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Does France Have a Fuel Poverty Trap?

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Does France have a fuel poverty trap?[1]

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In this article, we focus on fuel poverty. More specifically, we analyse this phenomenon's dynamic by answering the following question: does France have a fuel poverty trap? First, we define three states/situations into which individuals may be placed: the non-fuel poverty state, the fuel poverty state and the severe fuel poverty state. Second, we use a mover-stayer model that divides the population into two types of individuals: those who remain in the same state during the observation period (the stayers) and those who move across states (the movers). This model applies to longitudinal data from mainland France that shows that fuel poverty is not an absorbing state, i.e., it is not a trap. Therefore, fuel poverty is usually a transitory state. Using two econometric models (logit and multinomial logit), we then identify the stability and mobility determinants in different states. As expected, on the one hand, there is a relationship between income and the likelihood of an individual staying in the same state. On the other hand, poor housing implies a greater likelihood of stability in fuel poverty or severe fuel poverty. Another result is that the deterioration in fuel poverty status seems to stem more from difficult financial situations than from bad dwelling conditions.

JEL Codes: D21, D43, L13, L95

Keywords: Fuel poverty, mover-stayer model, logit, multinomial logit

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Executive Summary

Households increasingly struggle to heat their homes. These households experience fuel poverty, which can be defined as the difficulty or inability to adequately heat one's household at an acceptable cost. To identify the households that experience fuel poverty, different indicators can be used, including the energy effort rate[4], the Hills approach to a low income-high cost measure of fuel poverty (Hills, 2011) and subjective indicators (self-reported feelings of coldness). It is then necessary to characterise the households living in fuel poverty (using composition, income, dwelling type, heating type, etc.) to better design policies that combat energy poverty and target the population. However, measurements of fuel poverty are often one-time measures. As a result, it is impossible to know the phenomenon's dynamics (i.e., whether it is transitional or chronic) and the policies' impact on households and individuals. To our knowledge, most studies on fuel poverty in France are based on "ad hoc" surveys (e.g., the Enquête Nationale Logement[5]) and not on panels. However, to know the dynamics of the fuel poverty phenomenon, we need to use longitudinal data. We are interested in this dynamic as we address the following question: Does France have a fuel poverty trap?

Heating expenditures represent 71% of household energy costs (INSEE, 2008). We will concentrate on the difficulty of heating one's home as it is a proxy measure of fuel poverty for which we have the necessary panel data to achieve our goal, i.e., to study the dynamic nature of the phenomenon in order to adequately assess public policies' impacts on the fuel poor. We use the 2009-2011 waves of France's Statistics on Resources and Living Conditions (SRCV), which make

[4] Households that spend more than x% of their income on energy bills are considered to be experiencing fuel poverty. The threshold x used by the French National Institute of Statistics and Economic Studies (INSEE) is 10%.

[5] The French National Housing Survey.

it possible to distinguish three types of individuals: (1) the non-fuel poor, (2) the fuel poor and (3) the severely fuel poor.

Using a transition model called the '*mover-stayer model'*, we study individual paths (e.g., the passage from a non-fuel poverty state to a fuel poverty state or severe fuel poverty state), and we thus quantify the number of individuals who permanently remain in a particular state (i.e., stayers) and those that pass from one state to another (i.e., movers). This model, which has been applied to longitudinal data from mainland France, shows that fuel poverty is not an absorbing state, i.e., it is not a trap. The estimated proportions for stayers in France are as follows: 78% of the non-fuel poor will not fall into fuel poverty; 38% of the fuel poor will remain precarious; and 28% of the severely fuel poor will remain in this state. The fuel poverty state seems to be a transitory (i.e., temporary) state for movers, and movers' mobility appears to be very high. In other words, today's fuel poor may not be tomorrow's fuel poor, and vice versa. As poor housing conditions may lead individuals into fuel poverty, we look at the impact of these conditions on the percentage of stable individuals and on mobile transition probabilities. These probabilities depend on individual characteristics (status in the labour market, education level, etc.) To identify stability and mobility determinants in these different states, we use two econometric models (logit and multinomial logit). As expected, on the one hand, there is a relationship between income and the likelihood that an individual will stay in a particular state; on the other hand, poor housing conditions imply a greater likelihood of an individual's stability in fuel poverty or severe fuel poverty. Another result is that the deterioration of fuel poverty status seems to stem more from difficult financial situations than bad dwelling conditions.

1. Introduction

Access to energy is a global issue, and people increasingly do not have enough energy to cover their basic needs due to a lack of resources or poor living conditions. These people are the fuel poor. A number of indicators can be used to identify the fuel poor. The indicator most commonly used is the rate of energy effort, which is an expenditure-based measure. It represents the percentage of income that a household allocates to meet its energy needs. If this rate is higher than 10%, the household is considered to be experiencing fuel poverty. Proposed by Boardman in 1991, this 10% threshold is almost twice the median percentage of income that UK households allocated to energy supply in 1988[6] (Boardman, 1991). This indicator was long used as the official standard for measuring fuel poverty in UK by approximating domestic energy requirements based on normative modulated energy consumption. In response to criticism[7] related to this indicator, the British government adopted the Hills indicator in August 2013. According to this indicator, a household is fuel poor if its income falls below a particular income threshold[8] and if its normative modulated energy expenditure is higher than the energy expenditure threshold[9] (Hills, 2011).

France does not have an official indicator for national statistics on fuel poverty. However, a 10% threshold has been used in various studies (e.g., Devalière et al., 2011). In these studies, the energy effort rate is calculated from actual reported consumption, given the difficulty of modelling normative consumption with the available data. As a result, some atypical behaviours (e.g., restriction/deprivation or excess) that could be corrected with the original indicator (calculated via

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[6] In 1988, 30% of the poorest households in UK actually had an energy effort rate of 10%.

[7] For example, (1) there is a fixed threshold of 10% (threshold supported by data dating back to 1988), and (2) better-off households that over-consume are not excluded.

[8] This threshold is equal to the relative poverty line, which is set at 60% of the national median income, after housing costs (e.g., rent or mortgage payments) and energy costs (e.g., electricity bills) are deducted.

[9] The threshold is the median household energy expenditure.

modulated normative expenses) are not excluded. Hence, the energy effort rate that is calculated based on actual expenditures should not be used.

Other indicators were used to assess the number of fuel poor, including an indicator based on the minimum income level (see Moore, 2012) and another based on perceived coldness—a subjective measure of fuel poverty. According to the indicator based on the minimum income level, a household is living in fuel poverty if the income available after deducting housing costs and the minimum income level does not cover the household's energy expenditure. The minimum income level is defined as the income that is required to meet the household's sustenance needs. This indicator provides an idea of how many households are expected to reduce their spending on other goods to meet their energy needs. Using this approach depends on the availability of data on the minimum income level. Determining what income a household requires to allow its inhabitant(s) to live a decent life is subject to normative judgments and may fluctuate over time. Moreover, from country to country, perceptions about the income required to meet minimum standards of living can diverge considerably, which makes comparisons difficult. It is possible to use subjective indicators/declaratives, i.e., those that are based on opinions or perceptions, to identify households that live in fuel poverty. Among these indicators, individuals' feelings of coldness are customary measures. Hence, Chaton and Lacroix (2014) and Lacroix and Jusot (2014) determine a link between the subjective measure of fuel poverty (i.e., coldness) and self-reported health issues. Measures of fuel poverty that are based on these indicators, amongst others, are often one-off measures.

