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Fuel poverty and health condition: a panel data analysis

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Medical cost related to poor housing in France (Eurofound, 2016) :

- Direct : **930 millions euros**
- Indirect : **20,3 billions euros**

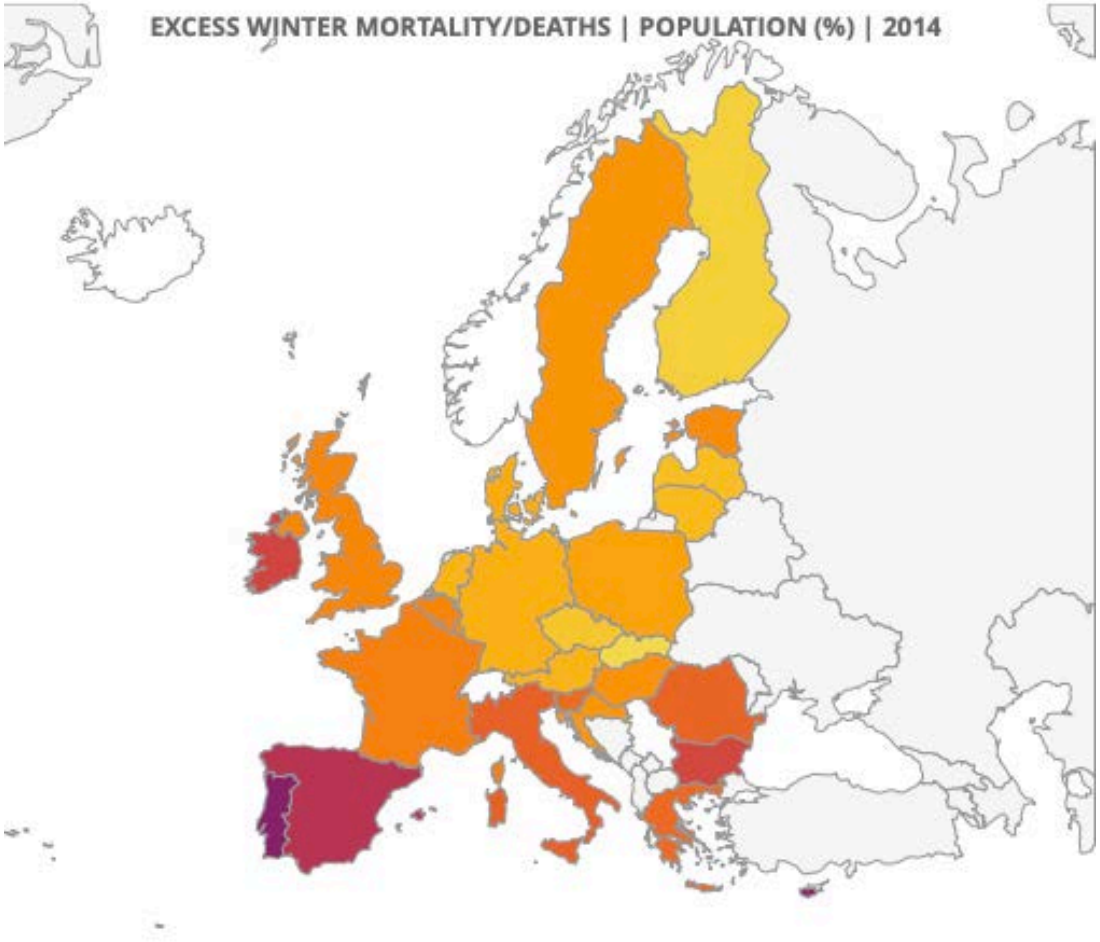
Poor housing conditions & health status

- Cold, damp housing, mold ➔ health (Peat et al., 1998; Platt et al., 1989; Hills, 2012; Maidment et al., 2014)
- Respiratory tract infections and coronary problems (National Heart Forum, 2003)
- Asthma, coughing and wheezing (Dales et al., 1991; Peat et al., 1998)
- Stress and depression (Shortt and Rugkasa, 2007)

