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Socioeconomic effects of reducing household carbon footprints through meat consumption taxes

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Socioeconomic effects of reducing household carbon footprints through meat consumption taxes

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Abstract

Beef and sheep products represent the largest emitters of greenhouse gases within the meat group. One way of encouraging Scottish households to substitute into purchasing lower carbon footprint meat products such as chicken is through a carbon consumption tax. In this paper, the effects of such a tax were studied using a dynamic per capita error correction version of the almost ideal demand system (AIDS). The data used in the analysis were from a Scottish household panel dataset for the years 2006-2011, which allowed disaggregation by three socioeconomic groups. The results suggest that the net application of meat taxes is likely to reduce demand for beef and sheep products irrespective of socioeconomic group. Application of all meat carbon consumption taxes has the potential to reduce household demand for meat products, resulting in a likely 10.5% reduction in Scottish meat emissions.

Keywords: Consumer behaviour, Demand system, Carbon footprint, Meat products, Scotland

1. Introduction

Meat products are the largest emitters of greenhouse gases (GHG) within the food chain and are responsible for 34.5% (cradle to distribution centre) of Scottish food chain emissions (CO_2e) (Audsley et al., 2009). However the carbon footprint of the different meat groups does differ with chicken and turkey having lower carbon footprints relative to beef and sheep which have the highest meat carbon footprints.

The supply side of the food chain has been studied with emphasis on how GHGs can be reduced through farming techniques such as carbon sequestration, yet there appears to be little work considering the demand side i.e. looking at demand for low carbon foods (Garnett, 2011).

If households can substitute chicken in place of beef or sheep then this could result in a decrease in household carbon footprints. The resulting likely substitution effect or overall reduced demand for meat products could be achieved through increasing retail prices using a carbon consumption tax. A carbon consumption tax has the potential to help meet the targets of the Climate Change Act (Scotland) 2009 (Scottish Government, 2009).

The purpose of this paper is to examine how a carbon consumption tax could change demand for meat products with respect to different social household groups. The resulting change in both Scottish household carbon footprint and subsequent emissions within the Scottish meat chain will also be examined. The structure of this paper is as follows: The literature review defines why meat is a high carbon footprint food and explains the basis of the carbon consumption tax. The next two sections explain the data and empirical model used in order to analyse the impact of a tax on household demand and carbon footprint. The final three sections will provide an analysis on the results in addition to the conclusions.

2. Literature review

Carbon footprints are expressed as a Carbon dioxide equivalent (CO_2e) which uses a Global Warming Potential (GWP) factor to take into account the strength of other GHGs relative to CO_2 (British Standards Institution, 2011). Meat products are categorised as having“very high” carbon content relative to “British/EU field crops” (British Standards Institution, 2011). However one of the reasons behind the difference of carbon footprint within the meat group is the level of feed conversion efficiency. A high level of feed conversion efficiency present in poultry equates to less input (i.e. feed) being required to produce more human edible output which is in contrast to lower feed efficiency and higher methane producing ruminant animals (Garnett, 2010).

A benefit of a carbon consumption tax is that it has lower monitoring costs relative to production level taxes (Wirsenius et al., 2011). In addition to this a production level tax may result in domestic producers being at a competitive disadvantage relative to foreign producers who would not be required to pay such a tax (Edjabou & Smed, 2013).

This paper should mention that consumer behaviour could be influenced through other factors such as education. Analysing the effects of education with regards to low carbon food products is beyond the scope of this study and it seems that price is still an important determinant of demand.

On a British scale qualitative research suggested that most consumers (within a sample) view price as being more important relative to carbon footprint as a determinant for purchasing food products (Upham et al., 2011). This is further supported by Scottish Government research (sourced from Kantar Worldpanel) which highlighted that for 2010 only 20.8% of Scottish consumers "try to buy environmentally friendly products" versus the UK figure of 21.4% (Scottish Government, 2012b). Therefore if consumers are unwilling to purchase lower carbon food products then government intervention through a pricing policy would appear an attractive option.

There has been some concern raised regarding the effectiveness of government pricing policies such as tax for reducing consumption of particular goods. Tiffin et al (2014) make reference to the idea that the "full burden" of a tax may not always fall entirely on the consumer due to pricing policies of the retailer. This creates a limitation for modelling carbon consumption taxes.

Sall and Gren (2012) emphasised the range of Stern's GHGs damage costs from \$0 - \$400 per ton which roughly translates (using Cederberg et al (2009) data) into "0 to 2.8 SEK per kilo CO_{2e}" (Sall & Gren, 2012). Sall and Gren (2012) opted for Swedish data (on revealed costs of CO_{2e}) due to their concern over the uncertainty of which value to use. A peer reviewed literature review finds that out of twenty eight studies the most likely marginal damage of CO_{2e} is \$50/tC (Tol, 2005). Tol (2005) selects this value based on taking into account discount rates of between 3-4% (Tol, 2005).

In order to get the ultimate level of tax for each product the authors use Equation 1 (Sall & Gren, 2012).

(1)

Where i represents emissions and j represents meat products (Sall & Gren, 2012). In (1) emission of products (e_{ij}) is multiplied by marginal damage cost (MD_i) (Sall & Gren, 2012). The tax rate calculated from (1) is then applied to the price elasticities of the different meat products which allows for the change of meat substitute products to be monitored (Sall & Gren, 2012). The differentiated tax applied to beef products is interesting as it would only decrease demand for beef by 11.1% (Sall & Gren, 2012). Taxing all the meat products simultaneously using their respective differentiated tax would reduce greenhouse gas emissions (from Swedish meat production) by approximately 27% (Sall & Gren, 2012).