In the present study, we define fuel poverty as the difficulty of heating one's home. This definition is similar to the one given in Article 11 of France's national commitment to the environment

(Grenelle II law[10]) on 12 July 2010: *a household that has difficulties disposing of the necessary energy to satisfy his basic needs due to the inadequacy of his resources or his living conditions is in fuel poverty under this Act*. Waddams Price et al. (2012) argue that the overlap between the energy effort rate and measures that are based on an individual's self-reported perceptions of household heating difficulties is minimal. Indeed, amongst households that felt that they had problems maintaining warmth, less than half showed expenditures that would classify them as fuel poor.

We will concentrate on the difficulty of heating one's home, as it is a proxy measure of fuel poverty[11] for which we have the panel data necessary to reach our goal, i.e., to study the dynamic nature of the phenomenon in order to adequately assess public policies' impacts on the fuel poor. Most studies on fuel poverty rely on one-off surveys—in other words, surveys in a static context (e.g., housing surveys)—instead of panel data. As a consequence, there are few studies on fuel poverty that have been carried out in a dynamic environment.

To the best of our knowledge, only Phimister et al. (2014) analyse the dynamics of energy poverty (in Spain from 2007-2010) using longitudinal data. They construct a Markov matrix that provides the probabilities of moving from fuel poverty to non-fuel poverty, and vice versa. To do so, they consider two measures of fuel poverty: an expenditure-based measure, i.e., the energy effort rate with a threshold of 10%, and a subjective measure, i.e., the individual's self-reported perceptions of household heating difficulties. Hence, they analyse the transitions into and out of fuel poverty. They observe that '*the proportion of the sample that can be characterised as persistently energy poor is substantially less than the proportion that is persistently income poor*.' Our study's objective is similar to that of Phimister et al. Indeed, we want to know whether fuel poverty is

[10] http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000022470434&categorieLien=id

[11] Heating expenditures represent 70% of household energy costs (INSEE, 2006).

transitory or chronic. However, our approach is more sophisticated than the one used by Phimister et al. On the one hand, we calculate the probability of moving from a fuel poverty situation (or state) to a non-fuel poverty state, or vice versa, and the probability of remaining in the same state. The calculation of probability addresses the following question: Does France have a fuel poverty trap? On the other hand, we identify the stability and mobility determinants between different states in the fuel poverty phenomenon.

For this purpose, we use a mover-stayer model that divides population into two types of individuals: those who remain in the same state during the observation period (i.e., stayers) and those who move across states (i.e., movers). Boag (1949)[12] developed this approach in the biomedical field, and it has been applied to model labour market transitions (Blumen et al., 1955; Dunsmuir et al., 1989, Fougère and Kamionka, 1992) and to model the recidivism of criminals (Schmidt and Witte, 1989). The model parameters, namely the proportion of stayers in each state and the interstate transition probabilities matrix for movers, are estimated via maximum likelihood methods. It is thus possible to deduce the proportion of individuals in each state on a stationary equilibrium and to identify the percentages of movers and stayers within these stationary proportions. To apply this type of model to fuel poverty in mainland France, we use longitudinal data from the Statistics on Resources and Living Conditions[13]. After this first analysis, we perform econometric estimations (logit and multinomial logit estimations) based on the same sample to identify the determinants that influence the probability that individuals will remain in fuel poverty (stayers) and the determinants that influence the probability that individuals will move between different states (i.e., movers). This analysis gives formal identification of individual stability or

[12] In biomedical literature, the mover-stayer model is known as the "cure model".

[13] This survey is a part of the European Union Statistics on Income and Living Conditions (EU-SILC).

transition determinants. The primary determinants that increase the risk of being fuel poor can be split in two large categories: (1) socio-economic determinants and (2) socio-demographic determinants.

Income level and occupational status on the labour market are identified as the major socio-economic determinants of fuel poverty (Healy and Clinch, 2004; Waddams and al., 2012; Scott et al., 2008). Therefore, a low income (or unemployment) puts pressure on household budgetary constraints. With a constant level of energy expenditures, an income decrease or a low level of income increases a household's risk being fuel poor. Moreover, individuals with low incomes are more likely to have energy-inefficient appliances (Brunner et al., 2012).

We can report that education level (Healy and Clinch, 2004; Huybrechs et al., 2011), household type (Healy and Clinch, 2004; Waddams and al., 2012; Scott et al., 2008), marital status (Healy and Clinch, 2004; Scott et al., 2008), housing tenure (Healy and Clinch, 2004; Whyley et al., 1997; Scott et al., 2008) and dwelling conditions (Whyley and Callender, 1997; Healy and Clinch, 2004; Scott et al., 2008) are the primary socio-demographics determinants. Huybrechs et al. (2004) explain that individuals with low levels of education do not have the same "capabilities" (Sen, 1983) to adopt energy-saving behaviours; as a direct result, these individuals may experience increases in their energy bills. In addition, budgetary constraints are tighter for single-parent families than they are for households with two adults and a child. In the same way, due to the significant economic cost of marital dissolution, divorce may make some individuals vulnerable to fuel poverty (Hoffman and Duncan, 1988). Compared with tenants, owners have better and more precise (accurate) control over their energy consumption and heating systems. Therefore, tenants may find it more difficult to save energy or improve household energy efficiency. Finally, dwelling conditions (e.g., damp, mould, and condensation) and building age are fuel poverty determinants (Healy and Clinch, 2004; Whyley and Callender, 1997; Scott et al., 2008). Therefore, the economic literature is relatively rich in information on fuel poverty determinants. However, most studies that identify fuel poverty determinants have been conducted in a static context. However, we feel that there is a need for a dynamic perspective to better and more accurately comprehend fuel poverty.

The remainder of this paper is organised as follows. Section 2 describes the France's Survey on Income and Living Conditions and provides some statistical analyses. We also define three states/situations in which individuals find themselves (i.e., non-fuel poverty, fuel poverty and severe fuel poverty); a mover-stayer model and econometrical specifications are also detailed. Section 3 discusses the results, and Section 4 concludes by suggesting some extensions of this research.

