An Analysis of Households Choice of Solid Fuels as a Primary and Supplementary Heating Fuel

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ABSTRACT

The residential sector in Ireland is a large user of solid fuels for space heating purposes. Solid fuels are commonly used to supplement other forms of heating rather than as the primary source. Using a survey data set of Irish households and a multinomial logit approach, differences between the household characteristics of primary and supplementary solid fuel users are identified, including for levels of education, age of dwelling, location and pro-environmental attitudes. Evidence also shows that increases in income lead to a transition away from primary solid fuel use but not supplementary consumption, suggesting that an energy stacking model explains the household's choice of heating fuels in Ireland. Given the established effects that solid fuels have on air quality and the scale of supplementary solid fuel use, policies to promote a transition to cleaner fuels need to account for the clear differences in the features of the two user groups.

Keywords: Solid fuels, Household energy use, Supplementary space heating, Energy ladder, Energy stacking

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1. INTRODUCTION

According to the World Health Organisation (WHO), the combined effects of ambient air pollution and household air pollution is associated with 7 million premature deaths annually.[1] While the issue is most prevalent for developing countries, levels of mortality due to poor air quality are also high in many developed countries. In Europe, it has been estimated that 275,000 premature deaths occurred in 2020 due to exposure from fine particulate matter ($PM_{2.5}$) concentrations above WHO guideline levels (European Environment Agency, 2022). The burning of traditional fuels or solid fuels, such as coal, peat and wood, for home heating purposes has been cited as the leading cause of $PM_{2.5}$ concentrations in Europe. Solid fuel combustion in households has been estimated to contribute more than 45% to total $PM_{2.5}$ emissions, almost three times more than road transport (Amann et al., 2018).

A clear first step in enabling the transition away from solid fuels is to develop a better understanding of this market for home heating. A unique feature of solid fuel use is its flexibility as

1. Source: WHO (https://www.who.int/health-topics/air-pollution#tab=tab_2).

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a primary fuel, but also as a supplementary fuel to heat certain rooms or to create a cosy atmosphere. Although there is evidence to suggest a transition away from the use of solid fuels as the primary fuel for heating is occurring in most developed countries, there is also evidence that its use as a supplementary source of heating is rising, even in urban areas (Amann et al., 2018). This is important because while solid fuels may be supplementary in terms of the heat provided, they could still be the primary particulate matter emission source for the household. There is however very little research internationally on the use of solid fuels as a supplementary source of heating with existing studies almost exclusively examining its use as the primary heating fuel (Chen and Pitt, 2017; Démurger and Fournier, 2011; Laureti and Secondi, 2012; Lillemo and Halvorsen, 2013; Özcan et al., 2013; Song et al., 2012; Song et al., 2018).

This present article addresses this gap in the literature by empirically examining the factors that determine the choice of solid fuel as a primary fuel and a supplementary fuel for home heating. A limited number of studies do consider the possibility of multiple heating fuels or energy stacking (Masera et al., 2000) in their analysis (Braun, 2010; Çelik and Oktay, 2019; Couture et al., 2012; Song et al., 2018; Vaage, 2000) but even at this, only Couture et al. (2012) make the explicit distinction between primary and back-up heating sources. Of relevance is the fact that the authors find a number of effects to differ when wood is defined as a primary energy source or as a back-up. For example, income decreases the probability of choosing wood as the main energy source but increases the probability of choosing wood as the back-up source. This provides evidence to suggest that the characteristics of households that use a solid fuel for primary heating purposes can be different to those households that use a solid fuel for supplementary heating purposes.

The focus of the study is on Ireland because its household sector is a large user of solid fuels, comprising of coal, peat and wood. Figures from Eurostat show that Ireland has a share of 17.2% of these fuels used in the residential sector for space heating, a figure which ranks second behind Poland (40.3%) among EU-27 countries.[2] Recent air quality reports published by the Environmental Protection Agency (EPA) in Ireland, also point to the burning of solid fuels as a strong contributor to $PM_{2.5}$ concentrations across cities, towns and villages in the country (Environmental Protection Agency, 2022) and research has also found that indoor emissions from open fires in households in Ireland, poses substantial hazards to older people's health (Maher et al., 2021). New solid fuel regulations, introduced in October 2022, will look to apply minimum environmental standards on solid fuels and extend the ban on the use of smoky coal nationwide. In tandem, there is the development of Ireland's first National Clean Air Strategy which is aiming to establish a policy framework to reduce air pollution emissions from its main sources. Therefore, lessons from an examination of solid fuel use in Ireland can feed into current national policy as well as policy in other countries with similar issues.

In addition to being a leading consumer of solid fuels, Ireland also uses a range of different solid fuels, with a substantial amount obtained from indigenous sources, specifically peat (sod peat harvested directly from bogs or manufactured peat briquettes) and wood, in addition to imported coal. Consequently, there are several research articles that have examined the determinants of solid fuel use using data from Irish households (Curtis and Pentecost, 2015; Curtis et al., 2018; Fu et al., 2014; McCoy and Curtis, 2018). Earlier studies examined the income effect and find coal and peat to be inferior goods with negative income elasticities while later studies have found strong positive effects for the proximity to a solid fuel resource, such as a peat bog, and negative effects for the presence of legislated solid-fuel sale restrictions, such as the smoky coal ban, and the availability of

2. Source: Eurostat. (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households#Energy_consumption_in_households_by_type_of_end-use). Figures refer to the year 2020.

the gas network in the locality. This, however, is the first study to examine the choice of solid fuels for home heating for both primary and supplementary use based on a data set of a representative survey of households in Ireland and is timely given the contemporary nature of this topic on the current policy agenda.

2. DATA AND METHODS

The data set to be analysed is a survey administered by the national statistics agency in Ireland, the Central Statistics Office (CSO), on the behaviours of households in relation to environmental awareness, waste management, and energy use, known as the *CSO Survey on Household Environmental Behaviours* (Central Statistics Office, 2016). The survey was carried out between April and June 2014 and the data set is based on responses from individuals representing 13,032 households.[3] The survey asked respondents to first identify the primary fuel or energy source that is used to heat their home and then whether any supplemental heating is used to heat their home, where respondents indicate both the appliance and fuels used for supplementary heating.

The methodology of this study follows that used by Couture et al. (2012). They define energy regimes based on different types of energy used by a household and types of use (i.e., energy for primary heating proposes and supplementary heating purposes). Given that the emphasis is on examining the factors determining the choice of solid fuels, they will be the focus in how the energy regimes are defined. Table 1 summaries the number and proportion of households in the sample using this categorization. Over a third of households do not use a solid fuel for either primary or supplemental heating. A little over 16% of households are recorded as using solid fuels for primary heating purposes, while close to half of households (46.95%) in the survey use solid fuels for supplementary heating purposes, highlighting the scale of this type of use. Of those that use solid fuels for supplementary heating, using oil as the primary fuel is the most common combination.