The approach taken by Edjabou and Smed (2013) for calculating carbon taxes appears to differ slightly relative to Sall and Gren (2012) mainly due to: the number of products used, sources of price elasticities and marginal damage cost selection. It would appear that neither of these two papers takes into account the different socioeconomic groups when studying the potential impact of carbon consumption taxes on demand. Edjabou and Smed (2013)'s study appears to be the only peer reviewed paper which covers all the major food groups using unconditional elasticities. The paper uses price and income elasticities which are mainly sourced from a previous study written by one of the authors whereby monthly data were used for the period 1997 – 2000 and is calculated using an almost ideal demand system (AIDS) (Smed et al., 2007; Edjabou & Smed, 2013). The authors have used updated prices for the year 2007 which were sourced from GfK Consumer scan Scandinavia (Edjabou & Smed, 2013).

The carbon dioxide equivalent (i.e. carbon footprint) data used in Edjabou and Smed (2013) paper were sourced from a Danish life cycle analysis. Two scenarios were estimated using Tol (2005)'s social cost of carbon (Scenario A) and Scenario B uses Stern's social cost data. Each scenario is split into two further sub scenarios: One whereby a tax is placed on food products relevant to the agricultural damage (Scenario 1) and the other which takes account of the existing Danish value added tax (VAT) on food products and adjusts the rate according to the carbon consumption tax (Scenario 2) (Edjabou & Smed, 2013). With regards to Scotland most food products do not have any VAT applied (HMRC, 2013) which means that uncompensated scenarios (Scenario 1) may be more applicable to the country. The uncompensated scenario tax rate was calculated through the aid of equation (2) whereby k_i is the carbon footprint i.e. CO_{2e} which is multiplied by social cost (p_k) of CO_{2e} (Edjabou & Smed, 2013).

(2)

Where i represents food group and k represents the price from the scenario (Edjabou & Smed, 2013). The results from the study found that Scenario 1 B would have the largest effect of reducing carbon footprint by 149-277 Kg CO_{2e} per person (Edjabou & Smed, 2013).

3. Data

This paper uses Audsley et al (2009) carbon footprint data which is cradle to regional distribution centre. A personal communication with the Carbon Trust[1] revealed that the organisation is unable to locate publicly available standard (PAS) 2050 studies for a variety of meat products. A PAS 2050 cradle to grave life cycle analysis (LCA) would have allowed a more representative account on the impact of meat consumption upon the environment in terms of GHG emissions. However, since methane emissions are included in the cradle to distribution chain which (especially ruminant) are a major contributor of GHG (González et al., 2011). Therefore the most environmentally damaging stage has been captured in the LCA carbon footprint data used in this paper.

Carbon footprints from British produced meat were used as there was little difference in carbon footprint values for other European countries (Audsley et al., 2009). The majority of meat products consumed in the UK are also produced in the UK (83%) or imported from other EU countries (7%) (Defra, 2014). Therefore the carbon footprints used in this paper are likely to reflect a realistic situation for the Scottish food chain[2]. Table 1 shows the difference between the carbon footprints of the different meat categories with ruminant animals having a higher carbon footprint relative to poultry.

Data regarding household purchases of organic meat products could not be found which are expected to have a different carbon footprint relative to non organic products. Organic pig and sheep meat both have lower carbon footprints relative to their respective non organic meats (Williams et al., 2006). However, organic ruminant products such as beef tend to have a higher carbon footprint since they are produced more extensively (Garnett, 2010).

[1] Warnatzsch, (2013)
[2] Audsley et al., (2009) calculated the meat emissions of the Scottish food chain using their overall British data

Table 1. Carbon footprints (Kg CO2e/Kg)

Kantar Worldpanel household panel data used in this study consists of Scottish household purchases for consumption at home for the years 2006 – 2011 for five meat products: beef, chicken, pork, turkey and sheep meat. These meat products can be disaggregated into the different cuts of meat, however as the life cycle analysis (LCA) data is on an aggregation of the cuts, the Kantar data has been modified to match the LCA categories. Each year of data is composed of thirteen periods which is preferable to using calendar months of data when analysing many years.

Only Households observed in the data, making purchases of meat products over a period of 40 weeks or more within a year were included in the study. This censoring of data was felt necessary in order to exclude households where meat did not feature dominantly within the weekly purchases.

A Kantar weighting factor has been used to account for the variation in population differences across Scotland. The unit prices used take into account the volume purchased and any discounts applied by the retailer. The Kantar data were also adjusted using the Scottish population[3] in order for per capita data to be formed.

The data were split into three socioeconomic categories (social groups) in order to allow for a proxy of household income. The social groups are based on information provided by the chief income earner or respondent such as employment status, tenure, qualification and working status (Meier & Moy, 2004). The census data obtained from National Records of Scotland (2013) make it plausible that the following three groups can be formed: Medium to high income earners (A, B & C1), Lower income earners (C2 &D) and non active in the labour market along with casually employed workers (E) (Ipsos-Mori, 2009). The total Kantar sample population was 2,118 household and Table 2 provides a breakdown of the sample population.

Table 2. Population sample data

From Figures 1, 2 and 3 it can be seen that with regards to chicken products there has been a recent increase in the expenditure budget shares amongst the medium to high income earners and non active in the labour market (in addition to casually employed workers) groups.