2. Methods

2.1. Data and sample statistics

2.1.1. Database

We use the 2009-2011 waves of France's Statistics on Resources and Living Conditions (SRCV). This survey is a part of the European Union Statistics on Income and Living Conditions (EU-SILC), which uses face-to-face interviews to collect information on income distribution, poverty, social exclusion and living conditions. It is used as a reference for income distribution comparisons among European Union member states and for Community actions against social exclusion. It is organised around a cross-sectional component and a longitudinal component. In this analysis, we use this survey's longitudinal component. This longitudinal component includes a sample of all individuals older than 15 years of age who occupy 16,000 dwellings (selected from the master sample) and a sampling frame for new housing. All of these individuals are followed over time, even when they move to other dwellings. Individuals who answered in all three waves

(2009-2011) and had not moved make up the sample used in this study. Therefore, our panel data are balanced. We have a sample of 11,965 individuals per year, and these individuals have been observed three times. In total, our sample includes 35,895 observations.

The database allows us to distinguish three categories of individuals: (1) the non-fuel poor, (2) the fuel poor and (3) the severely fuel poor. Therefore, the following three states can be defined:

The fuel poverty state (*FP*).

If a member of household answers "yes" to the following questions, then the household is considered to be living in fuel poverty: *Is it too hard or costly to adequately heat your dwelling?* and *Do you have the financial means to keep the correct temperature in your home?*

The severe fuel poverty state (*SFP*).

If a member of a household answers "yes" to *Is it too hard or costly to adequately heat your dwelling?* and "no" to *Do you have the financial means to keep the correct temperature in your home?*, then the household is considered to be living in severe fuel poverty, given the financial burden implied by the answer to the second question.

Non-fuel poverty state (*NFP*).

The rest of the population belongs to this category.

Hence, only the severely fuel poor cannot cope with their heating expenditures.

2.1.2. Descriptive statistics

The fuel poor accounted for slightly more than 25% of the sample examined (see Table 1). This proportion is significantly greater than the last estimation of the French National Institute of Statistics and Economic Studies (INSEE), which was 14.4% for 2006. One explanation for this gap is that INSEE uses the traditional threshold of 10% of household income for fuel expenditures to identify the fuel poor, which does not consider restriction phenomena. However, this gap primarily exists because total family income is not adjusted for one spouse and the number of dependants under the age of 18. Indeed, if we consider that a household is living in fuel poverty if

$$\frac{\text{Household energy expenditure (including a correction factor for no response)}}{\text{The number of consumption units (CUs)}} < 10\%,$$

then, using the same database for mainland France, 25% of households are found to be living in fuel poverty in 2009. The percentage is found to be approximately 27% in 2011.

Non-Fuel Poor		Fuel Poor		Severely Fuel Poor		Total	
Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
26,865	74.84	7,295	20.32	1,735	4.83	35,895	100

Table 1: Distribution of the sample among the states.

Some of the sample's socio-economic and demographic information is summarised in Table 2.

Sex	Female	Male				
	52.60	47.40				
Location (population density)	Rural	Urban				
	27.39	72.61				
Marital status	Single	Single-parent families	2 adults without dep. child	Two-adult family with children	Others	
	14.68	6.95	31.69	42.65	3.02	
Presence of mould and/or moisture	Yes	No				
	10.47	89.53				
Housing type	A farm, house or detached house		A town house or semi-detached house		Apartment	Other
	51.55		22.57		25.73	0.15
Occupancy status	Owner	Tenant		Free of charge		
	70.58	26.64		2.79		

Table 2: Descriptive statistics on the sample used (in percentages)

Therefore, 74% of individuals live with a partner; 70% are homeowners; and 10% report the presence of mould and/or moisture in their homes. In addition, almost 50% of individuals have a lower secondary level of education.

More than 6% of individuals report at least one of the following financial difficulties:

1) The inability to pay an electricity, gas, water or telephone bill on time over the past 12 months

due to money problems;

2) The inability to pay taxes on time over the past 12 months for money problems; and

3) The inability to repay credit on time due to money problems.

Based on household characteristics, Table 3 shows the individual sample distribution of the three states. This table indicates that 32% of couples without children and 45% of couples with children are among non-fuel poor are coupled individuals; in addition, 18% of couples without children and 35% of couples with children are among the severely fuel poor, and these couples constitute 74% of the sample. The table shows that 18 % of single-parent families are among the severely fuel poor, but this type of household constitutes less than 7% of the sample. The percentages confirm that the quality of housing has a significant impact on the fuel poverty state. In fact, nearly 25 % of individuals who claim to have mould and/or moisture problems in their homes are among the severely fuel poor, but these individuals make up only a little over 10% of the sample.

	NFP	FP	SFP
Female	57%	54%	59%
Rural	26%	31%	28%
Single person	6%	7%	16%
Single-parent families	32%	35%	18%
Couple without children	32%	35%	18%
Couple with children	45%	38%	35%
Financial difficulty	4%	8%	26%
Damp/musty conditions	6%	20%	25%
A farm, a house or a detached house	52%	54%	44%
A town house, semi-detached house	21%	27%	26%
Owner	74%	66%	55%
Tenant	24%	31%	43%
Employed	52%	43%	36%
Student	6%	6%	8%

Table 3: Individual sample distribution across the three states

Do people remain in fuel poverty? As explained in the following section, the mover-stayer model relates to this issue by ascertaining whether fuel poverty is an absorbent state.

2.2. Modelling

2.2.1. The mover-stayer model

The mover stayer model is an extension of the Markov chain model: $X(t) \in E$ is the value at time *t* of a given variable that is associated with every individual in a given population, where $E = \{1,...,K\}$, $K \in N$ is a discrete state space. $E = \{FP, SFP, NFP\}$ for our application. This model allows us to consider unobserved heterogeneity in the population, which is assumed to consist of two unobserved groups: a stayer group that contains individuals with zero probability of change $\left(X(t) \equiv X(0)\right)$ and a mover group that follows an ordinary Markov process (with the transition matrix $M = \|m_{ij}\|$, i, $j = 1,...,K.$). Let $s_i \in [0,1]$, the proportion of an individual starting from the i^{th} state, be a stayer. We have at our disposal observations about *T* successive years ($T = 3$ for our application). The estimation of parameters (s, M), where s is the vector $(s_1, \ldots, s_K)$ and M is as defined above, cannot be directly estimated because the stayers are not directly observable. Indeed, an individual who is observed to remain in his or her starting class might be a stayer, but a mover who has not moved and whose probability remains in the state *i* throughout the observation period is also non-zero (equal to $m_{ii}^T, i \in E$).

