Working Paper No. 626

June 2019

Distributional impacts of carbon taxation and revenue recycling: a behavioural microsimulation

Miguel Angel Tovar Reaños[a*], Muireann Á. Lynch[a]

Abstract: Carbon taxation is a regressive policy which contributes to public opposition towards same. We employ the Exact Affine Stone Index demand system to examine the extent to which carbon taxation in Ireland reduces emissions, as well as its distributional impacts. The Engel curves for various commodity groupings are found to be non-linear, which renders the particular demand system we have chosen more suitable than other methods found in the extant literature. We find that a carbon tax increase can decrease emissions, but is indeed regressive. Recycling the revenues to households mitigates these regressive effects. A targeted allocation that directs the revenues towards less affluent households is found to reduce inequality more than flat allocation that divides the revenues equally amongst all households; however both methods are capable of mitigating the regressive effects of the tax increase.

Keyword(s): Household energy demand, energy taxes, microsimulation, demand system

JEL Code(s): H23; Q18; H31

Acknowledgements: Tovar Reaños and Lynch acknowledge funding from the ESRI's Energy Policy Research Centre. We are grateful to Ankita Gaur and Ciarán MacDomhnaill for assistance with data processing and to ESRI seminar participants for helpful comments and suggestions. All remaining errors or omissions are our own.

Corresponding author: miguel.angeltovar@esri.ie

---

a. Economic and Social Research Institute, Dublin

1 Introduction

Concerns over climate change have motivated sustained efforts to reduce greenhouse gas emissions. In the spirit of Arthur Pigou (Pigou, 1952), carbon taxation or pricing has become the preferred tool of economists in reducing carbon emissions in an efficient manner (Nordhaus, 1993). While the appropriate level of carbon price has been the subject of some debate (most famously Stern and Stern (2007); Nordhaus (2007a,b)), the general principle enjoys broad acceptance amongst the academic community[1]. Translating this academic acceptance of carbon taxation to social acceptance is challenging (Carattini et al., 2017).The distributional implications of carbon taxation are of concern (Kolstad et al., 2014), with Farrell (2017) finding that carbon tax incidence is driven not only by income but by other socioeconomic characteristics. The efficacy of carbon taxation as a means of reducing emissions has also been questioned (Vasilakou, 2010; Patt and Lilliestam, 2018), compounding the affordability and distributional concerns.

Using the revenues of carbon taxation to compensate households for the costs incurred by carbon taxation is often proposed as a mechanism of mitigating these and other concerns, with Klenert et al. (2018a) providing a comprehensive summary of the range of revenue recycling mechanisms available to policy-makers. Revenue recycling, when correctly designed, can yield a "double dividend" of redistribution, especially if the tax system before the reform is non-optimal (Klenert et al., 2018b). The "carbon cheque" and other forms of lump sum transfers, where households receive an equal amount from the additional tax revenues, have been recently advocated by Nobel laureate economist and governments to increase public acceptability of carbon taxes. An improperly designed reallocation mechanism can potentially create more pressure on inequality than the tax itself. However, the research on distributional effects of different revenue recycling mechanism is narrow.

There is a large and growing literature on carbon taxation and so we restrict our attention to Ireland. Ireland has made poor progress in reducing carbon emissions and is projected to miss its carbon reduction targets by more than any other EU Member State (European Commission, 2018). In response to this, the Irish Parliament recently produced a report that advocated, amongst other measures, an increase in carbon taxation (Joint Committee on Climate Action, 2019). A carbon tax was introduced in 2010 which applies to non-ETS emissions and currently stands at €20 per tonne. Carbon pricing is thus envisaged as a core policy instrument to transit towards a sustainable economy (Department of Communications, Climate Action and Environment, 2017). There have been several studies performed in Ireland that use macro or computable general equilibrium models to determine the impact of carbon taxation on emissions and on the whole economic activity (see (Bergin et al., 2004; Wissema and Dellink, 2007; Conefrey et al., 2013; FitzGerald and McCoy, 1992)). On the microeconomic side, non-behavioural-microsimulation models have been used to estimate the distributional effects of the introduction of a carbon tax in Ireland (Scott and Eakins, 2004; Callan et al., 2009; Verde and Tol, 2009), taking various revenue recycling mechanisms into account. These models are partial equilibrium models and find that a carbon tax is regressive, but targeted revenue recycling can remove the regressive effects. A major assumption of these papers is zero price elasticity, where consumers do not reduce their consumption of carbon due to the tax increase. While this may be a plausible assumption in the short-run, it is does not apply in the long run.

Thus, to date, any research on carbon taxation in Ireland that examined changes in emissions in response to carbon taxation were in the macroeconomic/computable general equilibrium space, while research that considered distributional effects assumed that carbon emissions did not reduce in response to the tax. This paper, in contrast to general equilibrium models, considers microeconomic modelling that examines the distributional implications of carbon taxation while estimating the quantities of various goods consumed

---

[1] https://www.econstatement.org/

under an increase in taxation, and so captures any resulting changes in emissions. We do so by estimating the recently proposed Exact Affine Stone Index (EASI) demand system (Lewbel and Pendakur, 2009) using microdata from the Irish Household Budget Survey (HBS).

O'Donoghue (1997) is one of the few studies that uses a demand system approach with Irish data to model behavioural changes and analyse distributional effects of increases of energy taxes. While the use of demand systems in the economic literature to analyse this issue is not new (see Baker et al. (1989); Labandeira and Labeaga (1999); Labandeira et al. (2006); Böhringer et al. (2017), few studies analyse changes of welfare at aggregate level and inequality changes. In addition, existing literature assumes linear (see Deaton and Muellbauer (1980)) or quadratic Engel curves (see Banks et al. (1997)). Engel curves describe how household expenditure on a particular commodity changes across different levels of income. We use the EASI demand system because it is the only available methodology that allows for flexible representation of Engel curves. Demand systems have been used to study households' energy use and carbon emissions (Creedy and Sleeman, 2006; Pashardes et al., 2014; Tovar Reaños and Wölfing, 2018), but, to our knowledge, this is the first study employing the EASI demand system to investigate the distributional effects of carbon taxes. The model is extended to evaluate welfare changes at individual and aggregate levels caused by increases in energy prices via carbon taxation.

This paper examines the implications of several carbon taxation and revenue recycling mechanisms from both a distributional and an environmental point of view using Irish microdata. The original contributions of this paper are the use of the EASI demand system to estimate the impacts of carbon taxation, as well as the examination of the distributional implications of carbon taxation and revenue recycling in Ireland via microsimulation, while taking into account these behavioural changes induced by the tax. The results indicate that carbon taxation is an effective measure of reducing carbon emissions, with carbon tax increases of €30 and €80 being associated with emission reductions of 3.94% and 10.24% respectively. The tax is regressive, as measured by equivalent variation as opposed to flat allocation, but recycling carbon taxation revenues to households can mitigate these regressive effects, even with a relatively crude recycling mechanism of an equal lump sum payment per household. A more sophisticated recycling mechanism that targets the revenues to lower income households renders the total policy package progressive, reducing rather than increasing inequality.

The rest of the paper is structured as follows. Section 2 summarises the methodology of the EASI demand system and the derived measures, first outlined in Tovar Reaños and Wölfing (2018). Section 3 presents the data and estimation results. Section 4 outlines the data and revenue recycling scenarios employed while section 5 illustrates the potential of our model for microsimulation. Section 6 concludes.