[3] As no households from Shetland have been included in Kantar dataset, the Scottish population excluded the population of Shetland.

However Figure 2 implies the opposite for the lower income earners. For higher and lower income groups, beef expenditure budget shares appear to be stable over time.

There appears to be a strong seasonal pattern for turkey meat products around period 13 which corresponds to Christmas. From Figure 1, 2 and to a lesser extent Figure 3 it is clear that seasonality is a likely problem particularly for turkey products whereby household expenditure shares increases. Twelve seasonal dummies were used for all meat categories in order to reduce the potential problem of biased results.

Figure 1. Social groups A, B & C1 (higher income) - Evolution of meat expenditure shares for years 2006-2011

Figure 2. Social grade C2 & D (lower income) - Evolution of meat expenditure shares for years 2006-2011

Figure 3. Social grade E (lowest income) - Evolution of meat expenditure shares for years 2006-2011

4. Methods

As this paper is using time series data, an error correction version (dynamic) of an almost ideal demand system has been used in order to allow the calculation of the short run price and expenditure elasticities.

While the original an almost ideal demand system (AIDS) developed by Deaton and Muellbauer (1980a) has been widely used in demand analysis it seems plausible that the statistical problems which can arise through the use of time series data require a model which can account for such problems as autocorrelation. The error correction AIDS has been used by various authors: (Karagiannis et al., 2000; Klonaris & Hallam, 2003; Nzuma & Sarker, 2010; Wan et al., 2010).

This paper has used the R-package “Erer” from Sun (2012) and Sun (2014) which was used in the paper by Wan et al (2010). The package also calculates a static AIDS model which closely resembles Deaton and Muellbauer (1980a). Wan et al (2010) acknowledge that the static model represents the “long run” elasticities. A further advantage of using package “Erer” is the provision of various diagnostic tests such as the Breusch-Godfrey test (Edgerton et al., 1996).

Equation 3 represents the dynamic error correction version of the AIDS model and has been adapted from Wan et al., (2010). In order to emphasise that the model is at per capita level, h subscripts have been used. The speed of short run adjustment (λ) is calculated from the error residuals of the static AIDS model. The consumer habit coefficient (Ψ) is the dependent variable of meat expenditure share lagged by one period. Expenditure is represented by m whilst the stone price index is represented by P_t^* with real expenditure being derived from division of the two parameters. ϒ represents relative prices and D_k incorporates the 12 seasonal dummy variables.

(3)

Where Δ = first difference, Ψ = consumer habit coefficient, w_{iht}= the budget share of meat product i at household per capita level (h) with the inclusion of time (t) and j = other meat products. The Marshallian elasticities are used for calculating the carbon consumption tax as they include the full effects of prices (i.e., substitution and income effects) (Deaton & Muellbauer, 1980b). A possible weakness of the results is the fact that the elasticities are conditional, i.e., they assume an allocated budget for meat whereby consumers often make multistage decisions on how to allocate their expenditure to the different food groups. Therefore a change in expenditure on the meat group could also affect expenditure allocated to other food groups (Edgerton, 1997). The Hicksian price elasticities allow for an understanding of the different substitution relationships between the different meat products being investigated.

The dynamic error correction version of the AIDS model must still meet the four restrictions of demand theory in equation 4 originally imposed on the static AIDS model in order to produce plausible results[4] (Deaton & Muellbauer, 1980b):

(4)

In order to understand how a change in price affects the household carbon footprint, the nutrient elasticity method used by Huang (1996) has been adapted for the inclusion of carbon footprints. The most recent application of the nutrient elasticity using meat data on Scottish households is by Tiffin et al (2011). The original method proposed that the nutrient matrix (N) is calculated through multiplying the food share of each nutrient (S) by the demand price elasticities (D) as shown in Equation 5 (Huang, 1996).

[4] These restrictions are imposed during estimation.

(5)

This method is altered whereby carbon matrix (N) replaces the nutrient matrix to form the carbon elasticity. The food share of each nutrient is replaced with the carbon dioxide equivalent (carbon footprints) of the different meat groups (S). Data from Audsley et al., (2009) allowed for these shares to be calculated. The matrix of demand price elasticities (Marshallian) are calculated from the AIDS model and the overall calculation is still represented as Equation 5.

The calculation of the tax rates were based on Equation 2 which was sourced from Edjabou and Smed (2013) whereby the average prices for each meat category were from the most recent complete year (2011) were obtained and calculated by the marginal damage cost which was obtained from Tol (2005)[5]. The 2011 prices obtained from the Kantar panel data did not account for social grade as there is a risk that supermarket practices such as price discrimination could result in meat prices differing depending on variables such as location of retailer in prosperous or deprived areas. The tax rate can then be multiplied by the carbon elasticity in order to understand how effective a carbon consumption tax would be for changing Scottish household carbon footprints. Approximations of The National Records of Scotland (2013) census group shares for 2011 were used for factoring in the change in household carbon footprint as a result of the taxes.