Table 1: Number and Proportion of Households Using Primary and Supplementary Solid Fuel Heating Combinations, CSO 2014

Solid Fuel Combinations	n	%
Non-Solid Fuel users (Primary or Supplemental)	4,782	36.86
Solid Fuel Primary users	2,100	16.18
Gas Primary, Solid Fuel Supplemental	1,612	12.42
Oil Primary, Solid Fuel Supplemental	4,147	31.96
Other[a] Primary, Solid Fuel Supplemental	334	2.57
N[b]	12,975	100.00

[a]Includes electricity, lpg (liquefied petroleum gas), heat pumps, district heating and other unspecified heating methods.
[b]Total sample excludes 57 households who recorded no primary fuels or no supplemental fuels

Previous research, particularly in an Irish context, has tended to treat solid fuels as one homogenous product. As previously mentioned however, Ireland is unique in the range of solid fuels that are used. Such an approach is therefore limiting as it does not allow for the possibility

3. A twostage sample design is used. In the first stage 1,300 blocks are selected using Probability Proportional to Size (PPS) sampling and in the second stage 20 households are selected using Simple Random Sampling (SRS). This ensures that each household in the sample frame has an equal probability of selection. The actual achieved sample varies over time depending on the level of response.

of differences within the group of solid fuels users. This can be important for the design of policy to disincentivise the use of solid fuel by accounting for any possible heterogeneity with the overall group of solid fuel users. In addition, where research has provided an analysis of fuel heating combinations, the focus of the research has been on examining solid fuels as an aggregate (Braun, 2010) or singular specific solid fuels such as wood (Vaage, 2000 and Couture et al., 2012). Thus, this research will advance on previous studies in examining a broader range of solid fuels but also in the context of their use as both primary and supplementary fuels.

Table 2 defines the energy regimes using coal, peat and wood as the focus, in a similar way to the categories shown in Table 1.[4] Coal is the most popular solid fuel (used by 41.23% of households either as primary or supplementary fuel), followed by wood (37.85%) which is predominately as a supplementary fuel, and then peat (27.48%) which is used more as a primary fuel rather than as a supplementary fuel. In terms of fuel combinations, the most popular primary fuel is oil followed by gas, across all of the individual solid fuels.

Table 2: Number and Proportion of Households Using Primary and Supplementary Coal, Peat and Wood Heating Combinations, CSO 2014

Coal combinations	n	%
Non-Coal users (Primary or Supplemental)	7,621	58.77
Coal Primary users	878	6.77
Peat/Wood Primary, Coal Supplementary	190	1.47
Gas Primary, Coal Supplementary	1,194	9.21
Oil Primary, Coal Supplemental	2,893	22.31
Other[a] Primary, Coal Supplemental	192	1.48
N[b]	12,968	100.00
Peat combinations	**n**	**%**
Non-Peat users (Primary or Supplemental)	9,404	72.52
Peat Primary users	892	6.88
Coal/Wood Primary, Peat Supplementary	229	1.77
Gas Primary, Peat Supplementary	638	4.92
Oil Primary, Peat Supplemental	1,665	12.84
Other[a] Primary, Peat Supplemental	140	1.08
N[b]	12,968	100.00
Wood combinations	**n**	**%**
Non-Wood users (Primary or Supplemental)	8,059	62.15
Wood Primary users	330	2.54
Coal/Peat Primary, Wood Supplementary	526	4.06
Gas Primary, Wood Supplementary	1,029	7.93
Oil Primary, Wood Supplemental	2,803	21.61
Other[a] Primary, Wood Supplemental	221	1.70
N[b]	12,968	100.00

[a]Includes electricity, lpg (liquefied petroleum gas), heat pumps, district heating and other unspecified heating methods.
[b]Total sample excludes 64 households who recorded no primary solid fuels or no supplementary solid fuels

4. In the survey questionnaire, respondents could choose multiple fuels when asked to indicate what supplementary fuels they used.

In line with the approach taken by Couture et al. (2012), the data presented in Tables 1 and 2 will be the dependent variables in our models. Given that each represents a set of unordered categorical variables, an obvious choice for the estimation technique is the multinomial logit model (MNL). First formalised by McFadden (1974), the MNL model is a widely applied estimation technique on the choice of fuel or energy source for home heating and cooking (Braun, 2010; Couture et al., 2012; Curtis, et al., 2018; Laureti and Secondi, 2012; Pérez et al., 2020; Song et al., 2018). In the MNL model, the probability that the observed choice (y_i) is alternative j is given by:

$$P\{y_i = j\} = \frac{exp\{X_i\beta_j\}}{1+\sum_{k=1}^{J} exp\{X_i\beta_k\}} \; j = 0,1,2,\ldots,J \tag{1}$$

In practice the parameters specific to one alternative have to be set to zero in order to ensure the probabilities sum to one. Thus, slope coefficients (plus an intercept term) are estimated for all but one of the alternatives. This is somewhat restrictive, so an alternative approach is to estimate average marginal effects using the following formula:

$$\frac{dP\{y_i=j\}}{dx_i} = P\{y_i = j\}\left(\beta_j - \sum\nolimits_1^J \beta_J P\{y_i = j\}\right) \tag{2}$$

where β_j is the coefficient on x_i in alternative j. Marginal effects represent the change in the probability of being in a particular primary and supplementary heating category for a unit change in an explanatory variable. In the case of the discrete (or dummy) variables the unit change is a move from 0 to 1.

The *CSO Survey on Household Environmental Behaviours* data set contains a number of variables which can be used to characterise the decision maker of the household, the dwelling and the household's location. These include characteristics of the respondent such as age, highest education level completed and employment status, dwelling characteristics such as whether the dwelling has had a building energy rating (BER) audit conducted or not, the year of construction, the dwelling type, occupancy status and the number of rooms in the dwelling, and location characteristics including regional location and urban/rural location. The data set also records a number of variables related to attitudes to the environment including the number of energy saving products the household has installed in the last 10 years and the number of local and national environmental initiatives the respondent is familiar with. Table A1 in the appendix provides more information and descriptive statistics for the explanatory variables used in the analysis.

A limitation of the *CSO Survey on Household Environmental Behaviours* data set is the fact that household income is not directly recorded. Having household income as a variable allows one to examine the energy ladder model hypothesis (Leach, 1992). This assumes that households will shift their fuel usage to newer, cleaner, and more expensive fuels, as their income increases. The shift to more environmentally friendly fuels can also be related to the environmental Kuznets curve (EKC) hypothesis, where a positive relationship between environmental quality and incomes occurs as households transition to higher levels of income. While research shows a clear relationship between income and the choice of fuel used for home heating (Laureti and Secondi, 2012; Özcan et al., 2013), the energy ladder model has been criticised for placing too much of an emphasis on economic factors and the assumption that fuel transition occurs in a series of simple, discrete phases.

The energy stacking model mentioned previously, in contrast, assumes that households use a combination of fuels which may include those at both the bottom and top of the energy ladder. As such, it views modern fuels as partial, rather than perfect, substitutes for primitive fuels (van der Kroon et al., 2013). Several complementary reasons are put forward for energy stacking

behaviour including ensuring a consistent and secure supply of fuel and to insulate against the effects of fluctuating energy prices. Culture and social practices is another suggested explanation. Reeve et al. (2013), for example, examined how households justified their use of wood heaters in a location with a severe air pollution problem by describing wood burning as a natural and traditional activity promoting comfort and cohesion.

