Abstract

The difficult socio-economic context in France has generated a growing concern about a new dimension of the precariousness: the fuel poverty. Fuel poverty is characterized by the difficulty to warm his dwelling at a reasonable cost. More and more people are struggling to heat their homes and the consequencies, for health, of these restrictions can be following ones. On one hand, self-restriction behavior entailing living conditions in low temperatures may increase the severity of several cardiac and respiratory diseases, such as sinusitis or asthma. On the other hand, the financial burden induced by high costs to warm his dwelling may have deleterious consequences through a decrease of health expenditures and others expenditures. Nevertheless, until now no study has investigated the real causal impact of the fuel poverty on health, due to the lack of data providing information on both health status and fuel poverty. So, the objectives of this paper are to investigate and quantify the impact of the fuel poverty on different health indicators.

We use the 2010 French National Health, Health Care and Insurance Survey which provides for a sample of 5069 individuals information on health status, dwelling conditions and socioeconomic characteristics. We use a subjective measure of the fuel poverty using the following question: "During the last winter, has your household suffered from cold ? Inside your home for at least 24 hours?". To analyze the impact of fuel poverty on health status, a recursive bi-probit model is performed to deal with the potential endogeneity between fuel poverty and health status (self-assessed health, long-standing disease and poor mental health).

13.5% of the sample is fuel poor. Fuel poverty is more frequent among individuals with a low socioeconomic status. After controlling for the potential endogeneity problem, we find that fuel poverty increases the risk of reporting a poor health status, to have a long-standing disease, and to have a poor mental health.

Fuel poverty is identified as an important determinant of health status and of social health inequalities and this dimension should be taken into account in policies addressing social health inequalities.

Fuel Poverty is it harmful for health? Evidence from French health survey data

E.Lacroix [a] *, and F.Jusot [b]

[a]PSL, University Paris Dauphine Leda-Legos

[b]University of Rouen, PSL, University Paris Dauphine Leda-Legos

1. Background

The growing literature indicates that poor living conditions (unhealthy housing, education access, labor market access...) or low socio economics status are majors determinants of health and health inequalities (Jusot, 2006). Regarding poor living conditions, a section of energy economics concerns the fuel poverty concept. In France, fuel poverty was defined in the Article 11 of the national commitment to the environment (Grenelle II) of 12 July 2010: "*an household who has difficulties disposing of the necessary energy satisfy his basic needs due to the inadequacy of his resources or his living conditions is in fuel poverty under this Act ".* The french definition of fuel poverty appears as a interaction between households, their socio-economic situation and their dwelling. This one can create some cumulatives effects or constitute a ripple effect. Moreover, the fuel poverty can considered as a part of the Precariousness framework as the food precariousness, the health precariousness, the finantial precariousness. So, the fuel poverty can interact with the others types of precariousness. In this way, the fuel poverty constitute a additional source of weakening for individuals. In more general terms, the fuel poverty contribute to increase vulnerability to Poverty. The French National Institute of Statistics and Economic studies (INSEE) estimate that 3.8 million of households were fuel poors in 2006 (represent 14.8% of the population) whereas the percentage of fuel poors was 10.9% in 1996. More recently (October 2014), the national observatory of the fuel poverty estimate that one quarter of French individuals are fuel poors. This rapidly rising of the fuel poor increase the interest carry about this phenomenon and its consequences. In this article we will focus our analysis on the health consequencies induce by the fuel poverty. We can identify two types of consequences on health. On one hand, self-restriction behavior entailing living conditions in low temperatures may increase the severity of several cardiac and respiratory diseases, such as sinusitis, asthma. So, the fuel poverty influence health. On the other hand, the financial burden induced by high costs to warming his dwelling may have deleterious consequences through a decrease of health expenditures and others expenditures. So, the fuel poverty is a determinant of health inequalities.

In this article, we investigate the interaction between fuel poverty and health and we quantify the

*lacroixelie0@gmail.com

impact of the fuel poverty on different health dimensions in France.

The french context holds attention because we have a high level of social inequalities. So, the analysis of fuel poverty in a french context is highly interesting due to this national peculiarity. Finally, highlighting the bad consequencies of the fuel poverty on health could create a growing awareness by the policy makers to eradicate this growing phenomenon and bring into focus the high public stakes induced by the fuel poverty.

Before presenting the literature review, we need to present the different measures of the fuel poverty concept for a better understanding of the distinction between fuel poverty and dwelling conditions. Commonly, two different types of fuel poverty measures are used. First, the subjective approach is based on the households declaration concerning the possibiliby for them to obtain a adequate warmth in their dwelling (the cold sensation) or the ability to pay their bill to have a adequate energy consumption for example. Secondly, the objective approach of the fuel poverty. This objective approach can be distinguished in two different objective measures. First, the objective temperature measure, the internal room temperatures is collected to determinate if households have a 'adequate warmth' compared to a temperature threshold. This is the case in United Kingdom most of time. The second objective measure concerns the percentage of household income allocated to the fuel expenditures to warm his dwelling. Concerning this approach, three main remarks need to be done. First, the level of fuel expenditure can be considered as a actual level of fuel expenditure for an household or as a required level of fuel expenditures Secondly, the level of income can be considered after or before housing costs. And finally, the threshold, in other word the level of income allocated for the fuel expenditures above which an household is considered as a fuel poor or not, can be relative or absolute.

This presentation of these different measures of the fuel poverty needed to be done because most of time there is an ambiguity and a confusion between the fuel poverty and the dwelling conditions (mold, dampness dwelling, low efficiency level or cramped dwelling and so on) because fuel poverty is currently associated with low insulated houses. However, as we noted previously (i.e Grenelle II), the fuel poverty refers to the impossibility to satisfy his basics energy needs. So, the dwelling conditions could be a part of fuel poverty determinants. Nevertheless the fuel poverty and the dwelling conditions are not exactly the same thing but there are related.

2. Literature review

2.1. Dwelling conditions and health

As we said before, a growing literature has focused on the dwelling conditions and the body exposure to low temperatures consequencies on health rather than the fuel poverty consequencies on health specifically.