Frydman (1984) proposes a method for estimating m_{ij} and s that is based on a recursive procedure. The maximum likelihood estimator of m_{ij} for fixed *i* and *j* varying from 1 to *K* is given by the following recursive equation:

$$\hat{m}_{ij} = \frac{n_{ij}\left(1 - \hat{m}_{ii} - \sum_{k \neq i, k=1}^{j-1} \hat{m}_{ik}\right)}{\sum_{k \neq i, k=1}^{K} n_{ik}}, \; j \neq i, i, \; j \in E. \quad (1)$$

Starting from $j = 1$ if $i \neq 1$ and from $j = 2$ if $i = 1$, the estimator of m_{ii} ($\hat{m}_{ii}$) is the solution being comprised between $[0,1]$ of the following equation:

$$g(x) = \left[n_i^* - Ln_i(0)\right]x^{T+1} + \left[Ln_i(0) - n_{ii}\right]x^T + \left[Ln_i - n_i^*\right]x + (n_{ii} - Ln_i) = 0 \quad (2),$$

where $n_i(0)$ is the initial number of individuals in state *i*; $n_i(t)$ is the number of individuals in state *i* at time *t*; n_{ij} is the number of individuals in state *j* at time *t*, who were in state *i* at time $t-1$; and n_i is the number of individuals who continuously remain in *i* during all observation periods: $n_{ij} = \sum_{t=1}^{T} n_{ij}(t)$ and $n_i^* = \sum_{t=0}^{T-1} n_i(t)$.

Kamionka and Fougère (1992) generalise Frydman's method by including cases in which some of the s_i parameters are null. They demonstrate that if $s_i = 0$, then

$$\forall i, j = 1,\ldots,K,\ m_{ij} = \frac{n_{ij}}{n_i^*}. \quad (3)$$

2.2.2. Econometric modelling

Why are certain individuals more likely than others to remain in fuel poverty? To answer that question, we estimate two econometric models. One identifies the determinants of *stables*, i.e., individuals who remained in the same state during the three observation periods (2009, 2010 and 2011), and the other identifies the determinants of *mobiles*, i.e., individuals who moved across the different states between 2009 and 2011. In this subsection, we assume that *stables* are directly observable, unlike in the mover-stayer model. Therefore, the probability for a *mobile* to stay permanently in state *i* during all observation periods is positive in the mover-stayer model, (Fougère and Kamionka, 1992) whereas this probability is equal to zero in the two econometric models. Nevertheless, as we will see in the next section, the proportions of *stables* and *mobiles* in each state will be quite similar to the proportions estimated in the mover-stayer model. In what follows, the *s* index characterises the *stables* and the *m* index characterises the *mobiles.*

Stables **specifications.**

To identify the main determinants of *stables*, we perform logistic regressions for each state/situation. The logistic specifications model estimates the probability of an event occurring, and, in our case, this probability determines the likelihood of being a non-fuel poor *stable* (NFP_s), a fuel poor *stable* (FP_s) or a severely fuel poor *stable* (SFP_s) during the three periods of observations (2009-2011), given several exogenous variables that are represented in the X_i vector for the i^{th} individual. These exogenous variables contain socio-economic characteristics (e.g., income level, occupational status, and financial difficulties) and socio-demographic characteristics (e.g., education level, marital status, and housing tenure). Let NFP_{si}, FP_{si} or SFP_{si} be a binary variable that equals to 1 if the i^{th} individual is not in fuel poverty, in fuel poverty or in severe fuel poverty, respectively, during the years of observation, and 0 otherwise. The observable outcomes (to report his/her situation) are represented by a binary indicator variable, Y_i, as follows:

$$Y_i = \begin{cases} 1 & \text{if } Y_i^* > 0 \text{ to report the same sitation } Y_i \\ 0 & \text{otherwise,} \end{cases} \tag{4}$$

$$\Pr(Y_i = 1 | X_i) = 1 - \Phi[-X_i'\theta], \tag{5}$$

$$\Pr(Y_i = 0 | X_i) = \Phi[-X_i'\theta], \tag{6}$$

where $Y_i \in \{NFP_{si}, FP_{si}, SFP_{si}\}$, $Y_i^* \in \{NFP_{si}^*, FP_{si}^*, SFP_{si}^*\}$ is a latent dependent variable; Pr denotes probability; and Φ is the cumulative distribution function of the standard normal distribution ($N(0,1)$). Y_i^* is generated by the following linear regression model:

$$Y_i^* = \alpha_{Y_i} + \beta_{Y_i} X_i' + \varepsilon_{Y_i}, \tag{7}$$

where for each $Y_i \in \{NFP_{si}, FP_{si}, SFP_{si}\}$, α_{Y_i} is a constant, and β_{Y_i} is a vector.

***Mobiles* specifications.**

We analyse the determinants of transitions between different states (NFP_m, FP_m, SFP_m). The following transition matrix represents the transition probabilities between the different states (FP_m, SFP_m, NFP_m):

$$\Omega = \begin{pmatrix} \Omega_{NFP_m \to NFP_m} & \Omega_{NFP_m \to FP_m} & \Omega_{NFP_m \to SFP_m} \\ \Omega_{FP_m \to NFP_m} & \Omega_{FP_m \to FP_m} & \Omega_{FP_m \to SFP_m} \\ \Omega_{SFP_m \to NFP_m} & \Omega_{SFP_m \to FP_m} & \Omega_{SFP_m \to SFP_m} \end{pmatrix}$$

where $(j,k) \in \{FP_m, SFP_m, NFP_m\}$ and $t' \neq t$: $\Omega_{j \to k} = P(Y_{t'} = k / Y_t = j)$. Each $\Omega_{j \to k}$ can be written as a multinomial logistic regression by fixing the base outcome as the initial state. For example, the transition probability between the non-fuel poverty state (NFP_m) and a state (k) is as follows:

$$\Omega_{NFP_m \to k}(Y_{t+1} = k / X_{t,}\, Y_t = NFP_m) = \frac{\exp(X_t' \gamma_{NFP_m \to k})}{1 + \sum_{k \neq NFP_m} \exp(X_t' \gamma_{NFP_m \to k})}. \quad (8)$$

This specification is used to identify determinants that alter the probability of moving from one state/condition to another between 2009 and 2011.

3. Results

3.1. Fuel poverty is not a trap

Using the mover-stayer model presented in 2.2.1, it is possible to study individual trajectories and to quantify the proportions of individuals who were stayers and movers in each state. Table 3 shows the estimated **proportions of stayers** in the three states: 78% of the non-fuel poor will not fall into fuel poverty; 38% of the fuel poor will remain precarious; and 28% of the severely fuel poor will remain in this state.

Non-Fuel Poor	Fuel Poor	Severely Fuel Poor
78%	38%	28%

Table 3: Estimated proportions of stayers in each state.

Therefore, fuel poverty and severe fuel poverty do not constitute irreversible states because well under half of the fuel poor and severely fuel poor remain in the same state over the course of the observation period. Moreover, the proportions of stayers in fuel poverty and severe fuel poverty are lower than the proportion of non-fuel poor stayers.

The estimated **transition probabilities** between each state (for the movers) are shown in Figure 1.

