A SMALL AREA FUEL POVERTY INDICATOR FOR WALES

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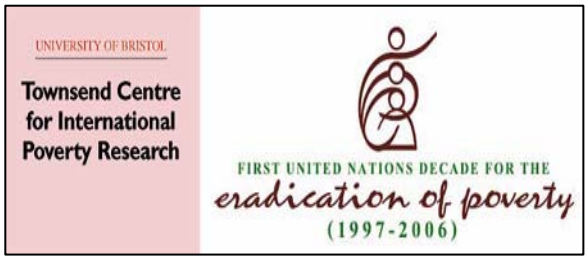

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Overview

This report provides small area estimates of the number and percentage of households that are likely to be living in fuel poverty. The 'small areas' are based on the 2001 Census definitions. Four different definitions of household income have been used:

1. Full income (e.g. net income *including* housing benefits)
2. Basic income (e.g. net income *excluding* housing benefits)
3. Equivalised Basic income (e.g. Basic income adjusted for household size and composition)
4. Equivalised Full income (e.g. Full income adjusted for household size and composition)

This is the fifth and final report of a fuel poverty research programme commissioned by the Welsh Assembly Government from the Centre for Sustainable Energy[1] and the Townsend Centre for International Poverty Research[2]. The other four reports are:

- *Moore, R (2003), Estimating SAP ratings from the 1997/78 WHCS and other data, working paper*
- *Moore, R (2004), Annual total required fuel costs in Wales in 1997, working paper*
- *Gordon, D, (2004), Fuel poverty in Wales: imputing income from the WHCS, working paper*
- *Moore, R. & Gordon, D.* (2004) *Fuel Poverty in Wales, 1997/98 'Full', 'Basic' and 'Residual' Income Estimates and Comparison with English Frequencies, working paper*

These previous reports were concerned with producing estimates of fuel poverty from the 1997/98 *Welsh House Condition Survey*. Although this work was successful, it was decided that the final part of this research project - to produce small area estimates of fuel poverty - should be postponed until the 2004 *Living in Wales* (LIW) survey data were available and the English small area fuel poverty estimates had been produced (Fahmy, Patsios and Gordon, 2007).

Section One: Small Area Fuel Poverty Indicators

1.1 Introduction

The 1997/98 *Welsh House Condition Survey* (WHCS) estimated that 222,000 households were eligible for assistance under New Home Energy Efficiency Scheme (HEES) because they lacked one or more of the measures available through the scheme. Approximately half of these households (117,000) contained at least one person over the age of 60. About 18% (40,000) were lone parent households and a further 14% (32,000) of households were eligible due to long term sickness or disability. The remainder (33,000) were other 'poor' households with children (DEFRA & DTI, 2001; WAG, 2003).

[1] http://www.cse.org.uk/

[2] http://www.bristol.ac.uk/poverty/

The first part of this research programme involved producing fuel poverty estimates for Wales using several different income definitions. Statistical models, based on the 1997/98 WCHS data, estimated fuel poverty rates in 1998 of 31% and 34% of Welsh households using the Full and Basic income definitions. Considerable progress was made between 1998 and 2004 and the LIW survey estimated that fuel poverty had fallen to 13% and 17% of Welsh households, respectively. Unfortunately, fuel prices today are significantly higher in real terms than in 2004, so it is likely that fuel poverty in Wales has increased considerably since these earlier estimates, reversing some of the gains that had been made. Model estimates suggest that there were 166,000 households in fuel poverty in Wales in 2005 and 243,000 in 2006 (BERR & DEFRA, 2007). EnergyWatch Wales has estimated that fuel poverty will increase to 270,000 households (22% of households) in Wales during 2008[3]. The purpose of this research report is to estimate and map the distribution of fuel poverty at small area level in order to help improve the targeting of alleviation measures.

The 2001 Census and the 2004 LIW have made a number of significant scientific and technical advances resulting in much more reliable and accurate estimates of small area fuel poverty than was previously possible, including:

1. *The 2001 Census Output Area Geography*

   Unlike the 1991 Census, the 2001 Census groups households into smaller and more comparable Output Areas (approximately 125 homes) which have common tenure and dwelling characteristics. This significantly improves the accuracy and predictive power of fuel poverty estimates at a sub-ward level.

2. *Improvements to 2001 Census indicators of fuel poverty*

   The 2001 Census includes new and improved questions potentially associated with fuel poverty, for example, improved questions on under-occupancy and unemployment and new questions on general health.

3. *The ability to link post coded data to the 2001 Census Output Areas*

   A key indicator of fuel poverty is the age and type of dwellings. The age of dwellings was not collected in the 2001 Census, however this information is available at postcode level from RESIDATA and can be matched to the Census small areas using postcode lookup tables.

4. *Improvements to energy use modelling and income measurement in the 2004 LIW*
   The 2004 LIW (WAG, 2004a,b) represents a major scientific advance over the 1997/98[4] *Welsh House Conditions Survey* (WHCS) for measuring fuel poverty. The 1997/98 WHCS did not include all the variables needed to calculate SAP ratings of dwellings and these calculations required the imputation of a considerable number of variables (Moore, 2003). By contrast, the 2004 LIW included a more comprehensive physical survey of dwellings which facilitated significantly more accurate SAP calculations. Household income was also measured in a more comprehensive and systematic manner in the 2004 LIW than in the 1997/98 WHCS.

[3] http://www.assemblywales.org/bus-home/bus-committees/bus-committees-third1/bus-committees-third-sc-home/bus-committees-third-sc-report/sc_3__fuel_poverty.htm

[4] The WHCS Household Survey was carried out in 1997 and the Property Survey was done in 1998.

Based on existing research into fuel poverty, it is therefore possible to estimate the vulnerability of different groups of households using the 2004 LIW survey data and to apply the resultant survey weights to 2001 Census data at a variety of spatial scales. This was done using a logistic regression approach to predict the odds of fuel poverty for different household types and then applying the results of these models (Full and Basic FPI) to 2001 Census data. This approach is sometimes referred to as synthetic modelling. Before carrying out the regression analysis, the following steps were undertaken:

- **Data harmonisation.** Harmonisation of data from the 2004 LIW to the 2001 Census for Wales
- **Re-weighting.** Post-stratification population weighting of 2004 LIW data to the 2001 Census for Wales
- **Residata matching.** Matching of Residata post-coded data on dwelling type, age and property value to 2001 Census OA geography
- **Selecting optimal splits.** The selection of optimal groupings of variable categories to best predict fuel poverty (e.g. using Exhaustive CHAID)

Sections 1.2 to 1.7 describe the model specification in more detail and Sections 1.8 and 1.9 present the results of the analyses for the 'full' and 'basic' income versions of the FPI.

1.2 Census-based Deprivation Indices

The approach adopted in this research builds upon earlier research into the use of 1991 Census data to predict fuel poverty in England (e.g. Baker et al., 2002, Fahmy, Gordon and Patsios, 2007). It also draws heavily upon a much broader body of research into Census-based indicators of deprivation (e.g. Gordon, 1995; Lee et al., 1995; Dorling et al, 2007). Census-based measures of deprivation are usually 'indirect' or 'proxy' measures of deprivation in that they typically measure characteristics associated with poverty (e.g. health status, overcrowding, etc.) rather than poverty itself. As such, their adequacy is dependent upon the model fit of the survey data used to derive the Census weightings.

As Census-based approaches are based on indirect measurement, individual components of the indicator need to be:

- Weighted to reflect the different probability each household type has of suffering fuel poverty; and
- Additive so that where an indicator consists of two variables it should yield higher fuel poverty rates for the variables added together than for either variable separately.

Weighted indicators also have the advantage that the results are much easier to understand. For example, it allows the researcher to make statements such as, "17% of households in Cardiff live in fuel poverty", rather than "Cardiff has a fuel poverty Z-score of -2.6". This protocol was successfully followed in previous research which developed a Fuel Poverty Indicator (FPI) for England based on the 1991 Census (Baker et al., 2002) and the 2001 Census (Fahmy et al, 2007).

1.3 Model Specification

Scientific approaches to the measurement of fuel poverty are based upon a set of *a priori* assumptions about the nature of fuel poverty drawn from existing research evidence. Ideally, we would seek to develop a measurement model of fuel poverty using one dataset and test the model using independent data.

Existing studies on individuals' and households' propensity to live in fuel poverty (e.g. Wicks 1978; Boardman, 1991; DTI/DEFRA, 2001; NEA, 2001, 2003; Wilkinson et al., 2001; Sefton, 2002) suggest that it is possible to identify two categories of fuel poor households:

1. *People with a relatively low income.* Groups known to suffer from high rates of relative poverty, e.g. lone parents, unemployed people, are also likely to suffer from high rates of fuel poverty. However, there are exceptions. Some social housing tenants, for example, live in properties with high energy efficiency standards, meaning that although they may have low incomes, they do not live in fuel poverty.

