instytut badań strukturalnych

IBS WORKING PAPER 09/2016
NOVEMBER 2016

Location, location, location. What accounts for regional variation of fuel poverty in Poland?

Maciej Lis
Agata Miazga
Katarzyna Sałach

ibs working paper 09/2016

November 2016

Location, location, location. What accounts for regional variation of fuel poverty in Poland?

Maciej Lis[♣], Agata Miazga[♦], Katarzyna Sałach[♥]

Abstract

The aim of this paper is to explain the regional variation of fuel poverty in Poland. The significant spatial variation of fuel poverty stems from differences in the buildings' characteristics, income and household composition as well as the diverse advancement of urbanisation processes. The variance analysis permit the conclusion that all these factors influence both energy affordability (LIHC) and thermal comfort (subjective) dimension of fuel poverty. Energy affordability depends mainly on household's income, whereas lack of thermal comfort is mainly due to low energy efficiency of a building. Even after factoring out the influence of these three factors there still remains a significant unexplained regional variation of lack of thermal comfort. We show that this unexplained variation is linked with the regional disparities of prices and outdoor temperatures.

Keywords: fuel poverty, LIHC, thermal comfort, energy affordability, regional variation, degrees of urbanisation

JEL: I32, R29, Q40

We would like to thank Piotr Lewandowski for his many helpful suggestions during the research process. We would also like to thank participants of 3rd ESPAnet Poland Conference for their insightful comments.

The publication was developed by a grant funded by the European Climate Foundation. Apply the usual disclaimers. All errors are our own.

ISSN: 2451-4373

[♣] Institute for Structural Research, Warsaw, Poland. E-mail: maciej.lis@ibs.org.pl.
[♦] Institute for Structural Research, Warsaw, Poland. E-mail: agata.miazga@ibs.org.pl
[♥] Institute for Structural Research, Warsaw, Poland. E-mail: katarzyna.salach@ibs.org.pl

Table of contents

1. Introduction

The fuel poor are persons experiencing problems with maintaining adequate temperature in their places of residence (lack of thermal comfort dimension) or those who reduce spending on basic goods due to high energy bills (energy affordability dimension - Boardman 1991, Hills 2011). Satisfying energy needs involves providing both comfortable temperature at home and access to energy sources (e.g. gas, electricity) which ensure biological and social functioning.

The spatial variation of fuel poverty is important from the policy perspective. The effectiveness of the instruments designed to reduce fuel poverty depends not only on correct identification of the group of people in need, but also on matching the type of aid to the characteristics of the poor in a given region (Roberts et al. 2015). Addressing the policies aimed at eradicating fuel poverty to specific regions reduced their cost by up to 2/3 in Northern Ireland (Elbers et al. 2007). Therefore, it is crucial to identify both the regions that are mostly affected by fuel poverty as well as the spatial variation of the causes of fuel poverty.

The analysis of the scope and structure of fuel poverty was carried out both for individual countries: Greece (Papada and Kaliampakos 2016a), Germany (Heindl 2015), Slovakia (Gerbery and Filcak 2014), or Italy (Valbonesi et al. 2014), and for international comparisons (Buzar 2007, Snell and Thomson 2013, Buzarovski and Tirado-Herrero 2015). They confirm the significance of the local specificity of fuel poverty conditions. In Poland, the studies on fuel poverty have focused on describing the structure of the poor and poverty determinants (Kurowski 2011, Stępniak and Tomaszewska 2014, Szamrej-Baran 2014, Miazga and Owczarek 2015, Szpor 2016, Lis, Miazga and Ramsza 2016, Lis, Sałach and Święcicka 2016) or mechanisms observed at the local level (Frankowski and Tirado-Herrero 2015), leaving the spatial dimension beyond main focus.

In general fuel poverty is concentrated in rural areas due to lower income of their inhabitants and lower energy efficiency of buildings in many countries (i.a. Baker et al. 2008, Illsley et al. 2007, Rugkasa and Shortt 2007, Walker et al. 2012, Snell and Thomson 2013). The larger a city is, the less severe fuel poverty becomes. In Great Britain, fuel poverty in rural areas is also caused by limited access to the gas distribution network, which is one of the cheapest heat sources in there (Baker et al. 2008). The distance between villages and larger urban centres might hamper the access to thermal retrofit and other resources improving energy efficiency of buildings (Boardman 2010). The fuel poor from rural areas are also more sensitive to increase in energy prices (Roberts et al. 2015). As a consequence the volatility of energy prices results in lower persistence of fuel poverty in rural areas.

Regional analyses of fuel poverty point to similar factors impacting the risk of fuel poverty. Fuel poverty in Great Britain concentrates in Northern Ireland (44% of the inhabitants of the region) and Scotland (33%), where the percentage of households connected to gas distribution networks is low (Illsley et al. 2007). The major cause of the spatial variation of the phenomenon are differences in household income level (e.g. Bordman 2010, Walker et al. 2012). Differences in average temperatures and energy efficiency of buildings, in turn, affect the energy costs needed to satisfy the thermal comfort (i.a. Baker et al. 2008, Walker et al. 2012, Bouzarovski and Tirado-Herrero 2015). The in-door temperature that satisfy thermal comfort varies by types of households. For instance, the elderly face highest risk of fuel poverty in England as a consequence of their higher thermal comfort standard and longer time spent at home (Baker et al. 2008).

Geographical location, both in terms of latitude and elevation, is an important determinant of the expenditures required for heating a dwelling. In Austria, Switzerland and Northern Italy, inhabitants of mountainous areas are more vulnerable to fuel poverty than those living in the lowlands (Papada and Kaliampakos 2016b). A typical house in Switzerland, situated 1,200 m above the sea level, is characterised by the demand for thermal energy twice times higher than for an identical house situated 200 m above the sea level. It is due to lower out-door temperatures and five months longer heating season. Similar results were obtained for Greece (Papada and Kaliampakos 2016a), where the number of heating days was strongly positively correlated with the elevation and much less correlated with other geographical variables, such as latitude, number of sunny days per year and distance from the sea.

Energy affordability and lack of thermal comfort constitute separate dimensions of fuel poverty and require different measures. These differences are also observed on the regional level (i.a. Fahmy et al. 2011, Papada and Kaliampakos 2016b). English households whose energy expenditures exceed 10% of their income coincide with the households declaring lack of thermal discomfort in the place of living only to a small extent (Fahmy et al. 2011). Differences arise also depending on methodological choices as regards equivalisation of income and energy expenditures (Baker et al. 2008).

The evidence on regional variation of fuel poverty, especially in post-communist countries is scarce. We aim to fulfill this gap by addressing the following questions:

1. What is the scale of regional variation of fuel poverty in Poland, both in terms of energy affordability and lack of thermal comfort dimensions?
2. What is the scale of spatial variation of three groups of fuel poverty determinants: characteristics of buildings, household structure and income, and level of urbanisation?
3. What is the role of region-specific factors in explaining fuel poverty variation? Does the impact of highlighted causes of fuel poverty vary by regions?
4. Can regional differences in climate and energy prices explain the component of regional variation of fuel poverty, which cannot be attributed to households' and buildings' characteristics?

The methods and data that let us deal with the above questions are presented in Section 2, which describes the construction of logistic regression model and the analysis of variance applied. Section 3 presents the results of the logistic model of fuel poverty risk and statistical analysis of the relations among the voivodship effects that have not been explained by the model. The impact of climate and energy prices is also considered. Section 4 presents the conclusions and policy implications.

2. Methods and data

2.1 Fuel poverty measures

In order to cover two dimensions of fuel poverty: energy affordability and thermal comfort, we use two measures of incidence of fuel poverty: the low income high cost measure (LIHC) and subjective measure of thermal comfort. **The LIHC measure**, proposed by Hills (2011), replaced the measure based on 10% share of energy bills in household's budget in England. This LIHC measure is based on the required energy expenditures. For a household to be classified as fuel poor according to the LIHC definition, it must simultaneously meet two criteria: low income (LI) and high required energy costs (HC). The HC criterion is met when the household required equivalent energy expenditures (the total expenditures for satisfying basic needs, such as heating buildings, heating water, lighting, cooking) are higher than the median in the entire population. The LI criterion is an income threshold determined individually for every household. It is computed by calculating 60% of the median of equivalent disposable income AHC (After Housing Costs). Such a procedure permits inclusion of the households that become income poor after paying their energy bills. The LI criterion is met when the household equivalent disposable income is lower than the income threshold. The high cost and low income thresholds are determined for every year and for every country separately and hence the basic property of this measure: relativity. The LIHC indicator should account for those who have to limit their basic consumption due to high energy bills.