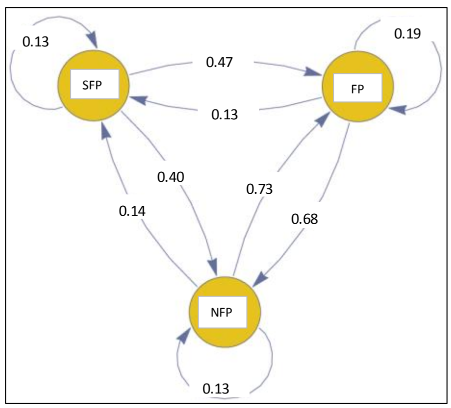

Figure 1: Estimation of ‘movers’ transition probabilities

The transition probability of moving from non-fuel poverty to fuel poverty is very high (at 0.73). For fuel poor movers, the probability of returning to a non-fuel poverty state is relatively high (at 0.68). In contrast, the probability of transitioning into severe fuel poverty is low (at a maximum of 14%). Therefore, for movers, it is more difficult to enter the severe fuel poverty state than it is to leave it. The transition probabilities of moving from severe fuel poverty to fuel poverty and from severe fuel poverty to non-fuel poverty are similar (approximately 0.4). These results provide relevant information. Fuel poverty seems to be a transitory (temporary) state for movers, and the movers’ mobility appears to be very high. In other words, today’s fuel-poor movers will not be fuel poor tomorrow. This observation thus confirms that fuel poverty is not a trap for movers. Indeed, the probability of movers staying in fuel poverty or severe fuel poverty is low (at 0.19 and 0.13, respectively). In addition, it seems that mobility between different states is important.

To consider the specific population's characteristics, the sample may be stratified. As poor housing conditions can lead an individual into fuel poverty, we opt to look at the impact of these conditions on the percentage of stable individuals and on mobile transition probabilities.

The impact of housing conditions on fuel poverty dynamics.

Types of dwellings.

Table 4 summarises the estimates of *stayer* proportions, which are stratified by housing type. We find that the percentage of *stayer* in severe fuel poverty is much more important for individuals living in detached houses than for those living in apartments or semi-detached houses.

	A farm, house or detached house	A town house, semi-detached house	Apartment
NFP	79%	76%	77%
FP	42%	39%	28%
SFP	35%	22%	24%

Table 4: Estimates of *stayer* proportions, stratified by housing type

Figures 2a through 2c give estimates of *mobile* transition probabilities according to dwelling type. Living in an apartment increases the probability of transitioning from the NFP state to the SFP state (23%, as opposed to 11% in detached houses or 12% in town houses/semi-detached houses). The other transition probabilities are relatively similar. Consequently, stratification by housing type shows that **individuals living in detached houses have more difficulties than those living in other housing types in coming out of fuel poverty or severe fuel poverty.**

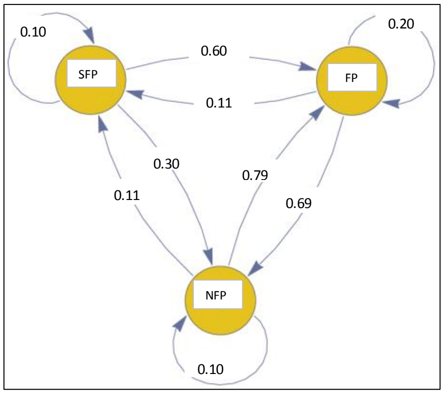

Figure 2a: Estimation of the transition probability for movers who live in detached houses/farms.

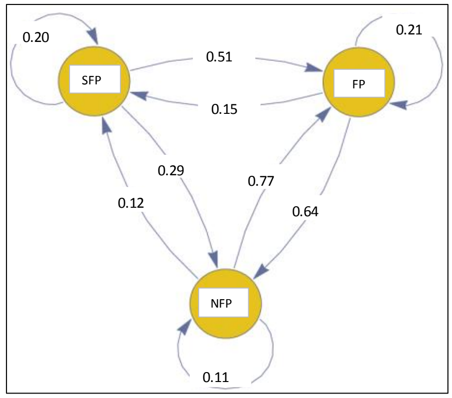

Figure 2b: Estimation of the transition probability for movers who live in town houses/semi-detached houses

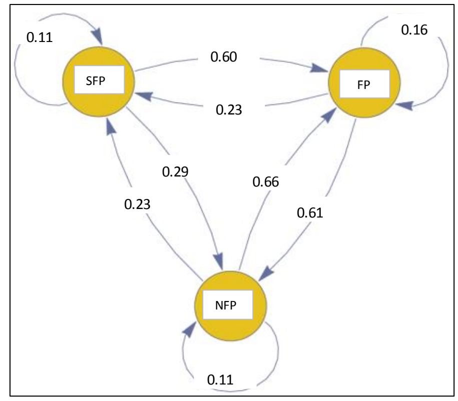

Figure 2c: Estimation of the transition probability for movers who live in apartments.

Population density.

Table 5 provides estimates of the proportions of *stayer* stratified according to location (rural/urban). The fuel poor and severely fuel poor show higher stayer percentages in rural areas than in urban areas.

	Urban	Rural
NFP	78%	77%
FP	34%	45%
SFP	27%	31%

Table 5: Estimated proportions of stayers in the states, stratified by dwelling location

Figures 3a and 3b give estimates of interstate transition probabilities based on whether the individual lives in an urban or rural area. The probability of transitioning from severe fuel poverty into fuel poverty is higher for individuals living in rural areas (0.57 against 0.43 in urban areas). In contrast, the probabilities of transitioning from severe fuel poverty to non-fuel poverty and from fuel poverty state to severe fuel poverty state are greater for individuals living in urban areas (0.16 against 0.11 in rural areas and 0.45 against 0.30 in rural areas, respectively).

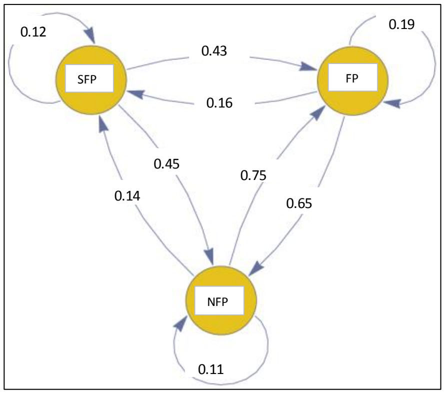

Figure 3a: Estimation of the transition probability for movers who live in urban areas.

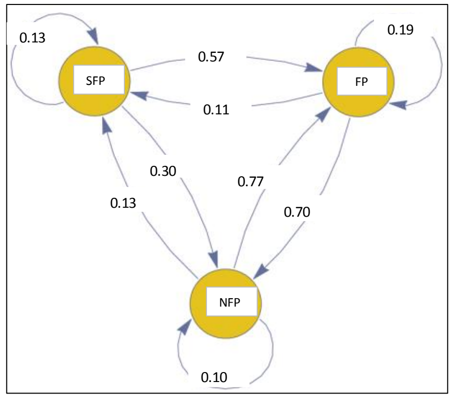

Figure 3b: Estimation of the transition probability for movers who live in rural areas.

The moisture problem.

