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Does France have a fuel poverty trap?☆

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ABSTRACT

In this article, we focus on fuel poverty dynamics by answering two questions: Does France have a fuel poverty trap and what are the determinants of staying in or moving out of fuel poverty? First, we define three states into which individuals may be placed, which are as follows: 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 the following 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 showing that fuel poverty is not an absorbing state. Indeed, a majority of the fuel-poor and the severely fuel-poor move to another, better state. Therefore, we can argue that France has no fuel poverty trap. Using two econometric models (logit and multinomial logit), we identify the stability and mobility determinants in different states. As expected, there is a relationship between income and the likelihood of an individual remaining in a particular state. Furthermore, poor housing implies a greater likelihood of stability in fuel poverty or severe fuel poverty. Another result is that deterioration in fuel poverty status seems to stem more from difficult financial situations than from bad dwelling conditions.

1. Introduction

In mainland France, 5.1 million households (12.5 million people or approximately 19% of the total population) experienced fuel poverty in 2013 (ONPE[2], 2016). That same year, according to the first barometer of fuel poverty published by the King Baudouin Foundation (2015), 21.3% of Belgian households were experiencing fuel poverty. In 2014, 34.9% of Scottish households were fuel-poor and 9.5% were living in extreme fuel poverty (The Scottish Government, 2015). Who are these households? What is fuel poverty? The matter is not a simple one because this phenomenon is difficult to qualify and quantify.

Fuel poverty can take many forms because it involves so many different interrelated factors such as poor energy efficiency; poor housing conditions; cold and damp living conditions; increasing unavoidable expenditure and less purchasing power and health problems. Thus, the above ONPE estimate is based on a set of indicators including, inter alia, the income level and feeling cold, just as there is no an official indicator for national statistics on fuel poverty in France. The Buildings Performance Institute Europe (BPIE, 2014) assesses the problem in European countries using three indicators: "*the inability of people to keep their homes adequately warm, to pay their utility bills and to live in a dwelling without defects (leakages, damp walls, etc.)*." According to Eurostat data, in 2014, 10.2% of Europeans were unable to keep their homes adequately warm, 9.9% were in arrears on their utility bills and 15.7% lived in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floors. On the one hand, these percentages are not close; on the other hand, the individuals concerned only partially overlap and their characteristics can vary widely.

Fuel poverty is a complex and difficult phenomenon to measure. Indeed, this phenomenon includes economic, social and energetic matters. This may partially explain why there is no common European definition of fuel poverty. The lack of consensus on a definition obviously makes it difficult to determine how to measure fuel poverty. In addition, in many countries such in France, national statistics have not explicitly considered this phenomenon. Consequently, there are rarely sufficient data available to fully measure the scale of the phenomenon. Despite this twofold problem of qualification and quantification, many programmes have emerged to confront the rise in fuel poverty. Moreover, the existence of substantial percentages of households in fuel poverty can lead to governmental responses.

☆ The views, assumptions and opinions expressed in this paper are those of the authors.

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[1] ⟨http://www.fime-lab.org/an/presentation⟩.

[2] ONPE: Observatoire National de la Précarité Energétique (French National Observatory of Energy Poverty).

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In France, the 12 July 2010 definition of national commitment to the environment (Article 11, Grenelle II law[3]) is as follows: *a household* that has difficulties obtaining 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. Therefore, this definition focuses on housing and ignores the energy cost of necessary mobility (i.e., the daily commute to and from the office, health, public services…). Once a fuel poverty definition has been chosen, one or more indicators should also be chosen to identify and characterise households in fuel poverty and to examine the dynamics of this poverty. The goal is to analyse fuel poverty not as an immutable and irreversible state but as a dynamic process.

Whereas other goods and services can often be substituted by cheaper alternatives, households in fuel poverty can be locked into their position. They do not have the resources to improve their homes' energy efficiency (Boardman, 2010; Hills, 2011). Increased income (the direct policy) could have a temporarily positive impact on the ability to pay bills, whereas improved energy efficiency (the indirect policy) will contribute to a permanent and sustainable reduction in fuel poverty (Hills, 2011). However, for poor households living in highly energy-efficient housing, that is to say, for households in social insecurity,[4] the opposite approach applies. Thus, these households' situations can be improved by increasing their income: improving their homes' energy efficiency is unnecessary (Hills, 2011).

To mitigate the impact of energy prices on vulnerable households, France established two types of means-tested assistance: the special gas solidarity tariff[5] (Tarif Spécial de Solidarité - TSS) and the basic necessity tariff[6] (Tarif de première nécessité - TPN) for electricity. These social arrangements in favour of the poorest households, which are direct policies, are not gas / electricity supply offers as such but flat-rate reductions that apply to the annual bill. These short-term measures will expire on 31 December 2017, and should be replaced by an energy voucher. Thus, since 1 May 2016, the energy voucher, new aid for payment of gas and electricity bills, has been available in 4 of France's 101 departments. One of the most important novelties of France's policy is that this aid concerns not only electricity and gas bills but also wood and fuel oil bills. The voucher used to pay bills has a temporary positive effect. It can also be used to fund energy-efficiency work in the home, thus providing a permanent effect. As a result, a voucher that represents a short-term measure to fight fuel poverty can be used as a long-term measure. Other long-term measures, such as the programme "Habiter Mieux"[7] (the indirect policy), partially funds renovations if they reduce energy consumption by at least 25%, are offered to low-income households.

This study on the dynamics of fuel poverty and identifying key determinants of either remaining fuel-poor or moving in and out of fuel poverty will provide relevant information to policy makers who wish to implement effective policies for reducing fuel poverty through a better targeting of people who are fuel-poor. Indeed, if fuel poverty is a transitory state, short-term measures such as direct subsidies for energy costs might be the most appropriate. However, if fuel poverty is a chronic phenomenon, long-term measures such as improving buildings' energy performance, must be taken. Nevertheless, for low-income households living in energy-inefficient housing, short- and long-term measures can be complementary.

As Roberts et al. (2015) note, it is important to understand the dynamics of fuel poverty "*because the welfare implications and thus policy measures will be different depending on how such poverty is experienced.*" These authors investigate urban/rural differences in fuel poverty levels and dynamics in the UK through both a descriptive analysis of the British Household Panel Survey and the estimation of discrete hazard models of energy poverty exit and re-entry. They note, inter alia, that on average, fuel-poor households in urban areas remain in their condition longer than fuel-poor households in rural areas. The latter nevertheless appear to be more vulnerable to rising energy prices. The authors conclude that policy effectiveness might be different in rural and urban areas.