2 Methodology

2.1 The Affine Stone Index (EASI) implicit Marshallian demand system

The methodology employed here is similar to that of Tovar Reaños and Wölfing (2018) where after estimating the EASI demand system from microdata, changes in welfare at household and aggregated level are estimated. The EASI (Lewbel and Pendakur, 2009) is the latest major advancement in the literature on household demand systems. It provides a first-order approximation of an arbitrary expenditure function from which a demand system can be derived. The estimated expenditure function must have all the properties that hold for a theoretical expenditure function (Varian, 1992). In order to estimate the EASI, only information on the expenditure for different goods and their prices are required. Unlike the Almost Ideal Demand System and its variations, the EASI demand system can represent the relationship between expenditure and income, the Engels curves, in a flexible manner. The generalized method of moments (GMM) estimator or an iterated linear approximation can be used to estimate the demand system. Lewbel and Pendakur propose the following expenditure function:

$$\begin{aligned}\log\left[C(\boldsymbol{p},y)\right] = y &+ \sum_{i=1}^{I} m_i(y,\boldsymbol{z})\log(p_i)\\ &+\frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} a_{ij}\log(p_i)\log(p_j)\\ &+\frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} b_{ij}\log(p_i)y\\ &+\sum_{i=1}^{I}\varepsilon_i\log(p_i)\end{aligned} \tag{1}$$

where

$$m_i = \sum_{r=0}^{R} b_r \log(y)^r + \sum_{l} d_{il}z_l\log(y) + \sum_{l} g_{il}z_l \tag{2}$$

and where p_i are commodity prices, y is the implicit household utility, and z_l are demographic characteristics. R is chosen by the modeller and determines the degree of the polynomial m_i. This specification allows for highly flexible Engel curves while still keeping the functional form quite comprehensible. $a_{i,j,l}$, $b_{i,j}$, $b_{i,r}$, $d_{i,l}$ and g_{il} are the parameters to be estimated. ϵ_i represent unobserved preference heterogeneity. Lewbel and Pendakur show that the implicit utility, y, can be expressed in the following way:

$$y = \frac{\log(x) - \sum_i w_i\log(p_i) + \frac{1}{2}\sum_i\sum_j a_{i,j}\log(p_i)\log(p_i)}{1-\frac{1}{2}\sum_i\sum_j b_{i,j}\log(p_i)\log(p_j)} \tag{3}$$

By applying Shephard's lemma to the cost function embedded in expression (1)[2], the following set of equations for the budget shares w_i is obtained:

$$\begin{aligned}w_i = &\sum_j a_{i,j}\log p_j + \sum_j b_{i,j}\log y\\ &+\sum_{r=0}^{R} b_{i,r}[\log y]^r + \sum_l g_{i,l}z_l + \sum_l d_{i,l}z_l\log y + \epsilon_i.\end{aligned} \tag{4}$$

Lewbel and Pendakur shows that (4) can be estimated with an approximation of y or with (3), with very similar estimates[3]. We use the first approach where approximating y reduces the computational burden of estimating the parameters of the system and standard errors using three-stage least squares (3SLS). The following restrictions ensure the theoretical consistence of the estimated expenditure function:

---

[2] Note that $\log(x) = \log\left[C(\boldsymbol{p},y)\right]$

[3] The authors approximate y by using $\log(x) - \sum_i \bar{w}_i\log(p_i)$ where $\bar{w}_i$ is the mean of the budget share.

$$\begin{aligned}
a_{i,j,l} = a_{j,i,l} \quad &\text{and} \quad \sum_i a_{i,j,l} = 0 \ \forall \ l, \\
b_{i,j} = b_{j,i} \quad &\text{and} \quad \sum_i b_{i,j} = \ 0, \\
\sum_i d_{i,l} &= \sum_i g_{i,l} = 0 \ \forall \ l, \\
\sum_i b_{i,r} &= 0 \text{ for } r \ \neq \ 0, \\
\sum_i b_{i,r} &= 1 \text{ for } r \ = \ 0,
\end{aligned} \tag{5}$$

We use information on intra-group variation of the aggregated consumption categories to obtain household-specific prices following Lewbel (1989) to further improve identification. Once the parameters in equation 4 are estimated, own-price elasticities (OPE) and expenditure elasticities (EE) can be computed as follows:

$$OPE = \left\{ \frac{\partial w_i}{\partial \log(p_i)} \right\} \frac{1}{w_i} - 1 \tag{6}$$

$$EE = \left\{ \frac{\partial w_i}{\partial \log(X)} \right\} \frac{1}{w_i} + 1 \tag{7}$$

We can describe the impacts of changes in welfare by estimating Hicks's equivalent variation (HEV). $HEV = C(p^0, U^1) - C(p^0, U^0)$, where U is the level of household utility. This follows Creedy and Sleeman (2006) and Tovar Reaños and Wölfing (2018).

2.2 Inequality and social welfare

"Equivalent income" (x^e) is defined by King (1983) as $y(p^1, x^e) = y(p^0, x^0)$ where y is the indirect utility as expressed in (3). "Equivalent income" (x^e) is the income level required in order to achieve the utility that prevails under the current income level, but at a different set of prices.[4] Tovar Reaños and Wölfing (2018) shows that (x^e) can be estimated as $x^e = x - HEV$. From this, we define a metric that aggregates changes in social welfare arising from changes in equivalent income and inequality, weighted by society's (or a Social Planner's) aversion to same, as follows:

$$\text{Social Welfare} = \underbrace{\frac{\sum_{h=1}^{H} \left(x^e * \sqrt{\text{hsize}_h} \right)}{\sum_{h=1}^{H} \text{hsize}_h}}_{\text{Mean equivalent income (MEI)}} \times (1 - A\epsilon), \tag{8}$$

where A is Atkinson's inequality index, ϵ is the inequality aversion parameter (from the perspective of a social planner), "hsize" is the number of people in the household, and H is the total number of households in our sample. This metric measures aggregate changes in social welfare.

The inequality aversion parameter is set at $\epsilon = 1.2$[5].

---

[4] Note that this definition is distinct from an unrelated definition of 'equivalent income' that appears elsewhere in the economic literature, namely that of a measure of income by a household member that accounts for household composition and economies of scale.

[5] Creedy and Sleeman (2006) choose $\epsilon = 0.2$ and $\epsilon = 1.2$. Our choice of ϵ seems to be a reasonable upper bound for this parameter, although we note here that Pirttilä and Uusitalo (2010) suggest that under certain circumstances, even higher values of ϵ may prove appropriate. We perform sensitivities on the choice of inequality aversion parameter in Appendix II.

3 Data and estimation

3.1 Household data, price data and commodity grouping

The dataset employed in this work is the Household Budget Survey (HBS), conducted by the Central Statistical Office (CSO) every five years. The purpose of the survey is to determine a detailed pattern of household expenditure, which in turn is used to update the weighting basis of the Consumer Price Index[6]. We use the waves from 1994, 1999, 2004, 2009 and 2015-2016 in this work, in a pooled cross-sectional manner. We also use indices for commodity prices for the same years provided by the CSO.

For the purposes of this study, the consumption goods were grouped into several categories: foods, housing, lighting and heating (which we also term “energy” throughout the course of this paper), transportation, education and leisure, and other goods and services. This aggregation is similar to that used in Tovar Reaños and Wölfing (2018) and Böhringer et al. (2017). This grouping largely follows the Classification of Individual Consumption According to Purpose (COICOP). As in Baker et al. (1989), we do not include the purchase of vehicles and white goods appliances. Instead, dummy variables for ownership of these goods are included in the analysis. The rationale for this is that the EASI demand system does not accommodate some aspects of intertemporal demand decisions, and so we ignore durable goods.

Summary statistics for the full dataset are shown in Table 1. In addition, dummy variables are included for whether a dwelling is in a rural area (according to the CSO classification of same), the age of the dwelling, whether the dwelling has gas fired central heating, a washing machine, a dishwasher and a fridge, and finally whether the household owns a car[7]. Dummy variables are also included for the year and quarter in which the data were collected.

Energy expenditure comprises expenditure on electricity, natural gas, liquid fuels and solid fuels. Transportation expenditure comprises petrol, diesel, maintenance, insurance and public transport. Carbon taxes in the non-ETS sector affect the prices of heating fuels and of fuels for private transportation, and so we can estimate the changes in the expenditure distribution as a result of the carbon tax’s effect on both groups. Pricing data was obtained from the price index from the CSO. Given that this is a price index, we do not have actual prices in monetary values. However, the precise evolution of prices for the goods categories observed in the expenditure data is sufficient to identify the EASI demand system.

Figures 1 to 3 graph the budget shares of expenditure for heating and lighting and diesel and petrol by expenditure quartile, along with the CO_2 emissions by quartile. The fact that expenditure shares on energy commodities is largest for the poorest households may confirm that carbon taxation is regressive, which tallies with previous research for Ireland and elsewhere. Richer households have higher emissions, however, which calls for the implementation of a progressive policy instrument that sees emissions taxation increasing with income. These observations motivate the current research.