The **subjective measure** of thermal comfort is based on respondents' declarations about the satisfaction level of their energy needs (or difficulty in satisfying them). The subjective measure corresponds best to the popular understanding of fuel poverty as an experience of lack of thermal comfort. From the viewpoint of policy targeting, this measure is rather useless, since a subjective impression cannot be a criterion granting access to social policy instruments. It could serve, however, the purpose of monitoring the dynamics of the phenomenon (Hills 2011). The subjective fuel poverty measure is based on answers to the question in Polish Household Budget Survey (Polish HBS): "Is, in your opinion, the home you live in sufficiently warm in winter (with serviceable heating and/or sufficient thermal insulation of the building)?". A negative answer from a respondent means that he or she experiences fuel poverty. The question in HBS differs from one in EU-SILC, which is "Can your household afford to keep its home adequately warm?". The one asked at HBS does not take the affordability directly into account and therefore our results cannot be directly compared to the analysis based on EU-SILC.

2.2 Data

The Polish Household Budget Survey (Polish HBS), carried out annually by the Central Statistical Office of Poland (CSO), provides data on the level and structure of household expenditures as well as the level and sources of the income earned. It also contains variables regarding household possession of durable goods and information about living conditions, subjective assessment of household financial situation as well as their demographic and social characteristics. The multidimensionality of the data and the sample size (36,626 households examined in 2014[1]) permits a regional analysis of fuel poverty.

[1]The sample used in the models amounted to 35,977 observations. It did not allow for households with a monthly income exceeding PLN 50,000 and persons declaring that their houses were heated with electric stove, since for this subsample, due to the impossibility to

The LIHC indicator adopted in this study is based exclusively on the data obtained from the Polish HBS both with respect to heating and electricity expenditures. The previous analysis of LIHC in Poland (Miazga and Owczarek 2015, Lis, Miazga and Ramsza 2016) utilized data of the Polish National Energy Conservation Agency (KAPE) for calculating the required heating expenditures. However, the required expenditures of KAPE considerably differ from the energy expenditures declared by households in the Polish HBS. Particularly significant discrepancies are noticeable in the case of single-family houses. According to KAPE assumptions, the expenditures on heating 1 m^2 should be 2-3 times higher for a detached house than for a dwelling in a block of flats, yet the Polish HBS data evidence an opposite relation: the average monthly heat expenditures in a block of flats amount to PLN 4.10 per m^2, in a single-family terraced house – PLN 2.70 per m^2, and in a single-family detached house – PLN 2.60 per m^2. It is an effect of an inaccurate measurement of energy efficiency of individual buildings in the Polish HBS, differences in the level of thermal comfort between residents of various types of buildings, and the use of cheap heating fuels, such as brushwood, garbage and saw dust, by residents of single-family houses.

The adoption of another methodology – using only the Polish HBS data for calculating the required energy expenditures as averages in the types of buildings – resulted in a drop of the fuel poverty estimation from 17.1% of the population in 2013 to 11.7% in 2014, and as regards households – 9.6%. This difference is purely due to change in methodology. According to the previous method the drop in LIHC in 2014 was 0.1 percentage point.

The data on the regional variation of energy prices was obtained from CSO database. The data on average temperatures is based on findings of Institute of Meteorology and Water Management (CSO 2015). The average annual air temperature is reported for 32 meteorological stations in Poland. For regions with more than one meteorological station we calculate the average of all available values.

2.3 Analysis of the fuel poverty measure variance

We analyse fuel poverty variation with the analysis of variance (ANOVA) method adapted to the logit model for binary dependent variable. The analysis of variance allows for (1) the assessment of the significance and of (2) the power of individual groups of variables for explaining both energy affordability and thermal comfort dimensions of fuel poverty.

As discussed in the introduction, there are five factors that influence the fuel poverty risk: characteristics of buildings, characteristics of households (including income), degree of urbanisation, local climate and energy prices. The former three are directly covered by the variables available in HBS and the latter are observable in other datasets on the regional level only. Each of the factors is composed of several, both continuous and discrete, variables. The influence of the individual factors on fuel poverty risk is not only direct, but also indirect. For example, the size and type of dwelling is influenced by the household income. Flats are concentrated particularly in larger cities, whereas detached houses – in villages. Voivodships differ significantly in terms of the degree of urbanisation. In order to account for direct and indirect impact of each factor the analysis of variance is carried out twofold. Firstly, the fit of the models with each group of variables is compared separately to the fit of the null model (with constant only). Secondly, the fit of the model with all variables (saturated model) is compared to the fit of the model with all but selected variables included. The influence of a given variable or set

separate heat expenditures from electrical energy expenditures, the values of LIHC fuel poverty were considered distorted. The descriptive statistics presented in the study refer to the full sample of 36,626 households.

of variables is examined for its significance with the Wald test and their power is measured by the change of the pseudo-R^2 measure of goodness-off-fit (McKelvey and Zavoina) (Veall and Zimmermann 1996) between appropriate models. We turn to pseudo-R^2 instead of the value of likelihood function due to interpretability of the results. The interpretation of McKelvey and Zavoina's pseudo-R^2 is similar to the one of R^2 in the linear model. In particular, completely random variables give the value of 0, and the model which perfectly describes the response variable will display pseudo-R^2 of 1. The growth of the measure by x% as a result of including a given group of variables in the model with the constant is hence interpreted as improved fitness of the model by x% and the **total (indirect and direct) influence** of a given group of variables on the fuel poverty variance. The drop of the pseudo R^2 after excluding a particular group of variables from the saturated model is interpreted as a **direct influence** of a given set of variables on explaining variance of fuel poverty.

Formally the analysis of variance is carried out with estimation of logit models, through maximization of likelihood function. The saturated model has the following form:

$$Y_i = f(\alpha + \beta B_i + \gamma D_i + \delta R_i + \lambda U_i) + \epsilon_i,$$

where:

Y_i – a discrete vector describing whether the household (i) is fuel poor (Y=1) or not (Y=0);

$f(x)$ – a logit function ensuring that the latent variable satisfies probability axioms, $f(x) = \frac{e^x}{e^x+1}$;

B_i – the matrix of discrete and continuous variables where each column describes the characteristics of the building and flat (year of construction, area etc.);

D_i – the matrix of discrete and continuous variables where each column describes the socioeconomic characteristics of the household (income, number of children, socioeconomic group, etc.);

R_i – the matrix of discrete variables where each column describes whether the household *i* belongs to voivodship *j* (*j* – the column number);

U_i – the matrix of discrete variables where each column describes whether the household *i* belongs to the place with the degree of urbanisation *j* (*j* – the column number).

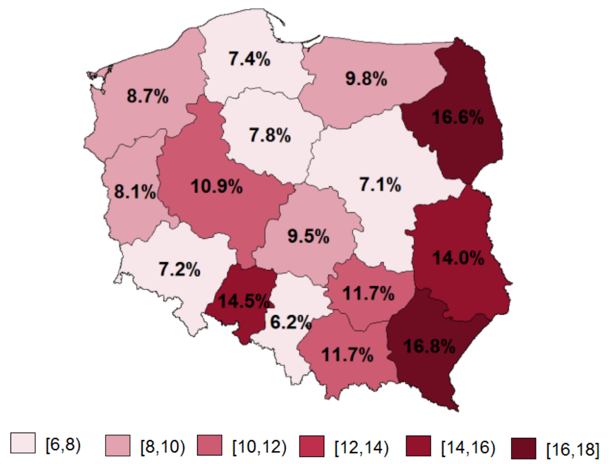
The models are estimated for relative poverty and subjective poverty separately. Interactions between groups of variables and voivodships are estimated separately by introducing the Cartesian product of those variables as a separate group of dummy variables ($B_i \# R_i, D_i \# R_i, U_i \# R_i$). The same analysis (exempt for the including interaction terms) is repeated 16 times for each voivodship in order to measure the impact of each factor on the regional level.

3. Spatial variation of fuel poverty in Poland

3.1 Regional variation of fuel poverty incidence

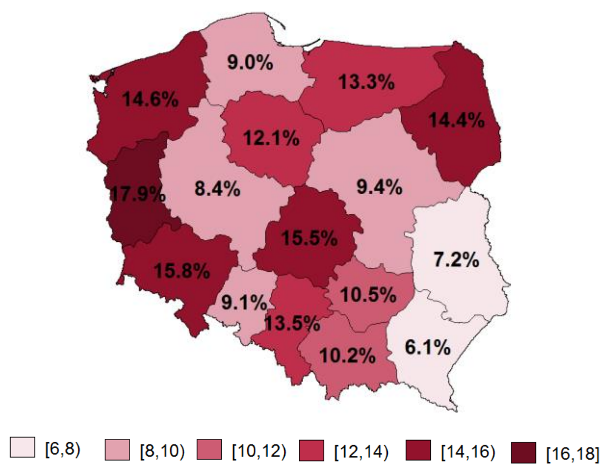
Poland consists of 16 NUTS-2 regions called voivodships. Most populous ones (*Mazowieckie* and *Śląskie)* have around 5 million inhabitants whereas the population of the least populous ones (*Lubuskie* and *Opolskie*) is about 1 million. According to the Polish HBS data of 2014, affordability (LIHC) dimension of fuel poverty was experienced by 9.6% of households in Poland (1.3 million), i.e. 4.5 million people and its incidence varied a lot among regions. In accordance with the LIHC measure, fuel poverty concerned mainly eastern voivodships: *Podkarpackie* (17% of households), *Podlaskie* (17%) and *Lubelskie* (14%); as well as *Opolskie* (15%). Its lowest level was recorded in the richest regions: *Śląskie* (6%), *Mazowieckie* (7%), *Dolnośląskie* (7%), and *Pomorskie* (7%) (Figure 1). Hence, the difference in the risk of fuel poverty between the extreme voivodships was almost triple.