Nevertheless, most studies on fuel poverty rely on one-time surveys[8]—in other words, surveys in a static context (e.g., housing surveys)—instead of panel data. Consequently, few studies on fuel poverty have been carried out in a dynamic environment.

To the best of our knowledge, aside from Roberts et al. (2015), there is only one study on the dynamics of fuel poverty that uses longitudinal data. Phimister et al. (2015) analyse transitions into and out of fuel poverty in Spain from 2007 to 2010 using a Markov matrix that provides the probabilities of moving from fuel poverty to non-fuel poverty and vice versa. They observe, *"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. (2015) and Roberts et al. (2015). Indeed, we want to know whether fuel poverty is transitory or chronic. However, our approach is slightly different than those mentioned above. 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, along with the probability of remaining in the same state. In addition, we identify individuals who are at risk of fuel poverty. The probability calculation addresses the following question: Does France have a fuel poverty trap or is it mostly a transitory state? On the other hand, we identify the stability and mobility determinants between different states in the fuel poverty phenomenon. 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 formally identifies determinants of individual stability or transition.

The results show that, in France, fuel poverty is not an absorbing state. Indeed, a majority of the fuel-poor move to another, better, state. Therefore, fuel poverty is usually a transitory state and we can argue that France has no fuel poverty trap. Nevertheless, more than one-third of households are stayers in fuel poverty states and the proportion of vulnerable individuals to fuel poverty is approximately 15%. As expected, on the one hand, there is a relationship between income and the likelihood of an individual remaining in the same state. Indeed, 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. Moreover, poor housing implies a greater likelihood of stability in 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. We find that certain determinants (e.g., divorced, students and single-parent families) have different impacts on fuel poverty dynamics. Consequently, it is important to consider different sub-populations—i.e., the chronic fuel-poor (stayers) and the transitory fuel-poor (movers)—to best address fuel poverty.

The remainder of this paper is organised as follows. In Section 2, we

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

[4] It is possible that households are living in a high energetic performance accommodation and are facing extreme financial condition (e.g. after job losses, divorce etc.). It should be mentioned that tenants of social housing tend to be in housing that is already relatively efficient from an energy performance. Just because they are poor and live at a given time in energy-efficient housing doesn't mean they will be excluded from our study, quite the contrary. They should be seen as fuel poor households according to the official definition in France (article 11; Grenelle II law).

[5] This tariff was set up by the Decree of 13 August 2008.

[6] This tariff was set up by the Decree of 8 April 2004.

[7] In English that is "to live better".

[8] Notable among these studies are those discussing measures of fuel poverty in France (such as Legendre and Ricci (2015)).

discuss the main indicators of fuel poverty and explain that we use the difficulty of heating one's home because it is a proxy measure of fuel poverty. Section 2 also describes the database, which defines three states/situations in which individuals find themselves (i.e., non-fuel poverty, fuel poverty and severe fuel poverty); the model used for the study on the dynamics of fuel poverty (a mover-stayer model) and econometrical specifications are also detailed. Section 3 provides statistical analyses and discusses results and policy implications. Section 4 concludes by suggesting extensions.

2. Methods

2.1. Data and the measurement of fuel poverty

2.1.1. Database

We use the 2009–2011 waves of France's Statistics on Resources and Living Conditions SRCV, published by the French National Institute of Statistics and Economic Studies (INSEE). This survey is a part of the European Union Statistics on Income and Living Conditions (EU-SILC), which uses personal interviews to collect information on income distribution, poverty, social exclusion and living conditions. This survey is used as a reference for comparing income distributions among European Union member states and for European Community actions to combat social exclusion. It is organised around a cross-sectional component and a longitudinal component. In this analysis, we use the 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), with 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 did not move comprise the sample used in this study. There are two reasons that our study is based on only three years. On the one hand, the survey's rotating structure restricts the length of years observed. Indeed, each individual is followed up and interviewed over a maximum of four years. Therefore, our panel data are balanced.[9] On the other hand, for consistent winter temperature between the various years, we only use the data from 2009 to 2011 because the winter temperature for 2008 is quite different than the temperatures in 2009–2011. Indeed, the deviation from the mean is equal to +1 °C in 2008 and approximately −1 °C for 2009, 2010 and 2011 (see Appendix A).

Finally, we have a sample of 11,521 individuals per year; these individuals have been observed three times. Overall, our sample includes 34,563 observations.

2.1.2. Choice of measure for fuel poverty

As highlighted in the introduction, there is no common European definition of fuel poverty and consequently, there is no consensus about the best way to determine whether a household is in fuel poverty. Numerous indicators are used to identify the fuel-poor. Trinomics' (2016) rapport gives an assessment of indicators used in the literature and in official reports. The most commonly used indicator is the budget share, 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. This 10% threshold is almost twice the median percentage of income that UK households allocated to energy supply in 1988[10] (Boardman, 1991). This indicator (hereinafter referred to "10% metric") was long used as the official standard for measuring fuel poverty in the UK by approximating domestic energy requirements based on normative modulated energy consumption. In response to criticism[11] related to the "10% metric", the British government adopted the Hills indicator in August 2013. According to this indicator (called LIHC[12] indicator), a household is fuel-poor if its income falls below a particular threshold[13] and if its normative modulated energy expenditure is higher than the energy expenditure threshold[14] (Hills, 2011).

France does not have an official indicator for national statistics on fuel poverty. However, ONPE (2016) uses three indicators: (i) Energy Effort Rate (EER_3d)[15] which should not exceed 10%, reduced to the first three income deciles; (ii) LIHE indicators[16] which consider that a household is fuel-poor if the two conditions of low income and high energy expenditures are met; iii) Cold indicator which is a subjective indicator based on the feeling of the households in terms of thermal comfort. Given the difficulty of modelling normative consumption with the French data that are available, the energy expenses are reported expenses. As a result, some atypical behaviours (e.g., restriction/deprivation or excess) that could be corrected with the original indicators ("10% metric" and LIHE calculated via modulated normative expenses) are not excluded.

Measures of fuel poverty that are based on these indicators, amongst others, are often one-off measures.