---

[6] See https://www.cso.ie/en/methods/housingandhouseholds/householdbudgetsurvey/

[7] A robustness check on the impact of car ownership is performed in Appendix III.

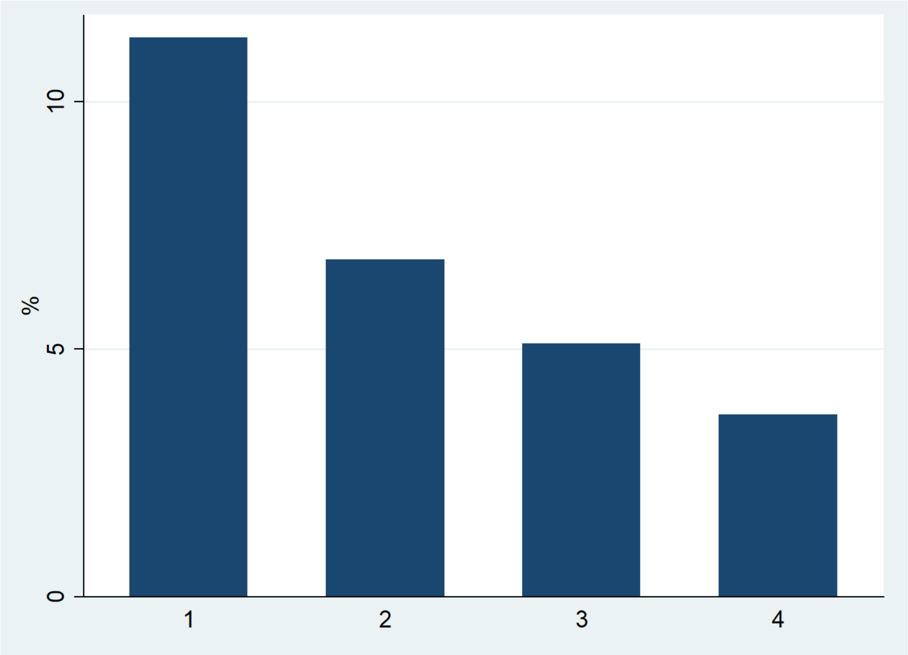

Figure 1: Budget share of heating and lighting expenditure by quartiles.

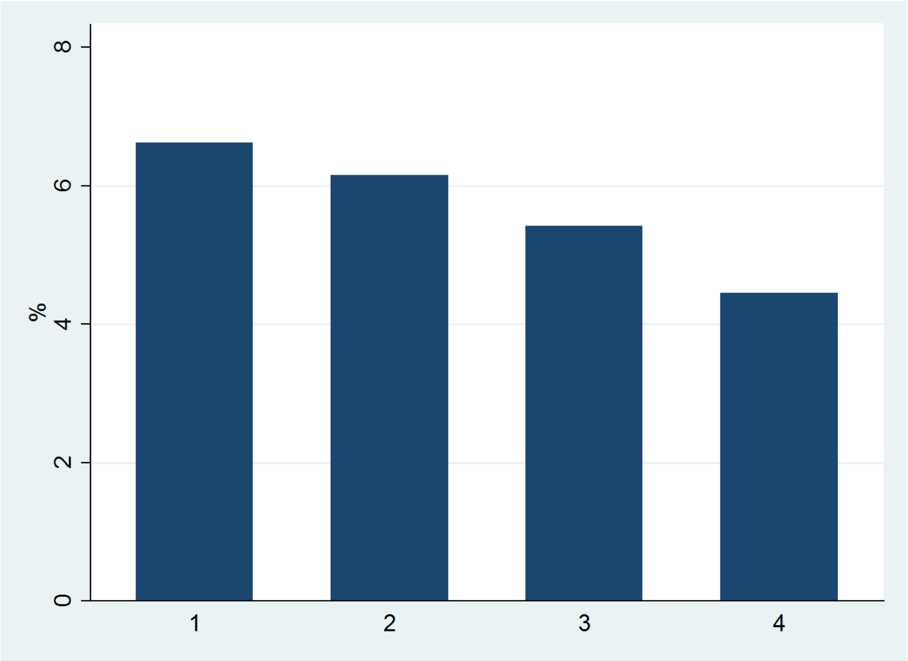

Figure 2: Budget share of transport expenditure by quartiles.

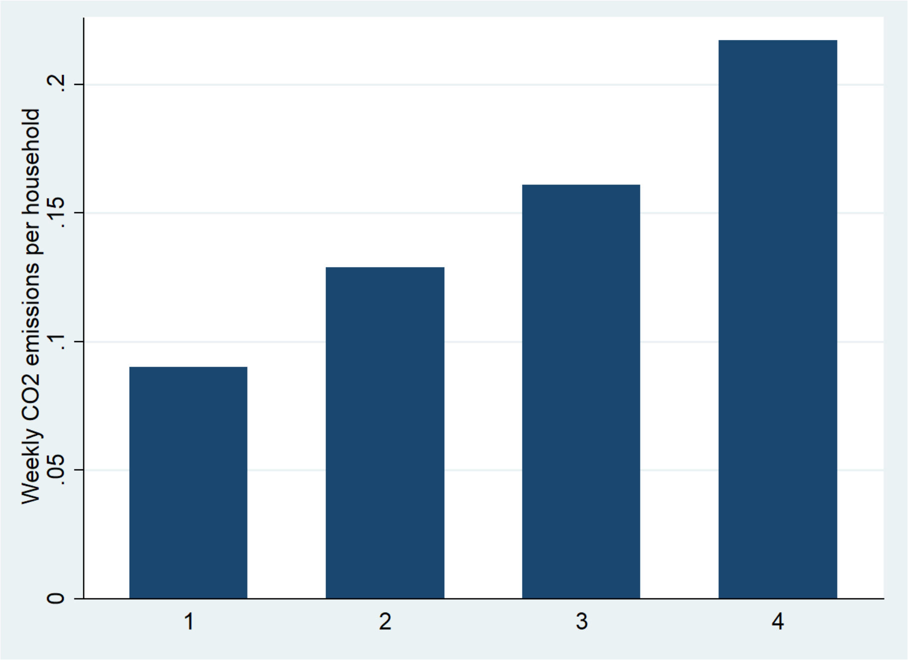

Figure 3: Emissions by quartile

3.2 Estimation

Figure 4 displays non-parametric kernel regressions of budget shares for each of the commodity groupings over the log of total household consumption. Even for this non-parametric regression, each of these curves are nonlinear. This indicates that a traditional Almost Ideal or Quadratic Almost Ideal demand system, which have been applied to Irish HBS data previously (most recently Savage (2016)), would not appropriately capture the budget effects for some commodity groups.

Turning to the EASI estimates, we find statistically significant and greater than zero parameters for the polynomials of up to degree six (see Table 2). This confirms the nonlinearity of the Engel curves and justifies the approach taken in this paper.

We also perform two robustness checks on the above model, one where we restrict our attention to households that own cars and a second where we exclude variables relating to the ownership of white goods. The results of these robustness checks appear in Appendix III and are discussed in the microsimulation section below.

3.3 Elasticities

Table 3 shows the own price and expenditure elasticities for each commodity group. The expenditure elasticity of energy is lowest of all commodity groups, which is a natural consequence of the fact that energy is (a) a necessary good and (b) has few substitutes. Transport's own price elasticity is second lowest, for similar reasons.

Tables 4 and 5 show the elasticities for households in the lowest and highest expenditure quartiles, respectively. Higher expenditure households have higher own price elasticities for both energy and transport, relative to lower expenditure households. This is most likely also due to the limited substitution possibilities of energy, and can be regarded as an example of what Angus Deaton called Pigou's Law (Deaton, 1974), which states that price elasticities of demand are proportional with income. These elasticities partly drive the regressive nature of energy taxation, even when behavioural responses are taken into account. Table 6 shows the cross-price elasticities for each of the commodity groups.