2. *People with low/moderate incomes living in energy inefficient housing.* This group may have an overall standard of living above the income poverty threshold. However, the poor energy efficiency standards of their housing (coupled with, in some cases, under-occupancy) may push this group into fuel poverty. Single pensioners living in poorly insulated older dwellings make up the bulk of this group. Fuel poverty, in this case, is largely a problem of heating unmodified pre-WWII housing stock, combined with relatively low pension incomes.

1.4 Harmonisation of Definitions

Synthetic modelling of fuel poverty at a small area level involves determining the best sub-set of predictors of fuel poverty (based upon regression analysis) using the 2004 LIW survey and applying these weightings to 2001 Census small area data. In order to do this, it is clearly essential that the operationalisation of measures used in the analysis of the LIW is as consistent as possible with the definitions and measures in the 2001 Census. Hence, measuring instruments need to be harmonised across these datasets.

Official surveys are designed to meet different needs and have been commissioned by a range of authorities, resulting in important definitional differences across measures. These can have important effects on the distribution of key classificatory variables used in the construction of weighted, Census-based indices. In particular, the definitions used in the 2001 Census are somewhat different from those used in the 2004 LIW survey. This is not surprising given that the 2001 Census was a self-completion questionnaire whereas the data in the 2004 LIW was obtained from face to face interviews. In the 2001 Census, the concept of Household Reference Person (HRP) replaced Head of Household (used in 1991). This meant substantial and time-consuming re-coding of the 2004 LIW data was necessary to ensure that household-level indicators used to weight Census data were comparable across data sources.

As with the concept of HRP, the definition of many other potential key predictors of fuel poverty in England is also somewhat different in the 2001 Census compared with the 2004

LIW. The research team assessed the compatibility of 2004 LIW data with ONS 2001 Census definitions and outputs based upon a systematic review of Census tables using the SASPAC software package. In total, 43 question areas within the 2001 Census required detailed examination to enable consistent analysis of the two data sets and definitions applied. With respect to the LIW, these included:

- Household composition
- Household tenure status
- Employment status (HRP)
- Household shares accommodation
- Household shares WC or bath/shower
- Household lacks central heating
- Limiting illness
- Dwelling type
- Period of construction of dwelling
- Number of rooms in accommodation
- Occupancy rating

1.5 Data Harmonisation

The harmonisation of LIW and 2001 Census sources has *two* key components:

1. Harmonisation of definitions (as described above), and;
2. Harmonisation of the data itself in terms of the observed characteristics of the sample with respect to key grouping variables.

The weights derived from the LIW models clearly need to be estimated on the same basis as the data to which they are subsequently applied, namely 2001 Census small area data. In order to ensure comparability and consistency of data sources between the 2004 LIW and 2001 Census, it is necessary to re-weight 2004 LIW data to reflect the social-demographic distribution of the Welsh resident household population in 2001, with respect to key variables known to be associated with fuel poverty.

A post-stratification population re-weighting was applied to the 2004 LIW data to ensure consistency with 2001 Census estimates for the following characteristics:

- **Household type (9 categories):** Single; Single pensioner; All pensioners; Couple, no dependent children; Couple with dependent children; Couple with non-dependent children, Lone parent with dependent children; Lone parent with dependent non-children, Other.
- **Tenure Status (4 categories):** Owner occupier; Private renter; Local Authority renter; Registered Social Landlord / Housing Assoc. renter.

This re-weighting restores the 2004 LIW sample to the observed frequencies for Wales obtained from the 2001 Census. This re-weighting exercise was very successful and out of the total valid sample of 2,466 households only 2.2% of households were weighted with values greater than 3 or less than 0.33, with all values in the range 0.19 to 6.68.

1.6 Matching of RESIDATA to 2001 Census

A key indicator of fuel poverty that was not measured in the 2001 Census is the age of dwellings. Older houses (particularly pre-1920 construction) are more likely to be fuel inefficient than more modern dwellings[5]. Although the age of dwellings was not collected in the 2001 Census, this information is available at postcode level from RESIDATA. The team was able to accurately convert this post-coded information to 2001 Census Output Areas and other geographies using the Postcode to Output Area (PC to OA) lookup tables. Similar data linkages were possible with 1991 Census data. However, these were much less accurate as 1991 Enumeration Districts were not based on postcodes. By contrast, the Automated Zoning Procedure (AZP) used in the construction of 2001 Output Areas ensured that unit postcodes were grouped together into the larger Census output areas.

The research team successfully matched the RESIDATA unit postcode data for Britain on over 1.15 million 2001 Output Areas, representing a full or partial match rate of almost 100%. (For 13 of the 165,000+ Output Areas, RESIDATA records were missing and were therefore imputed on the basis of mean Lower Super Output Area values). As a result, it is possible to include 'age of dwelling' and 'property valuation' within the fuel poverty estimate models.

After the 2001 Census had been completed, a three level hierarchical geography of Super Output Areas (SOAs) was created for the following reasons:

"*SOAs avoid the problems caused by the inconsistent and unstable electoral ward geography. They are better for statistical comparison as they are of much more consistent size and each layer has a specified minimum population to avoid the risk of data disclosure (releasing data that could be traced to individuals). SOAs will not be subject to frequent boundary change, so are more suitable for comparison over time. In addition they will build on the existing availability of data for OAs.*"[6]

Lower Super Output Areas have a minimum population 1,000 and an average population of 1,500. They are made up from groups of Census Output Areas (typically 4 to 6). Middle Super Output Areas have a minimum population of 5,000 and an average population of 7,200. They are made up from groups of Lower Super Output Areas and constrained by the 2003 Local Authority boundaries. In Wales, there are 9,769 Output Areas, 1,896 Lower Super Output Areas and 413 Middle Super Output Areas.

1.7 Exhaustive CHAID

CHAID is an analytic technique for performing classification or segmentation analysis. It has many potential applications in the social sciences, including the use of survey data to inform policy making through the development of decision rules to select key predictors. CHAID stands for Chi-square Automatic Interaction Detection and is an exploratory data analysis method used to study the relationship between a dependent variable and one or

[5] A major reason for this is the use of solid wall, as opposed to cavity wall, construction in older buildings.

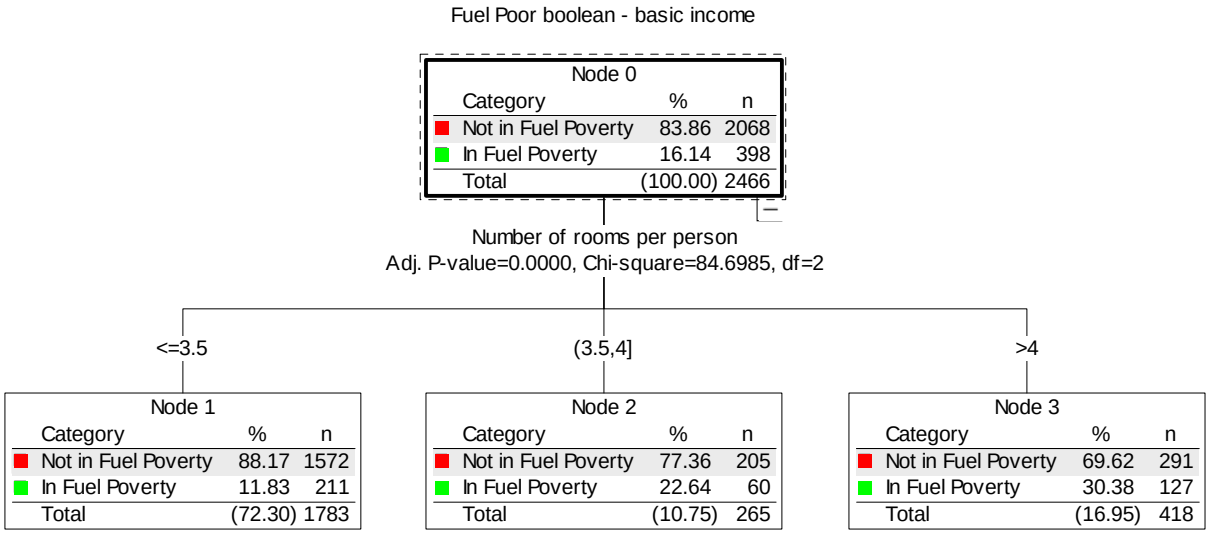
[6] http://www.neighbourhood.statistics.gov.uk/dissemination/Info.do?page=aboutneighbourhood/geography/superoutputareas/soafaq/soa-faq.htm

more predictor variables. CHAID modelling selects a set of predictors and their interactions that optimally predict the variability in the dependent measure.