In this study, we define fuel poverty as the difficulty in heating one's home because this definition is similar to that given on 12 July 2010 in Article 11 of France's national commitment to the environment (Grenelle II law), as noted in the Introduction. Waddams Price et al. (2012) argue that the overlap between the energy effort rate (10% metric) 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, fewer than half showed expenditures that would classify them as fuel-poor. Therefore the subjective indicator chosen affects the measurement of fuel poverty, like any other indicator. For example, according to the ONPE (2014), in mainland France, in 2006, 43% of fuel-poor according to LIHE_m^2 indicator are not fuel-poor according to EER_3d indicator.

Next, we concentrate on the difficulty of heating one's home, which is a proxy measure of fuel poverty[17] for which we have the panel data necessary to reach our goal, i.e., not only to analyse the dynamics of this precarious situation but also to identify individuals who are vulnerable to fuel poverty.

The database allows us to distinguish the following 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:

*2.1.2.1. 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 difficult or costly to adequately heat your dwelling? and Do you have the financial means to maintain the appropriate temperature in your home?

These households that find that it is too hard or costly to adequately

[9] Note that we used a balanced panel because to estimate the mover-stayer model, we need to use data that each individual observe in each period.

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

[11] 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.

[12] LIHC: Low Income High Cost.

[13] 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.

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

[15] Energy effort rate is the ratio between energy expenses reported and income of the household.

[16] LIHE_m^2 where the energy expenditure is divided by the size of the dwelling (in m^2) and LIHE_cu where the energy expenditure is divided by the consumption units (CU). To compare the standards of living of households of different sizes or compositions, it is unnecessary to use a measurement of income corrected by the consumption unit using an equivalence scale. The **OECD scale** is currently the most widely used scale and uses the following weighting: 1 CU for the first adult in the household; 0.5 CU for other persons aged 14 years or older; −0.3 CU for children under 14 years of age.

[17] Heating expenditures represent 70% of household energy costs (Besson, 2008).

heat their dwelling have experienced *difficulties obtaining the necessary energy to satisfy their basic needs*. Therefore, we consider them fuel-poor. These difficulties seem to be caused by inadequate living conditions. Such households may be living in housing that either is oversized or has poor thermal quality.

*2.1.2.2. The severe fuel poverty state (**SFP**).* If a member of a household answers "yes" to Is it too difficult or costly to adequately heat your dwelling? and "no" to Do you have the financial means to maintain the appropriate 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.

We drop individuals who we qualify as "inconsistent" because they answered no to the first question but yes to the second question. We cannot treat these individuals in any category. There are 756 such individuals over the three years studied.

2.1.2.3. Non-fuel-poverty state (NFP). The rest of the population belongs to this category. Thus, only the severely fuel-poor cannot cope with their heating expenditures.

It should be noted that with the subjective indicator that we have chosen there is a risk of underreporting given the existence of the risk of social desirability. This risk of social desirability could underestimate the prevalence of fuel poverty and possibly slightly modify the transition probabilities.

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

2.2. Models

2.2.1. The mover-stayer model

The mover-stayer model[18] 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. $E = \{FP, SFP, NFP\}$ is 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 ($X(t) \equiv X(0)$) and a mover group that follows an ordinary Markov process (with the transition matrix $M = \|m_{i,j}\|$, $i = 1, \cdots K$, $j = 1, ..., K$). 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 $(s_1, ..., s_K)$ 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:

$$\hat{m}_{ij} = \frac{n_{ij}(1 - \hat{m}_{ii} - \sum_{k \neq i, k=1}^{j-1} \hat{m}_{ik})}{\sum_{k \neq i, k=1}^{K} n_{ik}}, j \neq i, (i, j) \in E^2. \quad (1)$$

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

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

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

For s_i parameters:

$$s_i = \frac{n_i - n_i(0)m_{ii}^T}{n_i(0)(1 - m_{ii}^T)}. \quad (3)$$

Fougère and Kamionka (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

$$\forall\ i = 1, ..., K and j = 1, \cdots K,\ m_{ij} = \frac{n_{ij}}{n_i^*}. \quad (4)$$

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 model identifies the determinants of stables, i.e., individuals who remained in the same state during the three observation periods (2009, 2010 and 2011). The other model identifies the determinants of movers, i.e., individuals who moved across the different states between 2009 and 2011. In this subsection, we assume that stayers are directly observable, unlike in the mover-stayer model. Therefore, the probability for a mover to remain 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.

2.2.3. Stayer specifications

To identify the main determinants of stayers, 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 stayer (NFP_s), a fuel-poor stayer (FP_s)or a severely fuel-poor stayer (SFP_s) during the three periods of observation (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 1 if the *ith* 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:

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

$$\Pr(Y_i = 1/X_i) = 1 - \Phi[-X_i'\theta], \quad (5)$$

$$\Pr(Y_i = 0/X_i) = \Phi[-X_i'\theta], \quad (6)$$

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:

$$Y_i^* = \alpha_{Y_i} + \beta_{Y_i} X_i + \epsilon_{Y_i}, \quad (7)$$

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.

[18] Boag (1949) develops this approach in the biomedical field; it has been applied both to model labour-market transitions (Blumen et al., 1955; Dunsmuir et al., 1989; Fougère and Kamionka, 1992) and to model criminal recidivism (Schmidt and Witte, 1989).

2.2.4. Mover 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 (NFP_m, FP_m, SFP_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 $(j, k) \in \{NFP_m, FP_m, SFP_m\}$ and $t' \neq t$: $\Omega_{j \to k} = \Pr(Y_{t'} = k/Y_t = j)$. 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. 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.

2.2.5. Control variables

In the stayers and movers specifications, we include individual variables to control for current Social-Economic Status (SES). The economic literature is relatively rich in information on fuel poverty determinants. Although most studies that identify fuel poverty determinants have been conducted in a static context, SES is a point to which we can refer when we attempt to choose the control variables.

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 Price et al., 2012; Scott et al., 2008). Therefore, a low income (or unemployment) pressures household budgetary constraints. With a constant level of energy expenditures, an income decrease or a low level of income increases a household's risk of being fuel-poor. Moreover, individuals with low incomes are more likely to have energy-inefficient appliances (Devalière et al., 2011). We consider income quintiles that divide our sample into five equal-sized groups based on household income divided by the Organization for Economic Co-operation and Development's (OECD) equivalent scale.[19]

We can report that education level (Healy and Clinch, 2004; Huybrechs et al., 2011), household type (Healy and Clinch, 2004; Waddams Price et 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-demographic determinants. Huybrechs et al. (2011) explain that individuals with low levels of education do not have the same "capabilities" (Sen, 1999) of adopting energy-saving behaviours; as a direct result, these individuals may experience increases in their energy bills. We adopt four categories for the level of education (no education level, lower secondary level, higher secondary level and post-secondary level).