5. Results and Discussion

The results from the Phillips-Perron unit root test[6] suggest that all the share and price series do not contain unit roots in the first difference form (except for in level form where the Augmented Dickey Fuller test suggested that most series did contain unit roots). The cointegration (Phillips-Ouliaris cointegration results) results suggest that the expenditure shares are cointegrated with their respective independent variables (prices and expenditure). Therefore the error correction version of the dynamic almost ideal demand system can be run using this study's data. Table 3 displays the tax rates which are applied to the different meat categories. The tax rate incorporates the carbon footprint and the marginal damage cost of the meat

[5] The price index used was obtained from House of Commons (2012) in order to adjust 2005 prices

[6] Due to space constraints the Phillips-Perron, Phillips-Ouliaris and Augmented Dickey Fuller tests have not been included in this paper. These results are available from the author on request.

categories. Thus the highest emitters attract a higher tax rate as in the case of beef and sheep. It is important to note that equation 2 calculates price levels which are applied to the 2011 average price in order to obtain the tax rates in percentage terms.

Table 3. Tax rate

Tables 4, 5 and 6 show the effects of the respective meat taxes on the Marshallian elasticities. The price and expenditure elasticity results are presented in the appendix as tables A1- A4. Due to concerns regarding the potential regressive nature of taxes on lower income groups it is therefore important to ascertain the likely effects of the carbon consumption taxes on their demand. With regards to the taxes applied in Table 4, the wealthier households would likely reduce their demand for beef by 8.19% and sheep by 7.49%. However when the taxes are applied to chicken it may result in an increase in the demand for higher carbon sheep products by 2.56% thus rendering the chicken carbon consumption tax of little use for reducing demand of higher carbon food products. With regards to this particular example it demonstrates the importance of applying all meat taxes to their respective products in order for a reduction in demand of higher carbon red meats.

Table 4. Effect of taxes on Marshallian price elasticities of demand (Social grade A, B & C1)

The likely effect of the meat taxes effect on demand for meat products for the lower income households (Table 5) demonstrates that Beef taxes in particular will likely reduce demand for beef by 10.35% and turkey by 23.82%. Thus the potential benefit of reducing demand for high carbon beef may be counteractive as the demand for Turkey reduces by a greater proportion. With regards to sheep, lower income households are more price sensitive relative to wealthier households and a 15.42% reduction in demand for sheep may be possible through the consumer tax. The change in demand for lower income households with regards to chicken and turkey products is relatively small. This implies that the taxes may not affect demand for these lower carbon and relatively healthier white meats[7]. If the tax is applied to chicken products then demand for turkey is likely to increase by 6.73% which demonstrates these households substituting into a similar white meat.

Table 5. Effect of taxes on Marshallian price elasticities of demand (Social grade C2 & D)

[7] White meats are considered to be healthier for humans relative to red meats (McMichael et al., 2007)

Table 6 demonstrates that the likely effect of a beef tax could be effective in reducing demand for the lowest income households. However as these households are on very low incomes due to their non participation (in addition to casually employed workers) in the labour market, this is the group where taxes are of particular concern. A tax on beef products alone may result in demand for lower carbon and healthier chicken experiencing the largest drop in demand by 4.07% and yet a larger decrease of 7.33% for beef products. This may concern policy makers that the poorest in society may see a large reduction in their meat intake which could affect nutrient intake and yet this subsequently can help reduce household carbon footprints.

Table 6. Effect of taxes on Marshallian price elasticities of demand (Social grade E)

Table 7 has multiplied the carbon footprint elasticities from Table A5 (shows the effect of a 1% price increase) by the tax rates of Table 3 which results in an approximate calculation of how effective carbon consumption taxes could be for reducing the household carbon footprint. Overall Table 7 demonstrates that lower income households (C2 & D) would see their carbon footprint reduce by 131,393.72 t/CO_2e/y if all meat taxes were applied to their respective products. This is a likely result of the households being more price sensitive relative to the other groups.

The overall total (for all households) reduction of 246,327.26 t/CO_2e/y as a result of all the taxes being applied to the meat products would correspond approximately to a 10.5% reduction in meat emissions from the Scottish meat chain (cradle to distribution centre).

Table 7. Implied reduction of household carbon footprint through carbon consumption taxes

Applying the carbon consumption taxes to the Marshallian elasticities gave an approximate figure of how demand could be reduced. It is important to emphasise the word approximate since the elasticity results obtained from the AIDS model are conditional and not unconditional which would give a better indication of the likely income effect. The overall elasticity results suggest that if all taxes were simultaneously applied to their respective meat product then this would give the maximum impact on reducing households' carbon footprint which is similar to the result of Sall & Gren (2012). There is the potential problem highlighted by Tiffin et al (2014) and potentially applicable to meat products whereby retailers' discount their meat products or sell at below cost prices (due to promotions) which could distort the effectiveness of the carbon consumption taxes on household behaviour.

The carbon footprint reduction through meat consumption taxes would represent a 0.46% reduction in the Scottish government's 2011 emission targets. The 2011 emission targets were 53,404 Kt t/CO_2e (Scottish Government, 2012a). This may appear to be a largely insignificant reduction yet the carbon footprint data was only cradle to distribution centre and therefore does not take into account every stage of the life cycle of a meat product hence the footprint reduction through taxation is likely underestimated.

6. Conclusions

This paper offers an insight into how carbon consumption taxes could reduce the Scottish household carbon footprint through the resulting reduced demand for particularly red meat products. A meat based carbon consumption tax would be more effective if applied to all meat products mainly because meat is an overall high emitter of greenhouse gases. A potential problem with the tax is the potential regressive impact it may have on lower income households (C2 & D). However this household group would likely see the largest decrease in carbon footprint relative to the other household social groups.

