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Has fuel poverty changed and how should policy respond? Charting fuel poverty in Ireland from 1987 to 2015

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Abstract: This paper charts the incidence of fuel poverty in Ireland through the period 1987-2015 under alternative household survey-based metrics. The fuel poor population is decomposed by socioeconomic group to better understand the changing nature of fuel poverty and its determinants. Headline poverty metrics as calculated by Irish policy using a 10% income threshold correspond broadly to those calculated using alternative metrics, but subpopulation distributions differ. Those with high incomes and high fuel expenditures comprise a large share of those currently designated as fuel poor (up to 36%). A lesser but nevertheless substantial population currently designated as fuel poor have low incomes and low energy costs, a subpopulation whose vulnerabilities are perhaps better addressed through general social policy measures. I find that the incidence of fuel poverty has shifted through the analysed period. In 1987, fuel poverty was concentrated among households with a greater mix of dwelling and income-related vulnerabilities. In 2015, incidence has shifted towards those whose vulnerability is more predominantly signalled by income and sociodemographic attributes. The appropriate policy response requires a greater emphasis on tackling general material deprivation.

Keywords: Fuel poverty**,** Energy policy; Fuel poverty; Energy affordability
JELs: I3; Q4

1. INTRODUCTION

Fuel poverty[2] is the inability to afford adequate energy services in the home (DCENR, 2011). This paper charts the incidence of fuel poverty in Ireland through the period 1987-2015 to understand the nature of fuel poverty and the extent with which this has been measured correctly. Understanding the nature of the deprivation incurred and the populations affected can guide the appropriate policy response. In Ireland, fuel poverty has commonly been addressed as an element of energy and climate policy (e.g. DCENR, 2016; DCCAE 2019),[3]despite being an issue related to material well-being and public health (McAvoy, 2007; Liddell and Morris, 2010; IPH, 2009). Given this policy context, intervention has placed a strong emphasis on aiding households in obtaining adequate energy services, rather than aiding households in obtaining the resources to overcome material deprivation. This is an important distinction. Watson and Maitre (2015) suggest that fuel poverty is not a distinct type of deprivation but rather an aspect of general deprivation, with the appropriate policy response guided towards the factors that erode the ability to afford adequate material well-being (e.g. education, income), rather than focussing on the lack of a certain outcome (e.g. adequate household insulation).

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[2] Fuel poverty and energy poverty are often used interchangeably in the literature when discussing the affordability of adequate energy resources in the context of developing countries such as Ireland. This paper will use the term 'fuel poverty' as this is more commonly used in Ireland. This should not be confused with the term 'energy poverty' when employed in a development context, usually referring to inadequate access to energy.

[3] Irish and international climate action prioritises the targeting of 'fuel poor' households when making energy efficiency investments (DCCAE, 2019).

This paper provides two primary contributions to help inform this debate. First, this paper charts, for the first time, the evolving nature of fuel poverty and its determinants from 1987 to 2015. Total fuel poverty is measured according to two indicators - the 10% income threshold and the more novel 'low income high cost' approach - and populations experiencing fuel poverty are decomposed according to key socioeconomic indicators. There is a notable reduced incidence among sub-populations more likely to be faced with energy efficiency challenges (e.g. those in older dwellings or rented accommodation) and a trend of increasing incidence among those likely facing general material deprivation (e.g. those on low incomes or with lower levels of education). Most notably, indicators of general deprivation – sociodemographic indicators such as education and occupation – are persistent determinants throughout the duration of analysis. Receiving public support is of lesser significance through time. The increasing shift towards income as a determinant, the falling significance of housing-related factors, and the persistent significance of sociodemographic indicators of general deprivation indicates that Irish fuel poverty has been characterised by a shift towards factors associated with general material deprivation, as opposed to fuel-related deprivations, in determining fuel poverty incidence. This supports the hypothesis put forward by Watson and Maitre (2015); policy should focus on better targetting those households constrained in their ability to achieve adequate material well-being.

Second, this paper considers whether Irish policy has been measuring fuel poverty correctly. The primary indicator employed by Irish policy is the 10% income share indicator of Boardman (1991). A prominent metric in much of the fuel poverty literature, it has been superseded in many countries, such as the UK, by more nuanced approaches that consider both vulnerability and energy expenditure (e.g. Hills, 2012). The deficiencies of the 10% threshold approach have been well-documented, with Hills (2012) suggesting that 'flaws in the [10% indicator] have distorted policy choices, [and] misrepresented the problem'.

In the UK, the Low Income High Cost (LIHC) has become the favoured metric. This paper compares these two approaches. I decompose those categorised as fuel poor by the 10% income threshold according to LIHC defined subpopulations. While headline poverty metrics are similar, subpopulation distributions differ. It is found that up to 36% of households categorised as fuel poor by the 10% indicator had LIHC-defined 'high incomes', while up to a further 10% had LIHC-defined low energy usage. The difference between metrics was greater in 1987 and has declined through time, however the subpopulation differences matter for individual-based policy interventions (targeted energy efficiency upgrades, for example).

This paper is structured as follows. Section 2 will discuss the data and methodology. Section 3 will discuss the results and Section 4 will conclude.

2. DATA AND METHODOLOGY

This paper uses the anonymised Irish Household Budget Survey (HBS). The HBS has been collected at regular intervals since 1987; 1987, 1994, 1999, 2004/05, 2009/10 and 2014/15 waves are used in this paper. The data are collected by taking a representative random sample of all private households and recording their income and expenditures over a two-week period. Occupant socio-economic data are also recorded along with data on dwelling characteristics and appliance ownership. Responses are weighted to minimise any bias that may occur due to participant non-response. While the primary purpose of the HBS is to detail household-level income and expenditures to inform the calculation of consumer price indices, these data also provide a suitable platform for household-level microanalyses, such as that carried out in this paper.

To accomplish the stated research objectives, the empirical analysis is divided into two stages. The first stage charts the incidence of fuel poverty in Ireland throughout the period 1987-2015 according to two expenditure-based metrics; the 10% income threshold approach proposed by Boardman (1991) and a variant of the Low Income High Cost 'Hills approach' (Hills, 2012). The second stage calculates the determinants of fuel poverty status using logistic regression.

2.1. Fuel poverty measurement

The 'Boardman approach' defines a household as being fuel poor if they spend more than 10% of disposable income on fuel (Boardman, 1991). Fuel poor households are therefore defined as those with a ratio of fuel expenditure to disposable income greater than 1:10 (10%).

This metric has been criticised in the literature (see Robinson et al., 2018; Hills, 2012). For instance, some households may choose to spend a high proportion of their income on fuel, as opposed to being forced into this expenditure. This is particularly troublesome when one considers that wealthy householders with large dwellings may have proportionately high energy expenditures, especially if they choose to have energy-intensive consumption patterns (an extreme example would be the installation of a swimming pool). Such households would

be categorised as 'fuel poor' under the expenditure threshold. Further, the income threshold approach does not respond adequately to changes in income. These deficiencies are considerable, with Hills (2012) suggesting that 'flaws in the [10% indicator] have distorted policy choices, [and] misrepresented the problem'.

This has motivated alternative metrics of fuel poverty. Hills (2012) defined the 'Low Income High Costs' indicator, where a specific population is counted as fuel vulnerable if they are found to have both high energy expenditures and low income. This approach defines an income and energy expenditure threshold for calculation:

> 1) Income threshold: a household must have 60% or less of the national median equivalised 'residual income', or income after housing costs. This is calculated by first calculating disposable income after housing cost deductions of mortgage and rent payments. The household energy bill is then added to this threshold to ensure that household energy costs do not drive respondents over the threshold. Therefore, each household has a unique income threshold.
>
> 2) Energy costs threshold: this is the median equivalised energy cost for all households. Note, energy costs are also equivalised to account for household size and ability to pay.

To be considered fuel poor, a household must have both an income of 60% or less of the national median equivalised 'residual income' and energy costs greater than the median equivalised energy cost. The LIHC has one primary benefit and one primary weakness. As households with high energy consumption tend to be energy-inefficient, energy efficiency is highly prioritised in this central indicator. However, a high cost threshold has potential to emphasise large, under-occupied housing-units, as opposed to low-income households living in energy inefficient small properties (Belaid, 2018).

It should be noted that much of the literature uses 'modelled' energy costs in the LIHC indicator. This overcomes issues in revealed cost data where households may reduce their energy consumption due to income constraints and this is the favoured approach employed by UK policy. Some analyses, however, use revealed energy expenditures.

Given data constraints, we use the revealed expenditure data of the HBS and therefore cannot identify fuel-poor households forced to reduce their energy expenditure. The results of this paper should be interpreted in this context. Notwithstanding this caveat, the LIHC approach allows us to interrogate households classified as fuel poor according to the 10% income threshold approach. Those traditionally defined as fuel poor can be categorised as having low/high incomes or low/high energy costs, providing insight into the extent with which Irish policy has been counting those with high incomes in traditional estimations of fuel poverty prevalence.

The income threshold in the LIHC metric is defined as 60% or less of the national median equivalised 'residual' income plus energy costs. Residual income is calculated as disposable income less housing costs. Housing costs in this paper are defined as all house purchase payments associated with privately owned properties including ground rent, mortgage repayments (including subsidiary loan repayments), less any mortgage interest relief (2004/05). These data are readily available for survey waves from 1999 onwards. For survey waves in 1987 and 1994, imputed rents are used. While these do not capture the actual costs faced by each household, they are a suitable proxy for what one expects each household to be paying. A sensitivity analysis was carried out with and without all housing costs and the LIHC-defined poverty calculation varies by an insignificant amount.

The modified OECD-equivalence scale is used, where the incomes/energy expenditures are weighted according to household structure. A weighting of '1' is given to the first adult, '0.5' for each additional adult and '0.3' for each child (*). The household energy bill is added to the income threshold to ensure that household energy costs do not drive respondents over the threshold into fuel poverty; fuel poverty status is determined by ex-ante resource availability. Energy costs are also equivalised.

2.2. The determinants of fuel poverty

The second element of analysis discusses the determinants of being in fuel poverty through the 1987-2015 period. We use logistic regression to predict the probability of being fuel poor according to both 10% income threshold and LIHC-defined fuel poverty.

The general logistic regression model format may be defined as:

$$\log[\left({}^{p}/_{(1-p)}\right] = \beta_0 + \sum_{i=1}^{I} \beta_i X_i + \varepsilon_i,$$

Where p is the probability of being fuel poor, β_0 is an intercept term and $\sum^{I}{}_{i=1}\ X_i$ is a vector of I explanatory variables. β_i is the coefficient associated with explanatory variable i and ε_i is the error term. The general regression takes the following form.

$$Y_i = \beta_0 + \sum_{i=1}^{I} \beta_i X_i + \varepsilon_i$$

Yi is the observed binary response variable describing fuel poverty status where:

$$Y_i = \begin{cases} 1, if\ household\ is\ fuel\ poor \\ 0, if\ household\ is\ not\ fuel\ poor \end{cases}$$

Explanatory variables included in this analysis represent a range of socioeconomic and household variables that explain household consumption of fuel, informed by economic theory and the literature. Location is coded according to urban/rural dummies. Dummy variables are used to represent each category of occupation, education, social class and age of the Household Reference Person/Head of Household (HOH).[4] Further demographic characteristics include the number of adults and children in the household and whether the household head is female; a single parent or married. The number of adults and children in the household are captured by dummy variables, while the number of Old-Age Pensioners (OAPs) is captured by a continuous variable.

Disposable income decile is included. As income is used in the calculation of the 10% fuel poverty threshold indicator, this is not included as the calculation would reduce to an identity (Scott et al., 2008). The number of private loans indicates the degree of indebtedness for a household and their access to credit. This may affect a household's propensity to consume, especially in relation to capital expenditures. This is included as a dummy variable. Household size and type are included in the data and used as indicators of fuel poverty. Ownership of a dishwasher and tumble dryer are included as indicators of dwelling standard; as optional appliances for many homes, their absence may be correlated with lower general housing standards and greater fuel inefficiency. The presence of double glazing also acts as a proxy for dwelling energy efficiency.