In United Kingdom, many researches[2] indicated that the unhealthy housing, in particular with mold, dampness, was associated with chronic respiratory diseases and infections, even after potentially confounding factors, such as income, education, smoking or unemployement. With the LARES data (Large Analysis and Review of European housing and health Status), Ezratty & al. (2009) found a positive

[2]Bornehag & al., 2001; Peat & al.,1998; Hyndman & al.,1998; Platt & al.,1989; X.Bonnefoy, 2007; Healy & al., 2002).

relationship between bad energy efficiency housing and poor health as well as respiratory diseases. Finally, it appears that dampness and mold could create some mental disorders too. Hopton & al. (1996) estimated that dampness and mold affect mental health (stress and/or social exclusion). Overall, a substandard housing condition affect health by diverse ways.

But also, many studies have shown the negative impact of body exposure to low temperature. The World Health Organization (WHO, 1987) indicated that the impact of low temperature on health follows this classification:

- Less than $16°C$ temperature causes respiratory problems
- Less than $12°C$ temperature causes circulatory problems
- Between $5°C$-$6°C$, the risk of hypothermia is important

Wilkinson & al. (2001) analysed 80000 deaths due to cardiac diseases in England between 1986 and 1996. Upon matching these data with the *English House Condition* data to 1991, the authors found a significant relation between the indicator *Excess Winter Deaths*(EWD) and living in a *Cold-Homes.* The *Excess Winter Deaths* is a statistical indicator calculated by the Office for National Statistics, which permits to calculate the excess mortality that exists during the winter season. It is the difference between the number of deaths during the winter months (december to March) and the average of deaths during the four last months (Agust to November) and the four next months (April to July). Note that a Cold-Homes is a house with a low level of energy efficiency and with low indoor temperature. Also, Donalson (2010) highlighted that 40% of the Excess Winter Deaths were due to *Cold-Homes* in the annual report of *Chief Medical Officer* in 2009. Davie and al (2007) indicate that fuel poverty is a contributing factor to low indoor temperatures. Authors estimates, with a negative binomial model, that the low indoor temperatures have caused 1600 deaths corresponding at 16% of the total deaths in winter months in United Kingdom. In fact, the body exposure to low temperature affect health. It is shown by Collins & al. (1986), with a longitudinale study realized with 47 elderly individuals that have been exposed to low temperature during winter months in 1971-72 and 1975-76. The results suggest that the low temperature exposure is responsible for the increase of blood pressure and the blood viscosity. These two elements extend the risks of stroke and heart attack (Howieson & Hogan, 2005). The robustness of these results can be discussed because the number of observations is quite small. As we can see, the dwelling conditions is well documented. Nevertheless, there is much less literature concerning only the causal impact of the fuel poverty on health.

2.2. Fuel poverty and health

Five studies (Warm Front scheme; the Scottish Executive Central Heating Programme (CHP); the New Zealand Housing, Insulation and Health Study (HIHS); Housing, Heating and Health Study (HHHS); US Children's Sentinel Nutritial Assessment (C-SNAP) and The National Cenre for social Research (NATCEN)) have tried to identify the causal impact of fuel poverty on health with a rigorous methodology. The first four studies have used a quasi-experimental design with a treatment group (beneficiaries of a insulation program or a substantial heating subsidy) and a control group (households who were

eligible to the insulation program or a winter heating subsidy but they didn't benefit from them). The quasi-experimental design has been possible because these studies were integrated in parallel of these two measures. Also, studies were carried out in 2 steps:

- Before the dwelling insulation intervention or winter heating subsidy many informations were gathered about health characteristics (GHQ-12, SF-36) for the treatment group and the control group.
- After the intervention or implementation of heating subsidy, a new collect of information have been done.

This method enabled to identify if these helping measures had had a positive impact on heath indicators and we can note that different measures of the fuel poverty have been used. The CHP and Warm Front studies have used a formal temperature measure. So, an household was fuel poor if the temperature was below $16°C$ in either living rooms or bedrooms. For the HIHS and the HHHS, there was no screening for fuel poverty and households were considered in fuel poverty if they had very specific characteristics: a low income, leaved in a wooden house and at least one member of the household had a respiratory disease. Finally, the C-SNAP used a 4-item Home Energy Security Indicator[3] and the caregivers were interrogated to gather informations about health of their children. The results indicated a little improvement of the self-reported physical health and self-assessed health when the risks factors of fuel poverty are reduced (Green and al., 2008; Shortt and al., 2009; Howden-Chapman and al., 2008). The main findings concerned the impact of the fuel poverty on mental well-being, especially for the children population (Green and al., 2008; Howden-Chapman and al., 2008; Frank and al.,2006). Lindell and al.(2010) explained that the impact on health was probably low, due to a sample size problem, with many confounders factors. Moreover, we identify several limits to these studies. On one hand, for the Warm Front scheme, the causal impact of the fuel poverty on health cannot be established because all the participants weren't in fuel poverty (Green and al., 2008). For the HIHS and HHHS programs a selection biais seems unquestionable because the sample consisted of volunteers and with very specific characteristics so that the sample was not representative of the national population. On the other hand, these studies were usually used for an evaluation strategy of these isolation programs or helping measures rather than a real identification of the causal impact of the fuel poverty on health.

Note that the fifth study (NATCEN) did not used a quasi-experimental design. This study has compared across time the different levels of health status between children under 11 years old, using caregivered interviewes each year during five years, whether they had been able to keep the home warm during the previous winter. The results are quite similar to the C-SNAP study (Barnes and al., 2008).

A last study conducted by Healy (2004) estimated a negative relation between fuel poverty and health too. The fuel poverty measure was based on a declarative answer. A household was considered in fuel poverty if "*this household reported an inability to heat his home to an adequate, confortable temperature*".

[3]The household energy security indicator includes energy-secure, no energy problems; moderate energy insecurity, utility shutoff threatened in past year; and severe energy insecurity, heated with cooking stove, utility shutoff, or $\geq$1 day without heat/cooling in past year (John T. Cook and al. (2008)).