Exhaustive CHAID is an extension and development of CHAID which tests all possible merges of categories within each variable in order to determine optimal groupings (see Biggs et al., 1991). One application of exhaustive CHAID, segmentation analysis, identifies the best splits in nominal and categorical predictor variables on the basis of the Pearson Chi Square statistics (or equivalent tests for continuous data). All CHAID analyses described in this report were performed using SPSS Answer Tree v3.1.

Figure 1 below shows the optimal grouping of categories in the number of rooms per person (under-crowding) to predict fuel poverty using the basic income measure. The box at the top shows the overall fuel poverty rate as just over 16%. The lower three boxes show the fuel poverty rates for households with less than 3.5 rooms per person (nearly 12% fuel poor), 3.5 to 4 rooms per person (around 23% fuel poor) and more than 4 rooms per person (just over 30% fuel poor). On the basis of these analyses, it was decided to define under-occupancy as more than 4 rooms per person for the purpose of estimating fuel poverty.

Figure 1: An example of Exhaustive CHAID showing the optimal number of rooms per person (under-occupancy) to predict fuel poverty



1.8 Univariate Results

Initially, a range of variables were selected as potential predictors of fuel poverty on the basis of previous studies (e.g. DETR, 2000; NEA, 2001; Gordon et al., 2003; Fahmy et al, 2007). As a result of the harmonisation schedule (*see above*), these variables were also measured in similar ways in the 2004 LIW and the 2001 Census. The variables and their encodings are listed in Table 1 below, along with the following statistics:

1. The percentage within the sub-group fuel poor for both Basic Income (Column 1) and Full Income (Column 4), by comparison with all other sample members.

2. The Pearson Chi Square statistic for the relevant 2x2 table indicating the strength of association between measures compared with all other sample members (Columns 2 and 5).
3. The risk estimate indicating the odds of being fuel poor for each sub-group in comparison with all other sample members (Column 3 and 6).

Table 1: Univariate statistics for FPI Full and Basic Income: frequencies (%), Chi Square and odds ratios for 2x2 tables

	Basic			Full		
Variable	**%**	**X²**	**OR**	**%**	**X²**	**OR**
Household amenities						
Household shares accommodation	**60**	4	7.7	**20**	nc	[1.5]
Household lacks exclusive use of bath/shower/WC	**32**	[3]	[2.4]	**33**	5	3.1
Dwelling lacks central heating	**50**	172	6.3	**50**	226	8.2
Household characteristics						
Dwelling built pre-1919	**20**	12	1.5	**19**	28	1.9
Household overcrowded (bedroom standard)	**23**	[2]	[1.5]	**15**	nc	[1.1]
Household contains 2+ dependent children	**8**	25	0.4	**5**	37	0.2
Single pensioner household	**27**	42	2.3	**27**	68	2.9
Single non-pensioner household	**32**	61	2.8	**23**	24	2.1
Lone parent household (with dep children)	**25**	9	1.8	**11**	[<1]	[0.8]
Single person household with 5 or more rooms	**31**	81	3.0	**31**	120	3.8
HRP characteristics						
HRP unemployed	**39**	27	3.5	**21**	[3]	[1.7]
HRP not economically active	**29**	101	3.0	**22**	41	2.2
Local authority tenant	**26**	23	2.0	**11**	[2]	[0.7]
Private rental tenant	**30**	32	2.4	**19**	4	1.5

NOTE: '[..]' Not significant at .05 level. 'X²' Pearson Chi Square statistic (with continuity correction). 'OR' Bivariate Odds Ratio. 'nc' statistic not computed

For example, with respect to the Basic Income FPI, 27% of single pensioner households are fuel poor, as compared with 16% of the total weighted sample (Figure 1). The associated Chi Square statistic (42) is statistically significant and – again compared with all other sample members – single pensioners are more than twice (2.3 to 1) as likely to be fuel poor. A similar interpretation pertains to Full Income. In both cases, certain sub-groups stand out as especially vulnerable to fuel poverty and these confirm many of the principal findings arising from earlier research (e.g. DETR, 2000; NEA, 2000; Baker et al, 2002). These 'at risk' groups include:

- Households where the 'reference person' is unemployed or economically inactive.
- Those lacking household facilities or central heating
- Single person, single pensioner and lone-parent households
- Under-occupied households i.e. single person households with five or more rooms
- Households living in dwellings built before 1919

However, it is clearly important to consider the simultaneous effects of the 'risk markers', since many of these variables are themselves inter-correlated. Multivariate analysis techniques appropriate for use with non-continuous data were therefore used to address this. The next section discusses the results of the binary logistic regression analysis.

1.9 Multivariate Modelling of Basic and Full Income FPI

Investigating the simultaneous effects of the 'risk markers' associated with fuel poverty was achieved by using multivariate binary logistic regression analysis. This involved selecting variables through backward stepwise selection, using the likelihood ratio method (Hosmer and Lemeshow, 1989). Before running the logistic regression models, the research team checked for multivariate outliers through an examination of 'studentised' residuals[7]. This resulted in the deletion of a further 112 cases for the Basic Income FPI model and 100 cases for the Full Income FPI model, leaving a total of 2,367 (Basic) and 2,374 (Full) cases available for analysis.

Modelling Results

Initial model fitting was undertaken using backward stepwise logistic regression (likelihood ratio method) in which all parameters were entered in one block. Following suitable checks for multicollinearity and heteroskedasticity, significant model coefficients were then entered in one block in two separate logistic regression models[8].

A major assumption made in these models is that the relationship between fuel poverty and household characteristics are the same in all parts of Wales, i.e. that households with no central heating are equally likely to suffer from fuel poverty in both central Newport and rural Anglesey. Whilst this assumption may not be correct, a range of approaches are available to address this problem (although beyond the scope of this project). In particular, Geographically Weighted Regression techniques allow model estimates to vary spatially in relation to a range of user-defined parameters (Fotheringham et al., 2002).

The results from the logistic regression models provide an optimal sub-set of variables which can be used to estimate fuel poverty at small area level (Table 2). The detailed results of the logistic regression analyses are presented in Table 3 (Basic Income) and Table 4 (Full Income). The final model variables for the Basic and Full Income fuel poverty estimates are:

[7] A model residual is the difference between the predicted value for a case specified by the model and its observed value. The 'studentised' residual, named after William Gosset, (writing under the pseudonym 'student'), is derived by dividing the residual by the standard error of the residual with that case deleted. Inspection of studentised residuals is an important means of detecting outliers.

[8] *Multicollinearity* describes any strong linear relationship amongst explanatory variables in a regression model resulting in imprecise model estimates. If nominally different variables are in fact highly correlated they are redundant resulting in a danger of the model over-fitting the data. *Heteroskedasticity* refers to unequal variance in regression errors across values of our dependent variable resulting in biased model estimates. See Cook (1982) for further details.

Table 2: Optimal subset of variables found to predict fuel poverty (Basic and Full income definitions)

Basic Income	Full Income
• Households lacking central heating	• Households lacking central heating
• Dwelling build pre-1919	• Dwelling build pre-1919
• Under-occupied single person households	• Under-occupied single person households
• Single pensioner households	• Single pensioner households
• Single non-pensioner adult households	• Single non-pensioner adult households
• HRP unemployed	• HRP unemployed
• HRP not economically active	• HRP not economically active
• Local authority tenant	• Hhld shares bath/shower or toilet
• Private rental tenant	
• Lone parent households	

Once the 'overlap' between variables is allowed for, the most significant multivariate predictors of fuel poverty are a little different to the individual level predictors shown in Table 1. The overall odds of fuel poverty for each variable included in the model are given in the final column of each table. For example, considering the Basic Income fuel poverty indicator *(Table 3)* (and taking into account the simultaneous effects of these variables), single pensioners are almost three times (1:2.8) as likely to be fuel poor compared with other household types (see final column in Table 3). The statistical significance of the odds estimates can be calculated from the Wald statistic and standard error but all of the variables included in these models are significant at the p<.005 level.