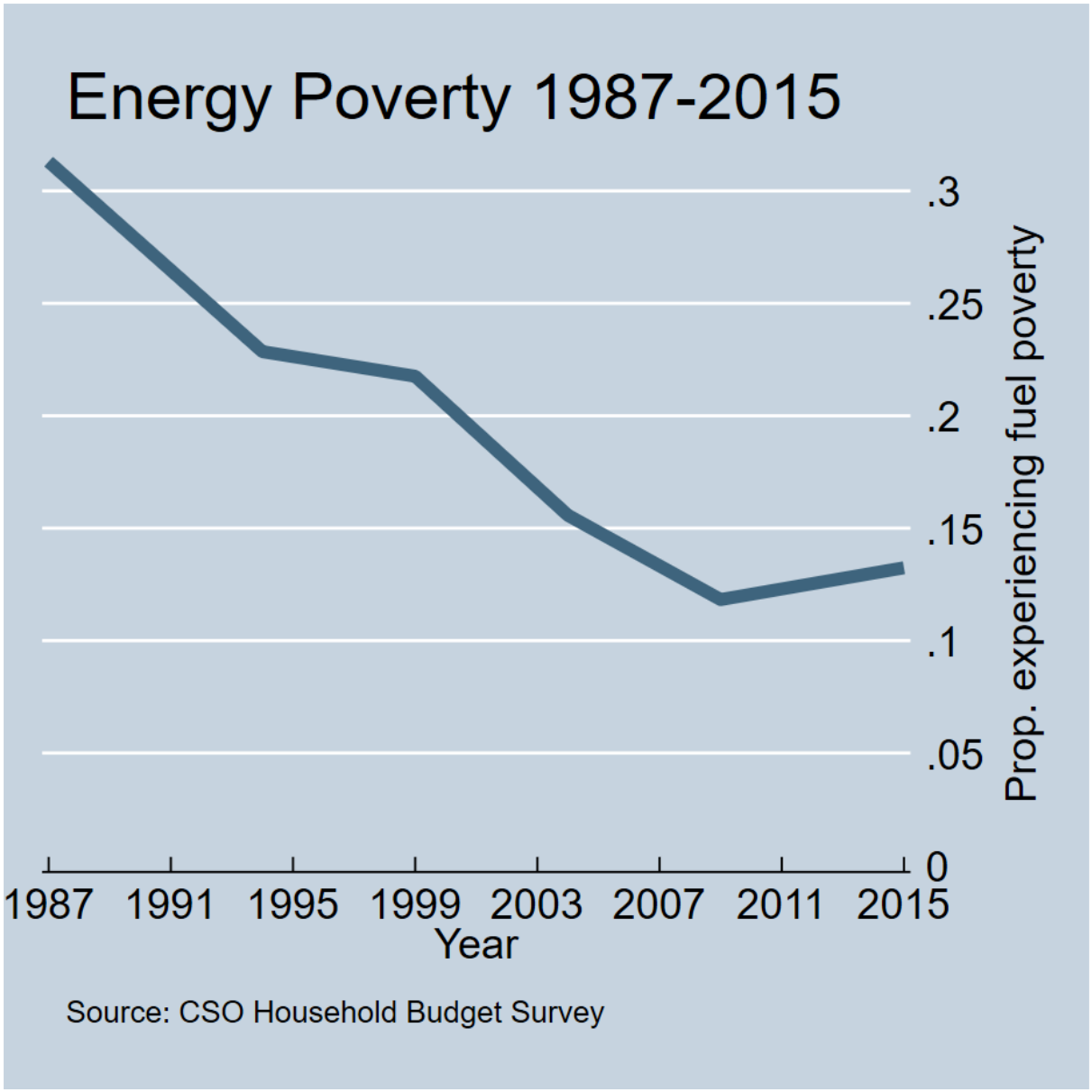
3. RESULTS

3.1. How has fuel poverty changed since 1987?

Figure 1 charts the trend in aggregate fuel poverty throughout the duration of analysis using the 10% income threshold metric. One striking feature of this trend is the strong rate of decline in fuel poverty throughout most of the duration, falling from 31.3% in 1987 to 11.8% in 2009/10. A slight increase in fuel poverty was observed in 2014/15, with 13.2% of the population experiencing fuel poverty during this survey period.

Figure 1: Fuel poverty in Ireland – 10% income threshold

[4] Pre-2009/10, the primary respondent was descrbed as the 'Head of Household'. This was no longer recorded in the 2009/10 release, subsumed by the 'Household Reference Person'. We refer to the 'Household Reference Person' for the 2009/10 and 2014/15 data.

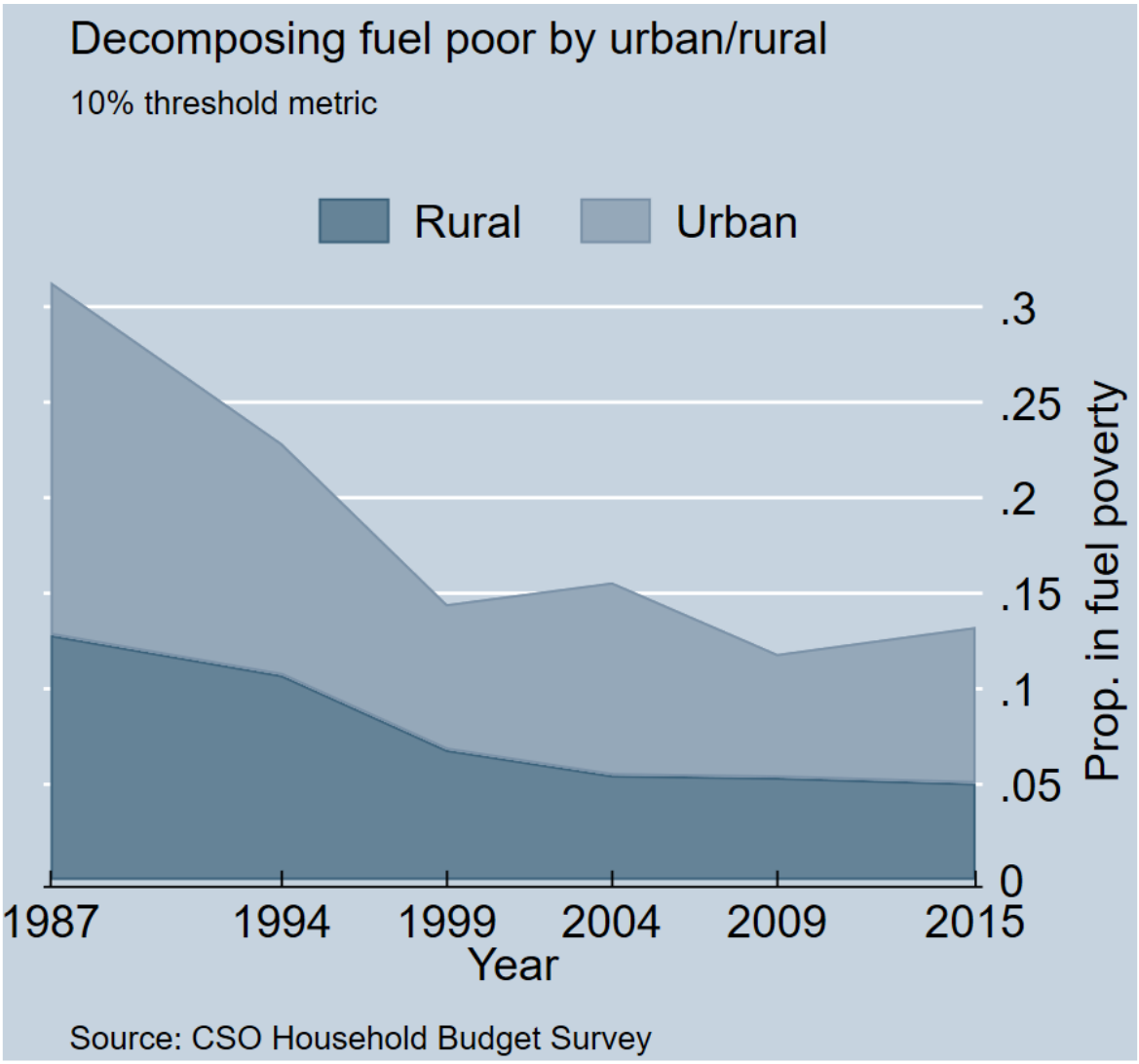


Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. Fuel poverty calculated according to 10% income threshold method. Income weighted according to OECD-modified equivalence scale.

To understand the factors driving this trend, the following discussion will decompose those experiencing fuel poverty according to various socioeconomic categories. Figure 2 decomposes fuel poverty by urban/rural divide. Urban fuel poverty exceeds rural fuel poverty throughout the duration of analysis, with this difference in the region of a 60-40 split. This difference narrowed in the 90s, with roughly equivalent rural and urban incidence until 2004. At this point, rural fuel poverty plateaued while urban fuel poverty began to grow. Therefore, the increase in fuel poverty experienced between 2009/10 and 2014/15 can almost entirely be explained by an increase in urban fuel poverty.[5]

Figure 2: Decomposing fuel poor by location

[5] Further research is required to understand why more changes are observed with respect to urban fuel poverty. One explanation could be that there is a stronger elasticity of fuel poverty outcomes with respect to either changes in income or the housing stock for urban rather than rural dwellers. Another potential explanation could be derived from concurrent economic changes. Focussing on the increasing urban fuel poverty of 2009-2015, and interpreted in the context of a trend of increasing urbanisation throughout this period, it is likely that this trend is due to, at least in part, the increasing urbanisation of settlement patterns during the post-2008 recovery.

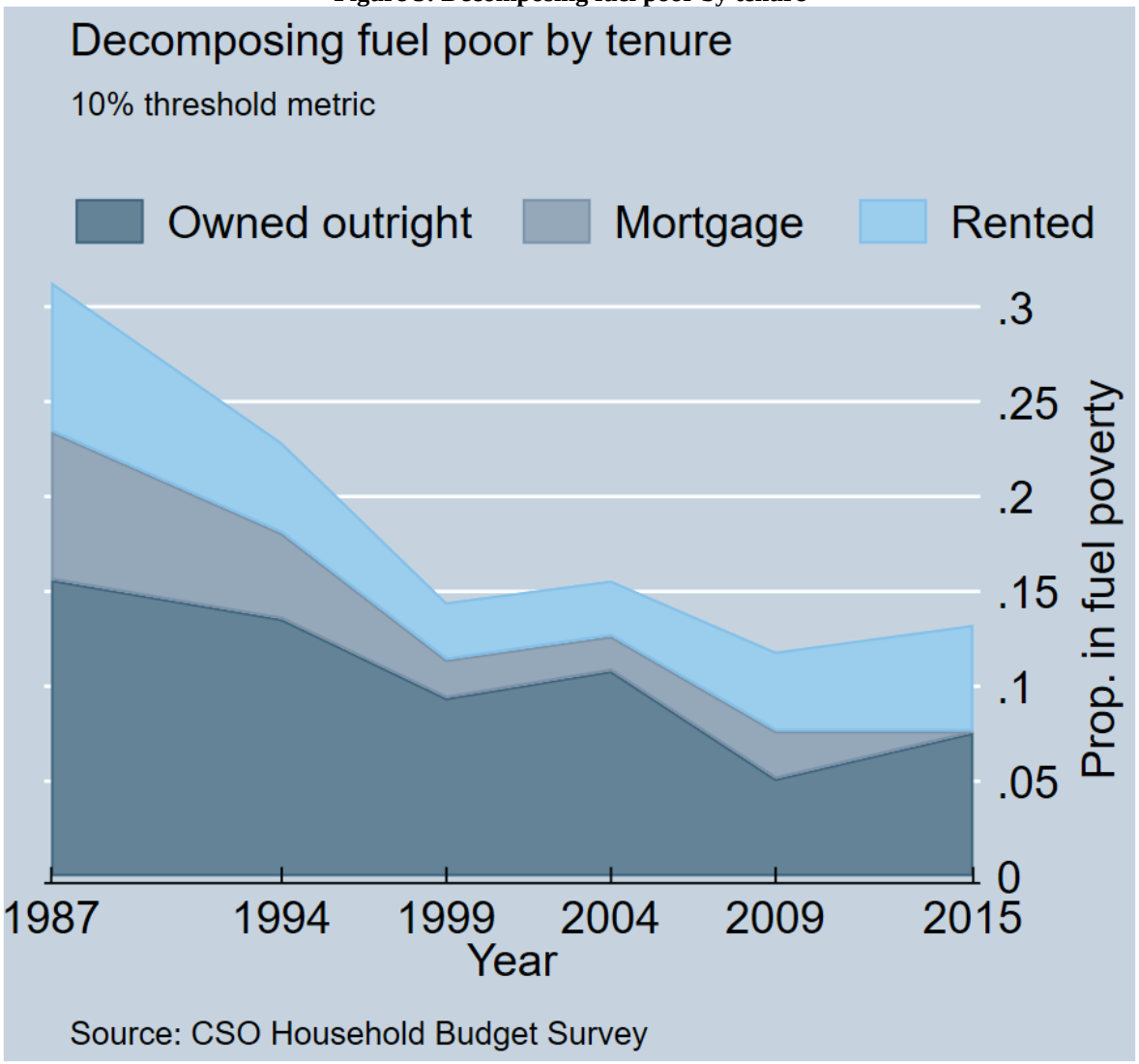


Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. Fuel poverty calculated according to 10% income threshold method. Income weighted according to OECD-modified equivalence scale.