For the health indicators, the author used subjective (self-assessed health status) and objective measures (number of visits to their general practitioner, A & E admittances and some chronic health outcomes such as asthma, hypertension) to identify the impact of the fuel poverty on health. Nevertheless, Healy only compared the different health indicators between the fuel poors and the non-fuel poors individuals. It was a descriptive statistical approach, and a potential endogeneity problem between the fuel poverty measure and the subjective health measure were not taken into account. Regarding, the potential endogeneity problem, fuel poverty is conditionned by the individual cold sensation level. But, it depends of the health status too. Furthermore, it is probably that a individual with a poor health status did not estimate that he is fuel poor because he can think that his cold sensation is due to his health disorders. So, it is necessary to take into account this potential simultaneity between fuel poverty and health status. Moreover, if it is the case the impact of the fuel poverty on health would be under-estimate.

Thus, regarding this literature review, the contributions of our paper are the following. First, we deal with this potential endogeneity problem between fuel poverty and health indicators with a recursive bivariate probit. Secondly, we use a French representative health database and thirdly, we use three different health outcomes, including a objective measure, to take into account to the different health dimensions.

The remainder of this paper is organized as follows. In the next section we describe our methodology: the database we used, the fuel poverty and health measures we adopted, the different control variables and the econometrical specification. After this section, we present the statistics descriptives and the results of our estimations and we conlude in a discussion section.

3. Methods

3.1. Data

We use 2010 wave of the National Health, Health Care and Insurance Survey (ESPS: "Enquête sur la Santé et la Protection Sociale") which is a national interview survey on health and healthcare consumption (Dourgnon and al., 2012). It interrogates a random sample of major health insurance beneficiaries (it covers 97% of the all population). In 2010, a set of questions about dwelling conditions has been added by the Institute for Health Surveillance (inVS:"institut national de Vieille Sanitaire"), including the subjective measure of the fuel poverty. 8305 households were interrogated in the 2010 wave: For each household, a member answered a main questionnaire (socio-demographics questions), and each member of the household answered a self-administrated questionnaire (personal questions: health informations for example), corresponding to 22805 individuals in total. For our purpose, we have a sample of 5069 observations aged over 18 years old. This significant decrease of our sample have two explanations. First, the question, that permits to identify people who living in fuel poverty, is only asked to the main household questionnaire. Secondly, the personal informations about health and health care is recovered by a self-administred questionnaire. So, there is a loss of information because many individuals partially completed his self-administred questionnaire (Dourgnon and al., 2012).

3.2. Measure of fuel poverty

We used a subjective measure of the fuel poverty, based on the thermal discomfort, with this following question: *"During the last winter, did you suffer from the cold in your dwelling during at least 24 hours?"* (ESPS, 2010) noted (FP). This thermal discomfort reflects the difficulties for an household to obtain an adequate warmth or energy consumption. This measure of the fuel poverty have several advantages compared to others**.** On one hand, this measure allows us to take into account, in an indirect way, the individual preferences. Indeed, this measure internalises the different lifestyles between individuals because each individual report his assessment of his personal situation. Moreover, for a european comparaison, it appears that the level of the temperature threshold for each country is different[4]. So, the comparison between europeans countries would be impossible. On the other hand, this measure enables us to avoid several pitfalls commonly associated with the objective measures of the fuel poverty. For the objective temperature measure, the major criticism is the high cost induced by the collect of inside temperature because dwellings need to be fitted with costly specific equipment. For the second objective measure, the percent of income spent for the fuel expenditures, two different criticisms are currently done. First, the most commonly threshold use by researchers is 10%[5] (Boardman, 2010). Nevertheless, this threshold is an "arbitrary" threshold fixation (Hills, 2011) and we can imagine that this median level of net income spent for fuel expenditures is not the same between French households and English households. Secondly, the level of income can be measured after or before the housing costs. And this threshold can be relative or absolute as the poverty for instance. And, there is not a consensual approach for these choices.

Finally, we can note that the subjective temperature measure is accurate for measuring the fuel poverty phenomenon because this subjective measure corroborate with the French definition of fuel poverty (i.e Grenelle II).

3.3. Measure of Health indicators

We use three different health indicators in our study to cover different health dimensions. The first indicator is the self-assessed health ("*How is your health in general?*" and the possible answers are:"*Very good, good, fair, bad, very bad*"). The second indicator is the long-standing disease ("*Do you have a long-standing disease for which your treatment is supported at 100% by health insurance or Social Security?*", "*yes or no*"). And the third indicator is the mental component of the Short Form-36 score. In the Short Form-36, five questions are used to create this mental score: "*Have you been felling particulary nervous?*", "*Have you felt so discouraged that nothing could cheer you up?*", "*Have you been felling calm and relaxed?*", "*Have you been felling sad and downhearted?*", "*Have you been felling happy?*" and five answers can be possible: "*Permanently, much time, occasionally, rarely, never*".Then these answers are added to obtain a numerical value.

All of these indicators are binary:

[4]For example, the threshold of inside temperature in English, Welsh and Northern Irish fuel poverty models is $21°C$ for the living room and $18°C$ for the others rooms of the dwelling. But this threshold is $23°C$ for the living room for disabled, infirm and ederly households in Scotland (H.Thompson, 2013).

[5]This threshold is the double of the median level of its net income spent by the English households for fuel expenditures, calculated from the 1988 the Family expenditure Survey for UK household.

- Self-assessed health: "reporting a fair, poor or very poor health" vs " good or very good health";
- Long-standing disease: "long-standing disease" vs "no long-standing disease";
- The mental component of the Short-Form 36 score "score-SF36 is less than 44" vs "more than 44". Indeed, 44 corresponds to the first quartile of the SF-36 score distribution in our sample. Thus, we consider that a individual have a poor mental health if his score is less than 44.

Let us note that these health indicators allow us to take into account the multidimensional aspect of health[6]. The self-assessed health is considered as a good predicator of the mortality (Idler and Benyamini, 1997); the long-standing disease refers to a disease that it has already been diagnosed, so it is a objective measure of health,and finally the mental health is measured with the mental component of the Short-Form36.