Table 3: LIW Basic Income Fuel Poverty Final Model: Binary Logistic Regression

Variable	B	se	Wald	Sig.	Exp(B)
Hhld lacks central heating	3.152	0.23	188	<.001	23.4
Dwelling build pre-1919	1.027	0.18	32	<.001	2.8
Under-occupied single person hhld	0.865	0.23	14	<.001	2.4
Single pensioner hhld	1.017	0.26	15	<.001	2.8
Single non-pensioner adult hhld	2.143	0.25	75	<.001	8.5
Lone parent hhld	0.965	0.29	11	<.005	2.6
HRP unemployed	2.940	0.34	74	<.001	18.9
HRP not economically active	2.245	0.19	135	<.001	9.4
Local authority tenant	0.944	0.22	18	<.001	2.6
Private rental tenant	1.014	0.22	21	<.001	2.8
	-5.347	0.25	463	<.001	0.0
Model Chi Sq. (df)					*690 (10)*
Nagelkerke R Sq.					*0.482*
N					*2367*

Table 4: LIW Full Income Fuel Poverty Final Model: Binary Logistic Regression

Variable	B	se	Wald	Sig.	Exp(B)
Hhld lacks central heating	3.507	0.23	227	<.001	33.4
Dwelling build pre-1919	1.090	0.18	38	<.001	3.0
Single person hhld with 5+ rooms	1.420	0.24	35	<.001	4.1
Single pensioner hhld	1.623	0.28	33	<.001	5.1
Single non-pensioner adult hhld	1.664	0.28	36	<.001	5.3
HRP unemployed	2.191	0.39	32	<.001	9.0
HRP not economically active	1.296	0.18	49	<.001	3.7
Hhld shares bath/shower or toilet	1.924	0.60	10	<.001	6.9
	-5.145	0.24	453	<.001	0.01
Model Chi Sq. (df)					*604 (8)*
Nagelkerke R Sq.					*0.463*
N					*2374*

The preliminary fuel poverty model derived from the 2004 LIW needs to be calibrated to the 2001 Census data for Wales to ensure that the weightings achieve 100% coverage. As the underlying regression equation is additive, the regression coefficients themselves (B) can be re-calibrated and applied directly to the 2001 Census small area statistics. The final weights used in deriving the small area estimates are shown below.

The number of Basic Income fuel poor households is equal to:

2.1% of Households lacking central heating
+ 0.7% of Dwellings built pre-1919
+ 0.6% of Under-occupied single person households
+ 0.7% of Single pensioner households
+ 1.4% of Single non-pensioner adult households
+ 0.6% of Lone parent households
+ 1.9% of Households headed by someone unemployed
+ 1.5% of Households headed by someone not economically active
+ 0.6% of Local authority tenants
+ 0.7% of Private rental tenants

The number of Full Income fuel poor households is equal to:

2.7% of Households lacking central heating
+ 0.9% of Dwellings built pre-1919
+ 1.1% of Under-occupied single person households
+ 1.3% of Single pensioner households
+ 1.3% of Single non-pensioner adult households
+ 1.7% of Households headed by someone unemployed
+ 1.0% of Households headed by someone not economically active
+ 1.5% of Households sharing use of a bath/shower or toilet

Based upon these empirically derived weights, the distribution of fuel poverty can then be estimated at any spatial scale of Census geography (including Output Area) by combining the Census and RESIDATA databases. The final results (overleaf) show the distribution of the fuel poverty estimates based upon the Basic and Full Income definitions at Mid-Super Output Area level. These data show that for both the Basic and Full Income fuel poverty is concentrated in urban areas and especially in the major urban conurbations (e.g. Cardiff, Newport and Swansea), as well as in the valleys and the more remote rural areas - particularly in North West Wales.

Figure 2: Basic Income Fuel Poverty at 2001 Middle Super Output Area Level (%)

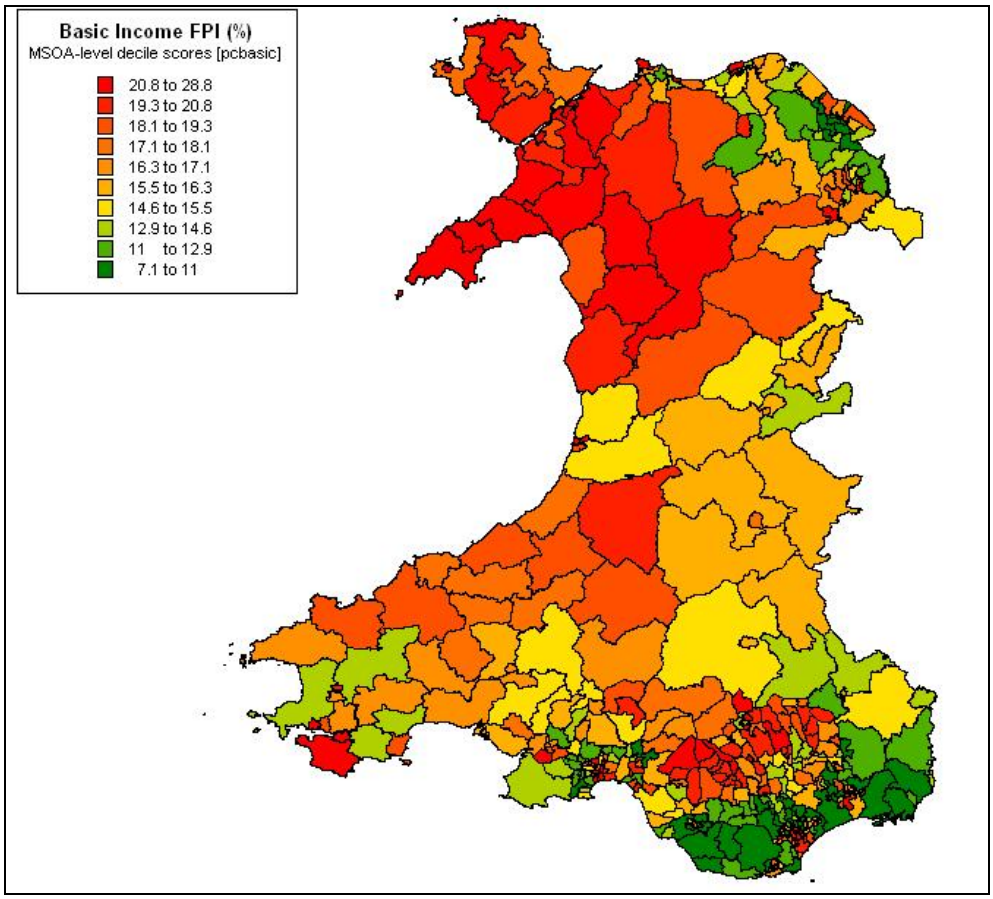


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Figure 3: Basic Income Fuel Poverty (%), MSOA deciles – South Wales

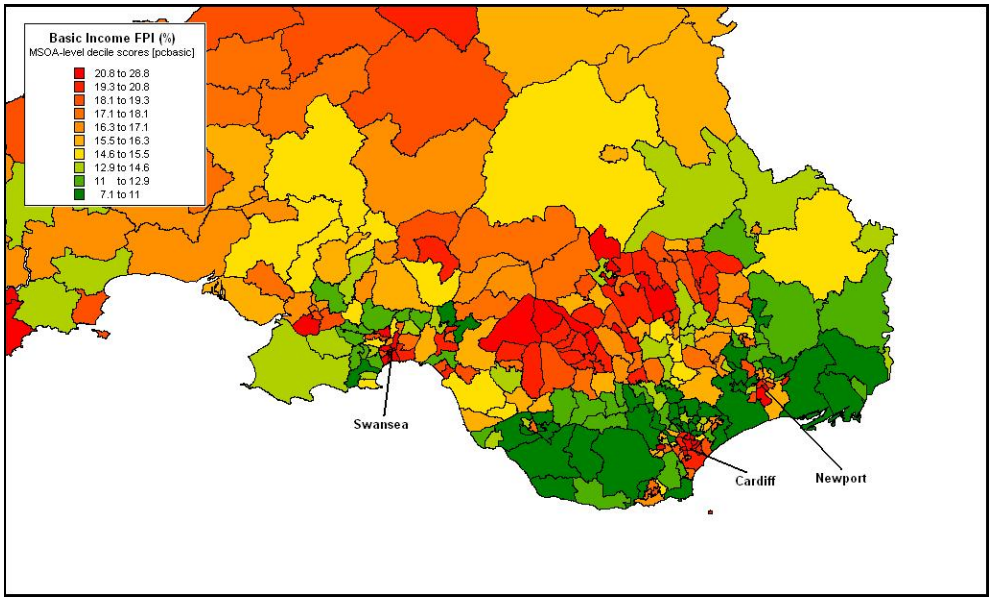

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Figure 4: Full Income Fuel Poverty at 2001 Middle Super Output Area Level (%)