Further insight may be obtained by considering changes in fuel poverty according to tenure status. Due to the principal-agent problem, homeowners are more likely to make capital investments to tackle fuel poverty (Davis, 2012). One would expect that Ireland's falling fuel poverty figures would be concentrated among this cohort. Figure 3 provides evidence to suggest that this has indeed been the case. In 1987, homeowners who owned their home outright comprised about 50% of those experiencing fuel poverty, with mortgage holders comprising a further 25%. As fuel poverty declined throughout the 90s, the absolute number of renters in fuel poverty stayed relatively constant, with reductions experienced among homeowners, both outright owners and mortgage-holders. However, the greatest reduction was experienced among mortgage holders,[6] suggesting that newly purchased dwellings were not entering fuel poverty; it is those households that were in possession for a longer duration that were experiencing fuel poverty. Further research may be required to confirm why this is the case; whether regulation or buying behaviour is driving the purchase of dwellings that are less susceptible to fuel poverty, or whether buyers belong to a socioeconomic cohort that can afford to avoid fuel poverty.

[6] Mortgage holders fall from 25% of the fuel poor in 1987 to 14% in 1999 to 0.5% in 2014/15

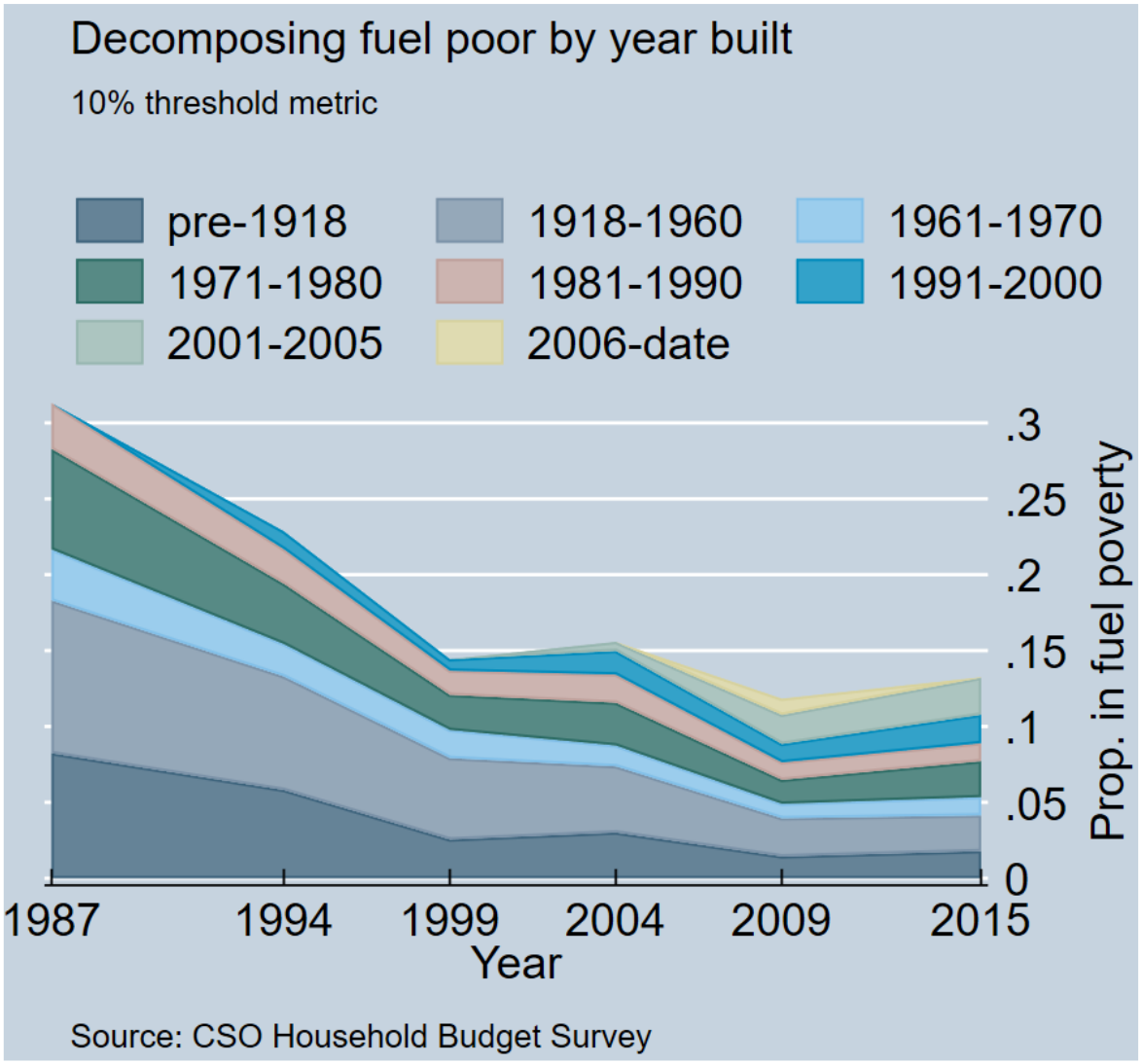
Figure 3: Decomposing fuel poor by tenure



Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. Fuel poverty calculated according to 10% income threshold method. Income weighted according to OECD-modified equivalence scale.

Motivated by the finding that homeowners, particularly new homeowners, are a falling proportion of the total population experiencing fuel poverty, Figure 4 tries to add further colour to this finding. Figure 4 shows that the oldest dwellings comprise a declining share of those experiencing fuel poverty. While much of this is to be expected – more modern dwellings are built with the passing of time – one would expect older homes to be less well-insulated and therefore to be a somewhat persistent feature of fuel poverty estimates. In 2015, 30% of all households in fuel poverty lived in dwellings built before 1960; 26% of all households in fuel poverty lived in dwellings built between 1961 and 1980; and 35% of all households in fuel poverty lived in dwellings built after 1980. As the analysis of Section 3.2 will show more conclusively, there is significant trend of association between year of construction and fuel poverty status in 2015, whereas this was the case in 1987. This trend provides evidence to suggest that the influence of dwelling standards may be having a declining influence on fuel poverty status throughout the 1987-2015 duration.

Figure 4: Decomposing fuel poor by year built



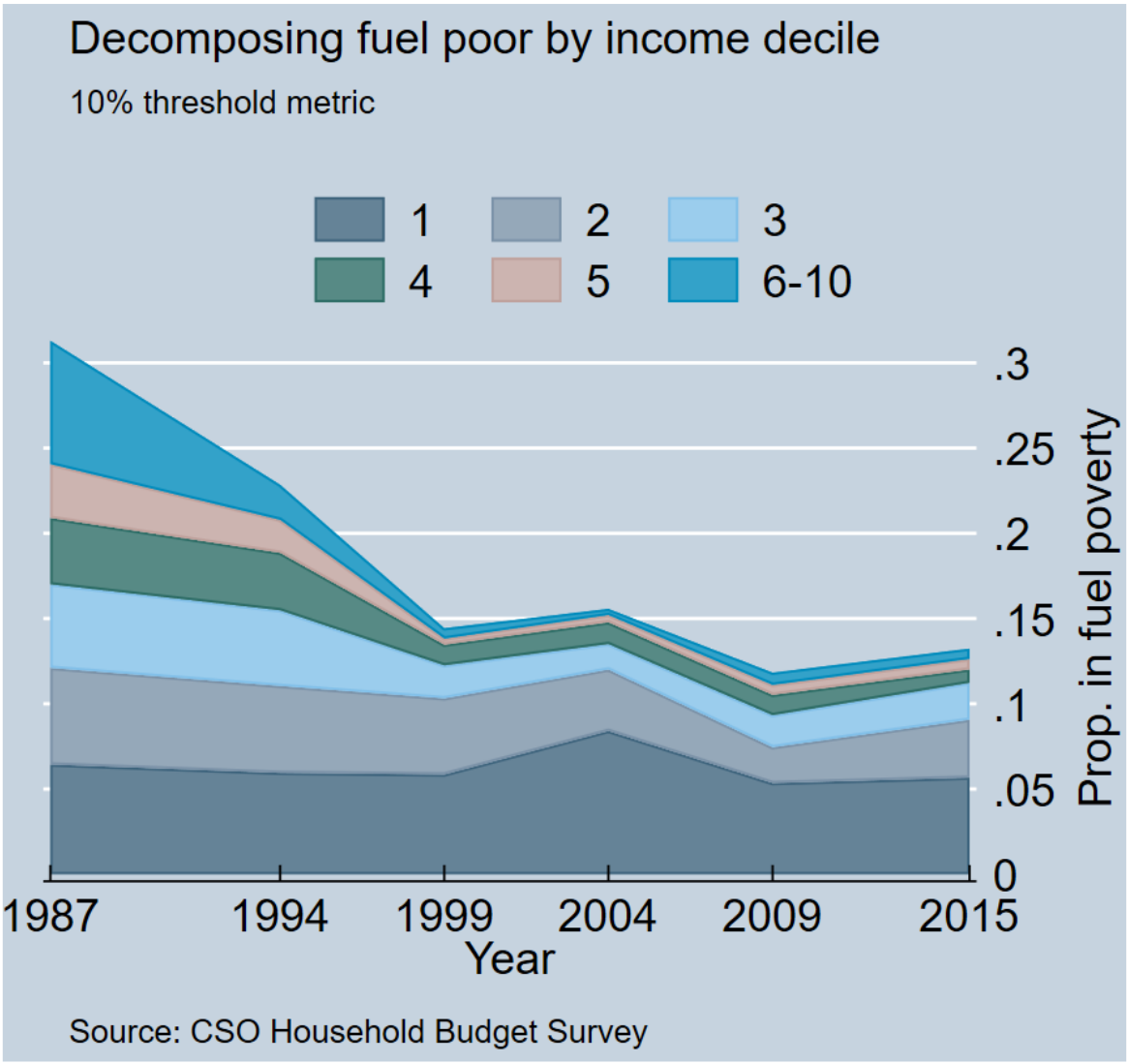
Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. Fuel poverty calculated according to 10% income threshold method. Income weighted according to OECD-modified equivalence scale.

While Figure 4 demonstrates a trend to suggest that dwelling characteristics are having a decreasing influence on fuel poverty status, Figure 5 suggests that income-related factors are having a growing influence on fuel poverty status.

Figure 5 shows a declining membership of higher income deciles and growing membership of lower income deciles in the fuel poor population. In 1987, 38% of all fuel poor households were in decile 1 or 2. In 2015, this had increased to 68%. Figure 5 shows that the absolute number of individuals in deciles one and two remains fairly consistent throughout the duration, with a notable decline among other deciles. In 2015, deciles 4-10 comprise 15% of all fuel poverty.

While low income is strongly correlated with fuel poverty status given the composition of the metric, it has become a stronger determinant as the duration of analysis has progressed. Together, Figures 4 and 5 lend evidence to suggest that income constraints are of growing importance relative to dwelling standard constraints in determining fuel poverty status.

Figure 5: Decomposing fuel poor by income decile



Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. Fuel poverty calculated according to 10% income threshold method. Income weighted according to OECD-modified equivalence scale.