3.4. Control variables

In our model, we include individual variables to control for current Social Economic Status (SES). Income is treated in five quintiles and it's measured as household income, divided by the Organisation for Economic Co-operation and Devlopment (OCDE) equivalent scale[7]. An additional category is added corresponding to missing information (14%). The level of education is separated in four categories (No education level; lower secondary level; high secondary level; Post secondary level). The occupational status is measured by the previous occupation for those retired or unemployed or by current occupation. We create a variable with nine categories (Farmers; self-employed; skilled white collar occupation; intermediate profession; clerical employees; trade and craft employees: skilled manual workers; unskilled manual workers and inactive). And finally, we integrate the gender (male or female) and the age of individuals in seven categories ([18-25]; [26-36]; [37-47]; [48-58]; [59-69]; [70-79]; [+80)

3.5. Statistical method

In order to estimate the association between fuel poverty and poor health status after control for SES, our analysis is done in two steps. First, we perfome three simple probits with the three dichotomous health incomes: self-assessed health (reported a fair, poor or very poor health), long-standing disease (yes or not) and a poor mental health score (less than 44) ignoring the potential endogeneity between health indicators and fuel poverty. Then, we estimate three recursive bivariate probits, for each health indicator, to deal with the potential endogeneity problem. The recursive bivariate probit is a king of model who estimate the probability to be in fuel poverty and the impact of the fuel poverty to the health indicators. Moreover, this model introduces a correlation between these error terms of the two equations:

[6]The World Health Organistaion defined health as follows: "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity".
[7]Equal 1 to the first household member, of 0.7 to each additional adult and of 0.5 to each child.

$$\begin{cases} FP = \begin{cases} 1 \text{ if } FP^* = \beta_{FP} SES + \delta_{FP} Z + \upsilon_{FP} > 0 \\ 0 \text{ if } FP^* = \beta_{FP} SES + \delta_{FP} Z + \upsilon_{FP} \leq 0 \end{cases}, \quad (1) \\ H = \begin{cases} 1 \text{ if } H^* = \beta_H SES + \alpha FP + \upsilon_H > 0 \\ 0 \text{ if } H^* = \beta_H SES + \alpha FP + \upsilon_H \leq 0 \end{cases}, \quad (2) \end{cases}$$

$$\text{with} \begin{pmatrix} \upsilon_{FP} \\ \upsilon_H \end{pmatrix} \rightarrow N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right].$$

So, this hypothesis allows us to control for potential unobservable heterogeneity. In our case, we think that the unobservable heterogeneity could be due to the individual cold sensation level (or cold intolerance level) that we cannot measure. We perform this estimation for each health indicator. These equations (1) and (2) estimate on one hand the probability to be fuel poor and the probability to report a "fair, poor or very poor health", "have a long-standing disease" or " have a poor mental health score. The coefficient α estimates the impact of the fuel poverty on the different health indicators. Finally, for this type of specification, we must integrate a variable in the equation (1) but not in the equation (2). This manipulation is required to perfom a correct identification of the model and to verify exclusion restriction (Maddala, 1983). This variable ($\delta_{FP} Z$) must be correlated with the fuel poverty but not with the different health indicators. So, we decided to use the *type of dweeling (Farm, house; Town, adjacent house; apartment; other)* as exclusion restriction because the fuel poverty literature identify the type of dwelling as a determinant of the probability to be in fuel poverty or not (INSEE, 2011). Noted that we clustered our estimations by regions (21 regions in France) to take into account about climate variations between the different regions.

The next section present the descriptive statistics, the probits estimations and the recursive bivariate probits estimations.

4. Results

4.1. Descriptive statistics

Table 1 and 1bis gives the distribution of the sample by Social Economic Status (SES), fuel poverty and health indicators. More than 13% of our sample are fuel poors. Regarding, the health indicators, more than 30% reported a fair, poor or very poor health, 20% have a long-standing disease and more than 20% have a poor mental health score.

Finally, our sample is composed by 41% of males and 59% of females. More than one third of individuals are skilled or unskilled manual workers. Regarding, the level of education, almost 45% have lower secondary level and a quarter have a post secondary level.

Variables	N	%
AGE and SES		
Age group, years		
[18;25]	347	6.85
[25;36]	952	18.78
[37;47]	1138	22.45
[48;58]	1072	21.15
[59;69]	761	15.01
[70;79]	499	9.84
>80	300	5.92
Gender		
Male	2065	40.74
Female	3004	59.29
Occupational status		
Farmers	212	4.18
Self-employed	395	7.79
Skilled white collar occupations	857	16.91
Intermediate profession	899	17.74
Clerical employees	451	8.90
Trade and Craft employees	373	7.36
Skilled manual workers	1218	24.03
Unskilled manual workers	559	11.03
Inactive	105	2.07
Net income		
1st quintile	864	17.04
2nd quintile	865	17.06
3rd quintile	871	17.18
4th quintile	755	14.89
5th quintile	967	19.08
Unknown	747	14.74
Level of education		
No education	762	15.03
Lower secondary	2266	44.70
Higher secondary	799	15.76
Post-secondary	1242	24.50

Table 1 - Statistics descriptives

Type of dweeling		
Farm, house	2635	51.98
Town, Adjacent house	882	17.40
Apartment	1477	29.14
Others	75	1.48
Fuel poverty		
No	4385	86.51
Yes	684	13.49
Health indicators		
Self-Rated health		
Very good	1016	20.04
Good	2351	46.38
Fair	1272	25.09
Bad	371	7.32
Very bad	59	1.16
Long-standing disease		
No	4058	80.06
Yes	1011	19.94
Bad mental health score		
No	4007	79.05
Yes	1062	20.95
Total	5069	100