Figure 1. LIHC fuel poverty rates in voivodships in Poland in 2014 [%]



Source: Own calculations based on the 2014 Polish HBS data.

Figure 2. "Lack of thermal comfort" (subjective fuel poverty) rates in voivodships in Poland in 2014 [%]



Source: Own calculations based on the 2014 Polish HBS data.

The subjective measure of fuel poverty shows similar scope with 11.5% of households in Poland declaring living in under heated accommodation in winter. Like in the case of the LIHC measure, regional variation of subjective measure was almost triple: from 6.1% of fuel poor households in *Podkarpackie* to 17.9% in *Lubuskie* (Figure 2). On the voivodships level the correlation between the affordability and subjective measures of fuel poverty is negative, i.e. the higher the percentage of the poor according to LIHC, the lower the percentage of the poor according to the subjective measure (Figures 1 and 2). Combining the two dimensions of fuel poverty (energy affordability and lack of thermal comfort) let us distinguish four groups of voivodships:

- the poorest (*Podlaskie*) – it is characterised by a high percentage of the fuel poor according to both LIHC and subjective measures. It is a voivodship with the second highest indicators of relative income poverty – 24% (CSO 2015).
- regions with high score of affordability dimension of fuel poverty (*Podkarpackie, Lubelskie, Opolskie, Wielkopolskie, Małopolskie,* and *Świętokrzyskie*) – they combine high scores at LIHC with low at subjective measure of fuel poverty. A majority of these voivodships are characterised also by a high percentage of relative income poverty.

- regions with high prevalence of lack of thermal comfort (*Lubuskie, Dolnośląskie, Łódzkie, Zachodniopomorskie, Śląskie, Warmińsko-Mazurskie, Kujawsko-Pomorskie*) – with high subjective poverty measure and low LIHC measure. Only two voivodships from this group are characterised also by a high percentage of the income poor: *Warmińsko-Mazurskie* and *Kujawsko-Pomorskie.*
- regions with the lowest intensity of poverty (*Mazowieckie* and *Pomorskie*). These voivodships are characterised by the lowest scale of both LIHC and subjective measures of fuel poverty. They also show low incidence of income poverty.

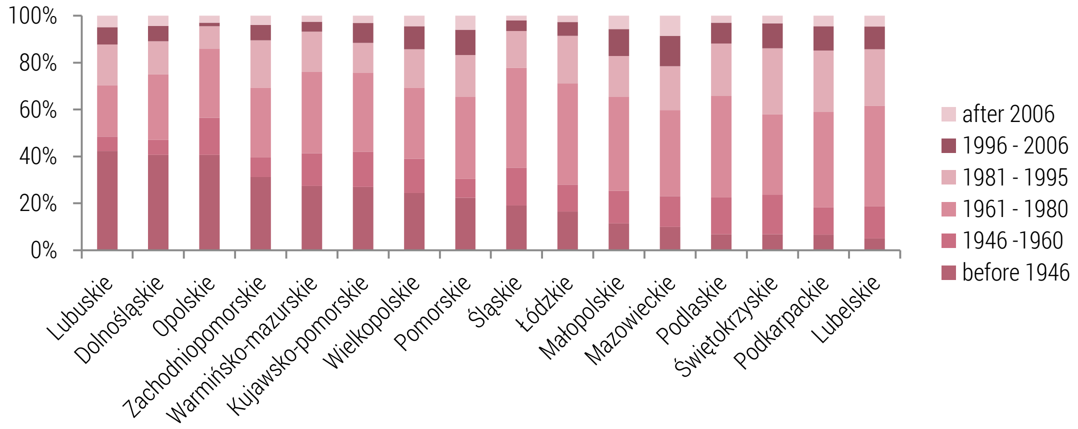
3.2 Variation of factors of fuel poverty

3.2.1 Characteristics of buildings

Buildings' characteristics differ a lot among regions, both in terms of thermal efficiency and the energy carriers. In 2014, 56% of households in Poland lived in blocks of flats and 38% in detached houses. Detached houses prevail in the east and south of Poland and the variation of the percentage of households in detached houses between individual voivodships reaches 47 percentage points (*Podkarpackie* – 63% versus *Zachodniopomorskie* – 16%). Detached houses dominate in rural areas (78% of households in villages), where they are usually heated with solid fuel. According to the calculator of the cost of heating of standard house[2], heating with natural gas is twice more expensive than coal or wood and simultaneously twice cheaper than with electricity. The use of solid-fuel stoves varies among voivodships. The highest incidence is recorded in *Warmińsko-Mazurskie* voivodship – 19.3% of households, which is nearly three times more than in *Mazowieckie* voivodship – 7.3%.

The age structure of buildings in Poland shows high spatial variation (Figure 3). The oldest buildings are located in the west and north of the country. In *Lubuskie* voivodship, 43% of households reside in pre-war buildings, and in *Dolnośląskie* and *Opolskie* voivodships – 41%, while the average for Poland is 20%. The highest percentage of buildings constructed after 1996 is recorded in voivodships with large urban centres: *Mazowieckie* (22%), *Małopolskie* and *Pomorskie* (17%). The age of the building is a clear sign of the energy efficiency.

Figure 3. Age structure of residential buildings by voivodships in Poland in 2014 [%]



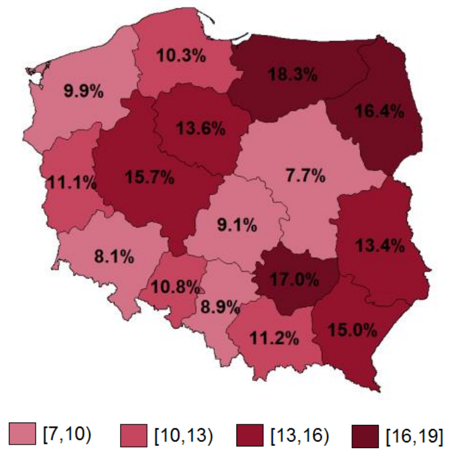
Source: Own calculations based on the 2014 Polish HBS data.

[2] Calculator of required heating energy http://ag-dar.vaillant-partner.pl/kalkulatory-on-line 17 October 2016

3.2.2 Characteristics of households

Household income is one of the major determinants of the fuel poverty (e.g. Boardman 2010, Walker 2012) despite the fact that fuel and income poverty coincide only in ca. 30% of households in Poland (Miazga and Owczarek 2013). The median disposable income in Poland amounted to PLN 3,167 per month in 2014. The lowest average disposable income was disclosed by households in north-eastern, rural regions of Poland (*Podlaskie*, PLN 2,800 per month, *Warmińsko-Mazurskie*, PLN 2,811 per month) and eastern ones (*Lubelskie*, PLN 2,902 per month). North-eastern voivodships are characterised also by a high percentage of income poverty (*Warmińsko-Mazurskie*–18%, *Podlaskie*–16%) (Figure 4).

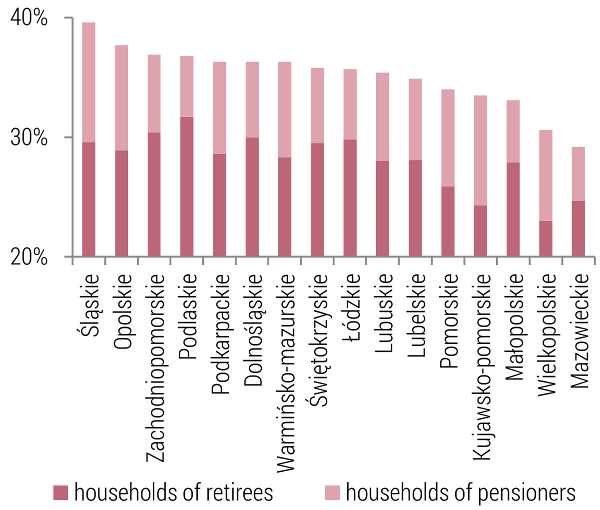
Figure 4. Income poverty incidence* by voivodships in Poland in 2014 [%]



Relative measure of income poverty.

Source: Own calculations based on the 2014 Polish HBS data.