3.2. What is driving the change in fuel poverty since 1987?

While the trends of Section 3.1 give insight into the changing composition of fuel poverty, further insight may be achieved by examining the determinants of fuel poverty using logit regression. This section will first discuss the determinants of fuel poverty in 2014/15. These findings will then be compared to the determinants in 1987,[7] discussing their evolution throughout the duration of analysis. Some notable shifts in the relative importance of these determinants throughout the entire duration of analysis will also be discussed.

3.2.1 Determinants of fuel poverty in 2015

Table 1 presents regression results outlining the determinants of fuel poverty for the 2014/15 data. Demographic traits are the strongest determinants of fuel poverty status, stronger than being in receipt of many social welfare benefits or indicators of dwelling standard.

Income decile is shown to be strongly correlated with fuel poverty status. This is to be expected as income is one of the two key factors involved in the fuel poverty calculation. On average, moving up one income decile reduces the likelihood of fuel poverty status by 0.399 times. This is a considerable reduction in the likelihood of being

[7] Full regression tables for all time periods are available in Appendix I. This section focuses on the 10% metric as this is the favoured in the Irish literature. Appendix II shows that the determinants for the 10% threshold metric are the same as for the LIHC metric.

fuel poor.[8] The greater then number of loans in a household, the less likely it is that a household is in fuel poverty in 2014/15. While somewhat counter-intuitive on first inspection, this may be indicative of the security required to be granted credit by financial institutions in 2014/15, as opposed to income constraints. While indicative of general living standards of the household, it is also indicative of capital constraints. This may also be capturing the availability of credit to finance energy efficiency upgrades.

Demographic indicators of general deprivation provide a strong set of indicators relating to fuel poverty status. Households with lower levels of education or households with an older household head are more likely to be in fuel poverty. Female headed households are more likely to be fuel poor, while households with children are more likely to be fuel poor.

Education and employment status/sector of employment have relatively little impact on fuel poverty status. One must take into account that much of the variation associated with these attributes is captured by income decile.
While there is a somewhat weak association between sociodemographic variables and fuel poverty status, there is arguably less evidence pointing to an influence of dwelling characteristics on fuel poverty. It is found that detached and semi-detached houses are more likely to be associated with fuel poverty, reflecting the greater thermal efficiency of attached housing. Housing age does not significantly affect fuel poverty status, a finding which corresponds to the graphical evidence discussed in Section 3.1. Similarly, double glazing ownership does not influence fuel poverty status. This affects both household fuel consumption and is an indicator of material well-being, both effects that one would expect leads to a lesser incidence of fuel poverty.

Tumble dryer ownership and dishwasher ownership are related to fuel poverty status. Although this does not determine fuel poverty, this is an indicator of dwelling standard. While this alone is not sufficient evidence to draw any conclusions, it would motivate further investigation to understand the association of fuel poverty with other indicators of housing standard. This information may then be used to better predict the prevalence of energy efficiency-driven fuel poverty, better guiding an appropriate policy response.

3.2.2 How have the determinants changed since 1987?

Comparing the findings of Table 1 with the findings of Table 2, a few key trends may be observed. First, income decile comes through less strongly as a key determinant of fuel poverty status in 2015. In 1987, moving up one income decile reduced the likelihood of fuel poverty status by 0.62 times. In 2015, the likelihood falls by 0.399. This suggests a growing influence of income on fuel poverty status as time has progressed. As the Tables of the Appendix show, the primary difference in this effect is between the 87-94 period, where coefficients were in the region of 0.48-0.62 and 1999-present, where coefficients fluctuated in the region of 0.36-0.41. These findings have important implications for the policy response; income-related social benefits are of greater importance in tackling fuel poverty in 2015 than in 1987.

Second, socioeconomic indicators of fuel poverty such as retirement or incapacity are much less strongly associated with fuel poverty status in 2014/15. These factors were more closely related to fuel poverty status in 1987, characterised by largely insignificant variation in 2014/15.

Finally, while double glazing was a significant driver of fuel poverty status in 1987, it was not in 2015. This suggests a declining impact of housing energy efficiency on fuel poverty status. However, indicators of general housing standard such as dishwasher and tumble dryer are consistently associated with fuel poverty, suggesting that general material deprivation may have a persistent role in fuel poverty status.

Taking these trends together suggests that income and general material wellbeing has a greater influence on fuel poverty in 2014/15 than in 1987. Identifying the affected population has changed from the targeting of groups clearly vulnerable to both low income and high fuel consumption, towards a greater emphasis on households facing low incomes. The appropriate policy response must therefore shift towards incorporating a greater emphasis on those with low incomes rather than those with certain dwelling characteristics. There is also evidence to suggest that policy should place a greater focus on the targeting of households with sociodemographic characteristics associated with general poverty and deprivation. The appropriate policy response thus corresponds largely to the findings of Watson and Maitre (2015).

[8] While the effect is likely to be non-linear, with a greater impact at lower deciles than higher deciles, the average effect is reported here for clarity.

Table 1: 1987 Determinants of Fuel Poverty – 10% income threshold

Logistic regression

Fuel poor (10% threshold)	Odds Ratio.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.62	.011	-26.22	0	.599	.643	***
Q loans	.959	.044	-0.91	.36	.877	1.049	
Built 1918-1960	1.112	.09	1.31	.19	.949	1.303	
Built 1961-1970	1.032	.11	0.30	.765	.837	1.273	
Built 1971-1980	.971	.088	-0.32	.748	.814	1.16	
Built 1981-1990	.914	.102	-0.81	.42	.735	1.137	
Detached	2.652	.432	5.99	0	1.927	3.648	***
Semi-d/terrace	2.395	.345	6.07	0	1.807	3.176	***
Other	1.765	.536	1.87	.061	.974	3.199	*
4-6 rooms	1.219	.148	1.63	.102	.961	1.546	
7+ rooms	1.625	.24	3.29	.001	1.217	2.171	***
Dishwasher	1.032	.134	0.24	.807	.8	1.333	
Tumble dryer	1.234	.095	2.74	.006	1.062	1.435	***
Double glazing	1.191	.107	1.94	.052	.999	1.421	*
OAP	.983	.074	-0.23	.818	.847	1.14	
Age HoH: 35-44	1.406	.122	3.91	0	1.185	1.668	***
Age HoH: 45-64	1.376	.198	2.21	.027	1.037	1.825	**
Female HoH	1.021	.108	0.19	.845	.829	1.257	
3+ adults	1.25	.099	2.82	.005	1.07	1.461	***
1-2 children	1.281	.109	2.92	.003	1.085	1.513	***
3+ children	1.498	.143	4.23	0	1.242	1.807	***
Single parent	1.232	.264	0.97	.331	.809	1.874	
Married HOH	.948	.293	-0.17	.863	.518	1.736	
Up to sec.school	.46	.427	-0.84	.403	.074	2.84	
o	1	.	.	.	.	.	
Non-man.	.889	.09	-1.15	.248	.729	1.085	
Manual	.853	.088	-1.53	.125	.696	1.045	
Unskilled/agri	.964	.119	-0.29	.768	.757	1.229	
Own a/c & farm	.84	.111	-1.32	.186	.648	1.088	
Other	.69	.139	-1.84	.066	.464	1.024	*
In work	1.174	.177	1.06	.287	.873	1.579	
PTE	1.152	.191	0.85	.394	.832	1.594	
Carer	7.792	12.065	1.33	.185	.375	162.068	
Unemployed	1.044	.109	0.41	.683	.85	1.281	
Unemp. ill	1.598	.309	2.43	.015	1.094	2.333	**
Home, educ	1.452	.237	2.29	.022	1.055	1.999	**
Retired	1.344	.219	1.81	.07	.977	1.851	*
Incapacity	1.558	.286	2.41	.016	1.087	2.233	**
o	1	.	.	.	.	.	
Urban	.932	.087	-0.76	.45	.775	1.12	
Q2	2.995	2.697	1.22	.223	.513	17.496	
Q3	1.479	1.33	0.44	.663	.254	8.618	
Q4	.912	.821	-0.10	.919	.156	5.322	
Q5	2.596	2.334	1.06	.289	.446	15.119	
Q6	3.037	2.733	1.23	.217	.52	17.726	
o	1	.	.	.	.	.	
Constant	.458	.425	-0.84	.4	.074	2.823	

Mean dependent var	0.320	SD dependent var	0.467
Pseudo r-squared	0.212	Number of obs	7699.000
Chi-square	2047.263	Prob > chi2	0.000
Akaike crit. (AIC)	7693.755	Bayesian crit. (BIC)	7999.504

*** *p<.01, ** p<.05, * p<.1*

Table 2: 2014/15 Determinants of Fuel Poverty – 10% income threshold

Fuel poor (10% income threshold)	Odds Ratio.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.399	.015	-24.25	0	.371	.43	***
Q loans	.932	.08	-0.83	.408	.787	1.102	
Built 1918-1960	1.018	.124	0.14	.885	.801	1.293	
Built 1961-1970	1.345	.217	1.84	.066	.981	1.845	*
Built 1971-1980	1.038	.129	0.30	.767	.813	1.323	
Built 1981-1990	1.034	.16	0.22	.827	.764	1.401	
Detached	3.101	.727	4.83	0	1.959	4.908	***
Semi-d/terrace	2.61	.565	4.43	0	1.708	3.988	***
Other	.483	.536	-0.66	.512	.055	4.255	
4-6 rooms	1.362	.262	1.61	.108	.934	1.985	
7+ rooms	2.309	.516	3.75	0	1.49	3.577	***
Dishwasher	1.245	.123	2.22	.027	1.026	1.511	**
Tumble dryer	1.32	.124	2.95	.003	1.098	1.587	***
Double glazing	.958	.132	-0.31	.755	.731	1.255	
OAP	1.289	.179	1.83	.068	.982	1.692	*
Age HoH: 35-64	1.817	.313	3.47	.001	1.297	2.547	***
Age HoH: 65+	1.238	.32	0.82	.41	.745	2.056	
Female HoH	1.311	.135	2.63	.008	1.072	1.604	***
3+ adults	1.124	.172	0.77	.444	.833	1.518	
1-2 children	1.46	.232	2.38	.018	1.068	1.994	**
3+ children	1.475	.422	1.36	.175	.841	2.585	
Single parent	.767	.196	-1.03	.301	.465	1.268	
Married HOH	1.325	.156	2.39	.017	1.051	1.669	**
Up to sec.school	.947	.105	-0.49	.622	.762	1.176	
Post-sec, degree	.883	.11	-1.00	.316	.692	1.126	
Non-man.	1.053	.135	0.40	.687	.819	1.355	
Manual	.806	.111	-1.56	.119	.615	1.057	
Unskilled/agri	.802	.143	-1.24	.217	.566	1.138	
Own a/c & farm	1.165	.2	0.89	.374	.832	1.631	
Other	.734	.136	-1.68	.094	.511	1.054	*
In work	1.262	.269	1.09	.275	.831	1.916	
PTE	.907	.153	-0.58	.564	.651	1.263	
o	1	.	.	.	.	.	
Unemployed	1.14	.291	0.51	.607	.692	1.88	
Unemp. ill	1.065	.328	0.21	.837	.583	1.947	
Home, educ	1.233	.305	0.84	.399	.759	2.003	
Retired	1.229	.307	0.82	.411	.753	2.006	
Incapacity	1.076	.294	0.27	.789	.63	1.837	
Other empl	1.763	.706	1.42	.157	.804	3.863	
Urban	.826	.101	-1.57	.117	.65	1.049	
Q1	1.328	.214	1.76	.078	.969	1.82	*
Q2	1.076	.161	0.49	.626	.802	1.443	
Q3	.645	.1	-2.84	.005	.476	.873	***
Q4	.808	.125	-1.38	.167	.597	1.093	
o	1	.	.	.	.	.	
Constant	.384	.146	-2.52	.012	.183	.809	**

Mean dependent var	0.137	SD dependent var	0.344
Pseudo r-squared	0.350	Number of obs	6834.000
Chi-square	1906.617	Prob > chi2	0.000
Akaike crit. (AIC)	3633.158	Bayesian crit. (BIC)	3933.663