Table 1bis

4.2. Multivariate analysis without dealing for endogeneity problem

Variables	Poor self-assessed health Marginal effect (sd)	Long-standing disease Marginal effect (sd)	Poor mental health Marginal effect (sd)
Age group, years			
[18;25]	REF	REF	REF
[25;36]	0.12*** (0.03)	0.06* (0.03)	0.02 (0.02)
[37;47]	0.20*** (0.03)	0.09** (0.04)	0.07*** (0.02)
[48;58]	0.30*** (0.03)	0.21*** (0.03)	0.11*** (0.01)
[59;69]	0.40*** (0.04)	0.30*** (0.03)	0.05** (0.02)
[70;79]	0.51*** (0.03)	0.40*** (0.03)	0.09** (0.03)
>80	0.54*** (0.05)	0.42*** (0.04)	0.04** (0.02)
Gender			
Male	REF	REF	REF
Female	0.02 (0.01)	-0.06*** (0.01)	0.07*** (0.12)
Net income			
1st quintile	REF	REF	REF
2nd quintile	-0.05* (0.03)	-0.002 (0.01)	-0.04** (0.01)
3rd quintile	-0.10*** (0.02)	-0.03** (0.01)	-0.08*** (0.02)
4th quintile	-0.08*** (0.03)	-0.03* (0.02)	-0.07*** (0.02)
5th quintile	-0.14*** (0.02)	-0.06*** (0.01)	-0.09*** (0.02)
Unknown	-0.08** (0.03)	-0.03* (0.02)	-0.05** (0.02)
Level of education			
No education	0.08*** (0.02)	0.006 (0.01)	0.01 (0.02)
Lower secondary	0.04** (0.02)	-0.02 (0.02)	-0.02 (0.02)
Higher secondary	REF	REF	REF
Post-secondary	-0.06*** (0.02)	-0.07*** (0.02)	-0.07*** (0.02)
Occupational status			
Farmers	-0.05** (0.02)	-0.01 (0.02)	-0.03 (0.04)
Self-employed	-0.04 (0.03)	-0.01 (0.02)	-0.01 (0.02)
Skilled white collar occupations	REF	REF	REF
Intermediate profession	0.04* (0.02)	0.01 (0.02)	0.05** (0.02)
Clerical employees	0.05** (0.02)	0.03 (0.02)	0.03 (0.02)
Trade and Craft employees	0.04* (0.02)	0.07** (0.02)	0.06** (0.02)
Skilled manual workers	0.03 (0.02)	0.025 (0.02)	0.01 (0.02)
Unskilled manual workers	0.01 (0.02)	0.02 (0.02)	-0.01 (0.02)
Inactive	0.09** (0.04)	0.02 (0.03)	0.06* (0.03)
Fuel poverty			
No	REF	REF	REF
Yes	0.11*** (0.02)	0.04*** (0.01)	0.13*** (0.01))

*p<0,1; **, p<0,05; ***p<0,01.

Table 2 - Probit estimations results

The table 2 reports the results for the multivariate analysis (probits estimations) for the three health indicators (poor self-assessed health, have a long-standing disease and poor mental heath score). We find that the fuel poverty is highly significant and negatively associated with our three health indicators

probit specifications. So, fuel poors have a 0.11 higher probability to report a poor self-assessed health compared to non-fuel poors. Also, the fuel poors have a 0.04 higher probability to have a long-standing disease. Finally, a fuel poor have a 0.13 higher probability to obtain a poor mental health score compared to the non-fuel poors. As expected, the probability to report a poor self-assessed heath and to have a bad mental health score is higher for women than men. Nevertheless, the probability to have a long-standing is higher for men than women. The inactives have a higher probability to report a poor self-assessed health and to obtain a poor mental health score than the skilled white collar occupations but the probability to have a long-standing disease is not significant for the inactive. We have the same type of results for the intermediate profession, clerical employees and trade & craft employees. Also, it appears that the trade & craft employees have a higher probability to have a long-standing disease than the skilled white collar occupations. Nevertheless, the most negative impact is for the inactive status compared to the other occupational status. Finally, the farmers have a lower probability to report a poor self-assessed health and to obtain a poor mental health score compared to the skilled white collar occupations. We can observed an increasing negative effect of the age on the first two health indicators (poor self-assessed health and have a long-standing disease). Nevertheless, for the poor mental health score, its appears that the most negatively effect of age is between [37;47] and between [70;79]. The first interval corresponds to labor force activity period and the possibility to move up the ladder. Thus, these elements can create some stress, anxiety. And the second interval corresponds to the retirement period. So, it's possible that this retirement period favours the appearance of depression symptoms due to the cessation of work. A high level of education decreasing the probability to have or report some health disorders. Finally, higher is the level of income, lower is the probability to report a poor self-assessed health, a long-standing disease or a poor mental health score.