Figure 5. Percentage of households of retirees and pensioners by voivodships in Poland in 2014 [%]



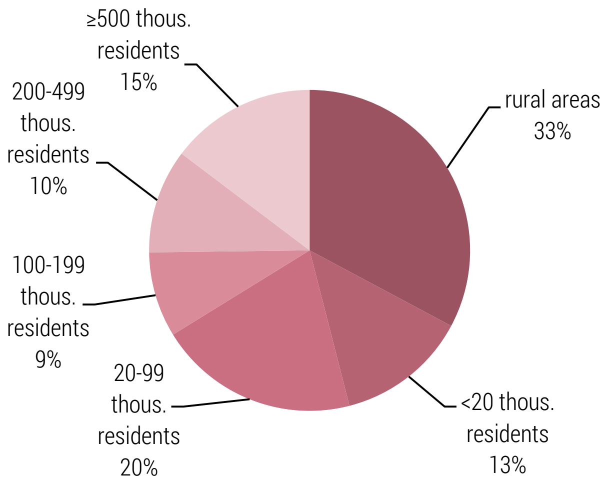
Source: Own calculations based on the 2014 Polish HBS data.

Fuel poverty is influenced also by the demographic structure of households as it determines thermal comfort preferences. Families with children, retirees and pensioners belong to the groups with the highest level of temperature standard. In 2014, the highest percentage of retiree households was recorded in the following voivodships: *Podlaskie* (32% of households), *Zachodniopomorskie* (31%) and *Dolnośląskie* (30%). The lowest percentage of such households is present in voivodships with large urban centres (Figure 5). Regional gap of the percentage of retiree households amounts to 8.7 percentage points.

3.2.3 Degree of urbanisation

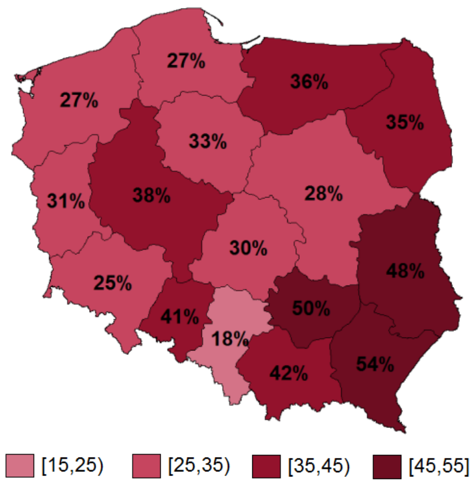
Almost 40% of Polish population lives in rural areas, but in case of household it is only 33% (Figure 6). It is due to more children and more multigenerational families living in the rural areas. The level of urbanisation varies along the east-west gradient (Figure 7). The highest percentage of rural households is recorded in eastern and south-eastern voivodships (*Podkarpackie* – 54%, *Lubelskie* – 48%, *Świętokrzyskie* – 50%). In the west, the percentage is ca. 30%, and the lowest one is noticed in *Śląskie* voivodship shows the highest degree of urbanisation with only 18% of population living in rural areas. Big cities with population of more than 500 thousand are located in only five voivodships: *Mazowieckie, Małopolskie, Łódzkie, Dolnośląskie,* and *Wielkopolskie.*

Figure 6. Locality population structure in Poland in 2014 [%]



Source: Own calculations based on the 2014 Polish HBS data.

Figure 7. Population structure in villages and cities of different size in Poland in 2014 [%]



Source: Own calculations based on the 2014 Polish HBS data.

3.3 Explaining the variance of fuel poverty

3.3.1 Causes of fuel poverty in Poland

In order to quantify the role of each factor (buildings, households, urbanisation) in explaining the variation of fuel poverty we build two logistic regression models. In the first one affordability measure of fuel poverty (LIHC) is dependent variable whereas in the second one the experienced lack of thermal comfort (subjective measure of fuel poverty) is modelled. All independent variables together are statistically significant in both models, but they explain the affordability dimension of fuel poverty much better (pseudo-R^2 of 61%) than in the case of lack of thermal comfort dimension (pseudo-R^2 of 19%). Hence, subjective fuel poverty is a phenomenon that is more difficult to explain with the use of variables available at HBS.

Starting with the interpretation of the estimates of the model for LIHC measure, households of blue-collar workers, farmers and the self-employed face greater risk of fuel poverty than white-collar workers (Appendix A.2). Lower income, larger floor area and more children significantly increase the risk of affordability dimension of fuel poverty. The risk factors include also living in detached houses, old buildings (built before 1970) and rural areas.

According to the estimates in the model for subjective fuel poverty measure the risk factors for experiencing lack of thermal comfort are similar to those for affordability, but some differences are meaningful. Gas and solid fuel stoves compared to central heating rise the risk of subjective and lowers the risk of affordability measures of fuel poverty. Other risk factors are similar.

The reasonable estimates of parameters let us follow with the analysis of variance of fuel poverty. The rise in the model fit compared to the null model (only constant) is a measure of both direct and indirect effects of every factor in explaining the variation of fuel poverty. Contrary, comparing the model fit with and without every factor (controlling for all others) let us measure the isolated, direct effect of given factor on the variance of fuel poverty.

Income and floor area are the key factors to explain the affordability dimension of fuel poverty (Table 1). Socioeconomic characteristics of households are the most crucial for explaining the LIHC measure variance (30% of total variance), and it is income that is almost exclusively responsible for this effect (27%). The size of household, the source of income or the number of children are definitely less important (4% in total). Characteristics of buildings explain 21% of LIHC measure variance. Floor area is predominant in the group as it explains 17% of the general variance. Energy efficiency of buildings, approximated by the age, type and heating method of the building, explains only the total of 4% variance. The urbanisation level and geographical location (voivodships) have a significant influence on the phenomenon but their contribution is considerably lower: 3% and 2%, respectively. The influence of the degree of urbanisation is largely indirect and takes place through differences in income and types of buildings between rural and urban areas. Therefore when compared to the null model the effect of degree of urbanisation rises by 8 times to 17%. A similar effect is observed in the case of voivodships – when there are no other variables, the influence of voivodships on the goodness-of-fit of the model is significant and explains 3% of the variance, and when other variables are controlled, it drops below 1%.

Table 1. Influence of selected groups of variables on explaining fuel poverty variation in Poland in total

Variable	Affordability measure (LIHC)		"Lack of thermal comfort" measure	
	direct impact	indirect and direct impact	direct impact	indirect and direct impact
Buildings characteristics	0.21***	0.24***	0.09***	0.16***
Floor area	0.17***	-	0.01***	-
Type of building	0.03***	-	0.001**	-
Type of heating	0.01***	-	0.01***	-
Building construction period	0.03***	-	0.03***	-
Socioeconomic characteristics	0.3***	0.3***	0.02***	0.07***
Number of children (under 14 years old)	0.01***	-	0.001***	-
Socioeconomic group	0.03***	-	0.002***	-
Disposable income of household [ln PLN]	0.27***	-	0.01***	-
Degree of urbanisation	0.02***	0.17***	0.002***	0.003***
Regional effect	0.003***	0.03***	0.02***	0.03***
Interactions between variables				
Voivodship x Degree of urbanisation	0.015**	0.026***	0.021***	0.033***
Voivodship x Buildings characteristics	0.008***	0.018***	0.004***	0.004***
Voivodship x Socioeconomic characteristics	0.001***	0.003***	0.001***	0.001***

*Note: The direct influence of the variable is calculated as a pseudo-R^2 decrease in the model after the removal of the variable in comparison to the base model. Pseudo-R^2 for the base model was 0.61 for the LIHC measure and 0.19 for the subjective measure. The direct and indirect influence was calculated as a pseudo-R^2 increase in comparison to the model only with the constant. In the case of models with interactions the direct influence is calculated as a pseudo-R^2 increase in comparison to the base model, while the direct and indirect influence is the pseudo-R^2 increase in the model with two groups of variables and interactions in comparison to the model without interaction (only with two groups of variables). Significance levels: *** p<0.01, ** p<0.05, * p<0.1.*

Source: Own calculations based on the 2014 Polish HBS data.

In case of lack of thermal comfort dimension of fuel poverty all variables explain 19% of variance. Contrary to the results of LIHC measure the characteristics of buildings are dominant factor, explaining 9% of variance. Within this factor the year of construction is the most important one (3%). Therefore, **thermal comfort is much more linked to thermal efficiency (its year of construction mainly) than to the floor area**. Socioeconomic characteristics, including income, account for merely 2% of subjective measure of fuel poverty variance. Income impact is indirect and it appears mainly through the characteristics of buildings. Higher income permits better living conditions. For a model with no other socioeconomic variables, the significance of income in explaining subjective fuel poverty measure increases to 7%. The degree of urbanisation explains less than 1% of subjective fuel poverty variance, no matter whether other factors are included. Compared to LIHC measure regional factor (voivodships) is more important and accounts for 2% even after controlling all other factors.