The importance of including other food groups must be highlighted in order to understand the overall effectiveness of food based carbon consumption taxes on reducing Scottish household carbon footprints. This is a limitation of the study and could be the basis of future work in this area. However this paper has provided evidence to suggest that such a tax could result in an overall 246,327.26 t/CO_2e/y reduction through less consumption of meat products. This translates into 10.5% of meat emissions being reduced from the Scottish meat chain. It is important to note that more work needs to be completed understanding the potential synergies between a carbon consumption tax and nutrient intake.

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Appendix I

Equations, Figures and Tables: "Socioeconomic effects of reducing household carbon footprints using meat consumption taxes"

$$\boldsymbol{tax_j = \sum_i^n e_{i,j}\, MD_i} \qquad \textbf{(1)}$$

$$\Delta \boldsymbol{p_{ik} = k_i \ \mathrm{x}\ p_k} \qquad \textbf{(2)}$$

Table 2. Carbon footprints (Kg CO2e/Kg)

Meat categories	Carbon footprints (Kg CO2e/Kg)
Beef	12.14
Chicken	2.84
Pork	4.45
Sheep meat	14.61
Turkey	3.76

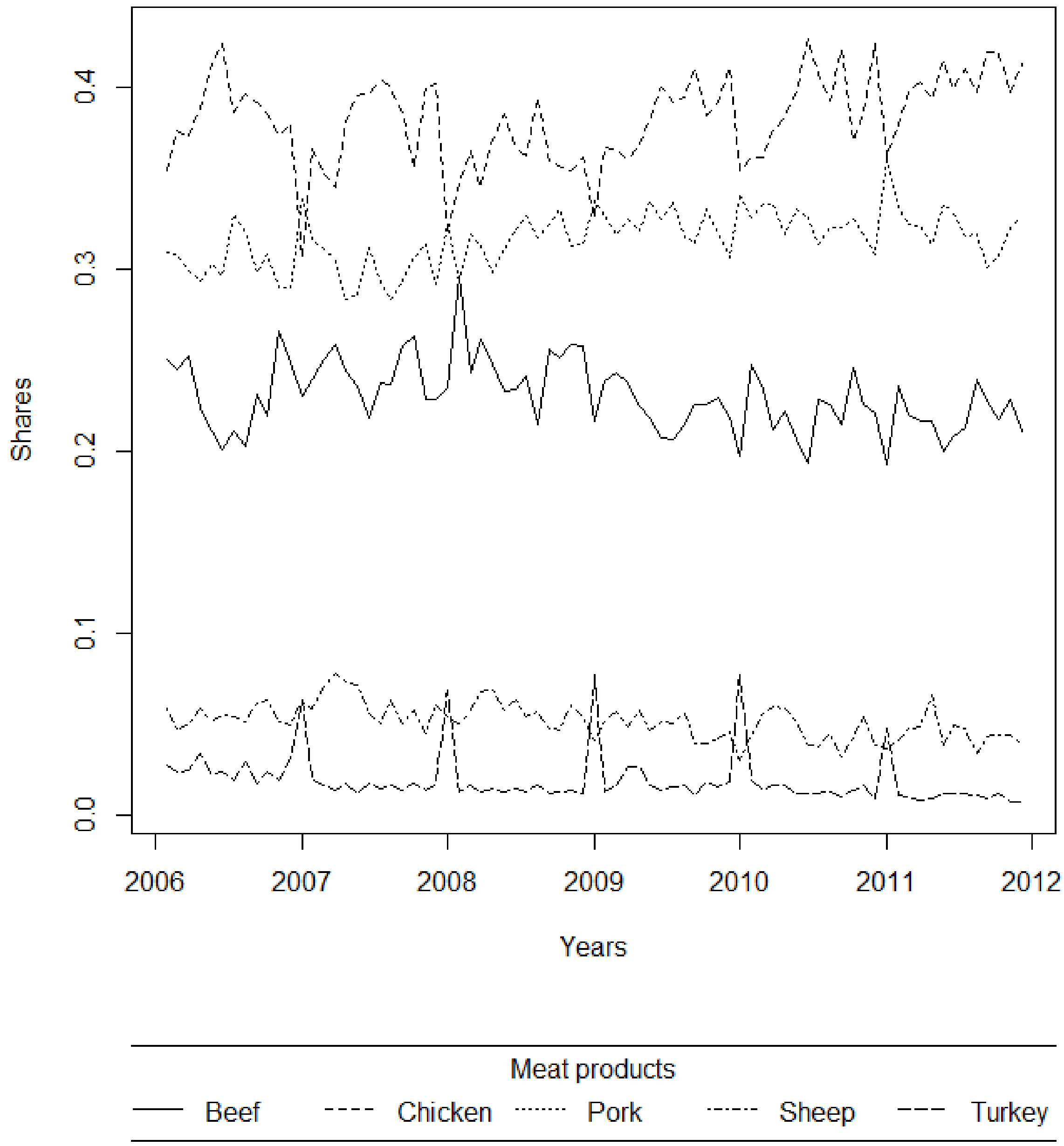
Source: (Audsley et al., 2009)

Table 2. Population sample data

Social Group	Kantar household numbers	Kantar household population shares (%)
A, B & C1	742	35
C2 & D	1,105	52
E	271	13