Direct comparison of our estimated elasticities with estimates in the literature is not possible because this is the first attempt to measure them using the EASI demand system. The few existing estimates for Ireland use a different aggregation approach. Nonetheless,

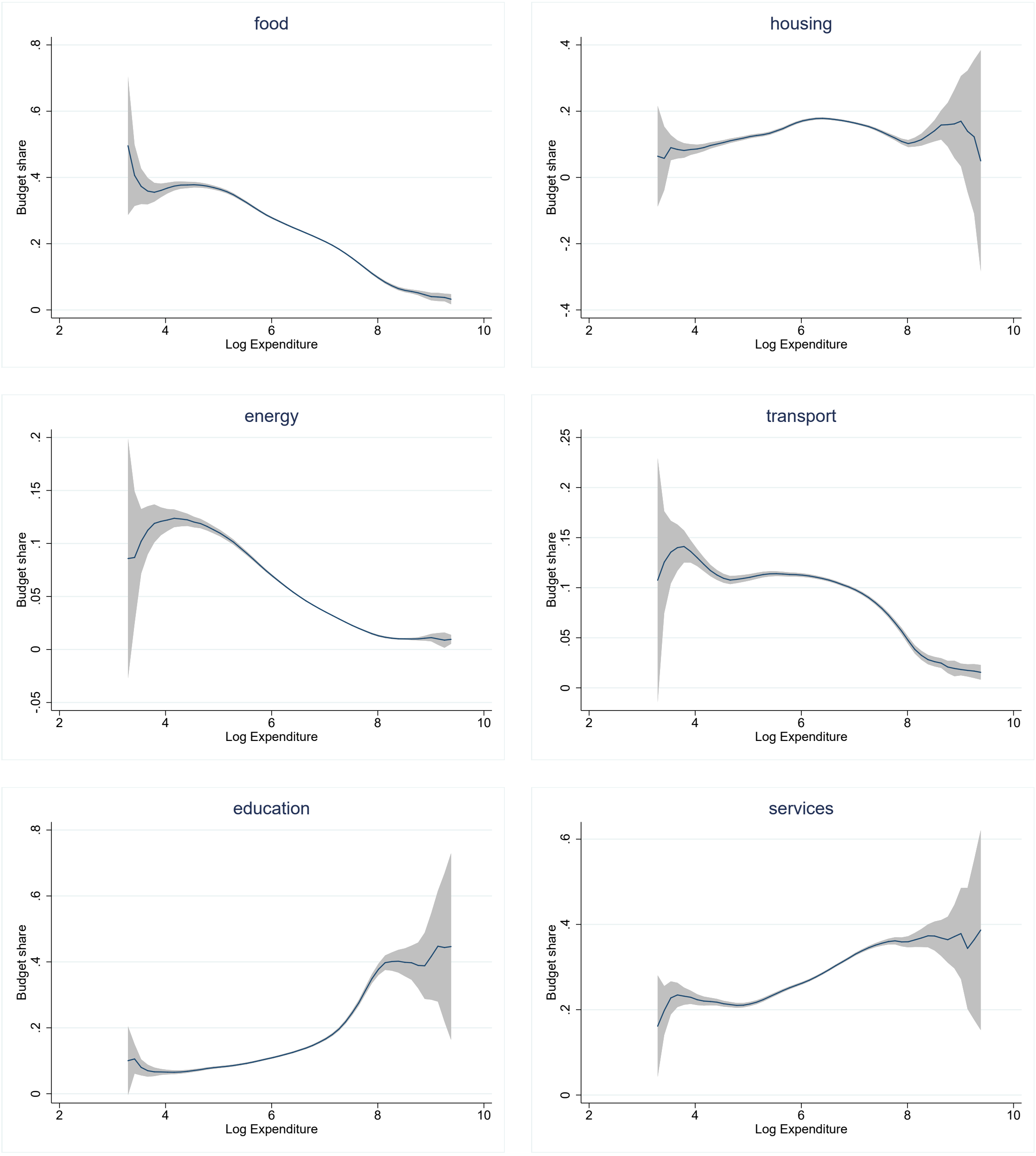

Figure 4: Non-parametric Engel curves: Expenditure share of commodities over monthly non-durable expenditure in thousand Euros, log scaled.

our estimated own price elasticities (OPE) for lighting and heating and transport are in line with estimates found in the literature. Pothen and Tovar Reaños (2018) found similar estimates for these metrics for Germany. While Savage (2016) included lighting and heating and transport in only one category, his estimates are not far away from our estimated OPE. Salotti et al. (2015) use a simplified AIDS model to compute expenditure elasticities for six different European countries and find heating fuel elasticities of between 0.12 and 0.47; the weighted average is 0.26, which compares well with our results of 0.211. In terms of transport, a wide range exists in the literature: the weighted average of exenditure elasticities found by Salotti et al. is 0.47, while Clements et al. (2006) study expenditure elasticities for 45 different OECD countries and report their average expenditure elasticity for transport as 1.58. Our estimate of 0.733 is within these two estimates. Our results are therefore within the bounds found in the extant literature, and any discrepancies may be explained at least in part by the fact that the EASI is more flexible and better able to accommodate non-linear Engel curves, as discussed above.

Regarding the rest of the commodity groups, our estimates for food are larger than those estimated by Savage (2016). He estimates OPE for food, tobacco and alcohol, while we follow the COICOP classification where alcohol, tobacco and dining out are included in the "food" category. This may account for the relatively high own price elasticity seen for this commodity group in our results[8].

4 Microsimulation data and scenarios

The demand system estimated above is now used to simulate the effect of carbon taxation on expenditure on the various commodity groups. For the purposes of the microsimulation, we use the 2015-2016 wave of the HBS as it has the most recent data available. The emissions factors and the fuel prices (in €/ kW) of the energy commodities were obtained from the Sustainable Energy Authority of Ireland[9]. Direct emissions only are considered. Furthermore, as this is a partial equilibrium model, changes in the supply of labour or commodities are not captured by the analysis. This shall be the focus of future research.

We consider two scenarios, which correspond to an increase in carbon taxation of €30 per tonne and €80 per tonne. These correspond to a total carbon tax of €50 per tonne and €100 per tonne, respectively. In the base case scenario, households face the existing carbon tax of €20 per tonne.

In addition, we consider two alternative mechanisms for allocating the revenue raised by the carbon taxation measure to households. Under the flat allocation scenario, every household receives an equal direct transfer, the magnitude of which is such that the total carbon tax revenue raised is exhausted. In the targeted allocation scenario, 50% of the revenue is recycled to houses in the same manner as the flat allocation. The remaining 50% is recycled to the two lower expenditure quartiles, in inverse proportion to the household's share of aggregate expenditure, according to equations (9) and (10):

$$\frac{\sum_h^H X_h}{X_h} = r_h \tag{9}$$

$$share_h = \frac{r_h}{\sum_h r_h} \tag{10}$$

where X_h is the total expenditure of each household h and $share_h$ is the share of the total carbon taxation revenues that accrues to household h. Equation (9) calculates the inverse of the proportion of total expenditure accounted for by each household h. Equation (10) normalises this metric in order to ensure that the sum of the shares of the revenue received by each household is one.

---

[8] Cross price elasticities are also provided in appendix I.

[9] See https://www.seai.ie/resources/publications/Energy-Emissions-2017-Final.pdf

In our results that omit revenue recycling, we essentially assume that the revenue is not used for any purpose and plays no role in public expenditure or taxation. While this is an unrealistic assumption, it is not possible to model all possible alternative uses for the carbon taxation revenue.

5 Microsimulation results

5.1 Initial incidence: household level

The tax paid by each household assuming no change in behaviour is shown in Tables 7 and 8 for a tax increase of €30 and €80, respectively. The regressive nature of the tax is clear, with the burden decreasing as total expenditure rises, for all households types.

Tables 9 and 10 consider Hick's equivalent variation for the different household types and quartiles, and so include the behavioural element of carbon emission reduction. The cost of the policy again decreases as expenditure increases, although the difference between the lowest and highest quartile is slightly lower than the tax burden with no behavioural response. The greatest cost is bourne by single households with children.

While the behavioural estimates displayed in Tables 9 and 10 show smaller estimates of welfare changes than the non-behavioural estimates in Tables 7 and 8, both approaches agree on the regressive nature of the policy. Banks et al. (1996) show that neglecting the effects of own and cross price elasticities when estimating welfare changes, as in the non-behavioural approach, can introduce considerable bias in the estimation of welfare changes. In addition, our approach allows us to estimate changes in emissions and in aggregate changes in welfare and inequality using metrics that are coherent with economic theory.