Table 7: Summary of costs and benefits to society of the six inadequacies

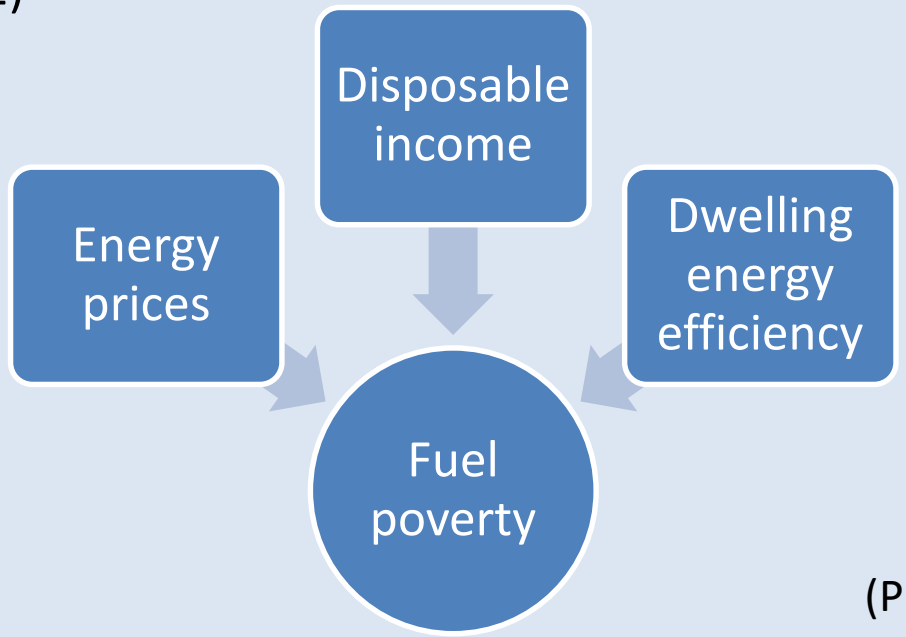
Country	Dwelling stock	Proportion of dwellings with three or more inadequacies out of six	Average unit cost of repair (€)	Total cost of repair (€ thousands)	Annual direct medical savings (in terms of healthcare provision) (€ thousands)	Annual indirect medical savings (€ thousands)	Annual total societal medical savings (€ thousands)	Payback (years)
SE	4,633,678	4.7%	16,759	11,400,835	24,070	453,533	477,603	23.87
FI	2,906,000	4.0%	8,180	3,290,242	25,204	505,377	530,581	6.20
AT	4,441,000	4.2%	9,926	3,460,576	29,484	603,007	632,491	5.47
LU	208,000	5.4%	8,815	301,650	2,627	53,275	55,902	5.40
DK	2,762,444	2.3%	7,123	2,297,609	27,062	551,947	579,009	3.97
LV	1,018,000	30.1%	5,439	4,421,745	68,099	1,385,795	1,453,894	3.04
NL	7,200,000	5.5%	4,450	5,180,915	84,262	1,703,448	1,787,710	2.90
DE	40,545,300	6.6%	9,066	52,652,715	943,858	19,849,699	20,793,557	2.53
BE	5,203,400	11.3%	5,832	6,590,226	133,221	2,762,613	2,895,834	2.28
FR	28,077,000	12.0%	6,586	44,583,984	930,427	19,444,533	20,374,960	2.19
EE	649,700	21.2%	5,370	2,437,639	54,621	1,133,034	1,187,655	2.05
RO	8,329,000	19.8%	3,928	22,093,431	514,865	10,497,212	11,012,077	2.01
LT	1,389,000	15.4%	5,175	4,530,039	121,346	2,538,965	2,660,311	1.70
SI	857,000	4.7%	2,755	353,949	10,001	203,628	213,629	1.66
CZ	4,101,635	8.9%	4,344	2,824,092	82,114	1,699,237	1,781,351	1.59
UK	27,767,000	11.0%	5,567	38,793,613	1,209,984	25,444,741	26,654,725	1.46
SK	1,994,900	7.2%	4,977	1,926,007	69,339	1,460,844	1,530,183	1.26
IT	28,863,000	11.2%	3,640	20,446,841	793,741	16,709,084	17,502,825	1.17
BG	3,918,200	13.4%	3,795	6,462,532	254,676	5,323,439	5,578,115	1.16
PL	13,853,000	19.1%	4,883	29,441,165	1,208,896	25,548,628	26,757,524	1.10
HR	1,923,522	10.9%	2,565	1,192,817	51,090	1,059,377	1,110,467	1.07
IE	2,019,000	6.5%	4,710	1,244,640	55,843	1,179,260	1,235,103	1.01
HU	4,400,000	14.3%	3,035	4,806,011	228,544	4,798,360	5,026,904	0.96
EL	6,384,000	15.7%	2,875	5,727,292	402,415	8,542,901	8,945,316	0.64
ES	25,208,000	6.3%	4,116	13,890,859	1,004,494	21,345,457	22,349,951	0.62
MT	223,900	7.9%	2,816	172,310	13,555	287,431	300,986	0.57
PT	5,878,700	9.9%	3,236	4,648,127	437,337	9,289,699	9,727,036	0.48
CY	433,212	15.0%	3,348	303,174	30,579	650,227	680,806	0.45
EU28	**235,187,591**	**10.6%**	**5,127**	**295,475,035**	**8,811,754**	**185,024,751**	**193,836,505**	**1.52**