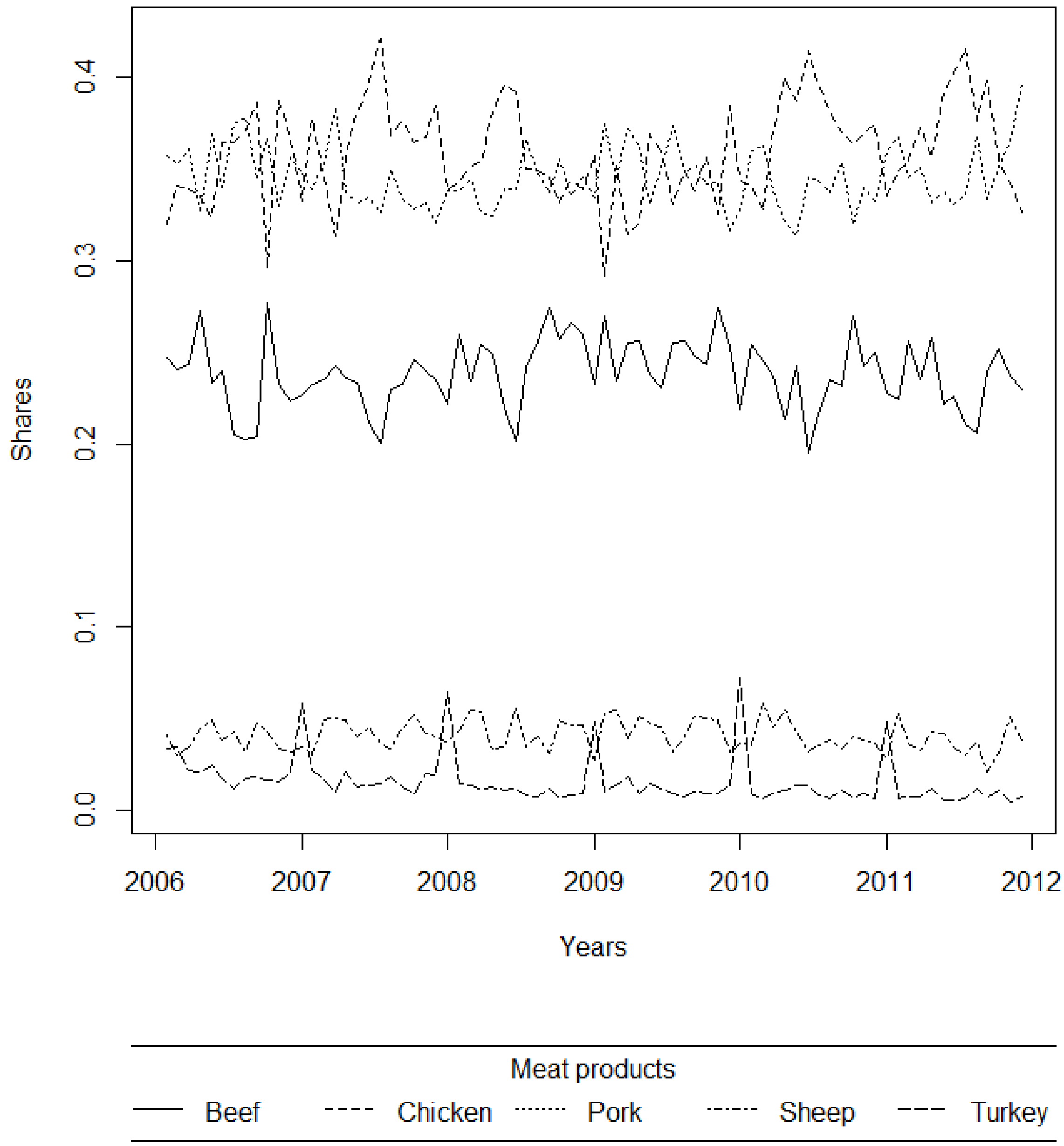
Source: Own elaboration based on Kantar Worldpanel data

Figure 4. Social groups A, B & C1 - Evolution of meat expenditure shares for years 2006-2011