In the analysis above, expenditure on private and public transportation was included together in the "transport" category, with a dummy variable accounting for car ownership. In practice, expenditure on private transportation is likely to prove more responsive to changes in fuel prices than expenditure on private transportation. In order to account for this, and to test the robustness of the model, we perform a check in which we restrict our analysis to the subset of the population that owns cars. The parameters from the EASI model and the distributional analysis can be found in Table 16 in Appendix III. The estimates for the equivalent variation in the absence of revenue recycling are presented in Tables 17 and 18. Comparing these results to those in Tables 9 and 10, the same patterns hold and the results are broadly similar. The regressive nature of the tax is again present. The aggregate effect is seen in Table 19, which again compares well with Table 11.

As a further robustness check we run the model excluding the dummy variables that account for ownership of vehicles and durable goods. The results are broadly similar, which suggests that these dummy variables are not driving the results and that instead the EASI demand system results are being driven by the expenditure shares and commodity prices themselves. Table 20 in Appendix III shows the full results of the model.

5.2 Initial incidence: Aggregate level

Table 11 shows the changes in the Atkinson index of inequality and in the equivalent income as the carbon tax increases. The changes in social welfare, as calculated by equation (8), are also shown. The regressive nature of the tax is again apparent, with inequality, as measured by the Atkinson Index, increasing. In addition, households see a reduction in their level of expenditure of 0.46% and 1.14% for carbon tax increases of €30 and €80 per tonne, respectively. Social Welfare is reduced by 0.57% and 1.34% for the two tax increases. In order to test the sensitivity of this result to the inequality aversion included in equation (8), we perform sensitivities on this value; the results are reported in Tables 14 and 15. The impact on Social Welfare from varying this parameter is not particularly pronounced, suggesting that the changes to Social Welfare are primarily driven by changes to equivalent expenditure rather than inequality aversion on behalf of the social planner. Table 14 also shows the changes in aggregate carbon emissions for the two tax increases. A tax increase of €30 reduces emissions by 3.94%, while a tax increase of €80 decreases emissions by 10.24%.

5.3 Impact of revenue recycling

We now present the results of returning the carbon taxation revenues to households via a revenue recycling mechanism.

The impacts of revenue recycling at aggregate level are presented in Tables 12 and 13. Both the flat and the targeted allocation reduce inequality (relative to the base case of the existing €20 carbon tax with no revenue recycling), as measured by the Atkinson index. However, the reduction is more pronounced under the targeted allocation. Furthermore, Social Welfare is increased under both scenarios, but particularly under the targeted allocation. The results suggest that combining carbon taxation with an appropriate revenue recycling mechanism can not only allay any concerns surrounding the regressive nature of carbon taxation, but that the policy can actually be net progressive, and may prove a useful tool for policy makers seeking to increase the distributive element of a given tax and welfare system.

The costs of the recycling mechanism have not been included here. However, the administration cost of the flat allocation mechanism is likely to be higher, as it entails facilitating a direct cash transfer to each household. The targeted mechanism, however, could be achieved by adjusting the existing taxation and welfare system, which should prove less onerous.

The targeted mechanism outlined here is necessarily crude due to a paucity of income data in the HBS. The general applicability of this research is however enhanced by this.

6 Conclusion

This paper used Irish microdata to estimate an EASI demand system which was in turn used to calculate the impact at household level of an increase in non-ETS carbon taxation. The behavioural response of consumers to carbon taxation was therefore captured. Emissions reduce by 3.94% in response to a carbon tax increase of €30 per tonne, while an increase of €80 per tonne reduces emissions by 10.24%.

The increase in carbon taxation is regressive, as energy expenditure makes up a greater proportion of the total expenditure of poorer households (relative to richer households). However, recycling the carbon taxation revenues mitigates this effect. A flat allocation, where the carbon tax revenue is divided equally amongst all households, yields a small decrease in inequality (as measured by the Atkinson Index) and a subsequent increase in Social Welfare. A targeted allocation, that directs more of the revenue towards poorer households, has more pronounced effects. The results indicate that a carbon tax coupled with appropriate revenue recycling can achieve two separate policy goals that are often thought to be mutually exclusive; namely those of decreasing both carbon emissions and income inequality.

Acknowledgements

Tovar Reaños and Lynch acknowledge funding from the ESRI's Energy Policy Research Centre. We are grateful to Ankita Gaur and Ciarán MacDomhnaill for assistance with data processing and to ESRI seminar participants for helpful comments and suggestions. All remaining errors or omissions are our own.

Appendix I: Results tables

Estimation results

Table 1: Summary statistics

Variable	**Mean**	**Std. Dev.**	**N**
Budget shares:			
Food	0.246	0.128	23456
Housing	0.157	0.141	23456
Energy	0.056	0.049	23456
Transport	0.102	0.075	23456
Education	0.148	0.174	23456
Services	0.292	0.167	23456
Prices (logs):			
Food	4.193	0.289	23456
Housing	3.225	0.533	23456
Energy	3.723	0.432	23455
Transport	3.524	0.565	23456
Education	3.445	0.908	23456
Services	2.832	0.885	23456
Total expenditure	841.5	688.7	23456

Table 2: EASI demand system; linear 3 Stage Least Squares estimation, estimated from equation (4). Estimated from equation (4). Estimates rounded to 3 digits

Regressor:	Dependent variable: budget share for ...				
	Food	Housing	Energy	Transport	Education
Polynomial coefficient:					
y1	0.949***	-0.099	0.358***	0.511**	-1.774***
y2	-0.670**	0.140	-0.293***	-0.599***	1.774***
y3	0.231*	-0.056	0.100**	0.291***	-0.876***
y4	-0.044	0.009	-0.017*	-0.071***	0.230***
y5	0.004	-0.001	0.002	0.009***	-0.030***
y6	-0.000	0.000	-0.000	-0.000***	0.002***
Household types:					
z1	-0.107***	-0.009	-0.013***	-0.019***	0.053***
z2	-0.110***	-0.056***	0.008**	0.014*	-0.023
z3	-0.058***	0.000	0.002	-0.002	0.091***
z4	0.000	0.000	0.000	0.000	0.000
z5	-0.020**	-0.081***	0.003	-0.002	0.021*
z6	-0.006	-0.051***	-0.003	0.001	0.031***
Interaction term:					
yz1	0.017***	0.011***	0.002	0.007***	-0.004
yz2	0.014***	-0.002	-0.002*	-0.008***	0.033***
yz3	0.009**	0.001	0.000	-0.001	-0.022***
yz4	0.000	0.000	0.000	0.000	0.000
yz5	0.004	0.013***	-0.001	0.001	0.002
yz6	0.011***	0.004	0.001	0.006***	-0.008**
Interaction between price and expenditure ($b_{i,j}$):					
ynp1	-0.033***	-0.002	0.008***	0.011***	0.015***
ynp2	-0.002	0.001	0.004***	0.002*	-0.000
ynp3	0.008***	0.004***	-0.027***	0.006***	0.003***
ynp4	0.011***	0.002*	0.006***	-0.026***	0.006***
ynp5	0.015***	-0.000	0.003***	0.006***	-0.051***
Price parameter ($a_{i,j,l}$)					
$a_{1,j,l}$	0.130***	-0.004	-0.024***	-0.035***	-0.049***
$a_{2,j,l}$	-0.004	0.031***	-0.022***	-0.021***	-0.004
$a_{3,j,l}$	-0.024***	-0.022***	0.115***	-0.024***	-0.018***
$a_{4,j,l}$	-0.035***	-0.021***	-0.024***	0.118***	-0.025***
$a_{5,j,l}$	-0.049***	-0.004	-0.018***	-0.025***	0.145***
constant	-0.110	0.226	-0.033	0.059	0.702***
N	23455				
R-squared	0.416	0.260	0.491	0.271	0.399
adjusted R2	220				

$*p < 0.10, **p < 0.05, ***p < 0.01$

Elasticities

Table 3: Uncompensated own price and expenditure elasticities for all households

Elasticity:	Food	Housing	Energy	Transport	Education	Services
Own Price	-1.012***	-0.961***	-0.426***	-0.706***	-1.312***	-1.368***
	(0.007)	(0.009)	(0.013)	(0.011)	(0.009)	(0.017)
Expenditure	0.537***	0.990***	0.211***	0.733***	1.834***	1.253***
	(0.012)	(0.023)	(0.020)	(0.019)	(0.030)	(0.020)