4.3. Recursive bivariate probit analysis dealing for the endogeneity problem

Variables	Fuel poverty	Poor self-assessed health	Fuel poverty	Long-standing disease	Fuel poverty	Poor mental health
	Marginal effect (sd)	Marginal effect (sd)	Marginal effect (sd)	Marginal effect (sd)	Marginal effect (sd)	Marginal effect (sd)
Age group, years						
[18;25]	REF	REF	REF	REF	REF	REF
[25;36]	0.04** (0.02)	0.07*** (0.03)	0.04** (0.02)	0.02** (0.01)	0.04** (0.02)	0.01 (0.02)
[37;47]	-0.001 (0.01)	0.14*** (0.04)	-0.002 (0.01)	0.05*** (0.02)	-0.003 (0.01)	0.06*** (0.02)
[48;58]	0.01 (0.01)	0.24*** (0.03)	0.01 (0.01)	0.15*** (0.02)	0.01 (0.01)	0.10*** (0.01)
[59;69]	-0.02 (0.02)	0.35*** (0.03)	-0.02 (0.02)	0.27*** (0.02)	-0.02 (0.02)	0.05*** (0.02)
[70;79]	-0.05*** (0.01)	0.48*** (0.03)	-0.05*** (0.01)	0.43*** (0.02)	-0.05*** (0.01)	0.10*** (0.03)
>80	-0.07*** (0.02)	0.52*** (0.04)	-0.07*** (0.02)	0.47** (0.04)	-0.07*** (0.02)	0.05** (0.02)
Gender						
Male	REF	REF	REF	REF	REF	REF
Female	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	-0.06*** (0.01)	0.01 (0.01)	0.06*** (0.01)
Net income						
1st quintile	REF	REF	REF	REF	REF	REF
2nd quintile	-0.07*** (0.01)	-0.02 (0.02)	-0.07*** (0.01)	-0.01 (0.02)	-0.07*** (0.01)	-0.02 (0.02)
3rd quintile	-0.13*** (0.02)	-0.06** (0.03)	-0.13*** (0.02)	-0.02 (0.02)	-0.13*** (0.02)	-0.05** (0.03)
4th quintile	-0.13*** (0.02)	-0.04 (0.04)	-0.13*** (0.02)	-0.02 (0.02)	-0.13*** (0.02)	-0.04 (0.04)
5th quintile	-0.15*** (0.02)	-0.09*** (0.03)	-0.15*** (0.02)	-0.04** (0.02)	-0.15*** (0.02)	-0.06** (0.02)
Unknown	-0.12*** (0.02)	-0.03 (0.03)	-0.12*** (0.02)	-0.01 (0.02)	-0.12*** (0.02)	-0.02 (0.02)
Level of education						
No education	0.03** (0.01)	0.07** (0.03)	0.03** (0.01)	-0.01 (0.01)	0.03** (0.01)	-0.004 (0.03)
Lower secondary	-0.01 (0.01)	0.04** (0.01)	-0.01 (0.01)	-0.02 (0.02)	-0.01 (0.01)	-0.02 (0.01)
Higher secondary	REF	REF	REF	REF	REF	REF
Post-secondary	0.01 (0.01)	-0.06*** (0.01)	0.01 (0.01)	-0.07*** (0.02)	0.01 (0.01)	-0.06*** (0.02)
Occupational status						
Farmers	0.01 (0.02)	-0.04* (0.02)	0.01 (0.02)	-0.01 (0.03)	0.01 (0.02)	-0.02 (0.03)
Self-employed	-0.004 (0.02)	-0.03 (0.02)	-0.007 (0.02)	-0.01 (0.02)	-0.004 (0.01)	-0.01 (0.02)
Skilled white collar occupations	REF	REF	REF	REF	REF	REF
Intermediate profession	0.01 (0.01)	0.03* (0.02)	0.01 (0.01)	0.01 (0.02)	0.01 (0.01)	0.04** (0.02)
Clerical employees	0.02 (0.02)	0.04* (0.02)	0.02 (0.02)	0.03 (0.02)	0.02 (0.02)	0.02 (0.02)
Trade and Craft employees	0.06** (0.03)	0.02 (0.02)	0.06** (0.03)	0.06*** (0.02)	0.06** (0.03)	0.05** (0.02)
Skilled manual workers	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	0.01 (0.02)
Unskilled manual workers	0.04** (0.02)	0.01 (0.02)	0.03** (0.02)	0.01 (0.02)	0.04** (0.02)	-0.02 (0.02)
Inactive	0.02 (0.03)	0.07** (0.04)	0.02 (0.03)	0.01 (0.03)	0.02 (0.03)	0.06* (0.04)
Fuel poverty						
No	.	REF	.	REF	.	REF
Yes	.	0.366*** (0.09)	.	0.16*** (0.06)	.	0.31*** (0.06)
Type of dweeling						
Farm, house	REF	.	REF	.	REF	.
Town, Adjacent house	0.05*** (0.01)	.	0.05*** (0.01)	.	0.05*** (0.01)	.
Apartment	0.06*** (0.01)	.	0.06*** (0.01)	.	0.06*** (0.01)	.
Others	0.02 (0.04)	.	0.02 (0.04)	.	0.02 (0.04)	.
Wald test of rho	chi2(1)=4.58	rho: -0.53**	chi2(1)=3.04	rho:-0.27*	chi2(1)=6.47	rho:-0.39**

*p<0,1, ***, p<0,05, ***p<0,01.

Table 3 - Recursive bivariate probit estimations results

The table 3 reports the results for the three recursive bivariate probits for all health indicators to treat the potential endogeneity problem between the fuel poverty and three health measures. First of all, we can note that the rho test for the three probit bivariate recursive are statically significant (poor self-assessed health, have a long-standing disease and a poor mental health score). So we can conclude that some inobservables individual characteristics have a simultaneous influence on the probability to be in fuel poverty and to report a poor self-assessed health or have a long-standing disease or a poor

mental health score. In the three recursive bivariate probits, the ρ coefficient is always negative. So, these unobservables individual characteristics increase the probability to be fuel poor and also increase the probability to report a good self-assessed health, not have a long-standing disease or have a good mental health score. As we noted previously, the different levels of cold sensation related to health status could be a part of these unobservables individual characteristics.

Also, as we can see the variable used to satisfy the exclusion restriction is highly significant, meaning that the type of dwelling strongly predicts the probability to be in fuel poverty or not. Concerning the rest of the determinants of the fuel poverty, we can see that people aged of [70;79] or more than 80 have a lower probability to be fuel poor than people aged of [18;25]. The gender has no impact on the probability to be fuel poor. Nevertheless, the level of income, the level of education and the occupational status have a impact on the fuel poverty probability. So, as for the poor self-assessed health outcome, higher is the level of income, lower is the probability to be fuel poor. So, a low level of income increases the pressure on the budgetary constraint of the households. Also, a low level of education increases the probability to be fuel poor. Bruybrechs (2004) justifies this result by the fact that individuals with a low level of education do not have the same level of "capabilities" (A.Sen (1999)) than individuals with a higher level of education. So, it would be more difficult from them to adopt behaviours of energy saving or to manage their levels of energy consumption. Finally, we can see that the trade & craft employees and the unskilled manual workers have a higher probability to be in fuel poverty than the skilled white collar occupations. All the results concerning the determinants of the fuel poverty are consistent with the fuel poverty literature (Healy & al., (2004); EPEE, (2009); Waddams and al., (2011); Huybrechs, (2011)). After controlling for endogeneity issues fuel poors have a 0.366 higher probability to report a poor self-assessed health compared to non-fuel poors. Also, the fuel poors have a 0.16 higher probability to have a long-standing disease. Finally, a fuel poor have a 0.31 higher probability to obtain a poor mental health score compared to non-fuel poors. The marginal effect for the self-assessed health is three times more important than the estimate without taking into account potential endogeneity issues. The estimate for the long-standing disease is four times more important with the recursive bivariate probit and two times for the poor mental health score estimation. Looking at these results, we conclude that the fuel poverty contributes to an increase of the health inequalities and that the low socio-economics status are more vulnerable to the fuel poverty and health disorders. Moreover, as we can see the impact of the fuel poverty on health is under-estimate without dealing for the endogeneity problem.

