper is the inability to match the Kantar data with the different demographic age groups. However, it should be seen as encouraging from a public health perspective that there is a likely decrease in fat intake and the increase in average vitamin D intake (created through meat carbon consumption taxes) represents approximately 3.81% of the recommended government daily intake.

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Appendix

Table 8 Expenditure elasticities

Products	Estimate	
Haddock	0.866	
Salmon	0.594	**
Beef	0.790	***
Chicken	1.124	***
Pork	1.191	***
Sheep	0.25	

Notes:
1/ Statistical significance: '*'=10%, '**'=5% or '***'=1%

Source: Own elaboration based on Kantar Worldpanel data

Table 9 Marshallian price elasticities of demand

	Haddock		Salmon		Beef		Chicken		Pork		Sheep	
Haddock	-1.04	*	-1.15		-0.64		2.07		-0.62		0.52	
Salmon	-0.14		-1.44	***	-0.12		1.54	***	-0.58		0.16	
Beef	-0.01		-0.03		-0.09		-0.69	***	-0.03		0.06	
Chicken	0.03		0.14	**	-0.52	***	-0.63	***	0.02		-0.16	*
Pork	-0.01		-0.09		-0.12		-0.01		-0.94	***	-0.03	
Sheep	0.05		0.12		0.38		-0.75		0.10		-0.15	

Notes:
1/ Statistical significance: '*'=10%, '**'=5% or '***'=1%
Source: Own elaboration based on Kantar Worldpanel data

Table 10 Hicksian price elasticities of demand

	Haddock		Salmon		Beef		Chicken		Pork		Sheep
Haddock	-1.04	*	-1.12		-0.44		2.379	*	-0.35		0.56
Salmon	-0.14		-1.42	***	0.01		1.749	***	-0.40		0.19
Beef	-0.01		0.00		0.10		-0.411	*	0.22		0.10
Chicken	0.03	*	0.19	***	-0.27	*	-0.225		0.37	***	-0.10
Pork	-0.01		-0.05		0.16		0.42	***	-0.56	*	0.03
Sheep	0.05		0.13		0.43		-0.66		0.18		-0.14

Notes:
1/ Statistical significance: '*'=10%, '**'=5% or '***'=1%
Source: Own elaboration based on Kantar Worldpanel data