Moisture has a significant impact on household fuel poverty dynamics. Thus, the percentage of *stayer* in non-fuel poverty is significantly higher among individuals living in a home without the presence of moisture (79 %) than among those living in damp housing (59 %) (see Table 6).

Mould and/or moisture	Yes	No
NFP	59%	79%
FP	38%	38%
SFP	35%	25%

Table 6: Estimated proportions of *stayers* in the states, stratified by the presence or absence of household moisture

Figures 4a and 4b give estimates of interstate transition probabilities based on whether the individual lives in damp housing. It is easier for individuals who live in non-damp housing to get out of fuel poverty and severe fuel poverty. Indeed severely fuel-poor and fuel-poor individuals have a higher probability of leaving these states when their dwellings are not damp (0.45 and 0.73, respectively) than when they are damp (0.27 and 0.45, respectively). In addition, a fuel-poor individual living in non-damp housing has a very low probability of becoming severely fuel poor (0.09) compared with those who live in damp housing (0.30).

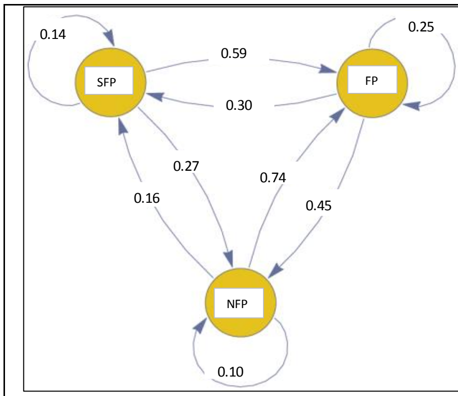

Figure 4a: Estimation of the transition probability for movers who live in damp housing.

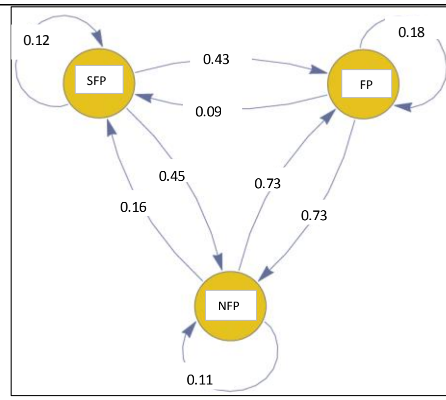

Figure 4b: Estimation of the transition probability for movers who do not live in damp housing.

These results confirm the idea that **housing quality has an impact on an individual's ability to adequately heat his or her dwelling.**

3.2. Econometrical estimation results

Table 7 gives the proportions of *stables* and *mobiles* in each state with the assumption that the probability of a mobile remaining in a state *i* during all observation periods is equal to zero. As we can see, the proportions of *stables* and *mobiles* in each state are quite similar to the proportions estimated with the mover-stayer model (see Table 2).

	Stable	Mobile
Non-Fuel Poverty	81%	19%
Fuel Poverty	40%	60%
Severe Fuel Poverty	30%	70%

Table 7: Proportions of stables and mobiles in each state

3.2.1. Econometric results for *stables*

Table 9 reports the logit specification estimations for people who remain in their state, i.e., stables. As expected, a high income level increases the probability of remaining in the non-fuel poverty state. In contrast, a low income level increases the probability of remaining fuel poor and, even more so, of remaining severely fuel poor. It appears that living with a partner (with or without children) is a good protection against stability in the severe fuel poverty state. In addition, living with a partner increases the probability of staying in non-fuel poverty state. This increases likely results from the fact that couples generally have more financial flexibility (due to cost sharing) than do single persons. A high education level also reduces the probability of remaining in fuel poverty or severe fuel poverty and reinforces an individual’s stability in non-fuel poverty. In terms of marital status, the probability of staying in fuel poverty is higher among the widowed than among single persons. Nevertheless, the widowed have a lower probability of staying in severe fuel poverty than single persons. Indeed, widowhood may include receiving of life insurance benefits from the deceased spouse, which can be substantial. Therefore, a comfortable financial position could explain a widowed person’s lower probability of staying in severe fuel poverty compared with a single person.

Variables	"Stables" Non Fuel Poor	"Stables" Fuel Poor	"Stables" Severe Fuel Poor
	Odd ratio (sd)	Odd ratio (sd)	Odd ratio (sd)
Net income			
1st quartile	REF	REF	REF
2st quartile	1.205***(0.05)	1.12 (0.08)	0.64* (0.11)
3st quartile	1.55*** (0.078)	1.02 (0.09)	0.26*** (0.06)
4st quartile	1.83*** (0.10)	0.73** (0.07)	0.11*** (0.04)
Level of education			
No education	REF	REF	REF
Lower secondary	1.08 (0.06)	1.19* (0.11)	0.72* (0.13)
Higher secondary	1.23** (0.09)	1.02 (0.13)	0.80 (0.22)
Post-secondary	1.17** (0.09)	1.16 (0.14)	0.61* (0.18)
Type of household			
Single person	REF	REF	REF
Single parent familly	0.91 (0.10)	0.97 (0.16)	1.08 (0.28)
Couple without children	1.21** (0.10)	1.20 (0.18)	0.12*** (0.05)
Couple with children	1.19** (0.09)	1.18 (0.18)	0.24*** (0.07)
Others	0.99 (0.12)	1.29 (0.26)	0.36*** (0.12)
Marital status			
Single	REF	REF	REF
Married	1.06 (0.06)	1.04 (0.11)	1.37 (0.36)
Widow	0.94 (0.10)	1.50** (0.26)	0.34** (0.12)
Divorced	0.93 (0.08)	1.16 (0.19)	1.25 (0.31)
Status on labor market			
Employed	REF	REF	REF
Student	0.96 (0.08)	1.19 (0.18)	1.22 (0.42)
Unemployed	0.77*** (0.06)	0.77* (0.11)	1.51* (0.36)
Retired	1.03 (0.08)	1.14 (0.15)	1.07 (0.34)
House-wife (or husband)	0.80** (0.07)	1.13 (0.17)	1.73* (0.54)
Others	0.74** (0.09)	1.02 (0.23)	3.02*** (0.95)
Type of dweeling			
Farm, house	REF	REF	REF
Town, Adjacent house	0.93 (0.05)	1.02 (0.08)	0.77 (0.15)
Apartment	1.71*** (0.10)	0.40*** (0.05)	0.68* (0.16)
Occupancy status			
Owner	REF	REF	REF
Tenant	0.66*** (0.04)	1.65*** (0.15)	0.63** (0.14)
Free of charge	0.87 (0.10)	1.23 (0.26)	0.67 (0.33)
Rural/Urban			
Urban	REF	REF	REF
Rural	0.96 (0.04)	1.17** (0.09)	1.26 (0.23)
Financial difficulties			
No	REF	REF	REF
One	0.54*** (0.04)	1.24** (0.14)	3.91*** (0.72)
At least two	0.32*** (0.03)	1.05 (0.18)	8.66*** (1.09)
Mould and/or humidity			
Yes	REF	REF	REF
No	3.21*** (0.17)	0.36*** (0.03)	0.34*** (0.06)