Note: The table is ordered by first year return on investment.



A ratio between average daily deaths in December–March versus other months

Fuel poverty : “having difficulty in heating their home because of the inadequacy of their resources and housing conditions” (Boardman, 1991, 2010; Hills, 2011, 2012)



(PDA, 2017)

- Europe : 50 to 160 millions fuel poor individuals (Effort energy rate > 10%)
- France : 3,5 millions fuel poor households

Economic and epidemiologic literature

- Nexus between air pollution and health (Cotoyannis and Jones, 2004; Neidell, 2004)
- Relationship between socio-economic characteristics and health (Lynch et al., 1997; Benzeval and Judge, 2001; Cutler and Lleras-Muney, 2017)

➔Very scarce literature on the link between fuel poverty and health

Case studies and experiments

- Impact of retrofitting plans, housing improvements and/or energy saving programs on health (Chapman et al., 2009; Howden-Chapman et al., 2007; , Shortt and Rugkåsa, 2007 ; Loyd et al., 2008, Sorrell, Dimitropoulos, & Sommerville, 2009)
- In a given region at a particular point in time.

Nonexperimental studies

- Link between fuel poverty and health (Chaton and Lacroix, 2015; Liddell and Morris, 2010)
- Cross sectional data : ignore the effects of health trajectories and climate hazards

Contribution of the paper

- Identifying a precise, direct and mid-term link between fuel poverty and health
- Does being fuel poor increases the risk of being in poor health?

Challenges

- Intermediate objective of public policy : tackling fuel poverty
- Final objective of public policy : improving public health

Methodology

- Dynamic probit models to test the influence of fuel poverty on health
- Control for state dependency of health
- Correction of endogeneity : unobserved heterogeneity affecting simultaneously fuel poverty and health

Database from the EU-SILC (Statistics on Income and Living Conditions)

- Wide range of variables (housing, socio-demographic, health)
  - Allows to evaluate self-reported health
  - Allows to create fuel poverty indicators (10% and LIHC)
- 239,477 observations
- 2008-2016

But necessity to merge with:

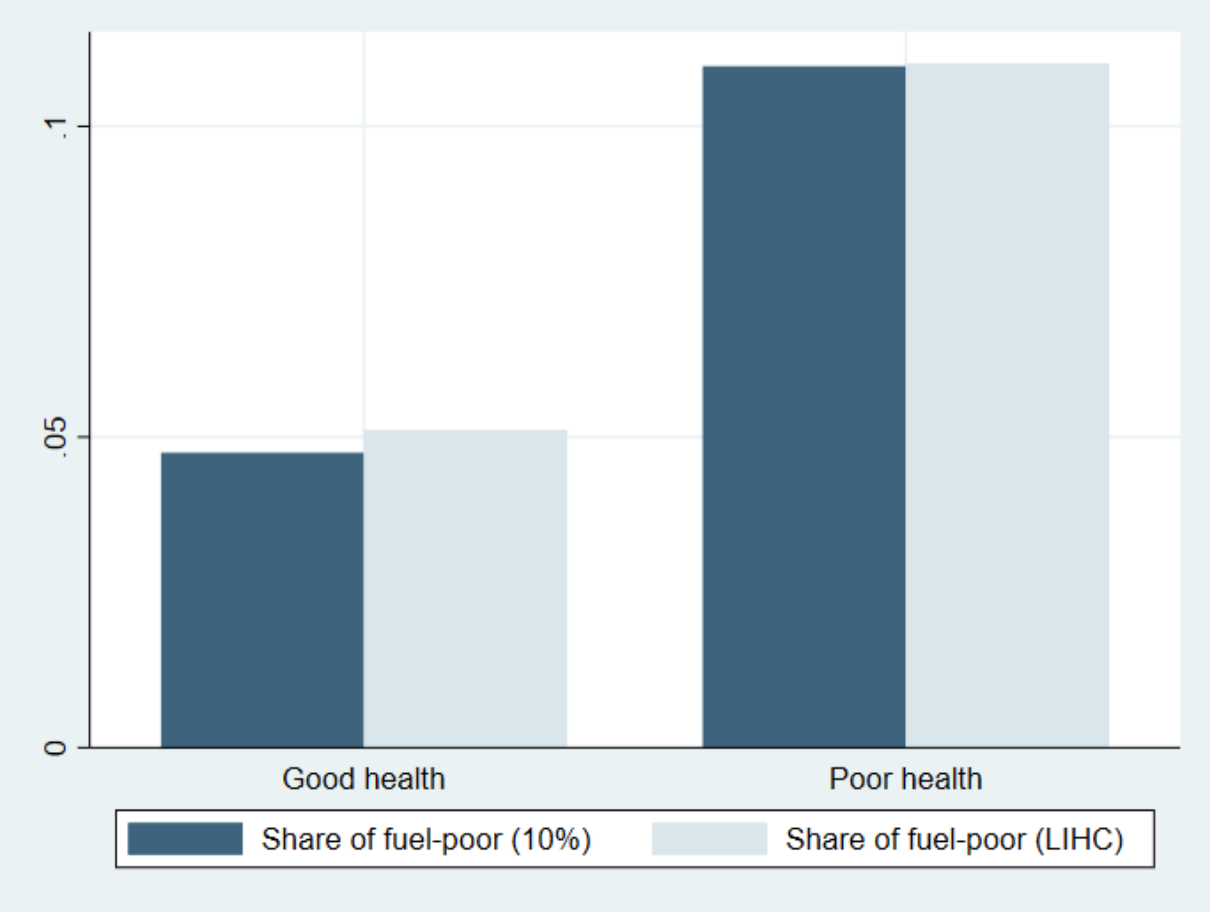
- Data from the French Atlas of Medical Demography for medical density
- PEGASE database for energy prices
- Climate variables from Meteo France

- **8.3% :** in poor health
- **37.3%** : declared a chronic disease
- **41%** : poor health ➔ improvement

- **4.78%** : fuel poor 10%
- **5.74%** : fuel poor LIHC

- **Statistical dependency** fuel poverty/bad health (Chi2 : Pr < 0,01)

Health status according to fuel poverty definition



Dependent Variables: health status

1/ self-reported health

How is your overall health?