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, because of the significant economic cost of marital dissolution, divorce may make some individuals vulnerable to fuel poverty (Hoffman and Duncan, 1988). We consider five categories of household: single person, single-parent family, couple without children, couple with children and other. In addition, marital status is introduced, giving us a variable with four categories: single, married, widowed and divorced.

Compared to 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).

Different variables related to the dwelling are introduced. First, the type of dwelling is decomposed into three difference categories (farm/house, town/adjacent house and apartment). Second, the occupancy status is divided into three classes (owner, tenant and free of charge). Moreover, the place of residence is divided into two categories (rural and urban). Third, the dwelling surface is treated in four intervals ($< 80\ \mathrm{m}^2$[, $[80–100\ \mathrm{m}^2$[, $[100–130\ \mathrm{m}^2$[and $> 130\ \mathrm{m}^2$[). Finally, we control these regressions through the "Study area and regional planning" variable (currently named "ZEAT"). Each "ZEAT" is a territorial subdivision of France and is the first category in the European Union's nomenclature of territorial statistical units (NUTS 1). This variable permits to exercise the maximum control over temperature differences among France's various regions. The main reason that we have used this geographical information instead of department is because this latter is not available in our database.

3. Results and discussion

3.1. Descriptive statistics

The fuel-poor accounted for slightly more than 25% of the sample examined (see Table 1). This proportion is significantly greater than during the last estimation of 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. Furthermore, this gap primarily exists because total family income is not adjusted for one spouse and the number of dependants under and over the age of 14.[20]

The proportion of non-fuel-poor has decreased by 1.5% between 2009 and 2011. In contrast, the proportion of fuel-poor increased by approximately 1.5%. Therefore, the proportion of severely fuel-poor remained fairly constant during this period. Some of the sample's socio-economic and demographic information is summarised in Table 2.

Therefore, 75% of individuals live with a partner; 71% are homeowners; and 10% report the presence of mould and/or moisture in their homes. In addition, almost 47% 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 because of money problems;
2) The inability to pay taxes on time over the past 12 months because of money problems; and
3) The inability to repay credit on time because of 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%

[19] See footnote 16 for the definition of the consumption unit (OCDE scale).

[20] Indeed, if we consider a household to be living in fuel poverty if $\frac{\text{Houshold energy expenditure (including a correction factor for no response)}}{\frac{\text{Level of income}}{\text{The number of cunsumption units (CUs)}}} > 10\%$ then, using the same database for mainland France, 25% of households were in fuel poverty in 2009. The percentage of fuel-poor people is approximately 27% in 2011. Note that if income was not divided by consumption units, as was the case with the original indicator, the percentage of energy-insecure households would be lower (approximately divided by two) and therefore, close to the 14.4% estimated by the INSEE.

Table 1
Distribution of the sample among the states.

	Non-fuel poor	Fuel poor	Severe fuel poor
2009	77.48%	19.30%	3.22%
2010	74.78%	21.95%	3.27%

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

Sex	Female	Male			
	52.47	47.53			
Location (population density)	Rural	Urban			
	27.71	72.29			
Type of household	Single	Single-parent families	2 adults without dep. child	Two-adult family with children	Others
	14.36	6.57	32.27	43.86	2.94
Presence of mould and/or moisture	Yes	No			
	10.35	89.65			
Housing type	A farm, house or detached house		A town house or semi-detached house		Apartment
	52.58		22.70		24.72
Occupancy status	Owner	Tenant		Free of charge	
	71.77	25.40		2.83	

Table 3
Individual sample distribution across the three states.

	NFP	FP	SFP
Female	51.63%	54.23%	60.95%
Rural	26.28%	31.76%	35.21%
Single person	13.33%	15.94%	28.42%
Single-parent families	5.96%	7.13%	17.16%
Couples without children	32.60%	33.24%	18.41%
Couples with children	45.52%	39.83%	30.83%
Financial difficulty	2.91%	5.79%	14.94%
Damp/musty conditions	6.34%	21.08%	35.75%
A farm, a house or a detached house	52.60%	53.75%	44.77%
A town house, semi-detached house	20.97%	27.52%	32.26%
Owner	74.13%	66.03%	53.08%
Tenant	23.11%	30.95%	43.70%
Employed	52.05%	43.58%	35.21%
Student	7.22%	6.95%	6.61%

of couples with children are among the non-fuel-poor; in addition, 18% of couples without children and 31% of couples with children are among the severely fuel-poor, and these couples constitute 74% of the sample. The table shows that 17% of single-parent families are among the severely fuel-poor, but this type of household constitutes less than 6.50% of the sample. The percentages confirm that housing quality has a significant impact on the fuel poverty state. Indeed, nearly 36% of individuals who claim to have mould and/or moisture problems in their homes are among the severely fuel-poor, but these individuals comprise only slightly more than 10% of the sample. Improving housing quality for some of these households could probably get them out of fuel poverty.

Do people remain in fuel poverty?

3.2. Fuel poverty is not a trap—it is mostly a transitory state

Using the mover-stayer model, we study individual trajectories and

Table 4
Estimated proportions of stayers in each state.

Non-fuel poor	Fuel poor	Severely fuel poor
80%	39%	33%

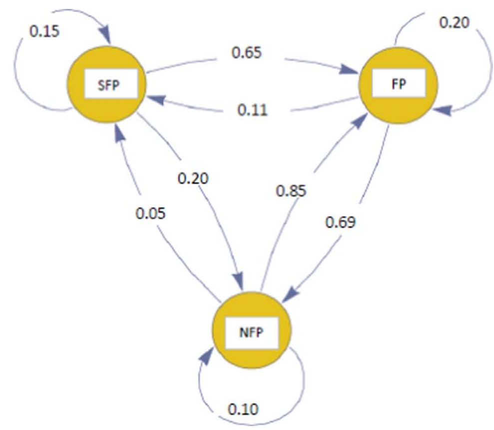


Fig. 1. Estimation of ‘movers’ transition probabilities.

quantify the proportions of individuals who were stayers and movers in each state. Table 4 shows the estimated proportions of stayers in the three states: 80% of the non-fuel-poor will not fall into fuel poverty; 39% of the fuel-poor will remain precarious; and 33% of the severely fuel-poor will remain in that 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. Additionally, the proportion of movers in the non-fuel-poverty state can be qualified as vulnerable. Indeed, these individuals are exposed to fuel poverty or severe fuel poverty. In our data, this category represents 20% of 26,274 (i.e., 5255) non-fuel-poor, so in other words, 15% (i.e., 5255/34563) of the individuals studied are vulnerable to either fuel poverty or severe fuel poverty.