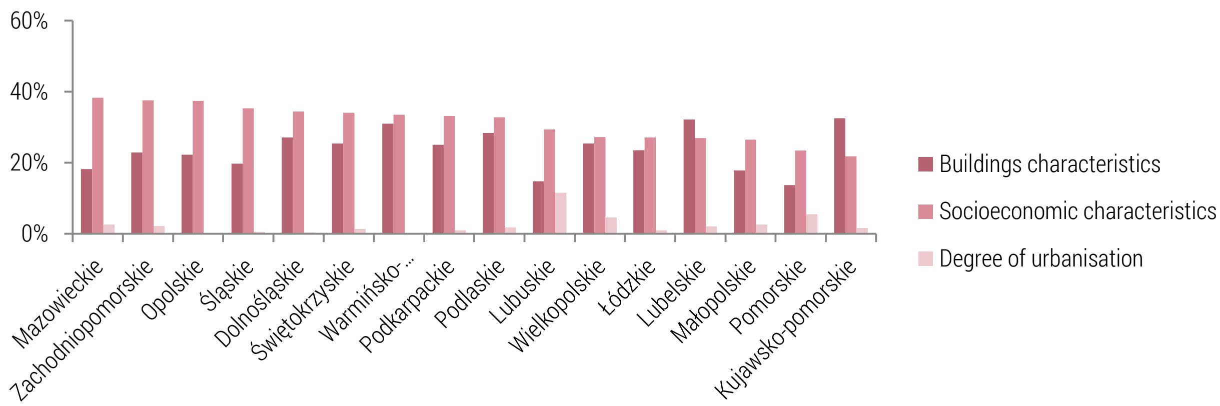
3.3.2 Regional diversity

In order to assess the regional variation of the impact of selected factors on fuel poverty in every region of Poland, we analyse separately the interactions between selected variables and regional dummies. All interactions were statistically significant, both for the affordability and subjective measures. However, a noticeable (more than 1%) influence on the goodness-of-fit of the models appears only in the case of interactions between dummies of voivodships and degree of urbanisation (Table 1). It means that even after controlling for buildings' and households' characteristics the difference in fuel poverty incidence among large cities, small towns, and villages varies between regions. On the contrary, the impact of energy efficiency and households characteristics is similar in each voivodship.

In order to identify the regional differences in the relative role of the specific factors in explaining the fuel poverty we conduct the analysis of variance for each region separately. Detailed estimates are presented in Appendix A.3, and the crucial statistics are presented at Figures 8 and 9.

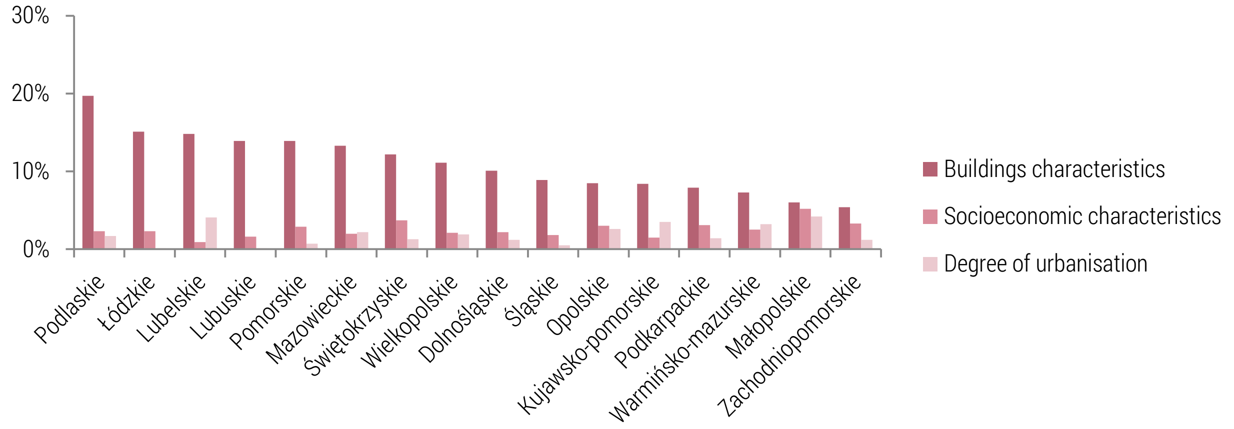
The regional models differ a lot in terms of goodness-of-fit. Buildings' and households' characteristics explain from 52% (*Śląskie*) to 88% (*Lubuskie*) of variance of LIHC measure and from 18% (*Śląskie i Zachodniopomorskie*) to 27% (*Lubelskie, Łódzkie, Małopolskie i Podlaskie*) of variance of subjective measure. In most cases they confirm the findings for Poland in general. There are, however, a few meaningful exemptions.

Figure 8. Direct influence of specific factors on the LIHC measure of fuel poverty in voivodships



Note: Figure shows decrease in pseudo-R^2 in restricted logistic regression models in comparison to saturated logistic regression model.
Source: Own calculations based on the 2014 Polish HBS data.

Figure 9. Direct influence of specific factors on subjective fuel poverty measure ("lack of thermal comfort") in voivodships



Note: Figure shows decrease in pseudo-R^2 in restricted logistic regression models in comparison to saturated logistic regression model.
Source: Own calculations based on the 2014 Polish HBS data.

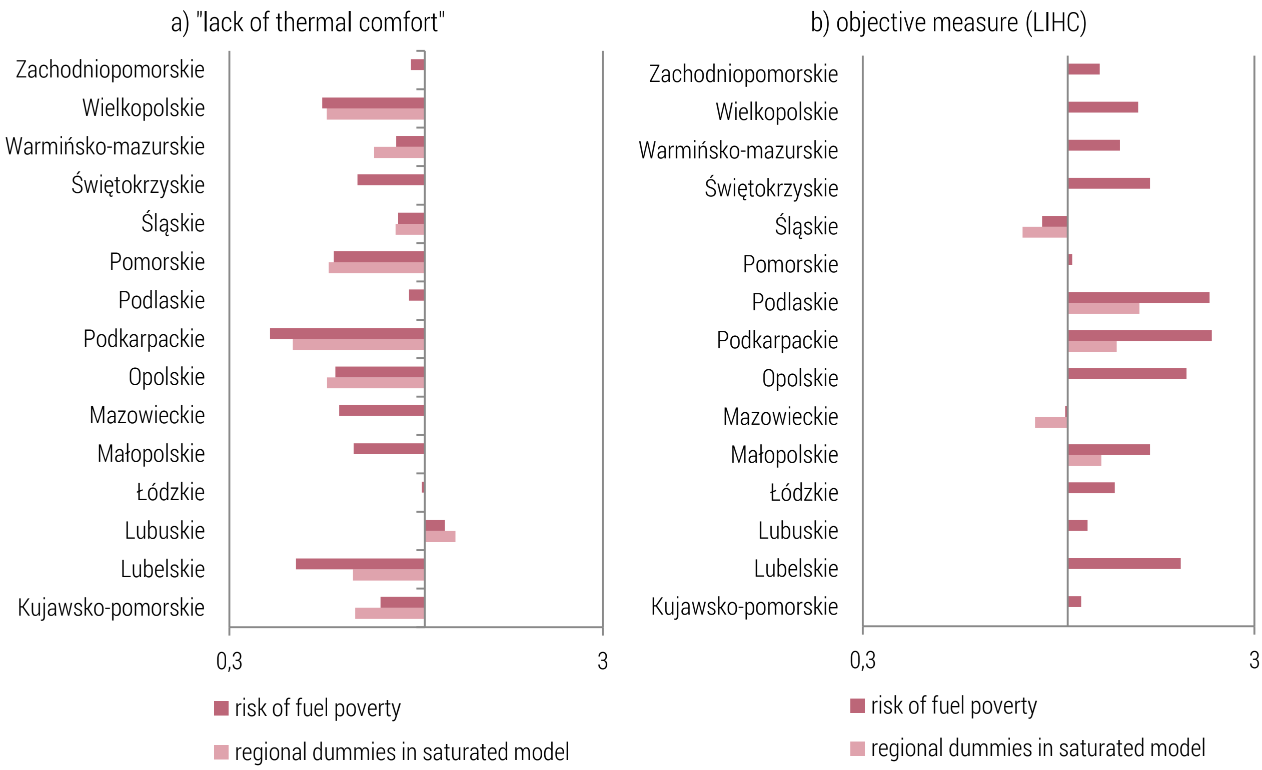
As far as the lack of thermal comfort dimension of fuel poverty is concerned, the influence of socioeconomic characteristics in general is low (2%), yet the regional analysis revealed high variation of the role of this group of characteristics between voivodships (Figure 9). The influence of socioeconomic characteristics was most visible in *Małopolskie* and *Świętokrzyskie* voivodships (5% and 4% of the explained variance, respectively). These voivodships belonged to the group of moderately rich (household median disposable monthly income in 2014: PLN 3.3 thousand and PLN 3.2 thousand, respectively), which corresponded to the low rate of subjective fuel poverty (10.2% and 10.5%).