5. Discussion and conclusion

This article quantify the causal impact of the fuel poverty on three different health dimensions (self-assessed healh, long-standing disease and mental health), with French health representative data. Results suggest that fuel poors have a 0.366 higher probability to report a poor self-assessed health compared to non-fuel poors. Also, the fuel poors have a 0.16 higher probability to have a long-standing disease. Finally, a fuel poor have a 0.31 higher probability to obtain a poor mental health score compared to non-fuel fuel poors. Also, the level of income, a high level of education and some occupational status (trade & craft employees and unskilled manual workers compared to skilled white

collar occupations) are significant determinants for fuel poverty and health status. So, we can confirm that the fuel poverty has a negative impact on the three different health indicators (poor self-assessed health, have a long-standing disease and have a poor mental health score) and more frequently for the low SES. In the same way, the fuel poverty contributes to the health inequalities.

Concerning the methodology of this article, we use the subjective measure of the fuel poverty based on the thermal discomfort and three different health dimensions (the subjective dimension of health (self-assessed health), a objective dimension (long-standing disease) and a mental dimension (mental component of the short-form 36 score) of health). The recursive bivariate probit model gives marginal effects more importante than the probit estimations for the three health indicators. So, our previous intuition was correct (i.e literature section). Also we can note that we performed a instrumental regression and the marginal effect of the fuel poverty for each health indicator is higher than the recursive bivariate probit marginal effect. Note that the different support tests[8] are validated (i.e Appendix 1). Concerning the exclusion restriction choice for our model, several potential candidates were available (the occupancy status, the presence of humidity on the dwelling, the level of temperature by French departments). Nevertheless, this condition of restriction must be uncorrelated with the different health measures but only correlated with the probability to be fuel poor. So, the type of dwelling met these requirements.

Finally, this study reinforces the idea that the eradication of the fuel poverty phenomenon is necessary and contributes to bring into focus the high public stakes induced by this phenomenon. Moreover, the increasing aspect of this phenomenon could have not negligible health implications. Indeed, the consequencies of it on the different health dimensions are significant. In this way, eradicate the fuel poverty could help reducing health inequalities and cancel a important vector of vulnerability to Poverty for individuals.

[8]The Kleibergen-Paap rank Wald F-statistic, the Sargan test and Hausman test.

6. References

Boardman, B, 2013, "Fixing fuel poverty: challenges and solutions, *Routledge*, 2013.

Bonnefoy, X., 2007, "Inadequate housing and health: an overview", *International Journal of Environment and Pollution*, Inderscience, 30, 3, 411-429.

Bornehag, C.-G.; Blomquist, G.; Gyntelberg, F.; Jarvholm, B.; Malmberg, P.; Nordvall, L.; Nielsen, A.; Pershagen, G. & Sundell, J., 2001, "Dampness in buildings and health", *Cutting the cost of cold: affordable warmth for healthier homes*, London: E&FN Spon Ltd.

Bound, J.; Jaeger, D. A. & Baker, R., 1993, "The cure can be worse than the disease: A cautionary tale regarding instrumental variables", *National Bureau of Economic Research Cambridge*, Mass., USA.

Bound, J.; Jaeger, D. A. & Baker, R. M., 1995, "Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak", *Journal of the American statistical association*, Taylor & Francis, 90, 443-450.

Brechling, V. & Smith, S., 1994, "Household energy efficiency in the UK", *Fiscal Studies*, Wiley Online Library, 15, 44-56.

Clinch, J. P. & Healy, J. D., 1999, "Dampness in buildings and health", *Indoor air*, unknown, 2001, 11, 72-86.

Collins, K., 2000, "Cold, cold housing and respiratory illnesses", *International Journal for Housing Science and Its Applications*, URAL & ASSOCIATES, 23, 203-216.

Collins, K., 1986, "Low indoor temperatures and morbidity in the elderly", *Age and Ageing*, Br Geriatrics Soc, 15, 212-220.

CRE, 2013, "Le fonctionnement des marchés de détail francais de l'électricité et du gaz naturel", Rapport 2011-2012.

Davie, G. S.; Baker, M. G.; Hales, S. & Carlin, J. B., 2007, "Trends and determinants of excess winter mortality in New Zealand: 1980 to 2000", *BMC Public Health, BioMed Central Ltd*, 7, 263.

Devalière, I.; Briant, P.; Arnault, D., 2011, "La précarité énergétique: avoir froid ou dépenser trop pour se chauffer", Insee première, 1351.

Donaldson, L., 2010, " 2009 Annual Report of the Chief Medical Offcer", Department of Health.

Dourgnon, P.; Rochereau, S; Rochereau, G., 2012, "Enquête sur la santé et la protection sociale 2010 ", *Rapport IRDES*, 1886.

European Fuel Poverty and Energy efficiency, 2009, "Diagnosis of causes and consequences of fuel poverty in Belgium, France, italy, Spain and United Kingdom", Deliverable 5.

Ezratty, V.; Duburq, A.; Emery, C.; Lambrozo, J., 2009, "Liens entre l'efficacité énergétique du logement et la santé des résidents: résultats de l'étude européenne LARES", *Environnement, risques et santé*, 8, 6, 497-506.

For Europe Copenhagen, W. H. O. R. O., 1987, "Health Impact of Low Indoor Temperatures: Report on a WHO Meeting-Copenhagen 11-14 November 1985", WHO.

Frank, D.; Neault, N.; Skalicky, A.; Cook, J.; Wilson, J.; Levenson, S.; Meyers, A.; Heeren, T.; Cutts, D.; Casey, P. and others, "Heat or eat: the Low Income Energy Assisstance Program and nutritional and health risks amoug childrenn less than 3 years of age", *Pediatrics,* Am Acad Pediatrics, 118, 5, e1293-e1302.

Green, G. & Gilbertson, J., 2008, "Warm Front better health: Health impact evaluation of the Warm Front scheme", Centre for Regional Economic and Social Research.

Healy, J. D. & Clinch, J. P., 2004, "Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures in Ireland", *Energy Policy*, Elsevier, 32, 207-220.

Healy, J. D. & Clinch, J. P., 2004, "Housing, fuel poverty, and health: a pan-European analysis", Gower Publishing, Ltd.

Hills, J., 2012, "Getting the measure of fuel poverty: final report of the Fuel Poverty Review", *Centre for Analysis of Social Exclusion*, London School of Economics and Political Science.