Significance levels: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 4: Uncompensated own price and expenditure elasticities for lowest quartile households

Elasticity:	Food	Housing	Energy	Transport	Education	Services
Own Price	-1.053***	-0.946***	-0.441***	-0.474***	-0.648***	-1.188***
	(0.009)	(0.018)	(0.011)	(0.015)	(0.022)	(0.021)
Expenditure	0.734***	1.397***	0.303***	0.482***	1.936***	1.378***
	(0.018)	(0.055)	(0.022)	(0.035)	(0.095)	(0.024)

Significance levels: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5: Uncompensated own price and expenditure elasticities for highest quartile households

Elasticity:	Food	Housing	Energy	Transport	Education	Services
Own Price	-1.070***	-0.907***	-0.630***	-0.856***	-1.620***	-1.463***
	(0.014)	(0.015)	(0.039)	(0.017)	(0.008)	(0.014)
Expenditure	0.415***	0.801***	0.313***	0.474***	1.780***	1.107***
	(0.021)	(0.029)	(0.049)	(0.027)	(0.024)	(0.016)

Significance levels: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 6: Own- and cross-price elasticities for all households

	Food	Housing	Energy	Transport	Education	Other
Food	-1.012	-0.173	-0.130	-0.140	-0.152	-0.181
Housing	-0.225	-0.961	-0.219	-0.253	-0.188	-0.133
Energy	-0.007	-0.170	-0.426	-0.112	-0.140	-0.219
Transport	-0.096	-0.218	-0.132	-0.706	-0.137	-0.173
Education	-0.290	-0.283	-0.307	-0.299	-1.312	-0.030
Other	-0.405	-0.346	-0.404	-0.398	-0.257	-1.368

All entries are statistically significant at the 1% level with the exception of Food-Energy (which has a standard error of 0.0123).

Distributional impacts of carbon taxation at household level

Table 7: Carbon tax burden as a (%) of total expenditure (increase of €30 per tonne) with no behavioural response

	1st quartile	2nd quartile	3rd quartile	4th quartile
Single no children	0.866	0.544	0.400	0.221
Single +65	1.138	0.708	0.446	0.332
2 adults no children	0.703	0.625	0.496	0.456
2 adults with children	0.734	0.691	0.563	0.441
Single with children	1.138	0.838	0.623	0.464
All households	0.986	0.702	0.578	0.465

Table 8: Carbon tax burden as a (%) of total expenditure (increase of €80 per tonne) with no behavioural response

	1st quartile	2nd quartile	3rd quartile	4th quartile
Single no children	2.309	1.451	1.066	0.589
Single +65	3.034	1.888	1.188	0.885
2 adults no children	1.875	1.667	1.324	1.216
2 adults with children	1.958	1.842	1.502	1.177
Single with children	3.034	2.234	1.662	1.237
All households	2.629	1.871	1.541	1.239

Table 9: Hick's equivalent variation estimates for carbon tax increase of €30 as a (%) of total expenditure

	1st quartile	2nd quartile	3rd quartile	4th quartile
Single no children	-0.834	-0.412***	-0.342***	-0.228***
Single +65	-0.941	-0.576	-0.415	-0.164***
2 adults no children	-0.767***	-0.575	-0.448	-0.477
2 adults with children	-0.770	-0.643	-0.465**	-0.372
Single with children	-1.006	-0.668***	-0.453**	-0.371
All households	-0.879	-0.590**	-0.478	-0.395*

Statistically signicant with respect to the sample mean in each quartile $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 10: Hick's equivalent variation estimates for carbon tax increase of €80 as a (%) of total expenditure

	1st quartile	2nd quartile	3rd quartile	4th quartile
Single no children	-2.052	-1.027***	-0.857***	-0.569***
Single +65	-2.282	-1.406	-1.025	-0.471**
2 adults no children	-1.878	-1.407	-1.104	-1.170
2 adults with children	-1.874	-1.598**	-1.152	-0.916
Single with children	-2.470***	-1.643**	-1.109	-0.924
All households	-2.151*	-1.456	-1.184	-0.975

Statistically signicant with respect to the sample mean in each quartile $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Distributional impacts at aggregate level

Table 11: Social Welfare for different carbon tax levels, initial incidence (Inequality aversion: 1.2)

Tax (€/tonne)	AI	% Δ AI	EI	% Δ EI	SW	% Δ SW	CO2 reduction
+30	0.16	0.40	562.40	-0.46	469.61	-0.54	3.94%
+80	0.17	1.04	558.59	-1.14	465.85	-1.34	10.24%

AI: Atkinson's Index, EI: Equivalent income, SW: Social Welfare

Table 12: Social Welfare with flat reallocation of revenues (Inequality aversion: 1.2)

Tax (€/tonne)	AI	% Δ AI	EI	% Δ EI	SW	% Δ SW
+30	0.16	-0.46	565.93	0.16	473.36	0.25
+80	0.16	-1.05	567.32	0.41	475.08	0.62

Table 13: Social Welfare with targeted reallocation of revenues (Inequality aversion: 1.2)

Tax (€/ tonne)	AI	% Δ AI	EI	% Δ EI	SW	% Δ SW
+30	0.16	-1.62	566.55	0.27	474.97	0.59
+80	0.16	-3.62	568.83	0.68	478.75	1.39

Appendix II:

Sensitivity results on the choice of the inequality aversion parameter

Table 14: Social Welfare for different carbon tax levels, initial incidence (Inequity aversion: 0.2)

Tax (€/tonne)	AI	% Δ AI	EI	% Δ EI	SW	% Δ SW
+30	0.03	0.43	562.40	-0.46	545.23	-0.48
+80	0.03	1.11	558.59	-1.14	541.42	-1.17

Table 15: Social Welfare for different carbon tax levels, initial incidence (Inequity aversion: 2.2)

Tax (€/tonne)	AI	% Δ AI	EI	% Δ EI	SW	% Δ SW
+30	0.28	0.36	562.40	-0.46	406.70	-0.60
+80	0.28	0.94	558.59	-1.14	403.06	-1.49

Appendix III: Results from the robustness checks

Robustness check I: car ownership

Table 16: EASI implicit Marshallian demand system; linear 3 Stage Least Squares estimation, estimates rounded to 3 digits. Estimated from equation (4). Dataset restricted to households that own cars. Bootstrap tandard errors in parentheses.

Regressor:	Dependent variable: budget share for ...				
	Food	Housing	Energy	Transport	Education
Polynomial coefficient:					
y1	1.812	-0.204	0.236	0.216	-2.416
	(0.525)	(0.397)	(0.110)	(0.209)	(0.931)
y2	-1.422	0.239	-0.198	-0.350	2.303
	(0.432)	(0.351)	(0.094)	(0.182)	(0.837)
y3	0.573	-0.102	0.065	0.176	-1.110
	(0.181)	(0.156)	(0.040)	(0.080)	(0.383)
y4	-0.127	0.021	-0.011	-0.043	0.285
	(0.041)	(0.037)	(0.009)	(0.019)	(0.095)
y5	0.015	-0.002	0.001	0.005	-0.037
	(0.005)	(0.004)	(0.001)	(0.002)	(0.012)
y6	-0.001	0.000	0.000	0.000	0.002
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Household types:					
z1	-0.136	-0.052	-0.011	-0.017	0.054
	(0.011)	(0.016)	(0.005)	(0.008)	(0.020)
z2	-0.132	-0.060	-0.002	-0.023	-0.025
	(0.013)	(0.019)	(0.005)	(0.008)	(0.029)
z3	-0.087	0.016	-0.005	-0.007	0.105
	(0.014)	(0.020)	(0.005)	(0.010)	(0.030)
z5	-0.036	-0.097	0.002	-0.006	0.038
	(0.008)	(0.012)	(0.003)	(0.006)	(0.016)
z6	-0.014	-0.058	-0.003	0.001	0.035
	(0.008)	(0.010)	(0.002)	(0.006)	(0.016)
Interaction term:					
yz1	0.024	0.024	0.001	0.006	-0.003
	(0.003)	(0.006)	(0.001)	(0.003)	(0.008)
yz2	0.019	0.003	0.000	0.004	0.040
	(0.004)	(0.007)	(0.001)	(0.003)	(0.012)
yz3	0.018	-0.002	0.002	0.000	-0.025
	(0.004)	(0.007)	(0.001)	(0.003)	(0.011)