There were only two voivodships (*Kujawsko-Pomorskie* and *Lubelskie*) where LIHC fuel poverty rate is determined more by characteristics of buildings than by socioeconomic characteristics (Figure 8). In *Lubelskie* high fuel poverty rate stems from the fact that inhabitants of this region have both low income and big houses. However, inhabitants of *Kujawsko-Pomorskie* voivodship have low income and small floor area on average. In *Lubelskie* and *Kujawsko-Pomorskie* voivodships, the influence of the level of urbanisation proved to be a few percentage points higher than the influence of the group of socioeconomic variables. In *Kujawsko-Pomorskie* one could observe the highest percentage of subjectively fuel poor households in the cities with population of 20-99 thousand in Poland (34% relative to 12% in cities with such a population in Poland in general).

3.3.3 Climate and energy prices

Characteristics of buildings, characteristics of households and the degree of urbanisation explain a majority of LIHC fuel poverty variation in regions. The regional dummies add very little to model fit (0.1%) and only some differences between voivodships dummies are statistically significant (Appendix A.2, Figure 10). Parameter estimates indicate that after factoring out the impact of buildings, households and degree of urbanisation the affordability dimension of poverty risk is the highest in: *Podlaskie, Podkarpackie* and *Małopolskie*, and the lowest in: *Mazowieckie, Pomorskie, Kujawsko-Pomorskie* and *Świętokrzyskie*.

Figure 10. Regional effects for fuel poverty measures in Poland in 2014 [odds ratios and percentage points]

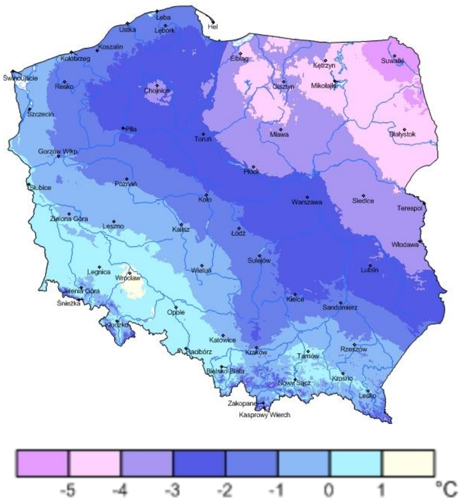


Note: ""Risk of fuel poverty" is defined as fuel poverty scale deviation from the scale in Dolnośląskie voivodship in percentage points. Regional dummies in saturated model present the results of logistic regression in the form of odds ratios. They do not take into account the impact of the buildings characteristic, socioeconomic characteristics and degrees of urbanization. Values higher than 1 indicate that a given analysed phenomenon is more likely to occur (here: fuel poverty), and ones lower than 1 – that it is less likely than for the reference level (REF: Dolnośląskie).The graph shows only statistically significant odds ratios (significance level: 0.1).
Source: Own calculations based on the 2014 Polish HBS data.

More than 2% of the variance of subjective fuel poverty measure is explained by the regional dummies even after inclusion of other variables (Table 1) compared to 0.3% in case of LIHC measure. Consequently, the additional factors, such as climate and energy prices, could explain subjective fuel poverty. In case of LIHC measure, the remaining regional differences are negligible.

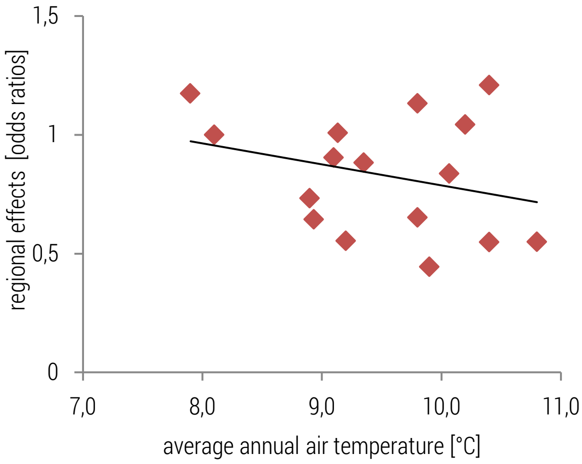
Climate influences outlays needed to keep the comfortable temperature in the buildings. Average annual outdoor temperatures vary to a limited extent among Polish voivodships. In 2014, the maximum difference was 3 degrees Celsius (7.9 degrees Celsius in *Podlaskie* compared to 10.8 degree Celsius in *Opolskie* voivodships). The coldest regions of Poland are located in the south (mountainous areas) and east of Poland (especially *Podlaskie* voievodeship; Figure 11). In Białystok, the capital city of *Podlaskie*, the minimum of average temperatures in January in the period 1999-2013 was -10.2 degrees Celsius in comparison to -5.9 degrees Celsius for the hottest provincial city – Wrocław (*Dolnośląskie* voivodship) (Dopke 2014). The correlation coefficient between estimates of regional dummies in the model of subjective fuel poverty measure and the average air temperatures in voivodships is -0.29 and although it is not statistically significant (due to low sample size of 16), it indicates the influence of regional climate variation on the perceived thermal comfort (Figure 12). High subjective poverty rate in *Podlaskie* voivodship could be partly attributed to lower outdoor temperatures. In the south of Poland, where average temperatures are lower due to elevation (*Podkarpackie* and *Małopolskie* voivodships especially), the regional effects in the subjective poverty model are also notably high.

Figure 11. Average air temperature in January 2014 in Poland [degrees Celsius]



Source: IMGW http://www.imgw.pl/klimat/ [as at 17/10/2016].

Figure 12. Correlation between regional effects of subjective fuel poverty variation [odds ratios] and average annual air temperatures [degrees Celsius] by voivodships in Poland in 2014



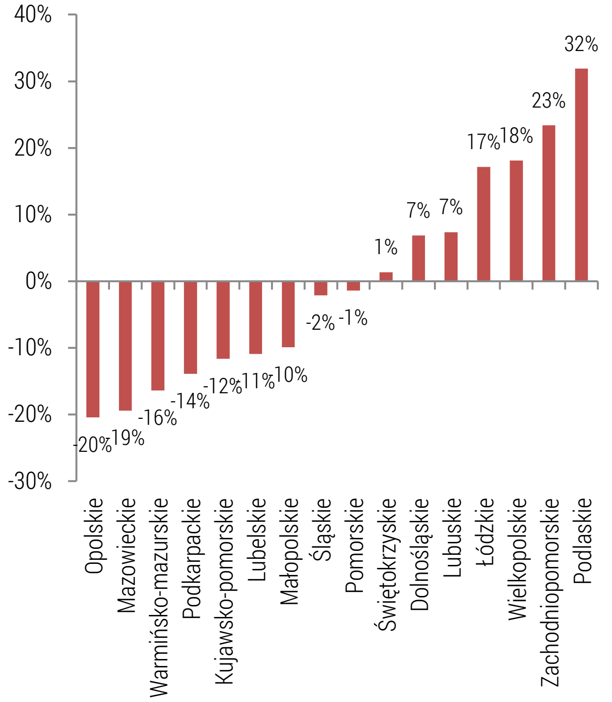
Note: The figure uses the logistic regression results in the form of odds ratios. Values higher than 1 indicate that a given analysed phenomenon is more likely to occur (here: fuel poverty), and ones lower than 1 – that it is less likely than for the reference level.

Source: Own calculations based on the 2014 Polish HBS and CSO (2015).

As far as prices of energy carriers are concerned (gas, power, central heating, coal), the greatest variation relates to the prices of district central heating. In 2014, the average price amounted to PLN 3.97 per 1m^2 and its variation between voivodships reached 40% (*Opolskie*: PLN 3.18 per m^2, *Podlaskie*: PLN 5.27 per m^2; Figure 13). The correlation coefficient between regional effects in the subjective fuel poverty model and prices of central heating equal 0.57 and it is statistically significant. The higher prices of central heating, the higher subjective fuel poverty rate (Figure 14). However, differences in central heating prices expressed in PLN per square metre are affected by energy efficiency of buildings and air temperatures: the lower they are, the higher energy needs. Consequently, the identified statistically significant correlation is also due to too crude measures of energy efficiency of the buildings.

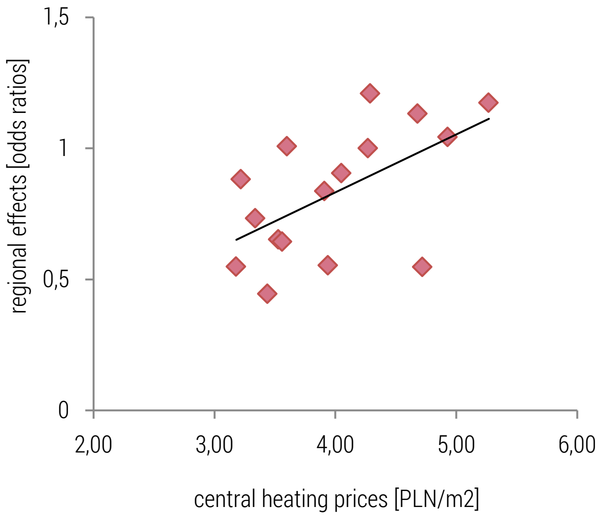
Prices of other energy carriers are less correlated with regional effects (electrical energy: correlation coefficient: 0.1, natural gas: -0.04, hard coal: 0.15) and show lower spatial variation. In 2014, the cost of 1 m^3 of methane-rich natural gas from the distribution network was ca. PLN 2.29, and regional differences were 12%. The regional variation of the hard coal price was 17%, with the national average at the level of PLN 802 per tonne. The price of electrical energy in Poland in 2014 amounted to PLN 0.64 per 1 kWh on average and the level of differences between voivodships was 10%.