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

The transition probability of moving from non-fuel poverty to fuel poverty is very high (at 0.85). For fuel-poor movers, the probability of returning to a non-fuel-poverty state is relatively high (at 0.69). In contrast, the probability of transitioning into severe fuel poverty is low (a maximum of 5%). 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 different (0.65 versus 0.20). 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 confirms that fuel poverty is not a trap for movers. Indeed, the probability of movers remaining in fuel poverty or severe fuel poverty is low for movers (at 0.20 and 0.15, respectively). In addition, it seems that mobility among states is important. Thus, from Table 4 and Fig. 1 we obtain the following degrees of "churn":

- 11.73% (respectively 0.2%) of non-fuel-poor will become fuel poor

Table 5
Econometric results for stables.

Variables	"Stables" non fuel poor Odd ratio (sd)	"Stables" fuel poor Odd ratio (sd)	"Stables" severe fuel poor Odd ratio (sd)
Net income			
1st quartile	REF	REF	REF
2st quartile	1.13** (0.06)	1.12 (0.08)	0.63** (0.12)
3st quartile	1.58*** (0.09)	1.02 (0.09)	0.20*** (0.07)
4st quartile	1.91*** (0.12)	0.73** (0.07)	0.07*** (0.03)
Level of education			
No education	REF	REF	REF
Lower secondary	1.14** (0.07)	1.19* (0.11)	0.073 (0.16)
Higher secondary	1.30*** (0.10)	1.02 (0.13)	1.02 (0.31)
Post-secondary	1.23*** (0.10)	1.16 (0.14)	0.61 (0.22)
Type of household			
Single person	REF	REF	REF
Single parent family	0.93 (0.10)	0.97 (0.16)	1.40 (0.44)
Couple without children	1.26** (0.12)	1.20 (0.18)	0.06*** (0.03)
Couple with children	1.28** (0.12)	1.18 (0.18)	0.23*** (0.08)
Others	0.94 (0.13)	1.29 (0.26)	0.14*** (0.08)
Marital status			
Single	REF	REF	REF
Married	1.16*** (0.08)	0.98 (0.12)	1.26 (0.40)
Widow	1.01 (0.11)	1.31 (0.25)	0.31*** (0.12)
Divorced	1.00 (0.10)	1.26 (0.23)	0.87 (0.26)
Status on labour market			
Employed	REF	REF	REF
Student	1.04 (0.10)	1.06 (0.18)	0.99 (0.43)
Unemployed	0.77** (0.07)	0.86 (0.13)	1.90** (0.56)
Retired	1.08 (0.09)	1.14 (0.15)	0.95 (0.39)
House-wife (or husband)	0.89 (0.09)	1.19 (0.19)	1.14 (0.57)
Others	0.77* (0.10)	1.10 (0.26)	2.89* (1.10)
Type of dwelling			
Farm, house	REF	REF	REF
Town, Adjacent house	0.88*** (0.05)	1.17* (0.11)	0.88 (0.23)
Apartment	1.56*** (0.12)	0.56*** (0.08)	0.45*** (0.15)
Occupancy status			
Owner	REF	REF	REF
Tenant	0.57*** (0.04)	2.27*** (0.24)	0.75 (0.21)
Free of charge	0.74*** (0.10)	1.38 (0.32)	0.74 (0.41)
Rural/Urban			
Urban	REF	REF	REF
Rural	0.94 (0.05)	1.17* (0.10)	1.26 (0.28)
Financial difficulties			
No	REF	REF	REF
One	0.49*** (0.04)	1.25** (0.28)	4.89*** (1.11)
At least Two	0.34*** (0.04)	1.16 (0.24)	11.14*** (2.29)
Surface			
[< 80 m^2]	REF	REF	REF
[80–100 m^2]	0.90 (0.07)	1.08 (0.14)	0.49** (0.51)
[100–130 m^2]	0.70*** (0.05)	1.73*** (0.23)	0.51* (0.18)
[> 130 m^2]	0.59*** (0.05)	2.18*** (0.31)	1.37 (0.46)
Area			
Ile de France	REF	REF	REF
Parisian basin	1.08 (0.09)	1.03 (0.16)	0.99 (0.38)
North	0.78** (0.08)	1.56** (0.27)	0.55 (0.30)
Est	0.81** (0.08)	1.28 (0.21)	0.95 (0.40)
West	1.20** (0.10)	0.95 (0.15)	1.23 (0.44)
South Ouest	0.97 (0.09)	1.23 (0.20)	1.60 (0.61)
Est center	1.02 (0.10)	1.25 (0.21)	0.20** (0.16)
Mediterranean	1.01 (0.9)	0.84 (0.15)	2.13** (0.80)

Regression adjusted by gender and age.
* $p < 10\%$.
** $p < 5\%$.
*** $p < 1\%$.

(respectively severe fuel poor) and then will exit this state of poverty;

- 35.78% (respectively 0.67%) of the households will get out of fuel and then will be in fuel poverty (respectively severe fuel poverty);
- 11.39% (respectively 0.67%) of the households in severe fuel poverty will not be in fuel poverty for some time, and will be in fuel poverty (respectively in severe fuel poverty).

Note that we have checked the adequacy of the mover-stayer model on our data in Appendix B.

Given that fuel poverty in France does not seem to be a trap, governments should generally be directed towards short-term policies, such as financial aid and more relevant approaches such as energy vouchers. For people locked in fuel poverty, these short-term measures could be supplemented by long-term policies such as thermal rehabilitation aids. However, to better targets these policies it is necessary to understand the characteristics of both stayers and movers. The econometric analysis below highlights these characteristics.