To allow for an analysis of the energy ladder and energy stacking models, a method to impute household income values into the *CSO Survey on Household Environmental Behaviours* data set is employed. This involves using a separate data set collected by the CSO, the *Household Budget Survey* (Central Statistics Office, 2017) which gives detailed information on a wide range of household and house characteristics, including household disposable income. The most recent HBS was collected during 2015/16, which is also not too distant from when the *CSO Survey on Household Environmental Behaviours* data was collected. To calculate the imputed household income values, a model predicting household disposable income using the HBS data set is first estimated, using explanatory variables that are common to both data sets. These include gender, work status and education of the household reference person, the number of workers in the household, the number of rooms in the dwelling and the ownership status of the dwelling. The estimated coefficients from the predictive model are then used to impute household income values in the *CSO Survey on Household Environmental Behaviours* data set for the same independent variables. A similar procedure was used by Curtis and Pentecost (2015) in estimating predicted household energy efficiency values from one data set to examine its relationship with Irish household energy expenditures in a different data set. Couture et al. (2012) also generated imputed household income values in their study, for those households that did not state their level of household income in the survey they collected to examine household energy choices and fuelwood consumption.

Table A2 in the appendix displays the results from the model to predict the natural logarithm of household disposable income using the HBS data set. The estimated coefficients are all plausible both in terms of sign and magnitude and approximately 41% of the variation in the natural logarithm of household disposable income is explained by the model, which is reasonable given that the data is cross sectional so low R-squares are not unexpected and the choice of explanatory variables is restricted to those that also appear in the *CSO Survey on Household Environmental Behaviours* data set. Figure A1 in the Appendix displays a plot of the observed values of the natural logarithm of household disposable income against the estimated residuals. Overall, the predicted natural log household disposable income values are within 5% of the observed natural log household disposable income values for 51% of observations and within 10% of the observed natural log household disposable income values for 83% of observations. The larger errors at very low levels of disposable income, correspond to a small proportion of the overall income distribution with approximately 1.4% of observed natural log household disposable income values being below 5 or approximately €150 per week.

3. ECONOMETRIC RESULTS

This section presents econometric results from estimating multinomial logit models using the data presented in Tables 1 and 2 as dependent variables. The results are presented as marginal effects and elasticities (for the household income variable) and the estimates for categories which include the use of solid fuels will be the focus of the discussion.

Table 3 examines the choice of solid fuels used for primary and supplementary heating where solid fuels are treated as one aggregate category. Very old individuals (aged 75+) are less likely to use solid fuels, supporting findings in previous literature (Özcan et al., 2013) which cite health

Table 3: Multinomial Logit Estimates, Primary and Supplementary Solid Fuel Combinations

	Solid Fuel - Not Used	Solid Fuel - Pri	Gas Pri-Solid Fuel Suppl	Oil Pri-Solid Fuel Suppl	Other Fuel Pri-Solid Fuel Suppl
Age of Respondent					
Under 35 (ref)					
35–54	–0.017*	0.017	0.010	–0.012	0.001
55–74	–0.009	–0.003	–0.004	0.011	0.005
75 +	0.092***	–0.060***	–0.036***	0.004	0.000
Education Level					
Primary (ref)					
Secondary	0.007	–0.060***	0.013	0.040***	–0.001
Tertiary	0.019	–0.087***	0.017*	0.048***	0.002
Unknown	0.054*	–0.046*	0.006	–0.027	0.013
BER Completed					
No/Unknown (ref)					
Yes	0.035***	–0.028***	–0.001	–0.005	–0.002
Construction Period					
Before 1960 (ref)					
1961–1980	0.038***	–0.041***	–0.039***	0.051***	–0.009**
1981–2000	0.039***	–0.032***	–0.027***	0.028**	–0.007*
2001 or later	0.069***	–0.094***	0.020**	–0.003	0.008
Unknown	0.108***	–0.057***	–0.066***	0.026	–0.010*
Dwelling Type					
Apartment (ref)					
Bungalow	–0.501***	0.109***	0.065***	0.341***	–0.015
Detached	–0.512***	0.073***	0.124***	0.336***	–0.021*
Semi-Detached	–0.456***	0.075***	0.142***	0.266***	–0.027**
Terraced/Other	–0.414***	0.105***	0.130***	0.196***	–0.017
Occupancy Status					
Rented/Other (ref)					
Owner Occupied	0.045***	–0.037***	–0.036***	0.024**	0.003
Region					
Dublin (ref)					
Border	–0.324***	0.153***	–0.082***	0.272***	–0.019***
Mid-East	–0.276***	0.094***	0.026**	0.174***	–0.018***
Mid-West	–0.283***	0.116***	–0.043***	0.220***	–0.009
Midland	–0.420***	0.323***	–0.077***	0.175***	0.000
South-East	–0.373***	0.109***	–0.053***	0.316***	0.001
South-West	–0.340***	0.102***	0.022**	0.213***	0.002
Western	–0.395***	0.268***	–0.114***	0.244***	–0.003
Urban/Rural					
Urban Areas (ref)					
Rural Areas	–0.118***	0.132***	–0.154***	0.126***	0.015***
Energy Saving					
0 Products (ref)					
1–2 Products	–0.009	–0.002	0.012	0.012	–0.013***
3–4 Products	–0.050***	0.003	0.026**	0.024*	–0.003
5 + Products	–0.064***	0.018	0.052***	–0.014	0.008
Environmental Initiatives					
0 initiatives (ref)					
1–2 initiatives	–0.047***	0.004	0.024**	0.005	0.014***
3–4 initiatives	–0.087***	0.013	0.036***	0.020	0.017***
5–6 initiatives	–0.098***	0.002	0.055***	0.018	0.023***
ln Disposable Income	0.068	–0.546***	0.234***	0.116**	–0.097
No. of Observations			12,975		
Pseudo R^2			0.2574		
LR χ^2 T-Stat			9220.44***		

***p-value<0.01, **p-value<0.05, * p-value<0.10

Pri – Indicated by respondents to be the Primary Fuel used. Suppl - Indicated by respondents to be the Supplementary Fuel used.

concerns and ease of use as reasons why older household members did not choose the traditional solid fuels. Those who are less educated are more likely to use solid fuels for primary heating purposes, a finding which is common in previous research (Chen and Pitt, 2017; Laureti and Secondi, 2012). Interestingly the effect is either not present or the opposite for those households using solid fuels as a supplementary fuel, highlighting one difference between primary and supplementary solid fuel users. The common assumption is that education can be linked to greater awareness about the health and environmental issues arising from solid fuel use and while this can be used to explain its negative association with primary solid fuel use, it does not help to explain the lack of or positive association with supplementary solid fuel use. Other reasons, like convenience or aesthetics, may explain why highly educated individuals choose solid fuels as a supplementary fuel.