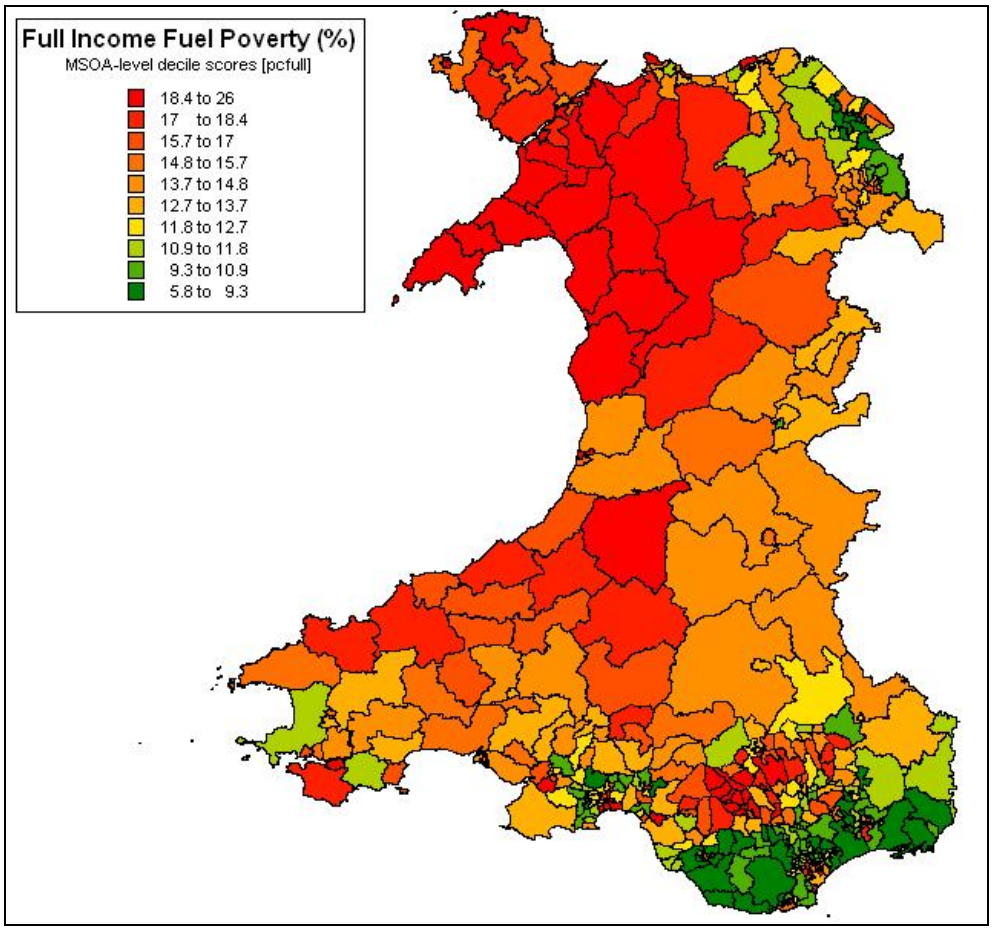

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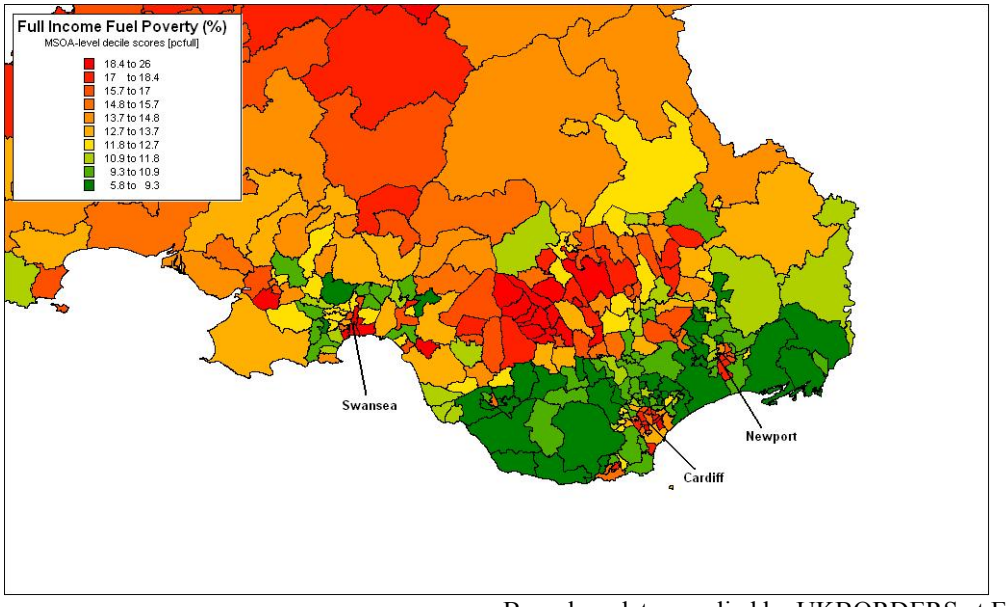
Figure 5: Full Income Fuel Poverty (%), MSOA deciles – South Wales



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1.10 Summary of Findings

The small area fuel poverty estimates take advantage of a variety of 21st Century scientific and technical advances in data collection. Specifically, these relate to changes in the output geography of the 2001 Census, improvements in Census topic coverage and linkage to post-coded data sources (notably RESIDATA) and similar improvements in the energy use modelling and income measurement methodology in the 2004 LIW (see Section 1.1). The process of data harmonisation and matching is complex and is described in detail in Sections 1.4 to 1.6. The modelling of these data has also been informed by advanced Exhaustive CHAID techniques in order to identify optimal splits in the categorical predictor variables pertinent to this study, as described in Section 1.7.

The initial, univariate associations between the various social and demographic characteristics of the LIW sample and fuel poverty status are described in Section 1.8. These indicate that the following risk factors are all associated with a statistically significant elevated risk of fuel poverty as measured using the Full Income definition: household lacks exclusive use of bath/shower/WC, dwelling lacks central health or was built before1919, single person household, under-occupied dwelling and Household Reference Person is unemployed or a private renter . However, estimating the relative weight of these 'risk markers' as predictors of fuel poverty in the real world requires a multivariate logistic regression analysis in order to model their simultaneous effects. The details of the multivariate logistic regression models are discussed in Section 1.9. The results show that the number of Full Income fuel poor households can be estimated to be equal to:

2.7% of Households lacking central heating
+ 0.9% of Dwellings built pre-1919
+ 1.1% of Under-occupied single person households
+ 1.3% of Single pensioner households
+ 1.3% of Single non-pensioner adult households
+ 1.7% of Households headed by someone unemployed
+ 1.0% of Households headed by someone not economically active
+ 1.5% of Households sharing use of a bath/shower or toilet

Preliminary mapping of these results at Mid-Super Output Area level reveals fuel poverty to be concentrated in urban areas and especially in the major urban conurbations (e.g. Cardiff, Newport and Swansea), as well as in the valleys and the more remote rural areas - particularly in North West Wales as detailed in Figures 2 to 5. Further visualisation of these data will be undertaken as part of the dissemination phase associated with this project.

Section Two: Different Treatments of Income for Measuring Fuel Poverty

2.1 Income Definitions Used in Fuel Poverty Studies

The extent and depth of fuel poverty is dependent on both the definitions used of both income and heating regime. An agreed definition of fuel poverty is essential so that the extent of the problem can be estimated and progress on tackling it can be monitored. It has been agreed to use two definitions of fuel poverty in England and Wales (DEFRA & DTI, 2001):

i) Definition for target setting
A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income (including Housing Benefit or Income Support for Mortgage Interest (ISMI)) on all household fuel use. This is sometimes called 'Full Income'.

ii) Additional Definition
A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income (not including Housing Benefit or Income Support for Mortgage Interest ISMI) on all household fuel use. This is sometimes called 'Basic Income'.

The UK Government's 'official' analysis of low income is published annually in the *Households Below Average Income* (HBAI) statistics which provide estimates of patterns of personal disposable income in Great Britain and of changes in income over time in the United Kingdom. The HBAI statistics concentrate on the lower part of the income distribution but provide comparisons with the upper part where appropriate. Income in HBAI refers to disposable household income: that is income (from earnings, self employment, benefits, occupational pensions, investments and other flows) after the deduction of income tax, National Insurance contributions, local government taxes and certain other deductions. Each person's income is aggregated across the household and adjusted to reflect its size and composition. This process is known as equivalisation and reflects the relative needs of households of varying size and composition (Frosztega, 2000). HBAI presents income analyses on two bases: Before Housing Costs (BHC) and After Housing Costs (AHC).

Income Before Housing Costs (BHC) includes the following main components:

- Usual net earnings from employment;
- Profit or loss from self-employment (losses are treated as a negative income);
- All social security benefits (including housing benefit, social fund, maternity, funeral and community care grants but excluding social fund loans) and tax credits;
- Income from occupational and private pensions;
- Investment income;
- Maintenance payments, if a person receives them directly;
- Income from educational grants and scholarships (including, for students, top up loans and parental contributions);
- The cash value of certain forms of income in kind (free school meals, free welfare milk, free school milk and free tv licence for those 75 and over).

Income is net of the following items:

- Income tax payments;
- National insurance contributions;
- Domestic rates / council tax;
- Contributions to occupational pension schemes (including all additional voluntary contributions (avcs) to occupational pension schemes, and any contributions to personal pensions);
- All maintenance and child support payments, which are deducted from the income of the person making the payment;
- Parental contributions to students living away from home.