3.3. Econometric results and discussion

3.3.1. Econometric results for stayers

Table 5 reports the logit specification estimations for people who remain in their state, i.e., stayers.

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 to an even greater extent, of remaining severely fuel-poor. A high education level reduces the probability of remaining in fuel poverty or severe fuel poverty and reinforces an individual's stability in non-fuel poverty. These results seems to confirm that individuals with a high level of education compared to individuals with low level of education do not have the same level of "capabilities" (Sen, 1999) to adopt energy-saving behaviours, and the direct consequence could be an increased energy bill (Byubrechs, 2004). The 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 decreases the probability of remaining in non-fuel-poverty state or fuel poverty state. We see a vicious cycle of unemployment compared to employed individuals. Compared with having a low income level or lower education level, the existence of significant financial difficulties has a similar impact on fuel-poor stables or severely fuel-poor stayers. 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 these individuals' precariousness. Long-term policies must be developed so that these stayers in fuel poverty escape. For stayers in fuel poverty, who perhaps endure permanent poverty, "*long-term measures, including structural changes in the labour market as well as investment in education, training, and special services are needed*" (Evason, 1981).

It appears that living with a partner (with or without children) is good protection against stability in the severe fuel poverty state. In addition, living with a partner increases the probability of staying in a non-fuel-poverty state, as marriage compared to singlehood. This increase likely results from the fact that couples generally have more financial flexibility (because of cost sharing) than do single persons. 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 the receipt 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 to a single person.

The probability of remaining fuel-poor is greater among renters. Tenants do not have full control of their heating consumption compared to owners (Healy and Clinch, 2004). Long-term measures that would encourage donors to improve the thermal quality of housing for these

Table 6
Econometric results for mobiles.

Variables	NFP→FP Odd ratio (sd)	NFP→SFP Odd ratio (sd)	FP→NFP Odd ratio (sd)	FP→SFP Odd ratio (sd)	SFP→NFP Odd ratio (sd)	SFP→FP Odd ratio (sd)
Net income						
1st quartile	REF	REF	REF	REF	REF	REF
2st quartile	1.08 (0.07)	0.60*** (0.09)	1.29*** 0.09)	0.62*** (0.10)	2.51*** (0.40)	2.50*** (0.43)
3st quartile	0.77*** (0.06)	0.40*** (0.07)	1.64*** (0.12)	0.49*** (0.09)	3.69*** (0.70)	2.75*** (0.54)
4st quartile	0.62*** (0.05)	0.11*** (0.03)	2.34*** (0.20)	0.18*** (0.05)	8.48*** (2.31)	4.47*** (1.23)
Type of household						
Single person	REF	REF	REF	REF	REF	REF
Single parent family	1.08 (0.14)	0.87 (0.20)	1.27* (0.17)	1.01 (0.23)	1.44 (0.65)	1.02 (0.27)
Couple without children	0.99 (0.11)	0.23*** (0.07)	0.95 (0.11)	0.23*** (0.07)	5.62*** (1.70)	4.80** (1.40)
Couple with children	0.94 (0.11)	0.31*** (0.08)	1.27** (0.15)	0.33*** (0.08)	6.4*** (1.67)	3.57*** (1.04)
Others	1.20 (0.12)	0.18*** (0.08)	0.92 (0.15)	0.19** (0.09)	1.51 (0.51)	1.28 (0.40)
Marital status						
Single	REF	REF	REF	REF	REF	REF
Married	0.72 (0.06)	0.66* (0.15)	0.89 (0.08)	0.73 (0.18)	0.64* (0.15)	0.65* (0.14)
Widow	0.90 (0.11)	0.43*** (0.11)	0.59*** (0.07)	0.29*** (0.08)	1.74* (0.53)	1.61 (0.48)
Divorced	0.82* (0.09)	1.01 (0.21)	0.75** (0.18)	0.85 (0.19)	0.96 (0.12)	0.99 (0.26)
Status on labour market						
Employed	REF	REF	REF	REF	REF	REF
Student	0.73** (0.10)	0.98 (0.31)	0.83 (0.10)	0.91 (0.29)	1.19 (0.39)	1.39 (0.48)
Unemployed	1.15 (0.14)	2.46** (0.54)	1.03 (0.13)	2.26*** (0.54)	0.62* (0.16)	0.77 (0.20)
Retired	0.94 (0.09)	0.97 (0.24)	1.02 (0.10)	0.99 (0.28)	0.76 (0.19)	0.61* (0.16)
House-wife (husband)	1.11 (0.13)	1.35 (0.38)	0.82* (0.38)	1.04 (0.30)	0.51** (0.13)	0.54** (0.14)
Others	0.95 (0.17)	2.20** (0.61)	0.80 (0.14)	1.58 (0.53)	0.52* (0.18)	0.45** (0.16)
Type of dwelling						
Farm, house	REF	REF	REF	REF	REF	REF
Town, Adjacent house	1.17** (0.07)	1.07 (0.17)	0.84*** (0.05)	0.90 (0.14)	0.88 (0.15)	0.89 (0.14)
Apartment	0.58*** (0.05)	0.30*** (0.07)	1.77*** (0.16)	0.74 (0.15)	3.64*** (0.84)	1.28 (0.27)
Occupancy status						
Owner	REF	REF	REF	REF	REF	REF
Tenant	1.91*** (0.14)	1.45** (0.25)	0.51*** (0.04)	0.73* (0.12)	0.47*** (0.09)	1.14 (0.18)
Free of charge	1.62*** (0.23)	0.76 (0.28)	0.75** (0.11)	0.69 (0.23)	0.95 0.37)	1.64 (0.65)
Rural/Urban						
Urban	REF	REF	REF	REF	REF	REF
Rural	1.01 (0.05)	0.88 (0.13)	0.89* (0.05)	0.79 (0.12)	0.76* (0.11)	0.73** (0.11)
Financial difficulties						
No	REF	REF	REF	REF	REF	REF
One	1.53*** (0.21)	3.94*** (0.81)	0.41*** (0.05)	2.12*** (0.46)	0.24*** (0.05)	0.45*** (0.10)
At least Two	1.43** (0.28)	8.58*** (2.22)	0.45*** (0.07)	3.59*** (0.95)	0.08*** (0.02)	0.15*** (0.05)
Surface						
[< 80 m^2]	REF	REF	REF	REF	REF	REF
[80–100 m^2]	1.20** (0.10)	0.87 (0.16)	1.04 (0.09)	1.02 (0.20)	1.11 (0.21)	1.11 (0.21)
[100–130 m^2]	1.56*** (0.13)	0.82 (0.16)	0.77* (0.07)	0.79 (0.16)	1.13 (0.25)	1.13 (0.25)
[> 130 m^2]	1.95*** (0.18)	1.53** (0.31)	0.66** (0.06)	1.12 (0.24)	0.70 (0.16)	0.70 (0.16)
Area						
Ile de France	REF	REF	REF	REF	REF	REF
Parisian basin	1.32** (0.13)	0.42*** (0.10)	1.39*** (0.13)	0.83 (0.20)	0.91 (0.24)	0.91 (0.24)
North	1.72*** (0.20)	0.63* (0.18)	1.07 (0.12)	0.72 (0.20)	1.10 (0.38)	1.10 (0.38)
Est	1.61*** (0.17)	0.65 (0.17)	0.94 (0.09)	0.62* (0.16)	1.06 (0.33)	1.06 (0.33)
West	1.01*** (0.11)	0.52** (0.21)	1.50*** (0.15)	0.82 (0.19)	1.27 (0.34)	1.27 (0.34)
South Ouest	1.27*** (0.14)	0.79 (0.19)	1.18 (0.12)	1.15 (0.29)	0.52** (0.14)	0.52** (0.14)
Est center	1.32*** (0.14)	0.38*** (0.11)	1.23* (0.13)	0.61* (0.18)	2.07* (0.77)	2.07* (0.77)
Mediterranean	1.11 (0.12)	0.82 (0.19)	1.69*** (0.18)	1.48 (0.37)	0.57** (0.16)	0.57** (0.16)