Howden-Chapman,.P.; Pierse, N.; Nicholls, S.; Gillespie-Bennett, J.; Viggers, H.; Cunningham, M.; Phipps, R.; Boulic, M.; Fjållstrom, P.; Free, S and others, 2008, "Effects of improved home heating on asthma in community dwelling children: randomised controlled trial", *The British Medical Journal*, BMJ Publications, 337.

Hopton, J. & Hunt, S., 1996, "The health effects of improvements to housing: a longitudinal study", *Housing studies*, Taylor and Francis, 11, 2, 271-286

Howieson, S. G. & Hogan, M., 2005, "Multiple deprivation and excess winter deaths in Scotland ", *The journal of the Royal Society for the Promotion of Health*, SAGE Publications, 125, 18-22

Huybrechs, F.; Meyer, S.; Vranken, J.; Campaert, G.; Moureau, Hé. & Storms, E., 2011, "La Précarité Energétique en Belgique ", Anvers

Hyndman, S., 1998, "Making connections between housing and health ", *Putting Health into Place: Landscape, Identity and Well-being*, Syracuse University Press, 191-207.

Idler, E. L. & Benyamini, Y., 1997, "Self-rated health and mortality: a review of twenty-seven community studies ", *Journal of health and social behavior*, JSTOR, 21-37.

Jusot, F., 2006, "The shape of the relationship between mortality and income in France", *Annales d'économie et de statistique*, JSTOR, 89–122.

Liddell, C. & Morris, C., 2010 "Fuel poverty and human health: a review of recent evidence", Cambridge university press, 38, 6, 2987–2997.

Maddala, G., 1983 "Limited-dependent and qualitative variables in econometrics", *Energy policy*, Elsevier, 3.

The Marmot review team for friends of the earth, 2011 "The health impacts of Cold and Fuel Poverty", Marmot Review Team, Department of Epidemiology & Public Health University College London,The baring fondation.

Peat, J. K.; Dickerson, J. & Li, J., 1998, "Effects of damp and mould in the home on respiratory health: a review of the literature ", *Allergy*, Wiley Online Library, 53, 120-128

Platt, S.; Mitchell, R.; Petticrew, M.; Walker, J.; Hopton, J.; Martin, C.; Corbett, J. & Hope, S., 2007, "The Scottish Executive Central Heating Programme: Assessing Impacts on Health ", *Scottish Executive*, Social Research.

Sen, A., 1999, "Commodities and capabilities", *OUP Catalgue*, Oxford University Press.

Shortt, N. & Rugkåsa, J., 2007, "Fuel poverty and ill health Northern Ireland: Results from a housing intervention", *Health & place*, Elsevier, 13, 1, 99-110.

Waddams, C.; Brazier, K.; Wang, W., 2012, "Objective and subjective measures of fuel poverty", *Energy policy*, Elsevier, 49, 33-39.

Whyley, C. & Callender, C., 1997, "Fuel poverty in Europe: evidence from the European household panel survey ", *Policy Studies Institute*, London

Wilkinson, P.; Landon, M.; Armstrong, B.; Stevenson, S.; Pattenden, S.; McKee, M. & Fletcher, T., 2001, "Cold Comfort: The social and environmental determinants of excess winter deaths in England, 1986-96 ", Policy press Bristol

7. Appendix 1: Instrumental estimation

Variables	Poor self-assessed health	Long-standing disease	Poor mental health
	Marginal effect (sd)	Marginal effect (sd)	Marginal effect (sd)
Age group, years			
[18;25]	REF	REF	REF
[25;36]	0.01*** (0.02)	0.03 (0.02)	0.01 (0.03)
[37;47]	0.17*** (0.02)	0.06*** (0.02)	0.08** (0.02)
[48;58]	0.28*** (0.02)	0.17*** (0.02)	0.11*** (0.03)
[59;69]	0.41*** (0.03)	0.30*** (0.02)	0.07** (0.03)
[70;79]	0.55*** (0.03)	0.48*** (0.03)	0.12*** (0.03)
>80	0.60*** (0.04)	0.52*** (0.04)	0.08** (0.04)
Gender			
Male	REF	REF	REF
Female	0.01 (0.01)	-0.07*** (0.01)	0.06*** (0.01)
Net income			
1st quintile	REF	REF	REF
2nd quintile	-0.02 (0.03)	-0.03 (0.03)	-0.01 (0.03)
3rd quintile	-0.06 (0.04)	-0.02 (0.03)	-0.03 (0.04)
4th quintile	-0.04 (0.04)	-0.02 (0.03)	-0.02 (0.04)
5th quintile	-0.09** (0.04)	-0.01 (0.04)	-0.03 (0.04)
Unknown	-0.03 (0.04)	-0.02 (0.03)	-0.002 (0.04)
Level of education			
No education	0.08*** (0.03)	-0.001 (0.02)	-0.01 (0.03)
Lower secondary	0.04** (0.02)	-0.01 (0.02)	-0.02 (0.02)
Higher secondary	REF	REF	REF
Post-secondary	-0.05** (0.02)	-0.05*** (0.02)	-0.07*** (0.02)
Occupational status			
Farmers	-0.04 (0.03)	-0.002 (0.03)	-0.02 (0.03)
Self-employed	-0.04 (0.03)	-0.003 (0.02)	-0.004 (0.02)
Skilled white collar occupations	REF	REF	REF
Intermediate profession	0.03* (0.02)	0.01 (0.02)	0.04** (0.02)
Clerical employees	0.04 (0.03)	0.02 (0.02)	0.02 (0.03)
Trade and Craft employees	0.02 (0.03)	0.04 (0.03)	0.05 (0.03)
Skilled manual workers	0.03 (0.02)	0.03 (0.02)	0.01 (0.02)
Unskilled manual workers	0.03 (0.03)	0.01 (0.02)	-0.03 (0.03)
Inactive	0.08 (0.05)	0.01 (0.05)	0.06 (0.05)
Fuel poverty			
No	REF	REF	REF
Yes	0.47** (0.22)	0.44** (0.19)	0.56** (0.21))
Instruments' strenght	12.22	12.22	12.22
Sargan test	0.366	0.69	0.428
Hausmann test	2.78*	4.691**	4.96**

*p<0,1, ***, p<0,05, ***p<0,01.