Figure 13. Deviations from average prices of central heating in voivodships in Poland in 2014 [%]



Source: Own calculations based on Local Data Bank (BDL) data.

Figure 14. Correlation between regional effects of subjective fuel poverty variation [odds ratios] and prices of central hearing [PLN/m^2] by voivodships in Poland in 2014



Note: The chart uses the logistic regression results in the form of odds ratios. Values higher than 1 indicate that a given analysed phenomenon is more likely to occur (here: fuel poverty), and ones lower than 1 – that it is less likely than for the reference level.

Source: Own calculations based on the 2014 Polish HBS and Local Data Bank (BDL) data.

4. Conclusions

The regional variation of fuel poverty in Poland is significant in both dimensions: energy affordability (LIHC measure) and lack of thermal comfort (subjective measure). At the same time, strong presence of one dimension coincides with low intensity of the other. *Podlaskie* voivodship is the only one that accumulated both dimensions of fuel poverty. Contrary, *Mazowieckie* and *Pomorskie* show low risk of both dimensions of fuel poverty. Others are significantly exposed to either subjective of affordability dimension of fuel poverty.

The energy affordability dimension of fuel poverty is mostly related to income and living area, whereas lack of thermal comfort to energy efficiency. Energy efficiency of buildings and household income are highly related to the degree of urbanisation. Large detached houses predominate in rural areas, while blocks of flats (with usually smaller floor area) in urban areas. Income is also higher in cities. The consequence of this spatial sorting is the concentration of troubles in energy affordability in rural areas and lack of thermal comfort in cities. Therefore, the instruments that aim to eradicate the affordability dimension of fuel poverty should focus on income inequalities, and energy efficiency of detached houses. In order to elevate the thermal comfort, in turn, it is crucial to improve the energy efficiency of old blocks of flats in cities.

Characteristics of buildings, characteristics of households and the degree of urbanisation together explain the majority of the variation of energy affordability dimension (LIHC measure) of fuel poverty. Lack of thermal comfort (subjective measure) is a more complex phenomenon, and it is more difficult to capture by aggregate variables. In order to improve the fit of the model subjective measure of fuel poverty more detailed data on energy efficiency of buildings are needed than those currently available in HBS.[3]

The component of regional variation in the lack of thermal comfort, that cannot be explained by characteristics of buildings and households, is related to the differences in prices of central hearing and average temperatures. Our results point to the need of separate research on the influence of prices of energy carriers on fuel poverty using energy prices at the household level. As regards better understanding of the influence of regional climate variation on fuel poverty, it is necessary to apply data at the level of subregions or counties. Clearly lower temperatures are noticed along the southern border of Poland (mountainous areas) and in the north-east of Poland. Further work on the regional variation of potential energy expenditure could also show a much important role of regional factors in shaping energy affordability dimension of fuel poverty (LIHC).

The strategies to eradicate fuel poverty should vary by regions due to strong regional variation of the causes of fuel poverty. Particular attention ought to be given to *Podlaskie* voivodship, which is characterised by the highest intensity of both energy affordability and lack of thermal comfort. Regional development strategies, which determine the structure of expenditures in the area of urban retrofit as well as development aid to rural areas should, as one of the goals, take eradicating fuel poverty into account. Moreover, strategies and actions should consider the intensity of both poverty dimensions and their causes in each region.

[3] There exists a module in Polish HBS regarding energy consumption in households that contains, among the others, data on energy performance of buildings. However, relatively small sample size (4576 observations) does not enable detailed studies.

References

Baker W., White V. and Preston I. (2008) "Quantifying rural fuel poverty" Report prepared by the Centre for Sustainable Energy to Eaga Partnership Charitable Trust, CSE, Bristol.

Boardman B. (1991) Fuel Poverty: From Cold Homes to Affordable Warmth Belhaven Press, London

Boardman B. (2010) Fixing fuel poverty: challenges and solutions Earthscan, London

Bouzarovski S. and Tirado Herrero S. (2015) "The energy divide: Integrating energy transitions, regional inequalities and poverty trends in the European Union" *European Urban and Regional Studies, 1-18*

Buzar S. (2007) Energy Poverty in Eastern Europe. Hidden Geographies of Deprivation Ashgate, Aldershot

Calculator of required heating energy http://ag-dar.vaillant-partner.pl/kalkulatory-on-line
17 October 2016

CSO (2015) Statistical yearbook of the regions – Poland Warszawa

Dopke J. (2014) "Średnie miesięczne temperatury powietrza w I kw. 2014 r. w polskich miastach" (avaiable anline: http://www.info-ogrzewanie.pl/artykul,id_m-100365,t-srednie_miesieczne_temperatury_powietrza_w_i_kw_2014_r_w_polskich_miastach.html 17 October 2016)

Elbers C., Tomoki F., Lanjouw P.F., Ozler B. and Yin W. (2007) "Poverty alleviation through geographic targeting: how much does disaggregation help?" *Journal of Development Economics 83: 198–213*

Fahmy E., Gordon D. and Patsios D. (2011) "Predicting fuel poverty at small-area level in England" *Energy Policy, 39: 4370-4377*

Frankowski J. and Tirado-Herrero S. (2015). *Energy vulnerability of the urban areas in Gdańsk. First results of the EVALUATE project*. Presentation given at the workshop "Energy vulnerability of urban areas", Gdańsk.

Gerbery D. and Filčák R. (2014) "Exploring multi-dimensional nature of poverty in Slovakia: Access to energy and concept of energy poverty" *Ekonomický časopis, 6: 579-597*

Heindl P. (2015) "Measuring fuel poverty: General considerations and application to German household data" *FinanzArchiv: Public Finance Analysis, 71(2): 178-215*

Hills J. (2011) "Fuel poverty. The problem and its measurement" *CASE report, 69, Department of Energy and Climate Change, London*

Illsley B., Jackson T. and Lynch B. (2007) "Addressing Scottish rural fuel poverty through a regional industrial symbiosis strategy for the Scottish forest industries sector" *Geoforum, 38: 21-32*

IMGW temperatures http://www.imgw.pl/klimat/ 17 October 2016

Kurowski P. (2011) "Ubóstwo energetyczne w Polsce na podstawie badań GUS z 2008 r" *Polityka Społeczna, 27: 17–22*

Lis M., Miazga A. and Ramsza M. (2016) "Dynamiczne własności miar ubóstwa energetycznego" *IBS Research Report 01/2016, Institute for Structural Research, Warsaw*

Lis M., Sałach K. and Święcicka K. (2016) "Heterogeneity of the fuel poor in Poland – quantification and policy implications" *IBS Working Paper 08/2016, Institute for Structural Research, Warsaw*

Miazga A. and Owczarek D. (2015) "It's cold inside – energy poverty in Poland" *IBS Working Paper 16/2015, Institute for Structural Research, Warsaw*

Papada L. and Kaliampakos D. (2016a) "Measuring energy poverty in Greece" *Energy Policy, 94: 157-165*

Papada L. and Kaliampakos D. (2016b) "Developing the energy profile of mountainous areas" *Energy*, *107: 205-214.*

Roberts D., Vera-Toscano E. and Phimister E. (2015) "Fuel poverty in the UK: is there a difference between rural and urban areas?" *Energy Policy 87: 216–223*

Rugkasa J., Shortt N. K. and Boydell L. (2007) "The right tool for the task: 'boundary spanners' in a partnership approach to tackle fuel poverty in rural Northern Ireland" *Health and Social Care in the Community, 15(3): 221-230*

Snell C. and Thomson H. (2013) "Reconciling fuel poverty and climate change policy under the Coalition government: Green deal or no deal" *Social Policy Review, 25: 23-45.*

Stępniak A. and Tomaszewska A. (2014) "Ubóstwo energetyczne a efektywność energetyczna. Analiza problemu i rekomendacje" *Instytut na Rzecz Ekorozwoju, Warszawa*

Szamrej-Baran I. (2014) "Identyfikacja przyczyn ubóstwa energetycznego w Polsce przy wykorzystaniu modelowania miękkiego" *Research Papers of the Wroclaw University of Economics, 328: 343-352*

Szpor A. (2016) "Energy poverty in Poland – buzzword or a real problem?" *IBS Policy Paper 02/2016, Institute for Structural Research, Warsaw*