A dwelling with a BER audit is less likely to choose solid fuels for primary heating purposes indicating that households using solid fuels for primary heating purposes are more likely to be living in energy inefficient dwellings. This finding supports previous work on Irish households by Curtis and Pentecost (2015). The same effect is not present however for households using solid fuels for supplementary purposes. Differences are also present by year of construction. Households living in very old dwellings (built before 1960) are more likely to use solid fuels as a primary fuel while households living in dwellings built between 1960 and 2000 are more likely to use an oil-solid fuel combination, and households living in newer dwellings being more likely to use a natural gas-solid fuel combination. Therefore, even though newer homes are transitioning to the use of modern fuels there is still a demand for traditional fuels as a back-up. These results stand in contrast to Braun (2010) who found that newly built dwellings were less likely to use multiple fuels (i.e., oil-solid fuel and gas-solid fuel) for heating.

In comparison to detached dwellings, semi-detached, terraced and apartments are all more likely to not use solid fuels, and are less likely to use an oil-solid fuel combination. There are particularly strong effects for apartments to not use solid fuels (except when it is combined with a fuel other than natural gas and oil, presumably electricity), which is not surprising given the lack of infrastructure for solid fuel use in apartments (Arabatzis and Malesios, 2011; Couture et al., 2012; Damette et al., 2018; Lillemo and Halvorsen, 2013). Owner occupiers are less likely to use solid fuel for primary heating and a natural gas-solid fuel combination, possibly reflecting the extent of renters, including those in local authority houses, that use these fuel options.

Both variables representing location effects generate large estimated marginal effects including for solid fuels as a primary fuel in the Midland and Western regions and for an oil-solid fuel combination in the South-East region. Households using a natural gas-solid fuel combination are more likely to be located in the Dublin, Mid-East or South-West regions, reflecting the availability of the natural gas pipeline in these regions. Being in a rural area, increases the likelihood of using solid fuels for primary and supplementary heating purposes, except where natural gas is used as the primary fuel. The fact that location has a strong association with fuel choice supports much of previous international (An et al, 2002; Arabatzis and Malesios, 2011; Peng et al., 2010; Song et al., 2012) and Irish research (Fu et al., 2014; McCoy and Curtis, 2018) and highlights the importance that proximity to a fuel resource plays.

Solid fuel primary users do not exhibit any evidence of an association with higher levels of adoption of energy saving products or higher levels of awareness of environmental initiatives, whereas there is some evidence of such positive environmental behaviors for solid fuel supplementary users, particularly those that use natural gas or other fuels as their primary fuel. Previous research is contradictory on the effect that attitudes to the environment has on solid fuel use. Curtis et al. (2018) and Lillemo and Halvorsen (2013) did not find any significant relationship, while in contrast, Damette

et al. (2018), found environmental considerations to positively influence the choice of wood. The novel finding in this study is that the effect may depend on whether the solid fuel is used for primary or supplementary purposes. The fact that supplementary solid fuel use is positively associated with good environmental behaviors for certain households, seems a contradictory result. One can reason however, that supplementary solid fuel users are less aware of the negative environmental effects associated with solid fuel use and/or choose to use solid fuels for other reasons such as fuel security or a hedonic choice as per the energy stacking theory. There may therefore be a role for policy makers to emphasize the negative effects of solid fuel use, particularly to those cohorts with pro-environmental behaviors that may respond more favorably to such guidelines.[5]

The estimated income elasticities show a strong association between income and fuel choices, in line with the energy ladder theoretical model. Increases in household income are negatively associated with using solid fuel as a primary source of heating and positively associated with using oil or natural gas. Interestingly, in the context of this study, increases in household income are positively associated with using solid fuels as a supplemental source of heating for oil and natural gas primary users. These findings suggest that the energy stacking theory is the more plausible framework as modern fuels (e.g., natural gas) are being used in combination with traditional fuels (e.g., solid fuels) as income increases, a finding which supports the results of Çelik and Oktay (2019).

As previously mentioned, examining solid fuels as one aggregate category may be limiting given the possibility of heterogeneity among solid fuel users. Tables 4, 5, and 6, estimate multinomial logit models in a similar fashion to Table 3, but with the focus on coal, peat and wood respectively. The objective is twofold, to see whether the differences between primary and supplementary solid fuel users identified in Table 3, are still present when looking at individual solid fuels and to see whether evidence of heterogeneity between coal, peat and wood users exists.

For several variables, a similar pattern emerges to that seen already in Table 3. For example, older respondents are less likely to use coal and peat as a primary fuel and coal, peat and wood as supplementary fuels if natural gas is used as a primary fuel. Additionally, each individual solid fuel is more likely to be used by rural households as primary fuels and supplementary fuels, except when natural gas is used as the primary fuel. There is also evidence of differences between primary and supplementary solid fuel users, even when examining the solid fuel on an individual basis. For example, the effect of education is negative if coal, peat or wood is used as a primary fuel but positive if they are used as supplementary fuels with either natural gas or oil as the primary fuel. Having a BER completed means that a household is less likely to use either coal or peat as a primary fuel, but no effect is present for their use as a supplementary fuel. Wood use is slightly different in that there is no effect for having a BER completed for its use as either a primary or supplementary fuel.

A number of differences in examining the individual solid fuels also emerge. These results illustrate examples of heterogeneity between the users of each type of solid fuel. For example, there is evidence for the use of coal as a supplementary fuel in newly built dwellings, when natural gas or oil are the primary fuels. Peat on the other hand is used in older dwellings, whether that be as a primary or a supplementary fuel. While wood use as a primary fuel is likely in older dwellings, there is less of an obvious pattern for its use as a supplementary fuel.

5. The possibility that pro-environmental behaviours are directly related to household income, as hypothesised in the literature on the Environmental Kuznets Curve (EKC), was examined. Additional MNL models were estimated with interaction terms for both variables also included. The estimated results did not however differ substantially from the results presented with insignificant interaction terms and the estimated income elasticities being of a similar sign and magnitude to the initial set of results. This suggests that pro-environmental behaviours are present across all levels of household's income.