Income After Housing Costs *(AHC)* is derived by deducting a measure of *housing costs* from the above income measure (DWP, 2003). Housing costs include the following:

- Rent (gross of housing benefit);
- Water rates, community water charges and council water charges;
- Mortgage interest payments (net of tax relief);
- Structural insurance premiums (for owner occupiers);
- Ground rent and service charges.

The fuel poverty 'target setting' measure, which includes all benefits received, approximates to the before housing costs definition used in *Households Below Average Income* (HBAI) statistics. The after housing costs definition of income used in HBAI is net of all housing costs. The fuel poverty 'additional definition', which excludes only those housing costs met by Housing Benefit or ISMI, is not consistent with the income measures used by either the Office for National Statistics (ONS) or the Department for Work and Pensions (DWP) for wider analysis of low income. .

2.2 Equivalisation of Income

Both international and UK standards are clear that, when comparing incomes of households of different sizes (numbers of people) income should be equivalised – adjusted for household size and composition. For example, the final report of the United Nations Expert Group on Household Income Measurement (Canberra Group) recommended "*that income should be adjusted to take account of household size, using equivalence scales.*"

Both the DWP and the European Union have now agreed that low income/poverty statistics should be equivalised using the Modified OECD Scale (Atkinson *et al*, 2001; DWP, 2003). Income used to calculate fuel poverty can also be adjusted using this scale. For example, a family of four with an annual income of £15,000 can be considered to be 'poorer' than a single person with an annual income of £15,000. If both these families live in a 1930's semi-detached house the heating and fuel costs of the family of four will be slightly greater than for the single person. However, some of the family of four's non-fuel costs will be much greater (*e.g.* their food costs, their clothing costs, etc.) - these costs have greater elasticity than fuel costs. Unless income is equivalised to take account of these additional costs then any fuel poverty calculation will inevitably underestimate the 'true' amount of fuel poverty amongst larger households and overestimate the extent of fuel

poverty amongst smaller households. This will result in a overestimate of the extent of fuel poverty in areas with high proportions of small households and an underestimate of the extent of fuel poverty in areas with high proportions of large households.

At present, the 'official' method for measuring fuel poverty makes some adjustments (equivalisation) to the estimated heating costs of a household based upon its composition. The definition of a 'satisfactory standard of heating' varies depending upon household type (DETR, 2000):

- For households in work or fulltime education it is considered to be 21°C in the living room and 18°C in the other occupied rooms for the whole house for 9 hours a day (morning & evening) – this is termed the *Standard* heating regime.

- For households likely to be at home all day it is considered to be 21°C in the living room and 18°C in the other occupied rooms for the whole house for 16 hours a day (all day) – this is termed the *Full* heating regime.

- For under-occupied households[9] it is considered to be 21°C in the living room and 18°C in the other occupied rooms for half of the house for 16 hours a day (all day) – this is termed the *Partial* heating regime.

Therefore, the fuel costs of households are adjusted based on their composition but the household income is not at present also equivalised. Performing adjustments to one side of the fuel poverty equation (fuel costs) but not to the other side (household income) risks producing misleading or difficult to interpret results.

To examine the geographic effects of income equivalisation on fuel poverty, both Full and Basic Income were equivalised using the modified OECD scale which was rescaled so that a two person household was the base comparison unit (rather than a one person household). This rescaling does not affect the validity of the equivalisation but does make for easier comparisons with LIW 2004 Full and Basic income fuel poverty estimates[10].

Table 5 shows how the risk of being fuel poor changes for different socio-economic and demographic groups when income is equivalised using the Modified OECD scale. The first column of data shows the risk of fuel poverty for equivalised Basic Income and the second shows the risk for un-equivalised Basic Income. Similarly, in Table 5, the third and fourth data columns give the odds for equivalised and un-equivalised Full Income.

It is clear that, for both Basic and Full Income, equivalisation results in an increased risk of fuel poverty for families with children and overcrowded households and a reduced risk of fuel poverty for single person households and under-occupied households. At the individual level, the most significant change is that more children and fewer pensioners are classified as fuel poor as a result of equivalisation of income.

[9] Under occupancy is defined in terms of the 1968 Parker Morris standard which set building regulations on the minimum floor area for a home depending on the number of occupants (DTI & DEFRA, 2002a,b).

[10] The Modified OECD equivalisation scale is 1.00 FIRST ADULT, 0.5 OTHER ADULTS (aged 14+ years), 0.3 CHILDREN UNDER 14. In this work, this scale has been multiplied by (1/1.5) to facilitate comparisons with the LIW fuel poverty results.

Table 5: Univariate Odds of Basic and Full Income Fuel Poverty - Equivalised and Un-equivalised Income Data

Description	Basic	Equivalised Basic	Full	Equivalised Full
Household amenities				
Household shares accommodation	7.7	5.0	[1.5]	5.9
Household lacks exclusive use of bath/shower/WC	[2.4]	[1.6]	3.1	[1.8]
Dwelling lacks central heating	6.3	5.2	8.2	6.8
Household characteristics				
Dwelling built pre-1919	1.5	1.7	1.9	2.5
Household overcrowded (bedroom standard)	[1.5]	**4.8**	[1.1]	**[4.0]**
Household contains 2+ dependent children	0.4	**2.4**	0.2	**2.3**
Single pensioner household	**2.3**	0.4	**2.9**	0.5
Single non-pensioner household	**2.8**	[1.0]	**2.1**	0.6
Lone parent household (with dependent children)	1.8	3.0	[0.8]	1.4]
Single person household with 5+rooms	**3.0**	0.6	**3.8**	0.7
Respondent characteristics				
Respondent unemployed	3.5	6.6	[1.7]	2.5
Respondent not economically active	3.0	1.6	2.2	1.2]
Local authority tenant	2.0	2.1	[0.7]	0.8]
Private rental tenant	2.4	2.4	1.5	1.6

2.3 Model Results

The results from the logistic regression models provide an optimal sub-set of variables which can be used to estimate fuel poverty at small area level (Table 6). The detailed results of the logistic regression analyses are presented in Table 7 (Equivalised Basic Income) and Table 8 (Equivalised Full Income).

Table 6: Optimal subset of variables found to predict fuel poverty (Equivalised Basic and Full income definitions)

Equivalised Basic Income

- Household lacks central heating
- Dwelling build pre-1919
- Overcrowded Household (bedroom standard)
- Household with 2 or more dependent children
- HRP unemployed
- HRP not economically active
- Local authority tenant
- Private rental tenant

Equivalised Full Income

- Household lacks central heating
- Dwelling build pre-1919
- Overcrowded Household (bedroom standard)
- Household with 2 or more dependent children
- HRP unemployed
- HRP not economically active

Table 6 shows that, once the 'overlap' between variables is allowed for (e.g. you can be both unemployed and live in a pre-1920 dwelling), the most significant multivariate predictors of fuel poverty are little different to the individual level predictors - with high risks of fuel poverty shown in Tables 5. Similarly, most of the variables that are important predictors of fuel poverty using the standard definitions of Basic and Full incomes (see Table 2) are also important when using equivalised income (see Table 6).

The main differences are that couple households with two or more dependent children and overcrowded households are important for estimating both equivalised Basic and Full Income Fuel Poverty. Conversely, single person households, under occupied households and lone parent households are more important for predicting Basic Income Fuel Poverty, using the standard definition. Similarly, single person households and under occupied households are more important for predicting Full Income Fuel Poverty using the standard definition. Basically, if income is equivalised, then larger households and overcrowded households become 'good' predictors of fuel poverty. If incomes are not equivalised, then small households (single person) and under occupied households are 'good' predictors of fuel poverty.