*** p<.01, ** p<.05, * p<.1

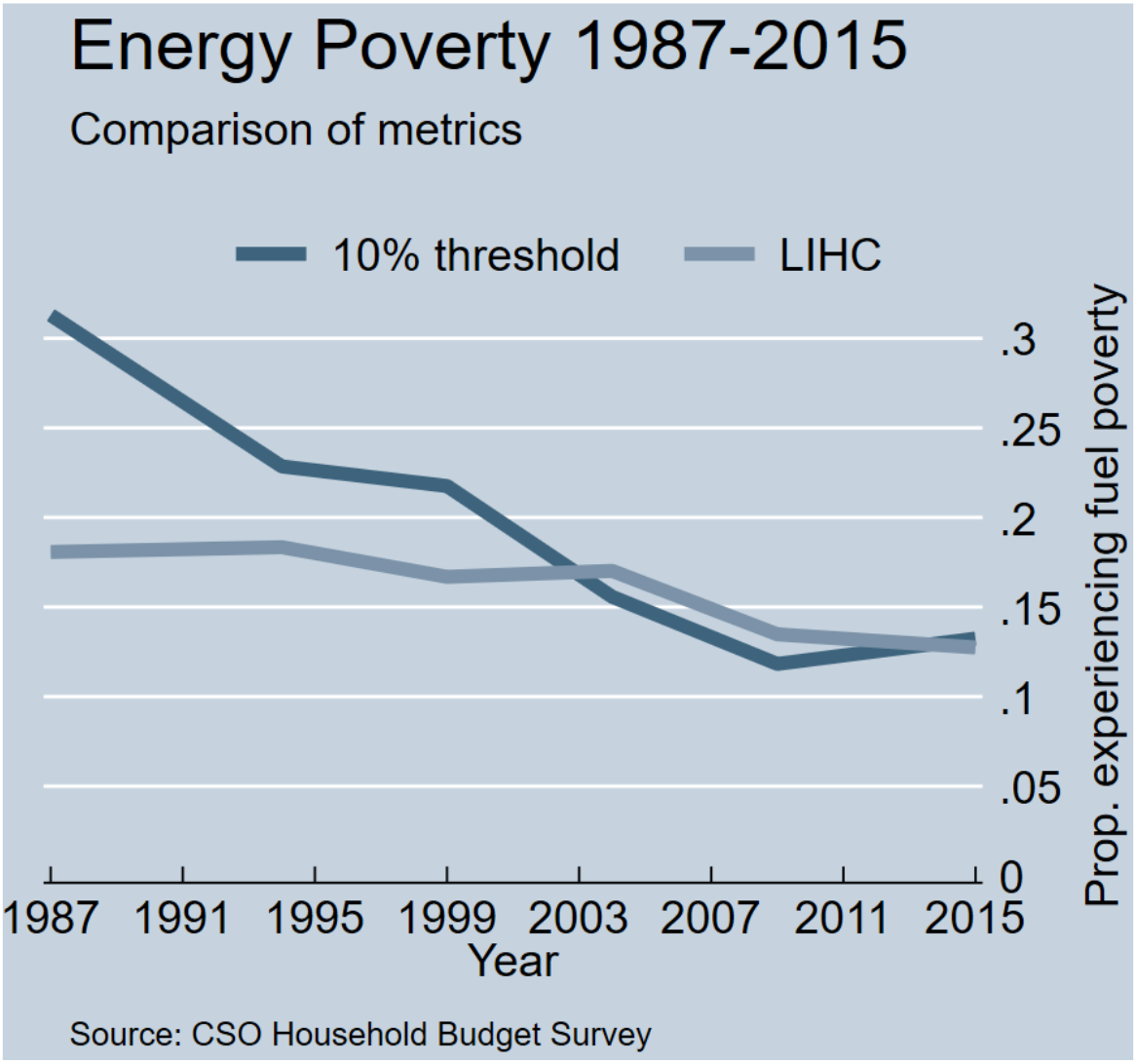
4. HAVE WE BEEN MEASURING FUEL POVERTY CORRECTLY?

4.1. General trends

The second contribution of this paper is to compare fuel poverty incidence as measured by the 10% poverty threshold with the alternative LIHC metric. While subjective measures are commonplace (Watson and Maitre, 2015), the 10% threshold has been the primary metric used by much of the academic literature (Scott et al., 2008) and Irish policy decision papers (DCCAE, 2019; DCENR, 2016). The 10% threshold has been criticised as not necessarily capturing those who are fuel poor (see Section 2). This discussion will quantify the extent with which misspecification may have been occurring in Irish fuel poverty statistics and whether one may observe a trend of increasing or decreasing prevalence.

Figure 6 first compares the total poverty rates calculated by both metrics. Of primary interest is the fact that the LIHC metric shows a much lesser rate of decline throughout the analysed period, perhaps providing a more stable metric of analysis. This may be attributable to the inclusion of housing costs and energy costs in the threshold calculation. Convergence is observed post 1999, with negligible difference in headline poverty rates from this period onwards.

Figure 6: Comparing fuel poverty metrics



Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. Fuel poverty calculated according to 10% income threshold method. Income weighted according to OECD-modified equivalence scale.

Figure 7 provides further insight into the relative composition of the 10% threshold metric and the LIHC metric. Each frame presents a scatterplot of household income against fuel expenditure for a single wave of the HBS dataset. There are three striking features from this set of figures. First, there is considerable overlap between households defined as fuel poor according to the 10% threshold and according to the LIHC threshold. However, there is a greater dispersion observed with respect to poverty defined by the 10% threshold. For 1987 and 1994, in particular, the 10% threshold metric captures many households with high incomes that the LIHC metric does not, perhaps driving the larger membership of fuel poverty status during this period.

Second, there are a number of outliers who do not appear to have high energy expenditures or low incomes, but are measured as being fuel poor according to the LIHC metric. This is likely due to the influence of housing and energy costs when defining household-specific thresholds. This is particularly prevalent in the 1999 and 2004/05 samples.

Finally, there is a trend of those being fuel poor 'bunching' more closely along the extreme left hand side of the plot with each successive survey wave. This indicates a greater centering of data around lower income groups. This finding corresponds to that of Figure 5; income is having a proportionally greater influence on fuel poverty status than energy expenditure as the duration of analysis has passed.

4.2. Decomposing 'fuel poor'

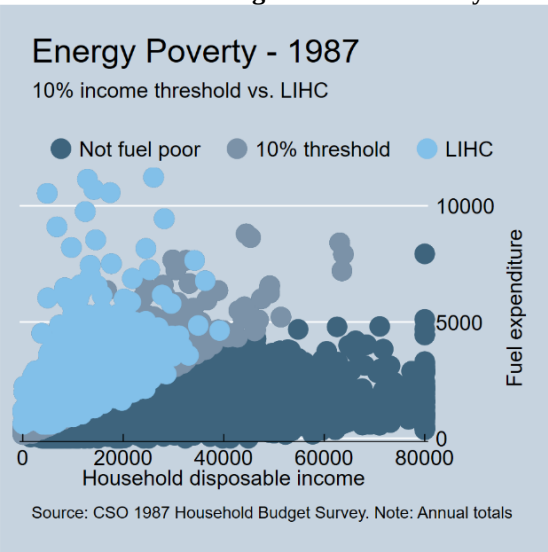
This section is concerned with identifying the extent with which Irish policy calculations effectively target those most vulnerable. Irish policy quantifies fuel poverty according to the 10% income threshold metric. This is decomposed into subcategories of 'Low Income High Cost' (LIHC); 'High Income High Cost' (HIHC); 'Low Income Low Cost' (LILC) and High Income Low Cost' (HILC). Membership of each group determined by income/energy costs being either above or below the relevant threshold, as defined in Section 2. This disaggregation is informative for policymakers who wish to understand whether the LIHC metric is superior. However, such an analysis must also consider those households who are not categorised as fuel poor according to the 10% threshold but are captured as fuel poor according to the LIHC metric. Each of these subpopulations are identified in Figure 10.

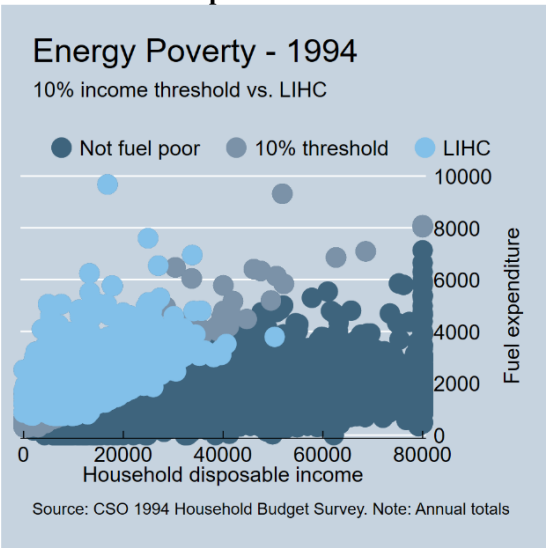
Figure 8 shows some striking results. In 1987, only 56% of households below the 10% proportion of income threshold be characterised as having Low Incomes and High Costs (LIHC). 36% had High Incomes and High Costs (HIHC), while 10% had Low incomes and Low costs (LILC). The share of LIHC households predicted as being in fuel poverty (according to the 10% threshold) rose to 80% in the 1999 wave of the HBS, falling back to 70% in the 00's. As the 1987-2015 duration progressed, LILC households diminished as a proportion of total fuel poor households, to about 6% of the total by 2014/15, with HIHC households plateauing at around 20%. Almost no households with high incomes and low costs (HILC) are categorised as fuel poor by the 10% poverty threshold. Assuming policymakers do not wish to target households with high incomes or low energy costs in their fuel policy strategy, the message and appropriate policy response to these findings is clear. Since 1987, up to 36% of populations designated as fuel poor have had high incomes. While fuel costs are relatively high for these households, so too are their incomes and therefore their fuel poverty status is subject to question. Indeed, fuel poverty status is not given to these households under the LIHC metric.

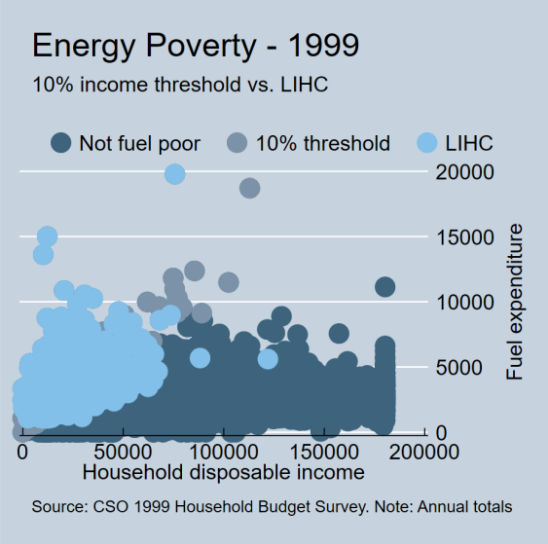
Up to 10% of populations designated as fuel poor have low incomes and low costs. These populations may be vulnerable as they have low incomes. However, they also have relatively low energy costs. This indicates that any experienced vulnerability is not an energy poverty issue but rather an issue of general material deprivation. This is a problem best addressed by wider social policy measures, as opposed to energy poverty policy.

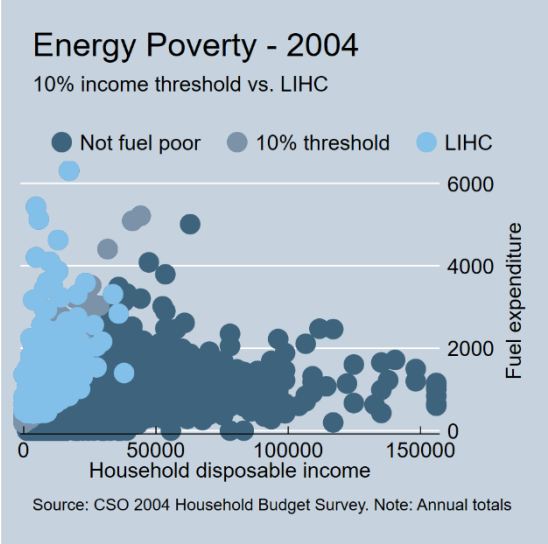
The final band on Figure 8 corresponds to households designated as fuel poor by the LIHC metric but not designated as fuel poor by the 10% income threshold. These households comprised 0.5% of the total population in 1987, but rose steadily throughout the duration to comprise 3.5% of the total population by 2014/15. By definition, these are households who have low incomes and high consumption, but whose consumption does not meet the 10% threshold. This final band results in very similar headline poverty figures in recent times; the households not counted by LIHC cancel out those not counted by the 10% threshold and both give similar headline figures. However, the subpopulation distribution differs greatly and this could have considerable impacts on policy. If energy-efficiency upgrades were targeted towards energy poor households, for example, many high income households would receive support, if eligibility was defined according to the 10% threshold.