Table 4: Multinomial Logit Estimates, Primary and Supplementary Coal Combinations

	Coal - Not Used	Coal - Pri	Peat or Wood Pri – Coal Suppl	Gas Pri-Coal Suppl	Oil Pri-Coal Suppl	Other Fuel Pri-Coal Suppl
Age of Respondent						
Under 35 (ref)						
35–54	–0.020	0.018**	–0.004	0.009	–0.003	0.000
55–74	–0.007	0.002	–0.002	–0.002	0.008	0.002
75 +	0.057***	–0.020**	–0.008	–0.027**	0.000	–0.002
Education Level						
Primary (ref)						
Secondary	–0.018	–0.023***	–0.008**	0.014*	0.037***	–0.002
Tertiary	0.003	–0.032***	–0.011***	0.012	0.034***	–0.005
Unknown	0.038	–0.014	–0.003	0.001	–0.013	–0.009
BER Completed						
No/Unknown (ref)						
Yes	0.030***	–0.015***	0.000	–0.008	–0.004	–0.004
Construction Period						
Before 1960 (ref)						
1961–1980	–0.019	0.002	–0.002	–0.029***	0.052***	–0.004
1981–2000	–0.022*	0.006	–0.003	–0.023***	0.044***	–0.002
2001 or later	–0.027**	–0.023***	–0.009***	0.028***	0.027***	0.003
Unknown	0.047**	–0.006	–0.009**	–0.048***	0.022	–0.006
Dwelling Type						
Apartment (ref)						
Bungalow	–0.335***	0.056***	0.006	0.034***	0.240***	0.000
Detached	–0.392***	0.037***	0.011*	0.096***	0.248***	–0.001
Semi-Detached	–0.380***	0.061***	0.009	0.111***	0.202***	–0.002
Terraced/Other	–0.352***	0.081***	0.005	0.099***	0.162***	0.004
Occupancy Status						
Rented/Other (ref)						
Owner Occupied	0.058***	–0.025***	0.000	–0.035***	0.010	–0.007
Region						
Dublin (ref)						
Border	–0.367***	0.123***	0.010***	–0.040***	0.272***	0.002
Mid-East	–0.210***	0.058***	0.011***	0.036***	0.110***	–0.005*
Mid-West	–0.255***	0.058***	0.016***	–0.011	0.194***	–0.001
Midland	–0.031*	0.028***	0.013***	–0.061***	0.052***	–0.001
South-East	–0.454***	0.093***	0.019***	–0.013	0.340***	0.015***
South-West	–0.404***	0.072***	0.021***	0.065***	0.230***	0.014***
Western	–0.099***	0.057***	0.015***	–0.080***	0.108***	–0.001
Urban/Rural						
Urban Areas (ref)						
Rural Areas	0.030***	0.030***	0.018***	–0.122***	0.045***	0.000
Energy Saving						
0 Products (ref)						
1–2 Products	–0.025**	–0.006	0.002	0.016**	0.016	–0.003
3–4 Products	–0.046***	–0.002	–0.001	0.029***	0.017	0.002
5 + Products	–0.013	–0.020**	0.006	0.034***	–0.015	0.007
Environmental Initiatives						
0 initiatives (ref)						
1–2 initiatives	–0.054***	0.005	0.008**	0.027***	0.006	0.008***
3–4 initiatives	–0.085***	0.016*	0.008**	0.036***	0.015	0.010***
5–6 initiatives	–0.091***	0.005	0.008**	0.052***	0.016	0.010***
ln Disposable Income	0.077***	–0.851***	–0.238	0.084	0.048	–0.153
No. of Observations			12,968			
Pseudo R^2			0.1821			
LR χ^2 T-Stat			3696.22***			

***p-value<0.01, **p-value<0.05, * p-value<0.10

Note: Pri – Indicated by respondents to be the Primary Fuel used. Suppl - Indicated by respondents to be the Supplementary Fuel used.

Table 5: Multinomial Logit Estimates, Primary and Supplementary Peat Combinations

	Peat - Not Used	Peat - Pri	Coal or Wood Pri – Peat Suppl	Gas Pri-Peat Suppl	Oil Pri-Peat Suppl	Other Fuel Pri-Peat Suppl
Age of Respondent						
Under 35 (ref)						
35–54	0.000	–0.002	0.002	0.006	–0.005	0.000
55–74	–0.005	–0.009	0.000	0.004	0.011	–0.001
75 +	0.016	–0.032***	–0.004	–0.015*	0.034**	0.000
Education Level						
Primary (ref)						
Secondary	0.007	–0.024***	–0.011***	0.005	0.021**	0.002
Tertiary	0.01	–0.038***	–0.016***	0.021***	0.019**	0.004
Unknown	0.033	–0.055***	0.007	0.007	0.004	0.004
BER Completed						
No/Unknown (ref)						
Yes	0.032***	–0.014**	–0.005	–0.009*	–0.003	–0.002
Construction Period						
Before 1960 (ref)						
1961–1980	0.038***	–0.025***	–0.004	–0.021***	0.017*	–0.005*
1981–2000	0.035***	–0.014**	–0.005	–0.023***	0.011	–0.004
2001 or later	0.058***	–0.045***	–0.014***	–0.002	0.001	0.001
Unknown	0.078***	–0.021**	–0.004	–0.038***	–0.012	–0.003
Dwelling Type						
Apartment (ref)						
Bungalow	–0.250***	0.064***	0.010**	0.034***	0.145***	–0.003
Detached	–0.235***	0.042***	0.010***	0.047***	0.142***	–0.006
Semi-Detached	–0.210***	0.026**	0.025***	0.058***	0.112***	–0.012**
Terraced/Other	–0.178***	0.030**	0.018***	0.051***	0.083***	–0.005
Occupancy Status						
Rented/Other (ref)						
Owner Occupied	0.035**	0.011	–0.013**	–0.021**	–0.017	0.005*
Region						
Dublin (ref)						
Border	–0.075***	0.042***	0.031***	–0.061***	0.071***	–0.008**
Mid-East	–0.147***	0.030***	0.015***	0.017**	0.091***	–0.006*
Mid-West	–0.144***	0.046***	0.017***	–0.039***	0.123***	–0.004
Midland	–0.421***	0.274***	0.007*	–0.031***	0.162***	0.01
South-East	0.009	–0.002	0.015***	–0.057***	0.039***	–0.004
South-West	–0.008	0.015***	0.012***	–0.039***	0.024***	–0.004
Western	–0.383***	0.197***	0.020***	–0.049***	0.207***	0.009*
Urban/Rural						
Urban Areas (ref)						
Rural Areas	–0.065***	0.053***	0.017***	–0.057***	0.048***	0.004
Energy Saving						
0 Products (ref)						
1–2 Products	–0.025**	0.002	–0.002	0.010*	0.023***	–0.009***
3–4 Products	–0.046***	–0.002	0.003	0.015**	0.036***	–0.006*
5 + Products	–0.040***	0.009	0.002	0.023***	0.008	–0.002
Environmental Initiatives						
0 initiatives (ref)						
1–2 initiatives	–0.043***	–0.008	0.005	0.017**	0.024*	0.005**
3–4 initiatives	–0.070***	–0.011	0.010**	0.025***	0.037***	0.008***
5–6 initiatives	–0.053***	–0.025**	0.007	0.030***	0.030**	0.011***
ln Disposable Income	0.021	–0.432***	–0.584***	0.335**	0.068	–0.021
No. of Observations			12,968			
Pseudo R^2			0.2197			
LR χ^2 T-Stat			3384.78***			

***p-value<0.01, **p-value<0.05, * p-value<0.10

Note: Pri – Indicated by respondents to be the Primary Fuel used. Suppl - Indicated by respondents to be the Supplementary Fuel used.