Regression adjusted by gender and age.
* p < 10%.
** p < 5%.
*** p < 1%.

fuel-poor tenants could get them out of fuel poverty.

Compared to living in an apartment, living in a detached house or on a farm increases the probability of remaining in fuel poverty and, to an even greater extent, 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 surface, the size of the dwelling is more important because the probability of stability in the fuel poverty state is both important and lower than the probability of stability in the non-fuel-poverty state. Nevertheless, for the severe fuel poverty state we observe that individuals living in bigger dwellings have a lower probability of stability in this state.

3.3.2. *Econometric results for movers*

Table 6 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 others to overcome fuel poverty or severe fuel poverty. Consequently, short-term measures such as social energy tariffs or energy vouchers can be adequate to relieve temporary distress.

Unemployed people's risk of moving from non-fuel poverty or fuel poverty to severe fuel poverty is high. Indeed, unemployment constitutes the primary contributing factor to state deterioration and increases the risk of enclosure (i.e., confinement). As in the case of stayers, financial difficulties substantially increase the risk of falling into 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. If households not only fall into fuel poverty or severe fuel poverty but also become precarious, then increased revenues from direct measures such as income transfers can improve their situation. However, if they risk enduring permanent poverty, it is preferable to take long-term measures, just as in the case of fuel-poor stayers.

Compared with living alone, living with a partner reduces the probability of aggravating fuel poverty (i.e., moving from fuel poverty to severe fuel poverty) and increases the probability of overcoming severe fuel poverty.

Another interesting result concerns single-parent families. The probability of those living in 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 trade-offs). Therefore, single-parent families may move artificially into non-fuel poverty.

Divorced people show the lowest probability of moving from fuel poverty to non-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 are at greater risk of becoming fuel-poor. Married persons are less likely to transition from non-fuel poverty to fuel poverty. Nevertheless, married persons in an initial state of severe fuel poverty have a lower probability of moving into non-fuel poverty.

Students have the lowest probability of falling into fuel poverty. This result seems to be counterintuitive, but may be potentially explained by the fact that students can either receive family financial support or restrain their heating consumption to save on costs (budget arbitrations), similar to single-parent families.

In terms of dwelling type, the results corroborate the econometric results for stayers. 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 or severe fuel poverty because tenants have less flexibility than owners in terms of equipment and heating consumption.

Additionally, the rural covariate corroborates the results for stayers. Indeed, the results show that rural residents experience being trapped in fuel poverty, a phenomenon that is more common in situations of severe fuel poverty. Compared to an urban resident, a rural resident in fuel poverty has a lower probability of achieving non-fuel poverty.

Finally, the larger the dwelling, the higher the probability of moving into fuel poverty for the non-fuel-poor; the smaller the dwelling, the lower the probability of leaving fuel poverty. Additionally, the non-fuel-poor who live in the largest dwellings ($> 130\ m^2$) have a higher probability of moving into severe fuel poverty; the other modalities are not significant. Indeed, the largest dwellings require higher energy consumption for warming. Nevertheless, for the fuel-poor, dwelling surface does not have an impact on moving into severe fuel poverty. Then, insofar as larger units are more expensive to heat, we can see that smaller housing is important to increase the probability of passing from the non-fuel-poverty state to the fuel poverty state.

However, the deterioration of fuel poverty status (i.e., passage from a state of fuel poverty to a state of severe fuel poverty) seems more attributable to financial difficulties than to housing conditions. If we acknowledge this result, financial assistance could be more suitable than improved housing for helping movers escape severe fuel poverty. These results show the multidimensional complexity of the fuel poverty phenomenon.

4. Conclusion and policy implications

This study is one of the few to examine the dynamics of fuel poverty. For this purpose, 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 (i.e., stayers) and those who move across states (i.e., movers). Consequently, the approach we use combine discrete time analysis taking into account unobserved heterogeneity (mixture of transition probabilities).[21] Fuel poverty is mostly a transitory (i.e., temporary) state. Nevertheless, it must not be forgotten that 38% are stayers in a fuel poverty state and 33% are stayers in a severe fuel poverty state. Additionally, the proportion of individuals who are vulnerable to fuel poverty is approximately 15%.

Our econometrics estimates show that for certain determinants (e.g., divorced, students and single-parent families), the impact on fuel poverty dynamics differs between *stayers* and *movers*, which underlines the need to consider different sub-populations, i.e., the chronic fuel-poor (stayers) and the transitory fuel-poor (movers). Consequently, it is necessary to take a dynamic approach to studying 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 would enable a much more efficient and precise targeting of public policies that seek to eradicate the fuel poverty phenomenon. Therefore, the various measures in place could be adjusted for and adapted to different fuel-poor populations because their determinants are different. In addition, the results of this study could inform future prevention measures.