yz5	0.008	0.017	-0.001	0.002	-0.002
	(0.002)	(0.004)	(0.001)	(0.002)	(0.006)
yz6	0.013	0.005	0.001	0.006	-0.008
	(0.002)	(0.003)	(0.001)	(0.002)	(0.005)
Interaction between price and expenditure ($b_{i,j}$):					
ynp1	-0.035	-0.001	0.006	0.015	0.015
	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)
ynp2	-0.001	-0.002	0.004	0.002	0.002
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
ynp3	0.006	0.004	-0.025	0.006	0.004
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ynp4	0.015	0.002	0.006	-0.034	0.008
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
ynp5	0.015	0.002	0.004	0.008	-0.057
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Price parameter ($a_{i,j,l}$)					
$a_{1,j,l}$	0.131	-0.009	-0.019	-0.050	-0.049
	(0.009)	(0.005)	(0.004)	(0.005)	(0.005)
$a_{2,j,l}$	-0.009	0.043	-0.021	-0.022	-0.011
	(0.005)	(0.007)	(0.003)	(0.004)	(0.004)
$a_{3,j,l}$	-0.019	-0.021	0.108	-0.023	-0.018
	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)
$a_{4,j,l}$	-0.050	-0.022	-0.023	0.147	-0.030
	(0.005)	(0.004)	(0.003)	(0.006)	(0.003)
$a_{5,j,l}$	-0.049	-0.011	-0.018	-0.030	0.166
	(0.005)	(0.004)	(0.002)	(0.003)	(0.007)
Heckman correction term	0.088	0.028	0.007	-0.028	-0.052
	0.008	0.007	0.003	0.005	0.009
Cons	-0.604	0.238	0.018	0.256	1.076
	(0.253)	(0.177)	(0.051)	(0.095)	(0.415)
N	19862				

$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 17: Hick's equivalent variation estimates for carbon tax of €50 for car owners only as a (%) of total expenditure

	1st quartile	2nd quartile	3rd quartile	4th quartile
Single no children	-0.768	-0.405	-0.284	-0.245
Single +65	-0.934	-0.574	-0.389	-0.229
2 adults no children	-0.959	-0.487	-0.412	-0.471
2 adults with children	-0.668	-0.639	-0.426	-0.360
Single with children	-0.920	-0.572	-0.405	-0.362
All households	-0.836	-0.576	-0.459	-0.381

Table 18: Hick's equivalent variation estimates for carbon tax of €100 for car owners only as a (%) of total expenditure

	1st quartile	2nd quartile	3rd quartile	4th quartile
Single no children	-1.897	-1.000	-0.702	-0.610
Single +65	-2.279	-1.394	-0.961	-0.558
2 adults no children	-2.338	-1.213	-1.020	-1.150
2 adults with children	-1.651	-1.594	-1.056	-0.886
Single with children	-2.257	-1.406	-0.992	-0.891
All households	-2.052	-1.424	-1.132	-0.938

Table 19: Social Welfare for different policies for car owners only (Inequity aversion: 1.2)

Tax (€/tonne)	AI	% Δ AI	EI	% Δ EI	SW	% Δ SW
+30	0.16	0.39	568.20	-0.45	476.33	-0.53
+80	0.16	1.01	564.44	-1.11	472.62	-1.30

Robustness check II: exclusion of various control variables

Table 20: EASI implicit Marshallian demand system; linear 3 Stage Least Squares estimation, estimates rounded to 3 digits. Estimated from equation (4). Excluding various dummy variables

Regressor:	Dependent variable: budget share for ...				
	Food	Housing	Energy	Transport	Education
Polynomial coefficient:					
y1	0.963***	-0.037	0.360***	0.486**	-1.795***
y2	-0.678**	0.085	-0.294***	-0.577***	1.793***
y3	0.231*	-0.032	0.101**	0.281***	-0.884***
y4	-0.044	0.004	-0.018*	-0.069***	0.231***
y5	0.004	-0.000	0.002	0.008***	-0.030***
y6	-0.000	-0.000	-0.000	-0.000***	0.002***
Household types:					
z1	-0.098***	0.000	-0.014***	-0.022***	0.049***
z2	-0.094***	-0.036***	0.006	0.010	-0.032**
z3	-0.053***	0.011	0.001	-0.003	0.087***
z4	0.000	0.000	0.000	0.000	0.000
z5	-0.022**	-0.082***	0.003	-0.001	0.022*
z6	-0.001	-0.043***	-0.004	-0.001	0.028**
Interaction term:					
yz1	0.017***	0.010**	0.002	0.006***	-0.004
yz2	0.014***	-0.005	-0.002	-0.008***	0.034***
yz3	0.010**	0.000	0.000	-0.002	-0.022***
yz4	0.000	0.000	0.000	0.000	0.000
yz5	0.005*	0.013***	-0.001	0.001	0.002
yz6	0.011***	0.002	0.001	0.006***	-0.007**
Interaction between price and expenditure ($b_{i,j}$):					
ynp1	-0.035***	-0.003**	0.008***	0.013***	0.015***
ynp2	-0.003**	0.001	0.004***	0.003***	0.000
ynp3	0.008***	0.004***	-0.027***	0.006***	0.004***
ynp4	0.013***	0.003***	0.006***	-0.028***	0.006***
ynp5	0.015***	0.000	0.004***	0.006***	-0.051***
Price parameter ($a_{i,j,l}$)					
$a_{1,j,l}$	0.142***	0.000	-0.024***	-0.051***	-0.050***
$a_{2,j,l}$	0.000	0.032***	-0.022***	-0.025***	-0.004
$a_{3,j,l}$	-0.024***	-0.022***	0.115***	-0.024***	-0.018***
$a_{4,j,l}$	-0.051***	-0.025***	-0.024***	0.135***	-0.023***
$a_{5,j,l}$	-0.050***	-0.004	-0.018***	-0.023***	0.146***
constant	-0.166	0.168	-0.030	0.097	0.728***
N	23455				
R-squared	0.407	0.252	0.489	0.267	0.398
adjusted R2	195				

$*p < 0.10, **p < 0.05, ***p < 0.01$

References

References

Baker, P., Blundell, R., Micklewright, J., 1989. Modelling household energy expenditures using micro-data. The Economic Journal 99, 720–738. URL: http://www.jstor.org/stable/2233767.

Banks, J., Blundell, R., Lewbel, A., 1996. Tax Reform and Welfare Measurement: Do We Need Demand System Estimation? The Economic Journal 106, 1227–1241. URL: https://doi.org/10.2307/2235517, doi:10.2307/2235517, arXiv:http://oup.prod.sis.lan/ej/article-pdf/106/438/1227/27041503/ej1227.pdf.

Banks, J., Blundell, R., Lewbel, A., 1997. Quadratic engel curves and consumer demand. The Review of Economics and Statistics 79, 527--539. URL: https://ideas.repec.org/a/tpr/restat/v79y1997i4p527-539.html.

Bergin, A., Gerald, J.F., Kearney, I., 2004. The macro-economic effects of using fiscal instruments to reduce greenhouse gas emissions. Environmental Protection Agency Johnstown Castle.

Böhringer, C., Landis, F., Tovar Reaños, M.A., 2017. Cost-effectiveness and incidence of renewable energy promotion in Germany. ZEW Discussion Papers 17-004. ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research. URL: https://ideas.repec.org/p/zbw/zewdip/17004.html.

Callan, T., Lyons, S., Scott, S., Tol, R.S., Verde, S., 2009. The distributional implications of a carbon tax in ireland. Energy Policy 37, 407--412.

Carattini, S., Carvalho, M., Fankhauser, S., 2017. How to make carbon taxes more acceptable. Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, London School of Economics and Political Science, London .

Clements, K.W., Wu, Y., Zhang, J., 2006. Comparing international consumption patterns. Empirical Economics 31, 1--30.

Conefrey, T., Fitz Gerald, J.D., Valeri, L.M., Tol, R.S., 2013. The impact of a carbon tax on economic growth and carbon dioxide emissions in ireland. Journal of Environmental Planning and Management 56, 934--952.