*p<0.1, **, p<0.05, ***p<0.01 Regressoions adjusted by gender and age

Table 8: Econometric results for stables

Analysis of an individual's status on the labour market indicates that unemployment has the strongest impact on the probability of remaining in severe fuel poverty and reduces the probability of remaining in non-fuel poverty state or fuel poverty state. We see the vicious cycle of unemployment. Compared with an employed individual, a housewife or househusband has a higher probability of staying in severe fuel poverty and a lower probability of staying in non-fuel poverty. Housewives or househusbands generally spend more time at home than do employed individuals;

therefore, their energy consumption is significantly higher than that of employed individuals. Compared with having a low income level or lower education level, having significant financial difficulties has a similar impact on fuel poor stables or severely fuel poor stables. Therefore, the higher the number of financial difficulties, the higher the probability of stability in fuel poverty or severe fuel poverty, and this effect is even more pronounced in the severe fuel poverty state. This result shows **enclosure** in the precariousness of these individuals.

The probability of remaining fuel poor is greater among renters. Tenants do not have full control of their heating consumption compared with owners (Healy and Clinch, 2004). Nevertheless, compared with owners, tenants have a lower probability of staying in severe fuel poverty, which could be explained by the fact that owners, unlike tenants, are responsible for the financial costs of property maintenance.

Compared with living in an apartment, living in a detached house or on a farm increases the probability of staying in fuel poverty and, even more so, in severe fuel poverty. We observe that the probability of staying in fuel poverty is higher among rural residents than among urban residents. For the other states, living in an urban or rural area does not have an impact on stability. In terms of housing conditions (i.e., damp or humidity), we can see that bad housing conditions increase the risk of staying in fuel poverty and severe fuel poverty. We note that some of the results on the impact of housing conditions on one's ability to stay in the same state appear to be different than those obtained through stratification. For example, according to the mover-stayer model, 79% of those living on farms, detached or a detached house and 77% of those living in apartments will remain non-fuel poor (see Table 4); nonetheless, the logit specification for the *stables'* probability of staying in non-fuel poverty has greatly increased for those who live in apartments (see Table 8). Apart from this example, the differences are relatively small. These differences can be explained by the fact that in contrast to the econometric modelling, the mover-stayer model considers a finite number of observation years (3 years for our study). Accordingly, certain stables during the three observation years are subject to movement in the years that follow. This potential movement has been included in the mover-stayer model but not in the logit model. However, the use of econometric models is indispensable and unavoidable when studying the impact of numerous factors on fuel poverty dynamics.

3.2.2. Econometric results for *mobiles*

Table 9 reports the results of these six multinomial logistic specifications.

Again, income level is a covariate with a very strong effect. Indeed, a high income level increases transition probabilities between states. High-income individuals are more likely than other individuals to overcome fuel poverty or severe fuel poverty.

Compared with living alone, living with a partner reduces the probability of aggravating fuel poverty (i.e., to move from fuel poverty and to severe fuel poverty) and increases the probability of overcoming severe fuel poverty. Furthermore, living with a partner rather than living alone reduces the probability of moving from non-fuel poverty to severe fuel poverty but increases the probability of moving from non-fuel poverty to fuel poverty. Therefore, it would seem that living with a partner reduces the risk of falling into severe fuel poverty but does not protect against fuel poverty.

Variables	$NFP \Rightarrow FP$	$NFP \Rightarrow SFP$	$FP \Rightarrow NFP$	$FP \Rightarrow SFP$	$SFP \Rightarrow NFP$	$SFP \Rightarrow FP$
	Odd ratio (sd)	Odd ratio (sd)	Odd ratio (sd)	Odd ratio (sd)	Odd ratio (sd)	Odd ratio (sd)
Net income						
1st quartile	REF	REF	REF	REF	REF	REF
2st quartile	1.08 (0.07)	0.59*** (0.07)	1.28*** (0.08)	0.65*** (0.08)	2.01*** (0.23)	1.97*** (0.23)
3st quartile	0.82** (0.05)	0.36*** (0.05)	1.42*** (0.09)	0.41*** (0.06)	3.96*** (0.58)	2.79*** (0.42)
4st quartile	0.73*** (0.05)	0.20*** (0.03)	1.93*** (0.14)	0.26*** (0.05)	8.04*** (1.63)	4.64*** (0.97)
Type of household						
Single person	REF	REF	REF	REF	REF	REF
Single parent familly	1.08 (0.12)	0.87 (0.15)	1.36** (0.16)	1.11 (0.20)	1.38* (0.26)	1.04 (0.19)
Couple without children	1.40 (0.11)	0.32*** (0.06)	0.91 (0.09)	0.30*** (0.06)	3.41*** (0.68)	3.88*** (0.80)
Couple with children	1.10 (0.11)	0.47*** (0.08)	1.22* (0.13)	0.45*** (0.08)	3.05*** (0.58)	2.73*** (0.54)
Others	1.15 (0.17)	0.10** (0.12)	0.82 (0.12)	0.40** (0.12)	0.94 (0.22)	1.02 (0.24)
Marital status						
Single	REF	REF	REF	REF	REF	REF
Married	0.76*** (0.05)	0.79 (0.12)	0.87* (0.07)	0.80 (0.14)	0.62** (0.10)	0.62** (0.10)
Widow	1.03 (0.11)	0.54** (0.11)	0.56*** (0.07)	0.33*** (0.07)	1.43 (0.32)	1.60** (0.36)
Divorced	0.89 (0.09)	1.02 (0.16)	0.76** (0.08)	0.81 (0.14)	0.90 (0.16)	0.89 (0.17)
Status on labor market						
Employed	REF	REF	REF	REF	REF	REF
Student	0.77** (0.09)	1.25 (0.26)	0.69*** (0.08)	1.17 (0.26)	0.84 (0.20)	1.11 (0.26)
Unemployed	1.05 (0.11)	1.94*** (0.31)	1.02 (0.11)	1.78*** (0.31)	0.71* (0.13)	0.74* (0.14)
Retired	0.95 (0.09)	0.92 (0.17)	1.03 (0.10)	0.95 (0.20)	0.78 (0.15)	0.70* (0.14)
House-wife (or husband)	1.14 (0.12)	1.37* (0.27)	0.84 (0.09)	1.10 (0.22)	0.57** (0.11)	0.59** (0.10)
Others	0.93 (0.15)	1.83** (0.39)	0.84 (0.14)	1.59* (0.42)	0.47** (0.11)	0.44** (0.13)
Type of dweeling						
Farm, house	REF	REF	REF	REF	REF	REF
Town, Adjacent house	1.11* (0.06)	1.003 (0.11)	0.98 (0.06)	0.85 (0.10)	0.84 (0.10)	0.77** (0.09)
Apartment	0.48*** (0.03)	0.59*** (0.08)	2.06*** (0.16)	1.18 (0.16)	1.55** (0.23)	0.58*** (0.08)
Occupancy status						
Owner	REF	REF	REF	REF	REF	REF
Tenant	1.57*** (0.10)	1.28** (0.15)	0.66*** (0.04)	0.84 (0.10)	0.69** (0.09)	1.10 (0.13)
Free of charge	1.42** (0.18)	0.67 (0.18)	0.77* (0.10)	0.59* (0.17)	0.99 (0.28)	1.60 (0.52)
Rural/Urban						
Urban	REF	REF	REF	REF	REF	REF
Rural	1.02 (0.05)	0.90 (0.09)	0.91* (0.05)	0.84* (0.09)	0.91 (0.09)	0.94 (0.10)
Financial difficulties						
No	REF	REF	REF	REF	REF	REF
One	1.41** (0.16)	2.66*** (0.42)	0.50*** (0.06)	1.66** (0.28)	0.31*** (0.05)	0.50*** (0.08)
At least two	1.64** (0.26)	9.32*** (1.63)	0.46*** (0.07)	3.73*** (0.68)	0.14*** (0.03)	0.24*** (0.05)
Mould and/or humidity						
Yes	REF	REF	REF	REF	REF	REF
No	0.32*** (0.05)	0.34*** (0.04)	4.16*** (0.30)	1.01 (0.12)	4.36*** (0.54)	1.10 (0.14)