Table 6: Multinomial Logit Estimates, Primary and Supplementary Wood Combinations

	Wood - Not Used	Wood - Pri	Coal or Peat Pri – Wood Suppl	Gas Pri-Wood Suppl	Oil Pri-Wood Suppl	Other Fuel Pri-Wood Suppl
Age of Respondent						
Under 35 (ref)						
35–54	–0.008	–0.001	0.007	0.007	–0.007	0.001
55–74	0.000	0.002	–0.004	–0.007	0.007	0.002
75 +	0.065***	–0.008	–0.024***	–0.028***	–0.007	0.002
Education Level						
Primary (ref)						
Secondary	0.01	–0.012**	–0.022***	0.008	0.015	0.000
Tertiary	0.006	–0.015***	–0.034***	0.014*	0.028**	0.001
Unknown	0.008	0.008	–0.023	0.008	–0.011	0.01
BER Completed						
No/Unknown (ref)						
Yes	–0.005	0.004	–0.008	0.010	–0.002	0.001
Construction Period						
Before 1960 (ref)						
1961–1980	0.036***	–0.018***	–0.006	–0.029***	0.026**	–0.010***
1981–2000	0.042***	–0.022***	0.001	–0.015**	0.002	–0.007*
2001 or later	0.051***	–0.024***	–0.022***	0.008	–0.015	0.003
Unknown	0.093***	–0.022***	–0.009	–0.047***	–0.008	–0.008
Dwelling Type						
Apartment (ref)						
Bungalow	–0.289***	0.003	0.024***	0.040***	0.223***	–0.001
Detached	–0.382***	0.010	0.028***	0.090***	0.256***	–0.003
Semi-Detached	–0.285***	0.002	0.036***	0.092***	0.162***	–0.007
Terraced/Other	–0.221***	–0.003	0.032***	0.083***	0.112***	–0.003
Occupancy Status						
Rented/Other (ref)						
Owner Occupied	0.044***	–0.010	–0.018**	–0.024**	0.006	0.002
Region						
Dublin (ref)						
Border	–0.159***	0.003	0.050***	–0.065***	0.180***	–0.010**
Mid-East	–0.195***	0.012**	0.037***	0.014	0.144***	–0.011**
Mid-West	–0.226***	0.022***	0.053***	–0.023**	0.175***	–0.001
Midland	0.023	0.003	0.034***	–0.077***	0.027**	–0.010*
South-East	–0.309***	0.030***	0.040***	–0.047***	0.281***	0.005
South-West	–0.269***	0.025***	0.048***	0.01	0.184***	0.003
Western	–0.015	0.001	0.042***	–0.084***	0.064***	–0.009*
Urban/Rural						
Urban Areas (ref)						
Rural Areas	–0.077***	0.034***	0.030***	–0.098***	0.100***	0.011***
Energy Saving						
0 Products (ref)						
1–2 Products	–0.027**	0.000	0.001	0.012	0.023**	–0.009***
3–4 Products	–0.068***	0.004	0.004	0.021**	0.037***	0.002
5 + Products	–0.093***	0.018***	–0.002	0.045***	0.022	0.010*
Environmental Initiatives						
0 initiatives (ref)						
1–2 initiatives	–0.042**	0.004	0.016***	0.017	–0.001	0.006
3–4 initiatives	–0.085***	0.006	0.022***	0.025**	0.024	0.008**
5–6 initiatives	–0.113***	0.017***	0.013**	0.036***	0.034**	0.013***
ln Disposable Income	–0.035	0.077	–0.770***	0.288***	0.127**	0.030
No. of Observations			12,968			
Pseudo R^2			0.1878			
LR χ^2 T-Stat			3636.27***			

***p-value<0.01, **p-value<0.05, * p-value<0.10

Note: Pri – Indicated by respondents to be the Primary Fuel used. Suppl - Indicated by respondents to be the Supplementary Fuel used.

Regional effects also show evidence of heterogeneity. Coal as a primary fuel is used in regions outside of Dublin (as well as its use as a supplementary fuel with peat or wood as the primary fuel). As a supplementary fuel with natural gas, this pattern is much less pronounced, being dictated by the availability of the natural gas pipeline. As a supplementary fuel with oil, there are strong regional effects for coal use for the Border, South-East and South-West regions, which is possibly linked to easier access to coal imports and urban coal markets.[6] Peat use as a primary fuel and a supplementary fuel with oil is strongly associated with the Midland and Western regions, which is where the majority of peat bogs are located. The regional effect is not as important for the use of wood with similarly sized marginal effects across the different categories. For wood, it appears that the rural effect dominates.

There is no evidence to suggest that primary users of coal and peat display pro-environmental behaviors in contrast to supplementary users of coal and peat who display positive marginal effects for these variables. An exception is wood, where primary users display some evidence (albeit weak based on the size of the marginal effect) for pro-environmental behaviors. Finally, the income elasticities for the individual solid fuels can be examined. Coal and peat as primary fuels are inferior goods while as supplementary fuels there is either no income effect or a positive effect for a natural gas-peat fuel combination. Interestingly, the income effect is insignificant for the use of wood as a main fuel suggesting that those households that use wood for this purpose are spread across the income distribution. The income elasticities are positive where wood is used as a supplementary fuel to either natural gas or oil and negative where wood is used as a supplementary fuel to coal or peat.

The difference between the pattern of income elasticities for wood in comparison to coal and peat is an interesting result. There may be several reasons for this. The installation of wood chip or wood pellet heating systems was grant aided by the Sustainable Energy Authority of Ireland under the Greener Homes Scheme (GHS) between 2006 and 2011. Previous research has found that household heating and more general retrofit investments are influenced by levels of income (Lillemo et al., 2013 and Aravena et al., 2016). Related to an extent has been the general trend toward the replacement of open fires with stoves in Irish households in recent years to increase heat output but also for a comfort or aesthetic effect. Wood is a more popular fuel in stoves relative to open fires, so this has likely increased the prevalence of wood use among higher income households, assuming once again that higher income households are the ones that are more likely to upgrade their stock of heating appliances. Finally, in comparison to coal and peat, there is a perception of wood as a renewable fuel, given that it can be regrown and its carbon emissions offset, and the fact that energy policy at EU level has tended to classify wood (or biomass) as a renewable fuel. Renewable fuels are more likely to be higher up the energy ladder in comparison to traditional solid fuels, and therefore used by households on higher incomes.

The results presented above for primary fuel use generally correspond with this previous literature. These include the existence of a negative relationship between firewood use and age (Lillemo and Halvorsen, 2013) and between firewood use and education (Démurger and Fournier, 2011; Song et al., 2018). Location is also found to be important with rural households much more likely to consume firewood especially relative to urban households (Arabatzis and Malesios, 2011; Song et al., 2012) and proximity to urban coal markets increasing the likelihood of using coal (Chen et al., 2006). Zhang et al. (2019) find income to negatively effect the choice of low-quality coal and Lillemo and Halvorsen (2013) find income to be insignificant in their study of household firewood demand, similar to the results presented above.

6. The Border region has close access to Northern Ireland for fuel imports and the South-East and South-West regions have large urban areas as well as ports with access to mainland Europe.