1. Very good
2. Good
3. Fairly good

→ Good health = 0

4. Bad
5. Very bad

→ Poor health = 1

2/ long term sickness declared (robustness check)

Do you have a chronic or long-term illness or health problem?

No = 0

Yes = 1

Fuel Poverty Variables

10% indicator (Boardman, 1991) :

An individual is considered fuel poor if its energy expenditure is over 10% of its disposable income

$$Energy\ income\ ratio = \frac{energy\ expenditures}{Income}$$

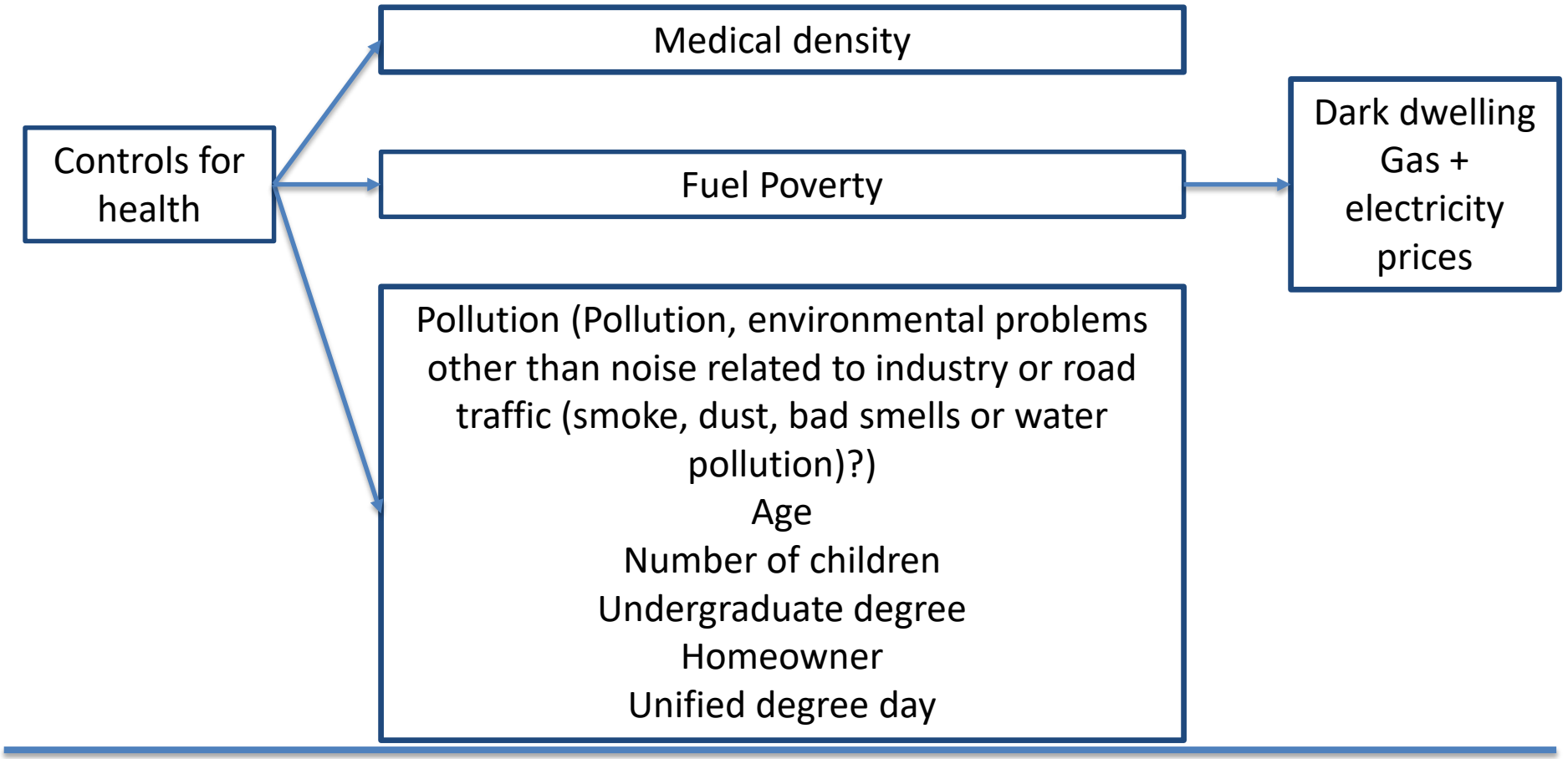
LIHC indicator (Hills, 2011, 2012) :