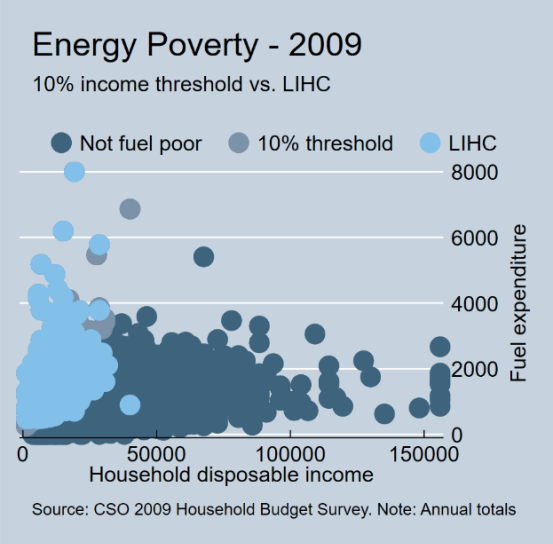
Figure 7: Fuel Poverty Distribution: Income vs. Fuel expenditure.

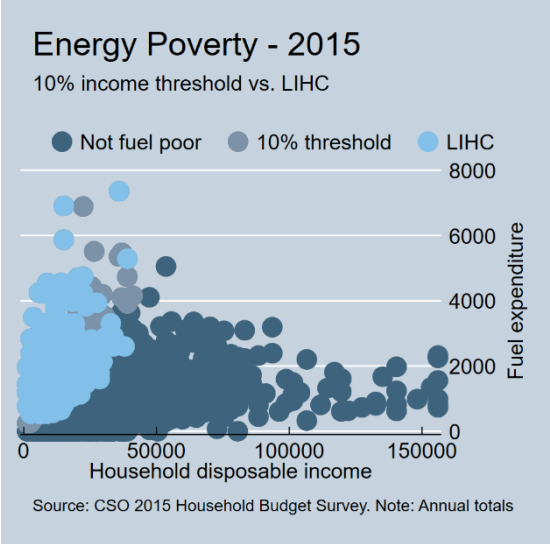






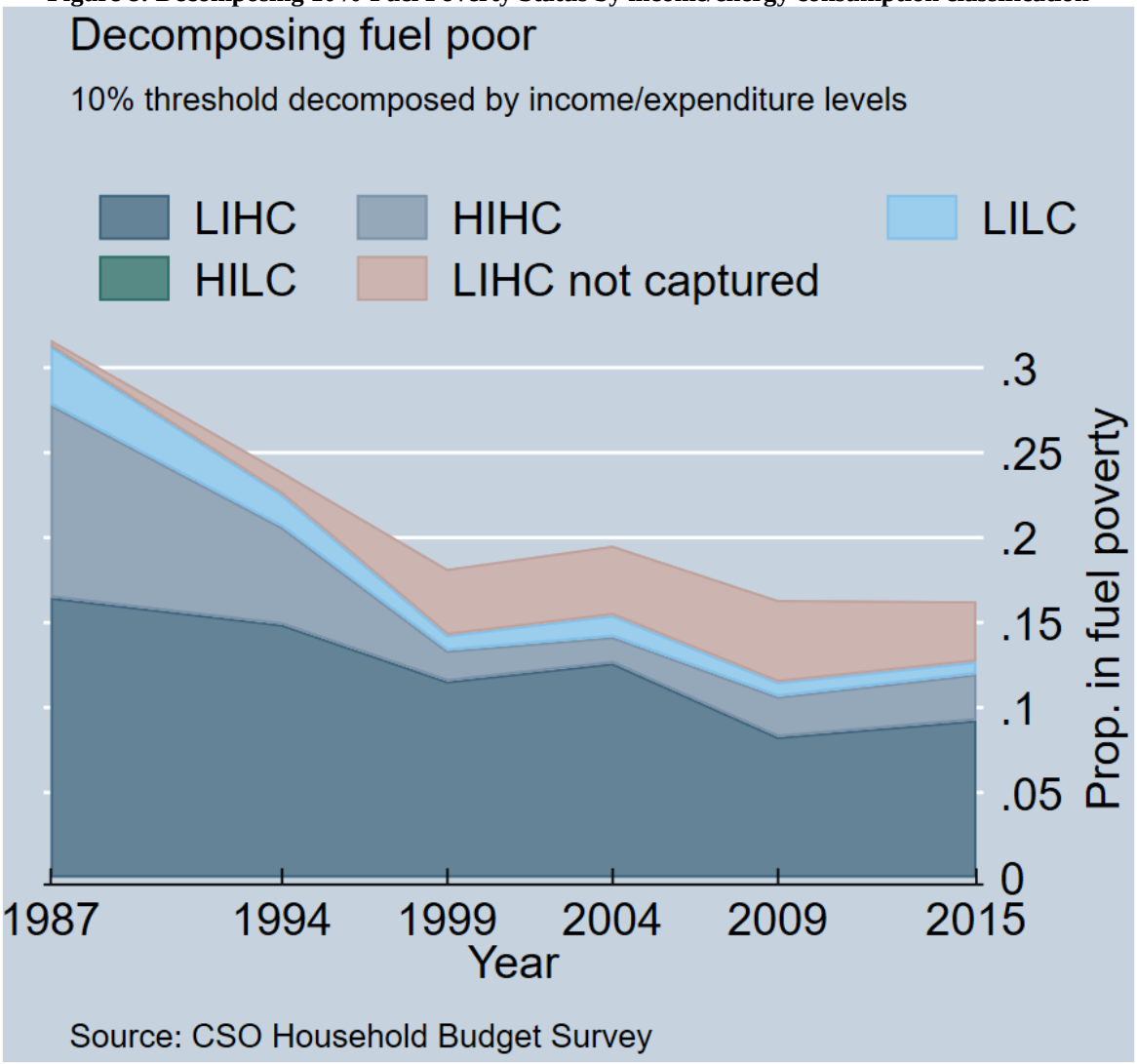






Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. Fuel poverty calculated according to 10% income threshold method. Income weighted according to OECD-modified equivalence scale.

Figure 8: Decomposing 10% Fuel Poverty Status by income/energy consumption classification



Note: Author's calculations using 1987; 1994; 1999; 2004/05; 2009/10 and 2014/15 Household Budget Survey data waves. LIHC, HIHC LILC and HILC all contribute to the 10% fuel poverty metric. "LILC not captured" denotes the portion of the LIHC-defined fuel poverty population not captured by the 10% poverty metric. Income weighted according to OECD-modified equivalence scale.

5. CONCLUSION

This paper charts the incidence of fuel poverty in Ireland through the period 1987-2015. The fuel poor population is decomposed by socioeconomic group to better understand the changing nature of fuel poverty and its determinants. Two fuel poverty metrics are compared; the 10% income threshold approach of Boardman (1991) and the LIHC 'Hills approach (Hills, 2012). A number of key findings emerge.

Income is found to play an increasing role in determining fuel poverty throughout the duration of analysis. In 1987, moving up one income decile reduced the likelihood of fuel poverty status by 0.62 times. In 2015, the likelihood falls by 0.399. Indicators of dwelling energy efficiency have an insignificant effect on fuel poverty in 2015 while indicators of general material deprivation have a persistently significant effect during both time periods.

The second contribution of this paper is to consider how effective Irish policy has been in measuring fuel poverty. The metric favoured by Irish policy has included a considerable proportion of high income households in estimations of fuel poverty incidence; since 1987, up to 36% of populations designated as fuel poor by the 10% income threshold metric have had high incomes. Up to 10% of populations designated as fuel poor have low incomes and low energy costs, a subpopulation whose vulnerabilities are perhaps better addressed through general social policy measures. While the LIHC metric does not include these subpopulations, it does count additional households not previously considered. While this means that headline poverty metrics are broadly similar, their subpopulation distributions differ greatly.

These findings have a number of implications for policy. First, if the identified trends continue, fuel poverty will become increasingly concentrated among households with lower incomes. This supports the hypothesis put forward by Watson and Maitre (2015); policy should focus on better targetting those households constrained in their ability to achieve adequate material well-being.

Secondly, this paper has provided evidence to suggest that the 10% income threshold has been capturing a large proportion of those with high incomes in energy poverty metrics. This is of particular importance for policy, such as energy efficiency upgrades targeting individual households based on fuel poverty status. Under the 10% threshold metric, many high income households may be deemed fuel poor, while a number of low income households who do not pass the 10% threshold are not considered.

Finally, this paper highlights a number of avenues for further research. This paper is limited to revealed costs – augmenting this analysis to consider modelled household costs would capture those households forced to reduce their expenditure due to budget constraints. Second, further analysis into why dwelling characteristics are of diminishing importance would help inform policy. Is there a general improvement in dwelling quality or are high-income households better able to select into energy-efficient dwellings than before? If the latter hypothesis were true, householders with higher incomes would be more likely to purchase more expensive dwellings. The extent with which income is correlated with dwelling standard is likely reflected in the extent with which energy efficiency is reflected in housing prices. Further research examining this relationship may inform an appropriate fuel poverty intervention.

This paper provides additional insight into the nature and extent of fuel poverty in Ireland. As climate policy places an increasing emphasis on the targeting of fuel poor households in energy efficiency interventions, this paper has an important message. First, it is important that the correct metrics are in place to target those who are most in need of public support and second, the appropriate policy intervention must reflect the nature of the experienced deprivation.

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Appendix I: Full regression tables.

Table A1: Determinants of Fuel Poverty (10% threshold) – 1987

Fuel poor (10% threshold)	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.739	.04	-5.57	0	.664	.822	***
Income decile sq.	.983	.005	-3.37	.001	.974	.993	***
Q loans	.968	.045	-0.70	.483	.884	1.06	
Built 1918-1960	1.114	.09	1.34	.179	.951	1.305	
Built 1961-1970	1.039	.111	0.36	.718	.843	1.282	
Built 1971-1980	.966	.087	-0.39	.7	.809	1.153	
Built 1981-1990	.915	.101	-0.80	.424	.737	1.137	
Detached	2.61	.423	5.92	0	1.9	3.586	***
Semi-d/terrace	2.352	.336	5.98	0	1.777	3.113	***
Other	1.792	.54	1.94	.053	.993	3.235	*
4-6 rooms	1.175	.142	1.33	.183	.927	1.489	
7+ rooms	1.612	.237	3.24	.001	1.208	2.151	***
Dishwasher	1.097	.146	0.69	.488	.845	1.423	
Tumble dryer	1.244	.096	2.83	.005	1.07	1.448	***
Double glazing	1.185	.107	1.87	.061	.992	1.415	*
OAP	.955	.073	-0.60	.548	.823	1.109	
Age HoH: 35-64	1.422	.124	4.05	0	1.199	1.686	***
Age HoH: 65+	1.442	.208	2.53	.011	1.086	1.914	**
Female HoH	1.03	.108	0.28	.78	.838	1.266	
3+ adults	1.241	.099	2.72	.007	1.062	1.451	***
1-2 children	1.256	.107	2.67	.008	1.062	1.484	***
3+ children	1.441	.139	3.78	0	1.193	1.742	***
Single parent	1.213	.259	0.91	.364	.799	1.843	
Married HOH	.933	.287	-0.22	.822	.511	1.705	
Up to sec.school	.47	.436	-0.81	.415	.076	2.892	
o	1	.	.	.	.	.	
Non-man.	.864	.088	-1.43	.152	.707	1.056	
Manual	.824	.086	-1.85	.064	.672	1.011	*
Unskilled/agri	.938	.116	-0.52	.604	.735	1.196	
Own a/c & farm	.839	.111	-1.32	.187	.647	1.089	
Other	.717	.145	-1.65	.1	.483	1.065	*
In work	1.103	.168	0.64	.52	.819	1.486	
PTE	1.133	.187	0.75	.452	.819	1.566	
Carer	8.389	13.537	1.32	.188	.355	198.289	
Unemployed	1.084	.113	0.77	.439	.883	1.331	
Unemp. ill	1.614	.311	2.48	.013	1.106	2.354	**
Home, educ	1.408	.229	2.10	.035	1.024	1.938	**
Retired	1.301	.213	1.61	.108	.944	1.793	
Incapacity	1.521	.28	2.28	.023	1.061	2.18	**
o	1	.	.	.	.	.	
Urban	.927	.087	-0.81	.418	.771	1.114	
Q2	2.925	2.613	1.20	.23	.508	16.843	
Q3	1.453	1.295	0.42	.675	.253	8.341	
Q4	.897	.801	-0.12	.903	.156	5.158	
Q5	2.546	2.27	1.05	.295	.444	14.616	
Q6	2.971	2.653	1.22	.223	.516	17.099	
o	1	.	.	.	.	.	
Constant	.372	.343	-1.07	.284	.061	2.269	