Only Couture et al. (2012) made the distinction between the primary and supplementary use of an individual solid fuel, however. Comparing their results with this study, both find similar effects for age and dwelling type on primary and supplementary use of wood, while a different effect is found for owner occupiers with Couture et al. (2012) finding a positive association to wood use for primary heating purposes in contrast to a negative effect found in this study. The respective effects that income has are also slightly different with Couture et al. (2012) finding a negative effect for primary wood use and a positive effect for supplementary wood use, while this study reports an insignificant income effect for primary wood use and a positive effect for supplementary wood use.

4. DISCUSSION

The results presented highlight a number of contributions to the literature. Primarily the results show the importance of considering whether solid fuels are being used for primary or supplementary purposes. This is because, the characteristics of households using solid fuels for either purpose appear to be different in many aspects. This study also extends the work of previous research by providing evidence that the differences that exist between primary and supplementary solid fuels use extend across not just wood but also other solid fuels, including coal and peat. The homogeneity of solid fuel users is also an assumption which should be disputed given the findings presented above. These features may be present in other countries with a dependence on solid fuel use and further academic work in this area would therefore be of interest. The study is therefore a valuable addition to the existing literature on factors determining the choice of traditional solid fuels for home heating purposes.

The results also present several policy implications. The recognition of the possibility that differences may exist between primary and supplementary solid fuels users can be an important element in the design of environmental policies allowing for a more effective implementation. For example, current retrofitting programs with financial incentives are targeting primary users of solid fuels but for supplementary users, alternative policy measures may be required when a deep retrofit is not an option, especially if these householders already occupy energy efficient homes with a modern primary heating system but still use solid fuels for convenience or hedonic reasons. In this instance policies which encourage the take up of environmentally friendly (i.e., low smoke and low sulphur) solid fuels and/or discourage the use of harmful solid fuels may be more applicable. The fact that supplementary users of solid fuels (especially those using natural gas as a primary fuel) display pro-environmental behaviors suggest such an approach may have some success. Moreover, the findings from this study can also help to inform the design and implementation of new solid fuel regulations when the focus is on specific solid fuels, given that differences between primary and supplementary users also exist at this level.

This study also provides evidence to suggest that Irish households follow an energy stacking model rather than an energy ladder model. This supports previous research by Çelik and Oktay (2019) and Song et al. (2018). Although households on higher levels of income do not choose traditional solid fuels as their primary fuel, a large majority still rely on solid fuels for supplementary heating purposes. Relying solely on household income increases (i.e., the energy ladder theory or EKC hypothesis) is therefore unlikely to solve the issue of poor air quantity from the use of solid fuels. Policymakers will need to be cognisant that any further policies are designed in such a way that the transition away from the use of solid fuels is complete and not a partial transition, otherwise householders will still use solid fuels as a backup source. Recently introduced building regulations reform can play a role here. Current regulations specify that new homes must reach a minimum A2

energy efficiency rating (or what is referred to a Nearly Zero Energy Buildings (NZEB)). Given that the rating calculation is based on such factors as insulation in the home, ventilation, and the efficiency of the heating system, this has meant that all new homes in Ireland are built without an open fireplace or flue. This will restrict the option to use solid fuels over time, particularly as a supplementary source, albeit in a gradual manner as the housing stock gets replenished.

5. CONCLUSIONS

This study had two main objectives. The first was to examine the factors that determine the choice of residential solid fuel use with a focus on differentiating its use as a primary fuel and as a supplementary fuel. The motivation for examining solid fuel use stems from the widely accepted view of its contribution to poor air quality and premature deaths. The transition away from the use of solid fuels is thus a key priority in the development of clear air strategies across the EU and other international jurisdictions. The second objective was to examine whether differences between primary and supplementary solid fuels users were still present, if individual solid fuels were examined in more granular detail. A related objective was to determine the extent of heterogeneity between different solid fuel users. These objectives are of specific relevance to the design of environmental policy in Ireland given the range of solid fuels used, particularly for supplementary heating purposes.

The study has found strong evidence to indicate that the associations between a number of socioeconomic characteristics of the household and solid fuel choice is different if the solid fuel is used for either primary or supplementary use. This finding broadens much of previous research in this area which tends to attribute certain characteristics to all solid fuel users. The view that solid fuels users are from lower income households is one of these, with this study showing that income increases are positively associated with supplementary solid fuel use. Furthermore, the results from this study show that not all solid fuel users are the same and there is evidence of heterogeneity among the group by fuel type which goes beyond the distinction between primary and supplementary users. Coal as a supplementary fuel is used in newer dwellings whereas peat is used in older dwellings for both primary and supplementary purposes. There are also strong regional differences between coal and peat use with both fuels being used in specific locations which reflect ease of fuel availability. Wood appears to be different to coal and peat it that its use, especially as a supplementary fuel, is more prevalent among higher income households.

The recognition that differences exist between primary and supplementary solid users and between coal, peat and wood users is important for the development of policy in the area. A one size fits all approach is unlikely to provide enough scope to enable a transition to occur across all cohorts within the residential sector. A range of policy measures is likely to be required and the success of any policy which discourages the use of non-sustainable solid fuels will have to be accompanied with policies which encourage the use of more sustainable alternatives. Relying on improvements in living standards or measures which bring households out of fuel poverty would also need to carefully consider whether such households transition to modern fuels as their primary fuel but maintain traditional and harmful solid fuels as their supplementary fuel. These policy conclusions are timely as Ireland is introducing new solid fuel regulations and developing a National Clean Air Strategy but are also applicable to other countries where solid fuels form a significant part of the residential space heating sector.

There are a number of avenues for future research in this area. The data set used in the study does not provide any information on the actual quantity of solid fuels used. It is reasonable to assume that primary users will require more solid fuels for heating purposes than supplementary

users but the question is by how much. And while the extent of supplementary solid fuel use, in terms of proportion of households, may be large, it is probable that there may be quite a large amount of variation in use across this cohort with some supplementary users consuming solid fuels on very rare occasions. Data on actual usage would therefore provide more valuable detail. Having repeated cross sections of data could also generate interesting insights as to whether the energy stacking theory persists over time or if the energy ladder theory becomes more relevant. More granular information on the fuels used would also be of benefit. This study advances on a great deal of previous research by providing a breakdown of solid fuels use by analysing coal, peat and wood separately. However, in the case of coal, a further breakdown between low smoke coal and other smoky coal would be useful especially to examine the effect of the smoky coal ban in urban areas. For peat, a breakdown between sod peat (or turf) and peat briquettes would also be useful as consumption of peat briquettes is common in smaller urban areas. Addressing these informational deficits would greatly enhance future research on this topic.