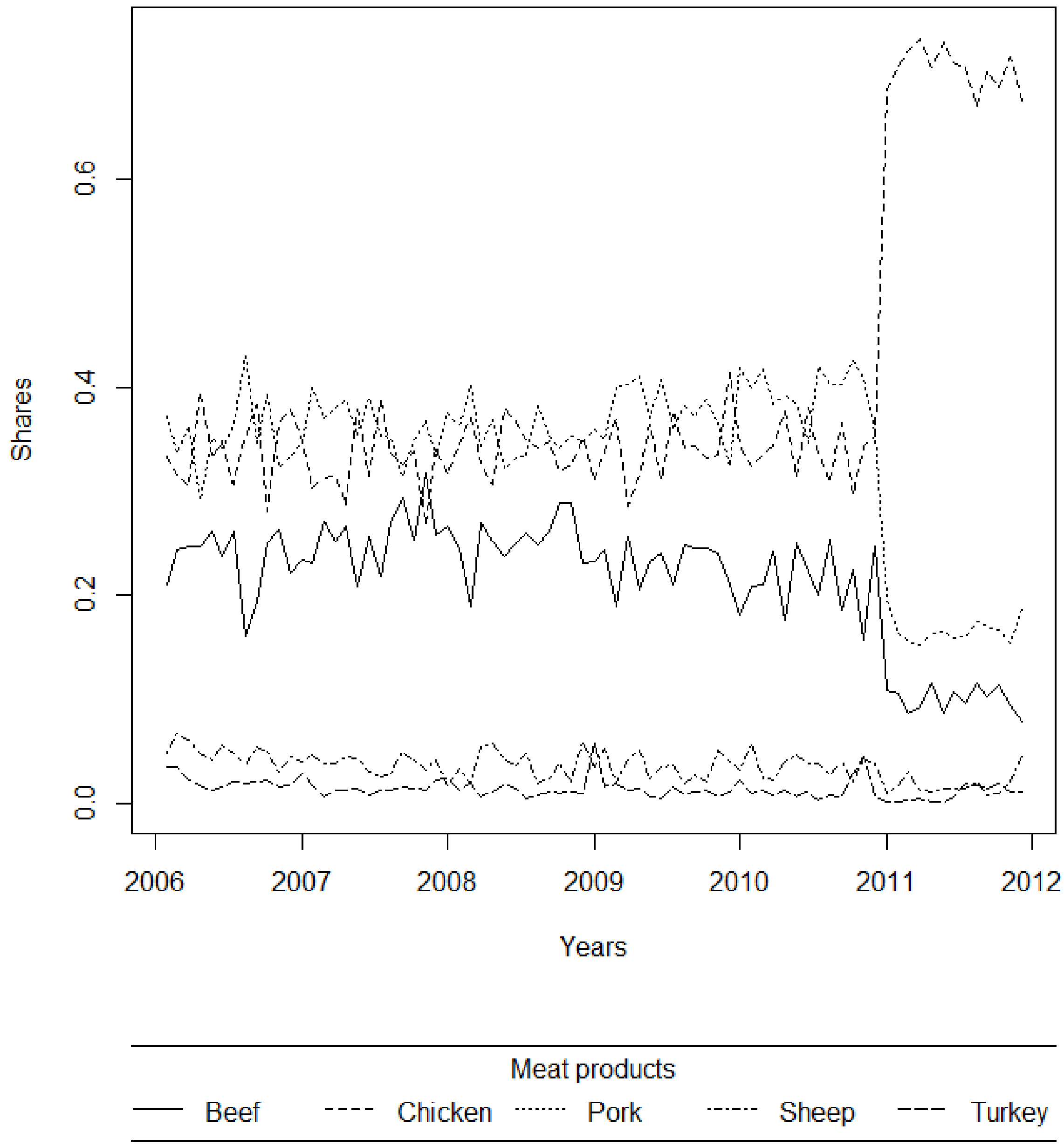
Source: Own elaboration based on Kantar Worldpanel data

Figure 5. Social grade C2 & D - Evolution of meat expenditure shares for years 2006-2011



Source: Own elaboration based on Kantar Worldpanel data

Figure 6. Social grade E - Evolution of meat expenditure shares for years 2006-2011



Source: Own elaboration based on Kantar Worldpanel data

$$\Delta w_{iht} = \psi \Delta w_{ith,t-1} + \lambda_i u_{it} + \beta_i^d \Delta \ln\left(\frac{m_{th}}{P_t^*}\right) + \sum_{j=1}^{N} \gamma_{ij}^d \Delta \ln p_{jt} + \sum_{k=1}^{K} \varphi\, D_{ik}^d + \xi_{iht} \quad \textbf{(3)}$$

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

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

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

Negativity[8] $c_{ij} = \gamma_{ij} + \beta_i \beta_j \log\left(\frac{x}{P}\right) - w_i \delta_{ij} + w_i w_j$ **(4)**

$N = S \times D$ **(5)**

Table 3. Tax rate

Products	Tax rate %
Beef	13.04
Chicken	3.16
Pork	6.27
Turkey	4.15
Sheep	12.04

Source: Own elaboration based on Kantar Worldpanel data

Table 4. Effect of taxes on Marshallian price elasticities of demand (Social grade A, B & C1)

	Effect of taxes on demand %				
	Beef	Chicken	Pork	Turkey	Sheep
Beef	-8.19	--	--	--	--
Chicken	--	-3.49	--	--	1.25
Pork	--	--	-4.73	--	-1.53
Turkey	--	--	--	--	--
Sheep	--	2.56 **1/**	-5.07	--	-7.49

Notes:

-- Elasticities are not statistically significant

1/ Value is positive

Source: Own elaboration based on Kantar Worldpanel data

[8] This matrix C must be negative semidefinite for the restriction of negativity to be satisfied (Deaton & Muellbauer, 1980b).

Table 5. Effect of taxes on Marshallian price elasticities of demand (Social grade C2 & D)

	Effect of taxes %				
	Beef	Chicken	Pork	Turkey	Sheep
Beef	-10.35	--	--	-0.48	--
Chicken	--	-2.33	-2.51	0.37	--
Pork	--	-0.98	-3.93	--	--
Turkey	-23.82	6.73	--	-3.14	--
Sheep	--	--	--	--	-15.42

Notes:

-- Elasticities are not statistically significant

Source: Own elaboration based on Kantar Worldpanel data

Table 6. Effect of taxes on Marshallian price elasticities of demand (Social grade E)

	Effect of taxes %				
	Beef	Chicken	Pork	Turkey	Sheep
Beef	-7.33	--	--	--	--
Chicken	-4.07	-3.05	-1.52	--	--
Pork	--	--	-3.20	--	-1.28
Turkey	--	--	--	--	--
Sheep	--	--	-11.78	--	--

Notes:

-- Elasticities are not statistically significant

Source: Own elaboration based on Kantar Worldpanel data

Table 7. Implied reduction of household carbon footprint through carbon consumption taxes