*p<0,1, **, p<0,05, ***p<0,01 Regressoions adjusted by gender and age

Table 9: Econometric results for mobiles

Another interesting result concerns the single-parent families. The probability of those living in fuel poverty or severe fuel poverty transitioning into non-fuel poverty is higher among single-parent families than among single persons. This result may seem counterintuitive. However, single-parent families may restrain their heating consumption to save on costs (budget arbitrations). Therefore, single-parent families may move artificially into non-fuel poverty.

Divorcées show the highest probability of moving from non-fuel poverty to severe fuel poverty, given the additional financial burden resulting from divorce (Hoffman and Duncan, 1988**)**. In contrast, widows have the least risk of falling into severe fuel poverty; they are more likely to overcome severe fuel poverty, but they are at greater risk of becoming fuel poor. Married persons are less likely to transition from non-fuel poverty to fuel poverty.

Students have the lowest probability of falling into fuel poverty and are more likely to move from severe fuel poverty to fuel poverty; however, they have the most difficulties in overcoming this state. The first two results seem to be counterintuitive, but they may be explained by the financial support that close family potentially gives to a student. However, not everyone is fortunate enough to benefit from such aid, and it is consequently difficult for some students to overcome fuel poverty. This result is consistent with our intuition that students are more vulnerable than employed persons. Although students' risks of moving from non-fuel poverty to severe fuel poverty are high, these risks are higher among housewives and househusbands (and even higher among the unemployed). Therefore, unemployment constitutes the primary contributing factor to state deterioration and increases the risk of enclosure (i.e., confinement). In contrast, retirees appear to be protected against such risks; in fact, they have the lowest probability of falling into severe poverty.

In terms of dwelling type, the results corroborate the econometric results for *stables*. Living in an apartment seems to protect individuals against fuel poverty and severe fuel poverty.

Renting increases the probability of falling into fuel poverty, i.e., moving from non-fuel poverty to fuel poverty or severe fuel poverty. Furthermore, tenants are much less likely than owners to overcome fuel poverty as tenants have less flexibility than owners in terms of equipment and heating consumption.

Additionally, the rural covariate corroborates the results for *stables*. Indeed, the results show that rural residents experience enclosure in fuel poverty. Compared with an urban resident, a rural resident in fuel poverty has a lower probability of achieving non-fuel poverty or moving into severe fuel poverty. High urban housing costs could explain this result.

As in the case of *stable*, financial difficulties and/or bad dwelling conditions substantially increase the risk of falling into the fuel poverty or severe fuel poverty. In contrast, the probability of overcoming fuel poverty or severe fuel poverty is low for individuals facing insolvency problems or/and those living in bad conditions. For individuals living in damp housing, the transition probability of moving from fuel poverty to severe fuel poverty does not appear to be significant. Consequently, the deterioration of fuel poverty status seems to be based more on difficult financial situations than bad dwelling conditions. If we acknowledge this result, financial assistance may be more suitable than improved housing for escaping severe fuel poverty.

These results show the multidimensional complexity of the fuel poverty phenomenon.

4. Conclusion

This study is one of the few that examines the dynamics of the fuel poverty phenomenon. The mover-stayer model presented in 2.2.1 reveals that fuel poverty is a transitory (i.e., temporary) state. Of the fuel poor living in damp and mouldy homes, 38% will remain in fuel poverty. The proportion of fuel-poor stayers with housing of decent quality is identical. However, people living in bad conditions show a higher probability of staying in severe fuel poverty (35%, compared with 25%). Likewise, it is much easier to stay in non-fuel poverty when you live in good housing (see Table 7). Housing quality does not seem to have a significant impact on the probability of falling in fuel poverty or severe poverty (see Figures 4a and 4b), which is confirmed by the estimates of the multinomial logistic model (see Table 10). These estimates suggest that the deterioration of fuel poverty status seems to be based more on difficult financial situations than bad dwelling conditions. It follows that financial aid may be more effective than improved housing conditions.

Obviously, low incomes, low education levels, financial difficulties and dampness increase the probability of staying in fuel poverty or in severe fuel poverty. Furthermore, for *mobiles*, these determinants increase the probability of transitioning into fuel poverty or severe fuel poverty.

Our estimates show that for certain determinants (e.g., divorcées, students and single-parent families), the impact on fuel poverty dynamics differs between *stables* and *mobiles*, which underlines the need to consider different sub-populations, i.e., the chronic fuel poor (*stables*) and the transitory fuel poor (*mobiles*). As a consequence, it is necessary to take a dynamic approach to study fuel poverty.

Our research gives the key determinants of different categories of fuel poor (i.e., the chronic fuel poor and the transitory fuel poor), along with determinants that affect individuals' trajectories. A better identification of these different sub-fuel poor populations and related determinants allows a much efficient and precise targeting of public policies that seek to eradicate the fuel poverty phenomenon. Therefore, the different measures in place could be adjusted for and adapted to different fuel poor populations as their determinants are different. In addition, the results of this study could inform future prevention measures.

Regarding actual measures to eradicate the fuel poverty phenomenon in France (e.g., 'Habiter mieux program', zero-rate eco-loans, Fond solidarité logement), it could be interesting to evaluate whether these measures encourage the fuel poor to do renovation work or to seek out financial aid. For example, these measures might not act as incentives for potential beneficiaries for a variety of reasons (e.g., too much of an investment for the household, a strong preference for the present state of things, or high-risk aversion). Therefore, future analysis should first evaluate public policy to determine whether these measures are appropriate and to identify the best incentivising measures for the fuel poor.

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