In conclusion, it appears that there is a need to implement short-term and long-term measures to implement jointly. In other words, short-term assistance (social energy tariff, energy vouchers) is useful to limit the transition from the non-fuel-poor state to a fuel poverty or severe fuel poverty state. Nevertheless, some of the long-term programmes (dwelling renovation) should be conducted so that "stayers in fuel poverty" can escape but also in order to avoid that some *movers* become stayers. Obviously, low incomes, low education levels, financial difficulties and dampness increase the probability of staying in fuel poverty or severe fuel poverty. Furthermore, for movers, these determinants increase the probability of transitioning into fuel poverty or severe fuel poverty. Consequently, increased incomes, investment in education, income transfers, and improving the housing thermal quality can raise people out of fuel poverty, and sometimes even out of poverty itself. For households pushed into transitory fuel poverty (movers) due to financial difficulties, financial transfers, social energy tariffs or energy vouchers help them to lift out of fuel poverty. However, measures of thermal renovation are more adapted to household rooted in fuel poverty.

Some extensions to this work are possible. First, it could be interesting to perform econometrical estimations in which explanatory variables represent a variation. For example, study the impact of job

[21] Note that a simple mixture of conditional hazard cannot take into account the presence of stayers while the mover-stayer model allows us to statistically identify and quantify the proportion of stayers in each state and the proportion of movers in each state, along with the transition probabilities for movers.

loss or the birth of a child during the observation period. Second, to simulate the impact of economic-policy reforms on the fuel-poor we can develop a microsimulation model. Finally, it could be interesting to extend this analysis to other European countries to identify whether the fuel poverty dynamics is similar or different and if the mobility and stability determinants are the same. The data used (EU-SILC), reference in the analysis of inequalities, allow this extension. The subjectivity of the indicator used is not a problem. In fact, it allows to aggregate existing differences between countries such as energy prices, temperatures and consumer behaviour. The results could enrich those of BPIE (2014) which uses, among others, the subjective indicator "*Inability to keep home adequately warm*" to describe the situation of fuel poverty in Europe in 2012.

Appendix A

See Fig. A1.

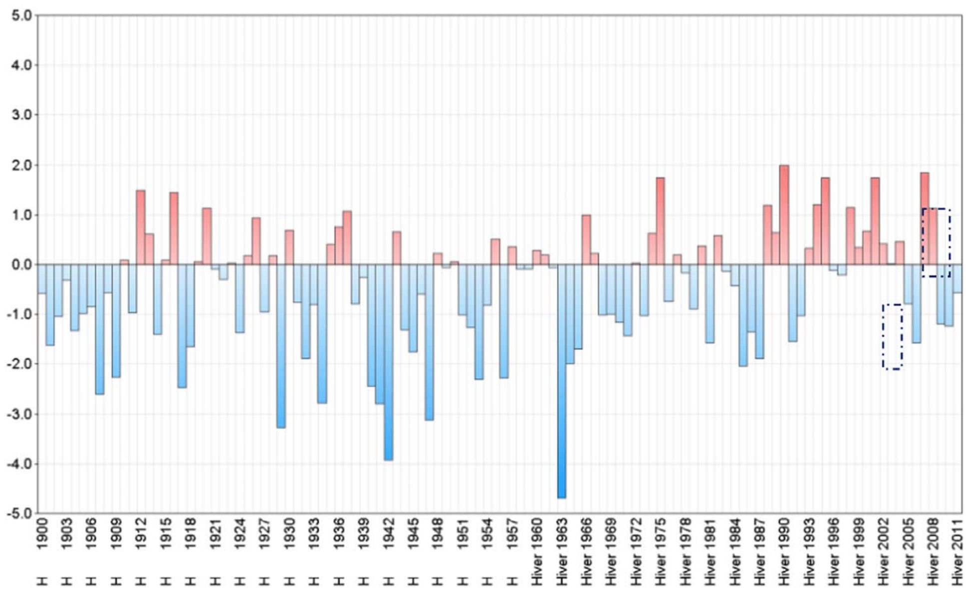
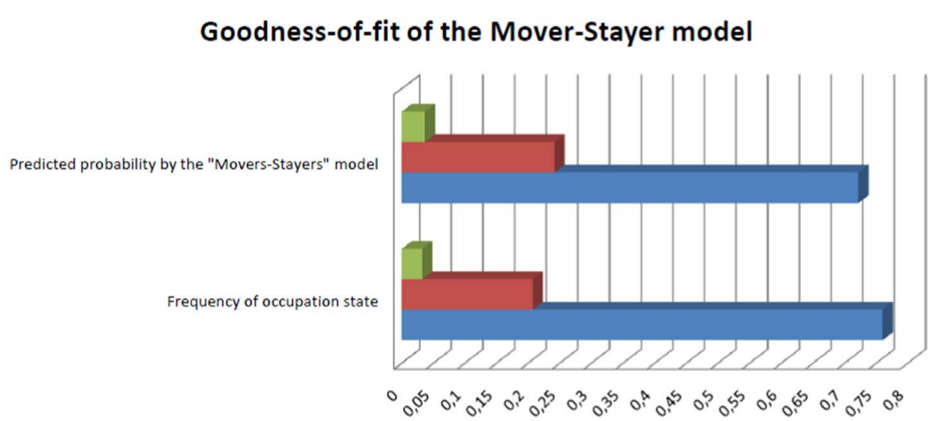


Fig. A 1. French winter temperatures since 1900 (i.e., http://www.meteofrance.fr/documents/10192/35608/25066-43.gif/)

Appendix B

See Fig. B1.



	Frequency of occupation state	Predicted probability by the "Movers-Stayers" model
Severe Fuel Poor	0,0324	0,0364946
Fuel Poor	0,2074	0,241603
Non Fuel poor	0,7602	0,721903

Fig. B 1. Goodness-of-fit of the Mover-Stayer model.

The following figure represents the goodness-of-fit of the mover-stayer model on our data. It represents the probability of the frequency of each state estimated by the "mover-stayer" model and the real frequency of each state in our data. As we can see, the mover-stayer model slightly underestimates the proportion of the non-fuel-poor and slightly overestimates the proportion of the fuel-poor. Nevertheless, it appears that the frequency of severe fuel poverty is correctly estimated. Finally, this model seems to be adequate for our data.

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