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APPENDIX

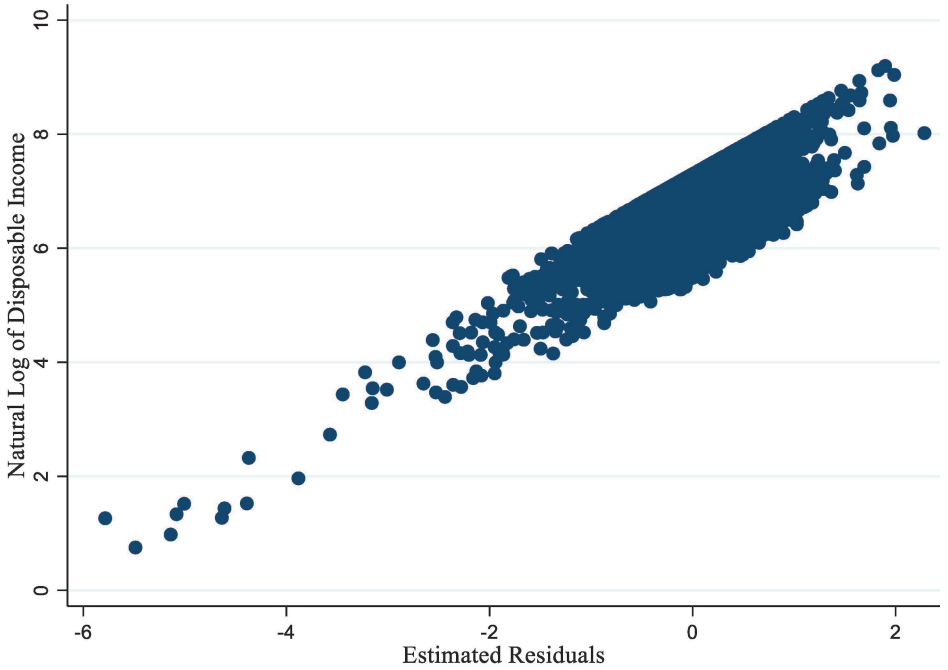
Table A1: Characteristics of Solid Fuel Primary and Supplementary Users (Proportion of Respondents), CSO 2014

	Solid Fuel Primary Users	Coal Primary Users	Peat Primary Users	Wood Primary Users	Solid Fuel Suppl Users	Coal Suppl Users	Peat Suppl Users	Wood Suppl Users
Age of Respondent								
Under 35 (ref)	0.104	0.125	0.089	0.091	0.144	0.145	0.139	0.131
35–54	0.377	0.391	0.360	0.385	0.454	0.451	0.439	0.454
55–74	0.408	0.379	0.426	0.433	0.322	0.324	0.331	0.335
75 +	0.111	0.105	0.126	0.091	0.080	0.080	0.090	0.079
Education Level								
Primary (ref)	0.325	0.343	0.328	0.270	0.147	0.156	0.163	0.170
Secondary	0.376	0.369	0.397	0.339	0.348	0.360	0.344	0.340
Tertiary	0.284	0.269	0.270	0.364	0.492	0.471	0.480	0.477
Unknown	0.014	0.019	0.004	0.027	0.013	0.013	0.013	0.013
BER Completed								
No/Unknown (ref)	0.887	0.902	0.896	0.824	0.838	0.843	0.850	0.834
Yes	0.113	0.098	0.104	0.176	0.162	0.157	0.150	0.166
Construction Period								
Before 1960 (ref)	0.309	0.253	0.328	0.406	0.216	0.211	0.233	0.235
1961–1980	0.180	0.196	0.173	0.158	0.190	0.190	0.197	0.187
1981–2000	0.271	0.288	0.281	0.200	0.269	0.272	0.268	0.276
2001 or later	0.169	0.173	0.157	0.191	0.274	0.277	0.254	0.251
Unknown	0.070	0.090	0.061	0.045	0.051	0.050	0.047	0.049
Dwelling Type								
Detached (ref)	0.452	0.298	0.530	0.648	0.427	0.414	0.420	0.463
Semi-Detached	0.171	0.259	0.110	0.106	0.280	0.291	0.283	0.251
Terraced/Other	0.144	0.246	0.072	0.067	0.147	0.158	0.144	0.134
Bungalow	0.223	0.183	0.284	0.167	0.137	0.130	0.143	0.144
Apartment	0.010	0.014	0.004	0.012	0.009	0.007	0.010	0.008
Occupancy Status								
Rented/Other (ref)	0.218	0.349	0.123	0.127	0.178	0.191	0.180	0.169
Owner Occupied	0.782	0.651	0.877	0.873	0.822	0.809	0.820	0.831
Region								
Dublin (ref)	0.022	0.034	0.007	0.033	0.152	0.136	0.182	0.138
Border	0.162	0.245	0.110	0.085	0.121	0.136	0.109	0.128
Mid-East	0.070	0.089	0.045	0.088	0.114	0.103	0.131	0.117
Mid-West	0.085	0.080	0.075	0.127	0.084	0.084	0.098	0.096
Midland	0.167	0.041	0.334	0.048	0.062	0.035	0.095	0.039
South-East	0.132	0.202	0.009	0.279	0.166	0.203	0.095	0.191
South-West	0.152	0.213	0.054	0.258	0.192	0.230	0.108	0.208
Western	0.209	0.097	0.367	0.082	0.109	0.073	0.182	0.083
Urban/Rural								
Urban Areas (ref)	0.327	0.497	0.219	0.167	0.557	0.578	0.539	0.500
Rural Areas	0.673	0.503	0.781	0.833	0.443	0.422	0.461	0.500
Energy Saving								
0 Products (ref)	0.359	0.483	0.275	0.258	0.307	0.316	0.296	0.292
1–2 Products	0.340	0.292	0.401	0.306	0.344	0.354	0.347	0.343
3–4 Products	0.207	0.177	0.222	0.245	0.232	0.227	0.245	0.241
5 + Products	0.094	0.049	0.102	0.191	0.117	0.104	0.112	0.123
Environmental Initiatives								
0 initiatives (ref)	0.062	0.065	0.066	0.045	0.041	0.041	0.033	0.040
1–2 initiatives	0.392	0.392	0.425	0.303	0.307	0.316	0.308	0.299
3–4 initiatives	0.395	0.415	0.381	0.379	0.441	0.438	0.454	0.446
5–6 initiatives	0.151	0.129	0.128	0.273	0.211	0.205	0.206	0.216
ln Disposable Income	6.41	6.29	6.46	6.58	6.63	6.61	6.61	6.62
Number of Observations	2,100	878	892	330	6,093	4,469	2,672	4,579

Table A2: Linear Regression Estimates using CSO Household Budget Survey data, 2015/2016

Dependent Variable: ln(disposable income)	Coefficients
Constant	6.130
Gender of HRP:	
Male	0.116***
Employment Status of HRP:	
Unemployed	–0.092***
Retired	–0.006
Student	–0.112*
Other	–0.127*
Education of HRP:	
Lower Secondary	0.048*
Higher Secondary	0.174***
Post Secondary	0.159***
Tertiary	0.418***
Unknown	0.364***
Number of Adults Working	
All Adults Working	–0.006
No Adults Working	–0.646***
Number of Rooms in Dwelling	
4–6 Rooms	0.227***
7 or more rooms	0.457***
Ownership Status	
Owned Outright	0.179***
Number of Observations	6,831
R-squared	0.4168
F-stat	324.65***

Figure A1: Scatter Diagram of Estimated Residuals against the Natural Logarithm of Disposable Income



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