Table 7: 2004 LIW Equivalised Basic Income Fuel Poverty Model: Binary Logistic Regression

Variable	B	se	Wald	Sig.	Exp(B)
Household lacks central heating	2.623	0.20	169	<.001	13.8
Dwelling build pre-1919	1.143	0.17	45	<.001	3.1
Overcrowded hhld (bedroom standard)	1.970	0.40	24	<.001	7.2
Hhld with 2 or more dependent children	2.197	0.18	149	<.001	9.0
HRP unemployed	3.031	0.32	92	<.001	20.7
HRP not economically active	1.434	0.18	66	<.001	4.2
Local authority tenant	1.385	0.21	43	<.001	4.0
Private rental tenant	1.279	0.21	37	<.001	3.6
	-4.582	0.20	526	<.001	0.01
Model Chi Sq. (df)					*588 (8)*
Nagelkerke R Sq.					*0.416*
N					*2363*

Table 8: 2004 LIW Equivalised Full Income Fuel Poverty Model: Binary Logistic Regression

Variable	B	se	Wald	Sig.	Exp(B)
Hhld shares accommodation	1.886	1.11	3	ns	6.6
Hhld shares bath/shower or toilet	1.394	0.75	4	ns	4.0
Hhld lacks central heating	3.208	0.21	230	<.001	24.7
Dwelling build pre-1919	1.305	0.17	58	<.001	3.7
Overcrowded hhld (bedrrom standard)	2.090	0.40	27	<.001	8.1
HRP unemployed	1.990	0.35	32	<.001	7.3
HRP not economically active	1.009	0.19	27	<.001	2.7
Hhld with 2 or more dependent children	2.427	0.20	153	<.001	11.3
	-4.669	0.21	488	<.001	0.01
Model Chi Sq. (df)					*502 (8)*
Nagelkerke R Sq.					*0.406*
N					*2351*

Tables 7 and 8 show that the four most important predictors of both equivalised Basic and equivalised Full income fuel poverty are if the dwelling lacks central heating, the Household Reference Person is not in work and if the household is large (couples with two or more children) and living in overcrowded accommodation. The fuel poverty models derived from the 2004 LIW need to be calibrated to the 2001 Census data for Wales to ensure that the weightings achieve 100% coverage. As the underlying regression equation is additive, the regression coefficients themselves (ß) can be re-calibrated and applied directly to the 2001 Census small area statistics. The final weights used in deriving the small area estimates are shown below.

The number of equivalised Basic Income fuel poor households is equal to:

1.6% of Households lacking central heating
+ 0.7% of Dwellings built pre-1919
+ 1.2% of Overcrowded households (bedroom standard)
+ 1.3% of Households with 2+ dependent children
+ 1.8% of Households headed by someone unemployed
+ 0.9% of Households headed by someone not economically active
+ 0.8% of Local authority tenants
+ 0.8% of Private rental tenants

The number of equivalised Full Income fuel poor households is equal to:

3.1% of Households lacking central heating
+ 1.3% of Dwellings built pre-1919
+ 2.0% of Overcrowded households (bedroom standard)
+ 1.9% of Households headed by someone unemployed
+ 1.0% of Households headed by someone not economically active
+ 2.3% of Households with 2+ dependent children.
+ 1.8% of Households sharing living accommodation
+ 1.3% of Households sharing use of a bath/shower or toilet

The effect of both equivalising incomes is that the Welsh fuel poverty rates increase slightly from 17% to 18% for Basic Income and from 13% to 14% for Full income.

Figures 6 to 9 show the geographical patterns of fuel poverty produced by using equivalised incomes. The maps are fairly similar to those based upon un-equivalised income (Figures 2to 5). However, the equivalised income maps show higher rates of fuel poverty in the 'poorest' inner city areas and in the South Wales valleys. Conversely, the fuel poverty rates are lower in the 'richer' rural areas (e.g. Monmouthshire, Pembroke, etc.).

Figure 6: Equivalised Basic Income Fuel Poverty (%), MSOA deciles

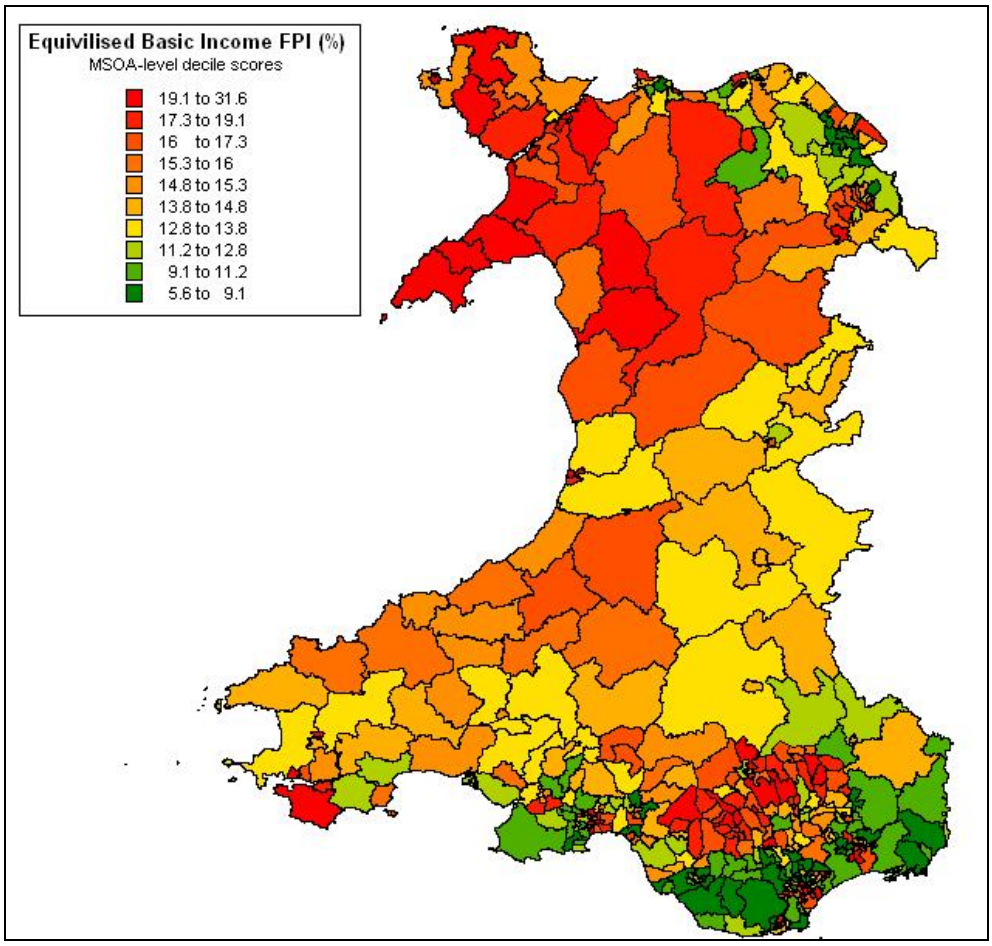

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Figure 7: Equivalised Basic Income Fuel Poverty (%), MSOA deciles – South Wales

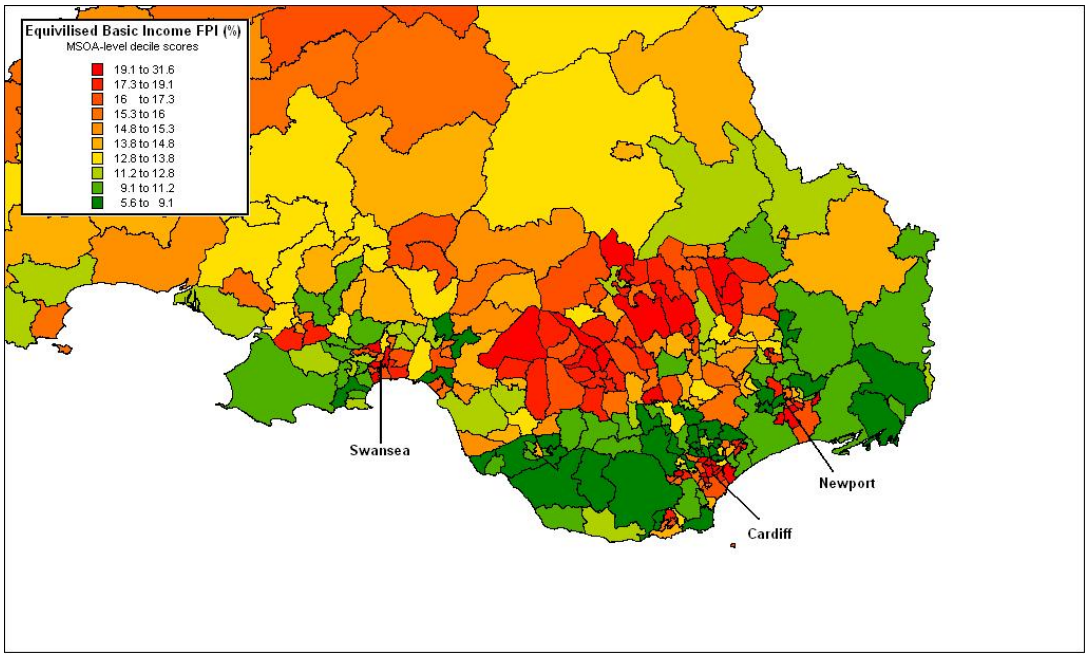

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Figure 8: Equivalised Full Income Fuel Poverty (%), MSOA deciles