Products	Social group A, B & C1 t/CO_2e/y	Social group C2 & D t/CO_2e/y	Social group E t/CO_2e/y	Total t/CO_2e/y
Beef	46,254.32	80,519.30	8,253.36	
Chicken	12,771.79 **1/**	5,350.77 **1/**	711.05	
Pork	44,267.67	9,207.56	9,991.00	
Turkey	--	17,966.87	--	
Sheep	18,067.20	29,050.76	160.72	
Total	95,817.40	131,393.72	19,116.14	246,327.26

Notes:

-- Elasticity is not statistically significant

1/ Value is positive

Source: Own elaboration based on Kantar Worldpanel data

Appendix II

Table A1. Social group A, B & C1 –Short term demand elasticities for meat **1/**

	Marshallian elasticities										Hicksian elasticities									
	Beef		Chicken		Pork		Turkey		Sheep		Beef		Chicken		Pork		Turkey		Sheep	
Beef	-0.628	***	0.017		-0.089		-0.036		-0.101		-0.435	**	0.338	**	0.176		-0.02		-0.058	
Chicken	-0.059		-1.103	***	-0.054		-0.028		0.104	*	0.203	**	-0.667	***	0.307	***	-0.006		0.162	**
Pork	-0.092		0.005		-0.754	***	0.011		-0.127	*	0.128		0.371	***	-0.451	***	0.029		-0.077	
Turkey	-0.426		-0.419		0.255		-0.402		0.231		-0.251		-0.128		0.496		-0.388		0.27	
Sheep	-0.501		0.809	*	-0.809	*	0.079		-0.622	*	-0.261		1.209	**	-0.478		0.098		-0.568	

Notes:

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

Source: Own elaboration based on Kantar Worldpanel data

Table A2. Social group C2 & D –Short term demand elasticities for meat **1/**

	Marshallian elasticities										Hicksian elasticities									
	Beef		Chicken		Pork		Turkey		Sheep		Beef		Chicken		Pork		Turkey		Sheep	
Beef	-0.794	***	-0.089		0.112		-0.155	***	0.033		-0.591	***	0.217		0.407	**	-0.102	**	0.068	
Chicken	-0.14		-0.736	***	-0.400	***	0.089	***	-0.007		0.144		-0.307	*	0.013		0.108	***	0.042	
Pork	0.066		-0.311	**	-0.627	***	-0.036		0.006		0.280	**	0.014		-0.315	**	-0.022		0.043	
Turkey	-1.287	***	2.128	***	-0.857		-0.757	***	0.251		-1.571	**	2.510	***	-0.489		-0.741	***	0.294	
Sheep	0.167		0.022		0.029		0.096		-1.281	***	0.397		0.37		0.364		0.111		-1.242	***

Notes:

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

Source: Own elaboration based on Kantar Worldpanel data

Table A3. Social group E –Short term demand elasticities for meat **1/**

	Marshallian elasticities										Hicksian elasticities						
	Beef		Chicken		Pork		Turkey	Sheep		Beef	Chicken		Pork		Turkey	Sheep
Beef	-0.562	*	-0.302		-0.132		0.012	0.075		-0.367	0.062		0.173		0.025	0.108
Chicken	-0.312	**	-0.965	***	-0.242	*	-0.047	-0.044		0.033	-0.32		0.298	**	-0.024	0.013
Pork	0.021		0.189		-0.510	***	-0.01	-0.106	*	0.11	0.356	**	-0.371	**	-0.004	-0.091
Turkey	0.479		-0.474		-0.074		-0.036	0.461		0.374	-0.671		-0.104		-0.043	0.444
Sheep	0.485		-0.163		-1.126	**	0.168	-0.148		0.653	0.151		-0.863		-1.106	-0.12

Notes:

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

Source: Own elaboration based on Kantar Worldpanel data

Table A4. Short term expenditure elasticities **1/**

	Short term expenditure elasticity by Social group					
	A, B & C1		C2 & D		E	
Beef	0.837	***	0.854	***	0.909	***
Chicken	1.14	***	1.193	***	1.61	***
Pork	0.956	***	0.902	***	0.415	***
Turkey	0.761		1.062	*	-0.491	
Sheep	1.044	**	0.967	**	0.784	

Notes:

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

Source: Own elaboration based on Kantar Worldpanel data

Table A5. Carbon footprint elasticities based in a 1% increase in price

Products	Social grade A, B & C1 Elasticity	Implied reduction t/CO_2e/y **1/**	Social grade C2 & D elasticity	Implied reduction t/CO_2e/y **1/**	Social grade E elasticity	Implied reduction t/CO_2e/y **1/**
Beef	-0.30	3,547.11	-0.64	6,174.79	-0.30	632.93
Chicken	0.34	4,041.71 **2/**	0.18	1,693.28 **2/**	-0.11	225.02
Pork	-0.59	7,060.23	-0.15	1,468.51	-0.76	1,593.46
Turkey	--	--	-0.16	1,492.26	--	--
Sheep	-0.36	4,353.54	-0.73	7,000.18	-0.02	38.73
	Total	10,919.18	Total	14,442.47	Total	2,490.13

Notes:

-- Elasticities are not statistically significant

1/ Total decrease in t/CO_2e/y when considering (weighted for social grade population) the entire meat supply chain from cradle to distribution centre

2/ Values were positive implying a t/CO_2e/y increase (this is a likely result of a strong complementary relationship)

Source: Own elaboration based on Kantar Worldpanel data