Mean dependent var	0.320	SD dependent var	0.467
Pseudo r-squared	0.213	Number of obs	7699.000
Chi-square	2058.800	Prob > chi2	0.000
Akaike crit. (AIC)	7684.219	Bayesian crit. (BIC)	7996.917

*** p<.01, ** p<.05, * p<.1

Table A2: Determinants of Fuel Poverty (10% threshold) – 1994

Logistic regression

fuelpoor_10pc	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.487	.013	-27.93	0	.463	.512	***
Q loans	1.017	.057	0.31	.76	.912	1.134	
Built 1918-1960	1.033	.09	0.38	.705	.871	1.226	
Built 1961-1970	.956	.119	-0.36	.719	.75	1.22	
Built 1971-1980	.939	.096	-0.62	.538	.768	1.148	
Built 1981-1990	.956	.115	-0.38	.705	.755	1.209	
Detached	3.228	.596	6.35	0	2.248	4.636	***
Semi-d/terrace	2.365	.385	5.29	0	1.719	3.254	***
Other	.96	.339	-0.12	.908	.48	1.919	
4-6 rooms	1.872	.257	4.57	0	1.43	2.449	***
7+ rooms	2.187	.379	4.52	0	1.557	3.071	***
Dishwasher	1.69	.205	4.32	0	1.332	2.143	***
Tumble dryer	1.084	.097	0.90	.37	.909	1.292	
Double glazing	.894	.071	-1.40	.162	.765	1.046	
OAP	1.211	.096	2.40	.016	1.036	1.415	**
Age HoH: 35-64	1.093	.126	0.78	.438	.873	1.369	
Age HoH: 65+	.819	.137	-1.19	.233	.591	1.137	
Female HoH	1.175	.125	1.52	.128	.955	1.447	
3+ adults	1.597	.154	4.84	0	1.321	1.929	***
1-2 children	1.356	.14	2.94	.003	1.107	1.661	***
3+ children	1.738	.23	4.17	0	1.341	2.253	***
Single parent	.928	.183	-0.38	.704	.63	1.366	
Married HOH	.437	.257	-1.41	.16	.138	1.386	
Up to sec.school	1.803	.296	3.58	0	1.306	2.488	***
Post-sec, degree	1.626	.282	2.80	.005	1.157	2.286	***
Non-man.	.851	.121	-1.13	.257	.644	1.125	
Manual	.902	.132	-0.71	.481	.676	1.202	
Unskilled/agri	.787	.131	-1.44	.15	.569	1.09	
Own a/c & farm	1.076	.187	0.42	.671	.766	1.512	
Other	.672	.155	-1.72	.085	.427	1.057	*
In work	1.284	.222	1.44	.149	.914	1.802	
PTE	1.21	.212	1.08	.278	.857	1.706	
Carer	.725	.844	-0.28	.783	.074	7.086	
Unemployed	1.353	.171	2.39	.017	1.056	1.734	**
Unemp. ill	1.266	.375	0.80	.426	.708	2.263	
Home, educ	1.512	.295	2.12	.034	1.031	2.217	**
Retired	1.436	.271	1.91	.056	.991	2.079	*
Incapacity	1.554	.316	2.17	.03	1.043	2.313	**
Other empl	3.334	2.747	1.46	.144	.663	16.763	
Urban	.951	.098	-0.49	.625	.776	1.164	
Q2	1.701	.757	1.19	.233	.711	4.069	
Q3	1.125	.491	0.27	.787	.478	2.645	
Q4	2.097	.916	1.69	.09	.891	4.938	*
Q5	3.827	1.669	3.08	.002	1.628	8.997	***
Q6	1.954	.856	1.53	.126	.828	4.61	
o	1	.	.	.	.	.	
Constant	.218	.114	-2.91	.004	.078	.608	***

Mean dependent var	0.235	SD dependent var	0.424
Pseudo r-squared	0.318	Number of obs	7865.000
Chi-square	2726.981	Prob > chi2	0.000
Akaike crit. (AIC)	5941.115	Bayesian crit. (BIC)	6261.743

**** p<.01, ** p<.05, * p<.1*

Table A3: Determinants of Fuel Poverty (10% threshold) – 1999

Logistic regression

fuelpoor_10pc	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.393	.015	-25.01	0	.365	.423	***
Q loans	1.039	.072	0.55	.581	.907	1.19	
Built 1918-1960	1.249	.137	2.03	.042	1.008	1.549	**
Built 1961-1970	1.154	.167	0.99	.322	.869	1.531	
Built 1971-1980	.959	.125	-0.32	.747	.742	1.238	
Built 1981-1990	1.013	.144	0.09	.925	.767	1.339	
Detached	2.127	.516	3.11	.002	1.322	3.42	***
Semi-d/terrace	1.637	.369	2.18	.029	1.052	2.547	**
Other	.679	.433	-0.61	.543	.195	2.367	
4-6 rooms	1.683	.29	3.02	.003	1.2	2.359	***
7+ rooms	2.231	.462	3.88	0	1.487	3.347	***
Dishwasher	1.504	.182	3.37	.001	1.187	1.906	***
Tumble dryer	1.103	.104	1.04	.299	.917	1.328	
Double glazing	1.089	.092	1.01	.312	.923	1.285	
OAP	1.091	.088	1.08	.281	.931	1.277	
Age HoH: 35-64	1.076	.174	0.45	.652	.784	1.476	
Age HoH: 65+	.867	.18	-0.69	.491	.576	1.303	
Female HoH	1.054	.125	0.44	.657	.835	1.331	
3+ adults	1.472	.193	2.95	.003	1.139	1.902	***
1-2 children	1.004	.14	0.03	.975	.765	1.319	
3+ children	1.589	.29	2.54	.011	1.112	2.271	**
Single parent	1.585	.37	1.97	.048	1.003	2.504	**
Married HOH	1.387	.616	0.74	.461	.581	3.314	
Up to sec.school	1.231	.199	1.29	.197	.898	1.689	
Post-sec, degree	1.048	.183	0.27	.789	.744	1.477	
Non-man.	.715	.115	-2.08	.038	.521	.981	**
Manual	.698	.095	-2.65	.008	.534	.91	***
Unskilled/agri	.516	.1	-3.41	.001	.352	.755	***
Own a/c & farm	.777	.128	-1.54	.124	.563	1.072	
Other	.999	.243	-0.00	.997	.62	1.61	
In work	1.137	.252	0.58	.561	.737	1.754	
PTE	.788	.147	-1.28	.202	.547	1.136	
Carer	3.335	3.802	1.06	.291	.357	31.156	
Unemployed	1.393	.28	1.64	.1	.938	2.067	
Unemp. ill	1.626	.467	1.69	.091	.925	2.856	*
Home, educ	1.195	.25	0.85	.396	.792	1.801	
Retired	1.11	.267	0.43	.666	.692	1.778	
Incapacity	1.117	.268	0.46	.645	.698	1.786	
Other empl	2.448	1.487	1.47	.141	.744	8.051	
Urban	.777	.083	-2.36	.019	.63	.959	**
Q2	1.086	.228	0.39	.696	.719	1.64	
Q3	.932	.164	-0.40	.69	.661	1.316	
Q4	1.61	.278	2.76	.006	1.147	2.258	***
Q5	2.862	.499	6.03	0	2.034	4.029	***
Q6	2.083	.357	4.27	0	1.488	2.916	***
o	1	.	.	.	.	.	
Constant	.714	.29	-0.83	.407	.322	1.585	

Mean dependent var	0.152	SD dependent var	0.359
Pseudo r-squared	0.385	Number of obs	7643.000
Chi-square	2503.075	Prob > chi2	0.000
Akaike crit. (AIC)	4097.276	Bayesian crit. (BIC)	4416.587

**** p<.01, ** p<.05, * p<.1*

Table A4: Determinants of Fuel Poverty (10% threshold) – 2004/05

Logistic regression

fuelpoor_10pc	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.362	.015	-24.23	0	.333	.393	***
Q loans	1.184	.077	2.60	.009	1.042	1.346	***
Built 1918-1960	.911	.11	-0.77	.442	.719	1.155	
Built 1961-1970	.829	.139	-1.12	.264	.597	1.152	
Built 1971-1980	1.225	.161	1.55	.122	.947	1.585	
Built 1981-1990	1.019	.147	0.13	.898	.768	1.352	
Detached	4.625	1.745	4.06	0	2.208	9.691	***
Semi-d/terrace	3.043	1.109	3.05	.002	1.49	6.215	***
Other	2.418	1.604	1.33	.183	.659	8.87	
Dwell: 4-6 rooms	1.901	.445	2.74	.006	1.202	3.009	***
Dwell: 7+ rooms	2.478	.658	3.42	.001	1.473	4.17	***
Dishwasher	1.064	.12	0.55	.583	.853	1.326	
Tumble dryer	1.355	.134	3.06	.002	1.116	1.645	***
Double glazing	.878	.087	-1.32	.187	.723	1.065	
OAP	.748	.06	-3.60	0	.638	.876	***
o	1	.	.	.	.	.	
o	1	.	.	.	.	.	
Female HoH	1.042	.129	0.33	.743	.817	1.328	
3+ adults	1.361	.211	1.99	.047	1.004	1.844	**
1-2 children	1.126	.182	0.73	.463	.82	1.545	
3+ children	1.601	.362	2.08	.038	1.027	2.495	**
Single parent	1.449	.326	1.65	.098	.933	2.251	*
Married HOH	1.401	.157	3.01	.003	1.125	1.745	***
Up to sec.school	.977	.143	-0.16	.873	.734	1.3	
Post-sec, degree	.847	.136	-1.04	.299	.618	1.159	
Non-man.	.98	.181	-0.11	.911	.683	1.406	
Manual	1.059	.187	0.33	.744	.75	1.497	
Unskilled/agri	.902	.194	-0.48	.631	.592	1.374	
Own a/c & farm	1.683	.329	2.66	.008	1.147	2.47	***
Other	.909	.205	-0.42	.672	.585	1.413	
In work	1.058	.228	0.26	.795	.694	1.613	
PTE	1.059	.202	0.30	.763	.729	1.539	
o	1	.	.	.	.	.	
Unemployed	1.226	.329	0.76	.448	.724	2.076	
Unemp. ill	.913	.4	-0.21	.836	.387	2.156	
Home, educ	1.845	.381	2.96	.003	1.23	2.766	***
Retired	1.536	.354	1.86	.063	.978	2.412	*
Incapacity	1.555	.378	1.82	.069	.966	2.504	*
Other empl	1.113	.942	0.13	.899	.212	5.845	
Urban	1.028	.128	0.22	.826	.805	1.311	
Q1	1.133	.185	0.77	.444	.823	1.559	
Q2	1.272	.172	1.78	.075	.976	1.658	*
Q3	1.011	.139	0.08	.939	.772	1.323	
Q4	.749	.106	-2.05	.04	.568	.987	**
o	1	.	.	.	.	.	
Constant	.419	.2	-1.82	.069	.164	1.069	*

Mean dependent var	0.140	SD dependent var	0.347
Pseudo r-squared	0.412	Number of obs	6880.000
Chi-square	2289.433	Prob > chi2	0.000
Akaike crit. (AIC)	3355.234	Bayesian crit. (BIC)	3642.362