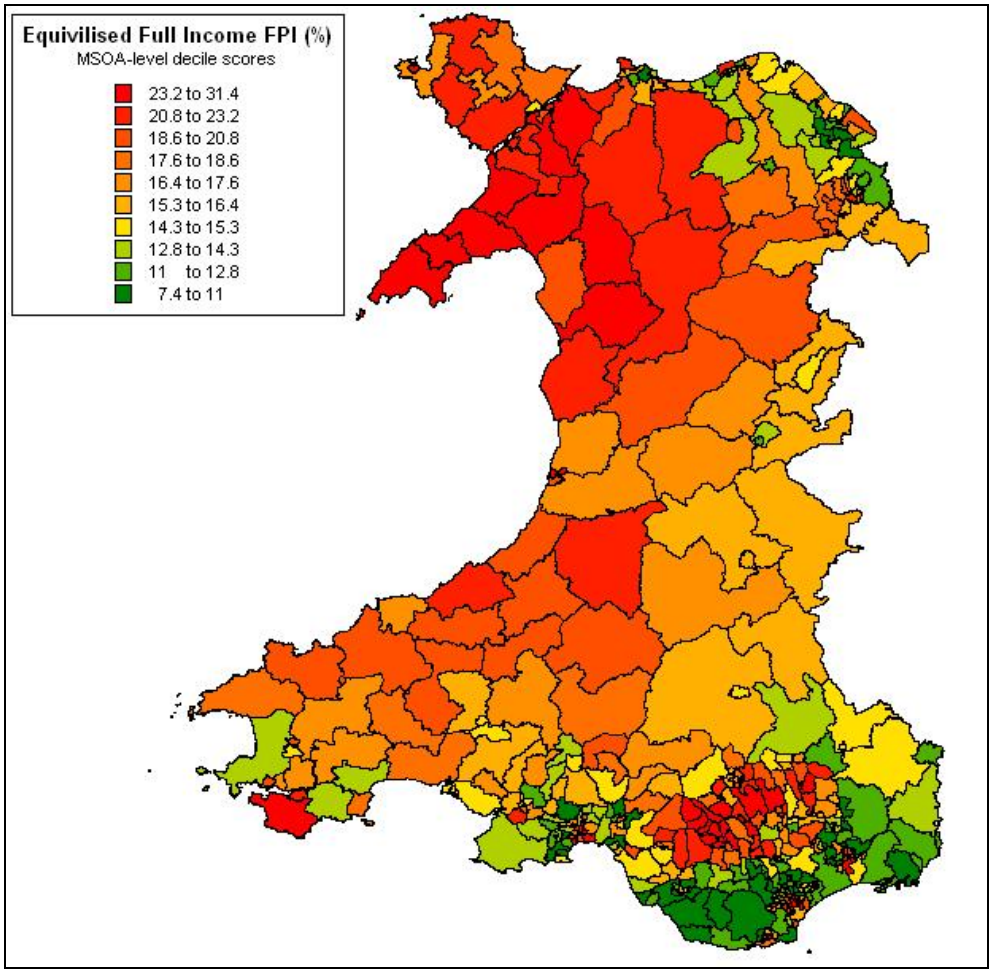

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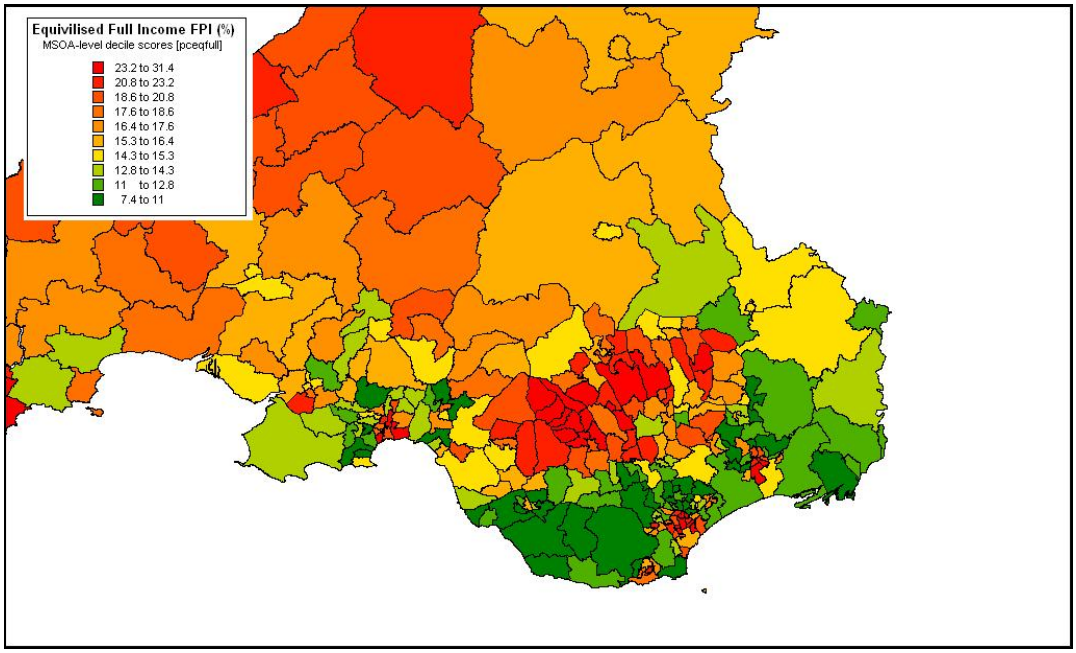
Figure 9: Equivalised Full Income Fuel Poverty (%), MSOA deciles – South Wales



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2.4 Summary of Findings

The rate of fuel poverty is relatively insensitive to the way Full and Basic Incomes are measured. Equivalising incomes (i.e. adjusting them for household size and composition) does not change the national rates of fuel poverty to any great extent. However, the composition and geography of the fuel poor does change.

If incomes are equivalised, then larger households and overcrowded households become more likely to be defined as in fuel poverty whereas, if incomes are not equivalised, then small households (single person) and under occupied households are more likely to be defined as fuel poor. At the individual level, income equivalisation results in more children and fewer pensioners being defined as fuel poor. Thus the 'risk' of fuel poverty becomes more like (but not identical to) the 'risk' of income poverty.

The geography of fuel poverty is also affected by income equivalisation. In particular, the map of fuel poverty in Wales becomes more like a map of income poverty, with increased rates of fuel poverty in inner city areas and in the South Wales valleys.

Conclusions

The Welsh Assembly Government is committed "*to end fuel poverty in vulnerable households*[11] *by 2010 … amongst non-vulnerable households in social housing by 2012*" and as far as reasonably practicable amongst all households by 2018 (WAG, 2003). In England, Scotland and Northern Ireland, the administrations have committed themselves to ending fuel poverty in all households by 2016.

Given the recent rapid increases in real fuel costs, there is very little likelihood that the 2010 target will be reached in any part of the UK and the 2016 targets for eradicating fuel poverty in England, Northern Ireland and Scotland may be over-ambitious. However, the Welsh target of fuel poverty eradication by 2018 may be achievable.

Eradicating fuel poverty is important. The Scottish Executive (2002) has argued that:

"*Fuel poverty has a negative impact on individuals, households, and communities. For individuals and households, the main negative impact of fuel poverty is its damaging effects on quality of life and health. The effects are both direct and indirect. Illnesses such as influenza, heart disease and strokes are all exacerbated by cold, and cold homes can also promote the growth of fungi and number of dust mites – often linked to conditions such as asthma.*

Less directly, households that have to spend a high proportion of their income on fuel have to compensate in other parts of their family budgets. This can lead to poor diet, or reduced participation in social and leisure activities, both of which can also impact on health and quality of life. These negative effects of fuel poverty can be particularly significant for vulnerable groups."

[11] vulnerable households are those containing children, or those with elderly, sick or disabled members.

The ability to find and target households suffering fuel poverty is vital to meet the Welsh Assembly Government's objective to eliminate this misery that is still suffered by thousands of households across Wales. As a result of improvements in the data sources and methodological advances made by this project, the new small area Fuel Poverty estimates should help policy makers and programme managers to target resources at areas of greatest need by identifying the small areas with the highest rates of fuel poverty.

The approach described here builds upon earlier research (*e.g.* Gordon et al., 2003, Fahmy et al 2007) in order to develop a range of predictive models of fuel poverty at the small area level. As such, these models represent 'best estimates' of the prevalence and distribution of fuel poverty and therefore need to be interpreted in the light of local knowledge and expertise. For example, the results may not be accurate in very 'atypical' areas such as the shopping centre in Cardiff.

The development of small area fuel poverty indicators is also clearly dependent upon the approach taken to the definition and measurement of income. The Full and Basic Income fuel poverty models, as described in this report, reflect the current official approach to the definition and measurement of fuel poverty and for this reason are to be preferred as a tool in policy-making and resource allocation.

The current definition of fuel poverty places emphasis on single person and single pensioner households and under-occupied dwellings. The official fuel poverty definition also accords greater recognition to the prevalence of fuel poverty in rural and suburban areas in preference to inner cities and the South Wales valleys. The small area fuel poverty estimates successfully produced by this research will help policy makers to more cost effectively and efficiently target the areas with the greatest levels of fuel poverty.

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