Creedy, J., Sleeman, C., 2006. Carbon taxation, prices and welfare in new zealand. Ecological Economics 57, 333--345.

Deaton, A., 1974. A reconsideration of the empirical implications of additive preferences. The Economic Journal 84, 338--348.

Deaton, A., Muellbauer, J., 1980. An almost ideal demand system. The American Economic Review 70, 312--326. URL: http://www.jstor.org/stable/1805222.

Department of Communications, Climate Action and Environment, 2017. National Mitigation Plan. Technical Report. URL: https://www.dccae.gov.ie/en-ie/climate-action/publications/Pages/National-Mitigation-Plan.aspx.

European Commission, 2018. EU and the Paris Climate Agreement: Taking stock of progress at Katowice COP. Technical Report. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0716&from=EN.

Farrell, N., 2017. What factors drive inequalities in carbon tax incidence? decomposing socioeconomic inequalities in carbon tax incidence in ireland. Ecological Economics 142, 31 -- 45. URL: http://www.sciencedirect.com/science/article/pii/S0921800915305012, doi:https://doi.org/10.1016/j.ecolecon.2017.04.004.

FitzGerald, J., McCoy, D., 1992. The economic effects of carbon taxes. Economic and Social Research Institute. URL: https://www.esri.ie/system/files?file=media/file-uploads/2015-07/JACB199204.pdf.

Joint Committee on Climate Action, 2019. Climate Change: A Cross-Party Consensus for Action. Technical Report. Available online: https://data.oireachtas.ie/ie/oireachtas/committee/dail/32/joint_committee_on_climate_action/reports/2019/2019-03-28_report-climate-change-a-cross-party-consensus-for-action_en.pdf.

King, M.A., 1983. Welfare analysis of tax reforms using household data. Journal of Public Economics 21, 183--214.

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., Stern, N., 2018a. Making carbon pricing work for citizens. Nature Climate Change 8, 669--677.

Klenert, D., Schwerhoff, G., Edenhofer, O., Mattauch, L., 2018b. Environmental taxation, inequality and engel's law: The double dividend of redistribution. Environmental and Resource Economics 71, 605--624. URL: https://doi.org/10.1007/s10640-016-0070-y, doi:10.1007/s10640-016-0070-y.

Kolstad, C., Urama, K., Broome, J., Bruvoll, A., Cariño-Olvera, M., Fullerton, D., Gollier, C., Hanemann, W.M., Hassan, R., Jotzo, F., et al., 2014. Social, economic and ethical concepts and methods. Climate Change 2014: Mitigation of Climate Change , 173--248.

Labandeira, X., Labeaga, J., 1999. Combining input-output analysis and micro-simulation to assess the effects of carbon taxation on spanish households. Fiscal Studies 20, 305--320. URL: http://dx.doi.org/10.1111/j.1475-5890.1999.tb00015.x, doi:10.1111/j.1475-5890.1999.tb00015.x.

Labandeira, X., Labeaga, J., Rodriguez, M., 2006. A residential energy demand system for Spain. The Energy Journal Volume 27, 87--112. URL: http://EconPapers.repec.org/RePEc:aen:journl:2006v27-02-a06.

Lewbel, A., 1989. Identification and Estimation of Equivalence Scales under Weak Separability. Review of Economic Studies 56, 311--316. URL: https://ideas.repec.org/a/oup/restud/v56y1989i2p311-316..html.

Lewbel, A., Pendakur, K., 2009. Tricks with Hicks: The EASI Demand System. American Economic Review 99, 827--63. URL: https://ideas.repec.org/a/aea/aecrev/v99y2009i3p827-63.html.

Nordhaus, W., 2007a. Critical assumptions in the stern review on climate change. Science 317, 201--202.

Nordhaus, W.D., 1993. Reflections on the economics of climate change. Journal of economic Perspectives 7, 11--25.

Nordhaus, W.D., 2007b. A review of the stern review on the economics of climate change. Journal of economic literature 45, 686--702.

O'Donoghue, C., 1997. Carbon Dioxide, Energy Taxes and Household Income. Papers WP090. Economic and Social Research Institute (ESRI). URL: https://ideas.repec.org/p/esr/wpaper/wp090.html.

Pashardes, P., Pashourtidou, N., Zachariadis, T., 2014. Estimating welfare aspects of changes in energy prices from preference heterogeneity. Energy Economics 42, 58--66.

Patt, A., Lilliestam, J., 2018. The case against carbon prices. Joule 2, 2494--2498.

Pigou, A., 1952. The economics of welfare. Routledge.

Pirttilä, J., Uusitalo, R., 2010. A 'leaky bucket'in the real world: estimating inequality aversion using survey data. Economica 77, 60--76.

Pothen, F., Tovar Reaños, M.A., 2018. The distribution of material footprints in germany. Ecological Economics 153, 237 -- 251. URL: http://www.sciencedirect.com/science/article/pii/S0921800918302076, doi:https://doi.org/10.1016/j.ecolecon.2018.06.001.

Salotti, S., Montinari, L., Amores, A.F., Rueda-Cantuche, J.M., 2015. Total expenditure elasticity of non-durable consumption of european households, in: JRC Technical Report EUR 27081 EN. European Union, p. 2015.

Savage, M., 2016. Indirect tax reform and the specification of demand: the case of ireland. International Tax and Public Finance 23, 368--399.

Scott, S., Eakins, J., 2004. Carbon Taxes: Which Households Gain Or Lose?. Environmental Protection Agency.

Stern, N., Stern, N.H., 2007. The economics of climate change: the Stern review. cambridge University press.

Tovar Reaños, M.A., Wölfing, N.M., 2018. Household energy prices and inequality: Evidence from german microdata based on the easi demand system. Energy Economics 70, 84--97.

Varian, H., 1992. Microeconomic theory. W. W. Norton & Company, New York .

Vasilakou, A., 2010. Making climate change work for us: European perspectives on adaptation and mitigation strategies--by mike hulme and henry neufeldt. Geographical Journal 176, 373--373.

Verde, S.F., Tol, R.S., 2009. The distributional impact of a carbon tax in ireland. The Economic and Social Review 40, 317.

Wissema, W., Dellink, R., 2007. Age analysis of the impact of a carbon energy tax on the irish economy. Ecological economics 61, 671--683.

Year	Number	Title/Author(s)
2019		
	625	Have Irish sovereign bonds decoupled from the euro area periphery, and why? *David Cronin, Peter Dunne, Kieran McQuinn*
	623	Modelling anglers' fish release choice using logbook data *Gianluca Grilli, John Curtis, Stephen Hynes*
	622	Recreational angling demand in a mixed resource fishery *Gianluca Grilli, Soumyadeep Mukhopadhyay, John Curtis, Stephen Hynes*
	621	Senior cycle review: analysis of discussions in schools on senior cycle pathways and structures in Ireland *Emer Smyth*
	620	FIR-GEM: A SOE-DSGE model for fiscal policy analysis in Ireland *Petros Varthalitis*
	619	The effects of an incremental increase in the Irish carbon tax towards 2030 *Kelly de Bruin, Aykut Mert Yakut*
	618	Household savings constraints, uncertainty and macroprudential policy *Philip Economides, Kieran McQuinn, Conor O'Toole*
	617	It's not just for boys! Understanding gender differences in STEM *Judith Delaney, Paul Devereux*
	616	Optimal development of electricity generation mix considering fossil fuel phase-out and strategic multi-area interconnection *Desta Fitiwi, Muireann Lynch, Valentin Bertsch*
	615	The effects of spatial position of calorie information on choice, consumption and attention *Deirdre A. Robertson, Pete Lunn*
	614	The determinants of SME capital structure across the lifecycle *Maria Martinez-Cillero, Martina Lawless, Conor O'Toole*
	613	Monetary policy normalisation and mortgage arrears in a recovering economy: The case of the Irish residential market *Rachel Slaymaker, Conor O'Toole, Kieran McQuinn, Mike Fahy*
	612	Can official advice improve mortgage-holders' perceptions of switching? An experimental investigation *Shane Timmons, Martina Barjaková, Terence J. McElvaney, Pete Lunn*

For earlier Working Papers see http://ww.esri.ie