Valbonesi P., Miniaci R. and Scarpa C. (2014) "Fuel poverty and the energy benefits system: The Italian case" Working Paper n. 66, The Center for Research on Energy and Environmental Economics and Policy at Bocconi University, Milano

Veall M. R. and Zimmermann K. F. (1996) "Pseudo R2 Measures For Some Common Limited Dependent Variable Models" *Journal of Economic surveys, 10.3: 241-25*

Walker R., McKenzie P., Liddell C. and Morris C. (2012) "Area-based targeting of fuel poverty in Northern Ireland: An evidenced-based approach" *Applied Geography*, *34: 639-649*

Appendices

A.1. Spatial variation of fuel poverty in Poland

Table A.1.1. Fuel poverty rates and number of fuel poor households in voivodships in Poland in 2014

Voivodship	Affordability measure (LIHC)				"Lack of thermal comfort"			
	Households		Population		Households		Population	
	%	thous.	%	thous.	%	thous.	%	thous.
Dolnośląskie	7,2%	78	9,0%	254	15,8%	171	16,2%	456
Kujawsko-pomorskie	7,8%	55	9,2%	188	12,1%	86	11,5%	236
Lubelskie	14,0%	101	16,4%	345	7,2%	52	6,7%	142
Lubuskie	8,1%	29	9,9%	102	18,0%	64	17,1%	18
Łódzkie	9,5%	90	13,2%	329	15,6%	146	15,2%	380
Małopolskie	11,7%	127	14,7%	473	10,2%	111	9,6%	310
Mazowieckie	7,1%	141	8,2%	441	9,4%	186	9,6%	516
Opolskie	14,5%	50	17,8%	178	9,1%	32	8,3%	82
Podkarpackie	16,8%	108	19,3%	401	6,1%	39	5,7%	119
Podlaskie	16,6%	69	17,8%	201	14,4%	60	13,2%	149
Pomorskie	7,4%	58	8,9%	195	9,0%	71	9,4%	207
Śląskie	6,2%	100	7,2%	304	13,5%	217	13,5%	570
Świętokrzyskie	11,7%	49	13,6%	172	10,5%	44	9,1%	115
Warmińsko-mazurskie	9,8%	47	10,8%	141	13,3%	64	14,0%	182
Wielkopolskie	10,9%	125	13,6%	488	8,4%	97	8,4%	302
Zachodniopomorskie	8,7%	53	10,6%	171	14,6%	88	14,5%	2
Total	9,6%	1 281	11,7%	4 384	11,5%	1529	11,1%	4176

Source: Own calculations based on the 2014 Polish HBS data.

Table A.1.2. Fuel poverty rates in villages and cities of different size in Poland in 2014

Degree of urbanisation	Structure of population [%]	Ratio of fuel poor measured as:		
		affordability (LIHC)	"lack of thermal comfort"	affordability (LIHC) and "lack of thermal comfort"
≥500 thous. residents	14,7	2,4	10,6	12,7
200-499 thous. residents	10,5	3,6	9,8	12,8
100-199 thous. residents	8,6	4,5	13,7	17,7
20-99 thous. residents	20,2	6,3	12,2	17,8
<20 thous. residents	13,2	9,4	10	18,6
Rural areas	32,8	18,2	11,9	27,9
Total	100	9,6	11,5	19,9

Source: Own calculations based on the 2014 Polish HBS data.

A.2. Logistic regression results (estimations of parameters)

		Dependent variable - fuel poverty measured as:	
		affordability (LIHC)	„lack of thermal comfort"
Voivodship	REF: *Dolnośląskie*		
	Kujawsko-pomorskie	-0.156	-0.428***
	Lubelskie	-0.0184	-0.441***
	Lubuskie	0.181	0.189*
	Łódzkie	-0.0177	0.123
	Małopolskie	0.199*	0.00731
	Mazowieckie	-0.192*	-0.126
	Opolskie	0.0450	-0.601***
	Podkarpackie	0.288**	-0.813***
	Podlaskie	0.423***	0.160
	Pomorskie	-0.122	-0.592***
	Śląskie	-0.265**	-0.179**
	Świętokrzyskie	-0.144	-0.101
	Warmińsko-mazurskie	0.0866	-0.312***
	Wielkopolskie	-0.00735	-0.603***
	Zachodniopomorskie	0.0902	0.0413
Degree of urbanisation	REF: ≥500 thous. residents		
	200-499 thous. residents	-0.853***	-0.274***
	100-199 thous. residents	-0.318**	-0.0890
	20-99 thous. residents	-0.124	-0.0602
	<20 thous. residents	0.194**	-0.364***
	rural areas	0.489***	-0.0782
Type of building	REF: block of flats		
	terraced house	2.030***	0.293
	detached house	2.012***	0.0749
	Floor area [m2]	0.0708***	-0.00117
Inter-actions	terraced house x floor area	-0.0436***	-0.00417*
	detached house x floor area	-0.0433***	-0.00336**
Type of heating	REF: central heating system		
	fuel stoves	-0.999***	0.914***
	electric stoves	-1.023***	0.692***
Building construction period	REF: 1961-80		
	before 1946	-0.357***	0.748***
	1946-1960	0.449***	0.357***
	1981-1995	-0.183***	-0.0799
	1996-2006	-1.321***	-0.347***
	after 2006	-1.437***	-1.169***

		Dependent variable - fuel poverty measured as:	
		affordability (LIHC)	lack of thermal comfort
	Disposable income [ln PLN]	-2.998***	-0.401***
Socioeconomic group	REF: White-collar workers		
	Blue-collar workers	0.593***	0.205***
	Retirees	-0.506***	-0.0360
	Pensioners	-0.211**	0.203***
	Farmers	0.521***	-0.0897
	Self-employed	0.382***	-0.0210
	Social beneficiaries	-0.859***	0.365***
	Beneficiaries of other non-income sources	-0.884***	0.105
	Number of children (under 14 years old)	0.289***	0.100***
	Constant	16.42***	1.078***
	No. of observations	35 977	35 977
	Pseudo R^2	0.378	0.106

*Significance levels: *** p<0.01, ** p<0.05, * p<0.1.*
Source: Own calculations based on the 2014 Polish HBS data.

A.3. Direct influence of specific factors on fuel poverty in voivodships

Table A.3.1. Direct influence of specific factors on affordability measure (LIHC) of fuel poverty in voivodships

Voivodship	Saturated model	Buildings characteristics	Socioeconomic characteristics	Degree of urbanisation
Dolnośląskie	0.69	0.27	0.34	0
Kujawsko-pomorskie	0.59	0.33	0.22	0.02
Lubelskie	0.65	0.32	0.27	0.02
Lubuskie	0.88	0.15	0.29	0.12
Łódzkie	0.66	0.24	0.27	0.01
Małopolskie	0.64	0.18	0.27	0.03
Mazowieckie	0.64	0.18	0.38	0.03
Opolskie	0.65	0.22	0.37	0
Podkarpackie	0.6	0.25	0.33	0.01
Podlaskie	0.68	0.28	0.33	0.02
Pomorskie	0.63	0.14	0.23	0.06
Śląskie	0.52	0.2	0.35	0.01
Świętokrzyskie	0.62	0.25	0.34	0.01
Warmińsko-mazurskie	0.63	0.31	0.34	0
Wielkopolskie	0.63	0.25	0.27	0.05
Zachodniopomorskie	0.64	0.23	0.38	0.02

Note: Direct influence is calculated as a decrease in pseudo-R^2 in restricted logistic regression model in comparison to saturated logistic regression model..
Source: Own calculations based on the 2014 Polish HBS data.

Table A.3.1. Direct influence of specific factors on subjective fuel poverty ("lack of thermal comfort") in voivodships

Voivodship	Saturated model	Buildings characteristics	Socioeconomic characteristics	Degree of urbanisation
Dolnośląskie	0.21	0.1	0.02	0.01
Kujawsko-pomorskie	0.25	0.08	0.02	0.04
Lubelskie	0.27	0.15	0.01	0.04
Lubuskie	0.22	0.14	0.02	0,00
Łódzkie	0.27	0.15	0.02	0,00
Małopolskie	0.27	0.06	0.05	0.04
Mazowieckie	0.22	0.13	0.02	0.02
Opolskie	0.21	0.09	0.03	0.03
Podkarpackie	0.19	0.08	0.03	0.01
Podlaskie	0.27	0.2	0.02	0.02
Pomorskie	0.22	0.14	0.03	0.01
Śląskie	0.18	0.09	0.02	0.01
Świętokrzyskie	0.19	0.12	0.04	0.01
Warmińsko-mazurskie	0.22	0.07	0.03	0.03
Wielkopolskie	0.23	0.11	0.02	0.02
Zachodniopomorskie	0.18	0.05	0.03	0.01

Note: Direct influence is calculated as a decrease in pseudo-R^2 in restricted logistic regression model in comparison to saturated logistic regression model..
Source: Own calculations based on the 2014 Polish HBS data.

instytut
badań
strukturalnych

www.ibs.org.pl