*** p<.01, ** p<.05, * p<.1

Table A5: Determinants of Fuel Poverty (10% threshold) – 2009/10

Logistic regression

fuelpoor_10pc	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.413	.017	-21.31	0	.381	.448	***
Q loans	1.022	.092	0.24	.81	.857	1.219	
Built 1918-1960	1.406	.199	2.41	.016	1.065	1.856	**
Built 1961-1970	1.211	.245	0.95	.343	.815	1.801	
Built 1971-1980	1.149	.184	0.87	.387	.839	1.574	
Built 1981-1990	1.26	.228	1.28	.202	.884	1.796	
Detached	2.497	.562	4.06	0	1.606	3.883	***
Semi-d/terrace	1.643	.318	2.57	.01	1.125	2.4	**
Other	1.065	.914	0.07	.942	.198	5.728	
4-6 rooms	1.048	.204	0.24	.808	.716	1.535	
7+ rooms	1.315	.322	1.12	.263	.814	2.125	
Dishwasher	1.54	.179	3.71	0	1.226	1.934	***
Tumble dryer	1.013	.113	0.12	.905	.814	1.261	
Double glazing	.935	.137	-0.46	.649	.701	1.247	
OAP	.74	.104	-2.14	.032	.562	.975	**
o	1	.	.	.	.	.	
o	1	.	.	.	.	.	
Female HoH	1.107	.133	0.85	.397	.875	1.4	
3+ adults	1.541	.265	2.52	.012	1.101	2.158	**
1-2 children	1.614	.258	2.99	.003	1.179	2.208	***
3+ children	2.571	.663	3.66	0	1.551	4.262	***
Single parent	.952	.212	-0.22	.826	.615	1.473	
Married HOH	1.706	.243	3.75	0	1.291	2.255	***
Up to sec.school	1.111	.137	0.85	.397	.871	1.415	
Post-sec, degree	1.05	.15	0.34	.731	.794	1.389	
Non-man.	.81	.138	-1.24	.215	.579	1.131	
Manual	.601	.111	-2.77	.006	.419	.862	***
Unskilled/agri	.88	.177	-0.64	.525	.594	1.305	
Own a/c & farm	1.098	.221	0.47	.641	.741	1.629	
Other	.94	.209	-0.28	.781	.608	1.453	
In work	1.279	.301	1.05	.294	.807	2.027	
PTE	1.435	.281	1.85	.065	.978	2.106	*
Carer	7.163	7.984	1.77	.077	.806	63.667	*
Unemployed	1.876	.475	2.49	.013	1.143	3.081	**
Unemp. ill	1.176	.399	0.48	.632	.605	2.288	
Home, educ	1.292	.341	0.97	.332	.77	2.168	
Retired	1.123	.324	0.40	.688	.637	1.978	
Incapacity	.747	.244	-0.89	.372	.394	1.416	
Other empl	.531	.382	-0.88	.379	.13	2.173	
Urban	1.062	.13	0.49	.622	.836	1.349	
Q1	1.001	.227	0.01	.995	.642	1.562	
Q2	1.48	.257	2.26	.024	1.054	2.079	**
Q3	2.242	.359	5.04	0	1.638	3.068	***
Q4	1.61	.27	2.84	.005	1.159	2.237	***
o	1	.	.	.	.	.	
Constant	.376	.143	-2.56	.01	.178	.794	**

Mean dependent var	0.106	SD dependent var	0.308
Pseudo r-squared	0.330	Number of obs	5890.000
Chi-square	1314.686	Prob > chi2	0.000
Akaike crit. (AIC)	2752.326	Bayesian crit. (BIC)	3039.609

*** p<.01, ** p<.05, * p<.1

Table A6: Determinants of Fuel Poverty (10% threshold) – 2014/15

Logistic regression

fuelpoor_10pc	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.399	.015	-24.25	0	.371	.43	***
Q loans	.932	.08	-0.83	.408	.787	1.102	
Built 1918-1960	1.018	.124	0.14	.885	.801	1.293	
Built 1961-1970	1.345	.217	1.84	.066	.981	1.845	*
Built 1971-1980	1.038	.129	0.30	.767	.813	1.323	
Built 1981-1990	1.034	.16	0.22	.827	.764	1.401	
Detached	3.101	.727	4.83	0	1.959	4.908	***
Semi-d/terrace	2.61	.565	4.43	0	1.708	3.988	***
Other	.483	.536	-0.66	.512	.055	4.255	
4-6 rooms	1.362	.262	1.61	.108	.934	1.985	
7+ rooms	2.309	.516	3.75	0	1.49	3.577	***
Dishwasher	1.245	.123	2.22	.027	1.026	1.511	**
Tumble dryer	1.32	.124	2.95	.003	1.098	1.587	***
Double glazing	.958	.132	-0.31	.755	.731	1.255	
OAP	1.289	.179	1.83	.068	.982	1.692	*
Age HoH: 35-64	1.817	.313	3.47	.001	1.297	2.547	***
Age HoH: 65+	1.238	.32	0.82	.41	.745	2.056	
Female HoH	1.311	.135	2.63	.008	1.072	1.604	***
3+ adults	1.124	.172	0.77	.444	.833	1.518	
1-2 children	1.46	.232	2.38	.018	1.068	1.994	**
3+ children	1.475	.422	1.36	.175	.841	2.585	
Single parent	.767	.196	-1.03	.301	.465	1.268	
Married HOH	1.325	.156	2.39	.017	1.051	1.669	**
Up to sec.school	.947	.105	-0.49	.622	.762	1.176	
Post-sec, degree	.883	.11	-1.00	.316	.692	1.126	
Non-man.	1.053	.135	0.40	.687	.819	1.355	
Manual	.806	.111	-1.56	.119	.615	1.057	
Unskilled/agri	.802	.143	-1.24	.217	.566	1.138	
Own a/c & farm	1.165	.2	0.89	.374	.832	1.631	
Other	.734	.136	-1.68	.094	.511	1.054	*
In work	1.262	.269	1.09	.275	.831	1.916	
PTE	.907	.153	-0.58	.564	.651	1.263	
o	1	.	.	.	.	.	
Unemployed	1.14	.291	0.51	.607	.692	1.88	
Unemp. ill	1.065	.328	0.21	.837	.583	1.947	
Home, educ	1.233	.305	0.84	.399	.759	2.003	
Retired	1.229	.307	0.82	.411	.753	2.006	
Incapacity	1.076	.294	0.27	.789	.63	1.837	
Other empl	1.763	.706	1.42	.157	.804	3.863	
Urban	.826	.101	-1.57	.117	.65	1.049	
Q1	1.328	.214	1.76	.078	.969	1.82	*
Q2	1.076	.161	0.49	.626	.802	1.443	
Q3	.645	.1	-2.84	.005	.476	.873	***
Q4	.808	.125	-1.38	.167	.597	1.093	
o	1	.	.	.	.	.	
Constant	.384	.146	-2.52	.012	.183	.809	**

Mean dependent var	0.137	SD dependent var	0.344
Pseudo r-squared	0.350	Number of obs	6834.000
Chi-square	1906.617	Prob > chi2	0.000
Akaike crit. (AIC)	3633.158	Bayesian crit. (BIC)	3933.663

*** p<.01, ** p<.05, * p<.1

Table A7: Determinants of Fuel Poverty (LIHC) -2015

LIHC	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Income decile	.342	.015	-25.20	0	.315	.372	***
Q loans	1.056	.086	0.67	.501	.901	1.239	
Built 1918-1960	.932	.117	-0.56	.575	.729	1.192	
Built 1961-1970	1.306	.219	1.59	.111	.94	1.815	
Built 1971-1980	.838	.11	-1.34	.179	.647	1.085	
Built 1981-1990	.89	.144	-0.72	.472	.648	1.222	
Detached	2.344	.511	3.91	0	1.53	3.593	***
Semi-d/terrace	2.021	.395	3.60	0	1.378	2.963	***
Other	.989	.851	-0.01	.99	.183	5.335	
4-6 rooms	1.056	.191	0.30	.764	.741	1.505	
7+ rooms	1.724	.375	2.50	.012	1.125	2.641	**
Dishwasher	1.072	.108	0.69	.493	.88	1.305	
Tumble dryer	1.239	.118	2.24	.025	1.027	1.494	**
Double glazing	.98	.137	-0.14	.885	.745	1.289	
OAP	.845	.132	-1.08	.281	.622	1.148	
Age HoH: 35-64	1.416	.219	2.25	.025	1.045	1.917	**
Age HoH: 65+	1.349	.35	1.15	.248	.811	2.244	
Female HoH	1.334	.141	2.74	.006	1.085	1.641	***
3+ adults	1.704	.252	3.61	0	1.276	2.276	***
1-2 children	3.437	.524	8.10	0	2.549	4.635	***
3+ children	5.047	1.268	6.44	0	3.084	8.259	***
Single parent	.521	.124	-2.73	.006	.326	.832	***
Married HOH	1.643	.198	4.13	0	1.298	2.08	***
Up to sec.school	1.021	.115	0.19	.851	.818	1.275	
Post-sec, degree	.866	.109	-1.14	.252	.676	1.108	
Non-man.	1.046	.14	0.34	.737	.805	1.359	
Manual	.989	.14	-0.08	.939	.75	1.304	
Unskilled/agri	1.069	.191	0.37	.708	.754	1.516	
Own a/c & farm	1.126	.201	0.66	.507	.793	1.599	
Other	.734	.14	-1.62	.104	.505	1.066	
In work	1.079	.247	0.33	.738	.69	1.689	
PTE	.769	.127	-1.59	.112	.556	1.063	
o	1	.	.	.	.	.	
Unemployed	.76	.198	-1.05	.292	.456	1.267	
Unemp. ill	.847	.262	-0.54	.592	.462	1.555	
Home, educ	.829	.212	-0.73	.465	.502	1.37	
Retired	.716	.192	-1.25	.212	.423	1.211	
Incapacity	.664	.188	-1.45	.148	.381	1.157	
Other empl	.644	.279	-1.01	.311	.276	1.507	
Urban	.836	.107	-1.41	.159	.651	1.073	
Q1	1.298	.213	1.59	.112	.941	1.79	
Q2	1.073	.164	0.46	.644	.795	1.448	
Q3	.698	.11	-2.29	.022	.513	.949	**
Q4	.737	.117	-1.93	.053	.54	1.004	*
o	1	.	.	.	.	.	
Constant	1.308	.49	0.72	.474	.628	2.724	

Mean dependent var	0.129	SD dependent var	0.335
Pseudo r-squared	0.352	Number of obs	6834.000
Chi-square	1853.108	Prob > chi2	0.000
Akaike crit. (AIC)	3495.381	Bayesian crit. (BIC)	3795.886

**** p<.01, ** p<.05, * p<.1*

DISCUSSION

Sean Lyons: I thank the speaker for his paper and asked him what steps are needed to overcome the lack of good indicators of housing quality, beyond using standard proxies such as age and type; in particular, we would like to be able to directly include a dwelling's efficiency. Another factor that might inform the urban/rural split you mentioned is the difference in the locally-available fuel mix. Urban areas would be much more likely to have access to natural gas, while many rural areas have only solid fuels, oil and electricity. If that is so, some of the difference in the urban and rural trends have to do with price variations among fuels.

Barra Roantree: I also thank Niall for his paper and asked two questions. His first question was in relation to tenure and the finding that a smaller number of renters were in fuel poverty - might this change if the fuel poverty rate were used instead? Barra's second question was in relation to SILC data, which has a different pattern to the expenditure measure; Barra asked whether Niall had examined these differences.

Gerry Brady: I mention that the CSO is looking at developing measures of energy poverty, using a combination of HBS, SILC and BER data, linked to energy consumption data. A report comparing 2011 and 2016 Census data, at household level, was published, examining central heating fuel. Households that moved from solid fuel to central heating was associated with a change of occupants - suggesting path dependence in energy consumption habits.

Dorothy Watson: I congratulate Niall for an interesting paper on an important topic. I ask if he could say a little more on how the profile of those identified as fuel-poor might vary by the choice of measure used?

Siobhan Carey: I ask what factors in relation to the household itself are relevant for fuel poverty, such as size and age. She also mentioned that, due to the nature of social welfare payment levels and their link to the measure of deprivation used, it might be worth analysing elderly-only households, regardless of income level.

Daire McCoy: I also congratulate Niall on an interesting paper. I note that the composition of fuel usage will have changed a lot over the sample period, in particular towards gas. These bring issues of measurement, such as metered versus self-reported. I ask whether Niall had been able to decompose those identified as fuel-poor by the primary means by which they heated their home and how that varies over time?