An individual is considered fuel poor if its energy expenditure is over the median of the population, and its disposable income is below a poverty threshold

$$Equivalized\ disposal\ income\ \leq 60\%\ (Equivalized\ median\ disposal\ income)$$
$$Equivalized\ fuel\ expenditures\ \geq\ Required\ national\ median\ fuel\ expenditures$$

1- To be fuel poor
0- Otherwise

Other control Variables



Model

With $$h_{it}^{*} = \delta y_{it-1} + \alpha X_{it} + \beta W_{it} + \gamma \widehat{FP_{it}} + \sigma E[u_i|y_{i0}] + u_i^{*} + v_{it}$$

$$FP_{it}^{*} = \theta_1 X_{it} + \theta_2 W_{it} + \theta_3 Gas\_p_{it} + \theta_4 Elec\_p_{it} + \theta_5 GasElec\_p_{it} + \theta_6 D_{it} + u_i' + v_{it}'$$

And $$h_{i0}{}^{*} = \gamma Z_{i0} + \theta u_i + \varepsilon_i$$

With :

- $\boldsymbol{h_{it}^{*}}$ as the self reported health status, 1 for poor health and 0 for good health
- $\boldsymbol{h_{it-1}}$ as the lagged health status,
- $\boldsymbol{y_{i0}}^{*}$ health status in the beginning of the period
- $\widehat{FP}$ the predicted value of fuel poverty
- $\boldsymbol{X_{it}}$ vector of observed variables (age, level of education, homeowner, etc.)
- $\mathbf{W_{it}}$ Vector of living conditions (air pollution and climate)
- $\boldsymbol{E[u_i|y_{i0}]}$ Mill's ratio
- Z_{i0} including exogenous attributes affecting health status in the first period

Estimated results for controlling initial conditions

	Poor health			Chronic disease		
	Coef.	St.Err.	Sig	Coef.	St.Err.	Sig
Fuel poverty 10%	0.246	0.032	***	0.170	0.027	***
Other control variables	Yes			Yes		
Medical density	-0.001	0.000	***	-0.001	0.000	***
Constant	-1.882	0.428	***	-0.752	0.306	**
Observations		45918			45921	
Pseudo R-squared		0.117			0.115	
Chi-square		3249.936			6953.236	
Percent correctly predicted	90.9%			69.5%		
Wald test	chi2(1) = 7.71 p= 0.0055			chi2(1) = 62.54 p= 0.0000		
LR test	chi2(1) = 7.74 p= 0.0054			chi2(1) = 62.71 p= 0.0000		

**** p<0.01, ** p<0.05, * p<0.1- Bootstrap 5000 replications*

NB: The medical density i.e. the ratio of physicians (practitioners or specialists) to the population in a geographic area, is used as an exogenous instrument (Z_{i0}) to explain the health status at time t_0 (Chaix, Veugelers, Boëlle, & Chauvin, 2005; Macinko, Starfield, & Shi, 2003)

Estimated results for binary probit regression on fuel poverty

	Fuel poverty 10%			Fuel poverty LIHC		
	Coef.	St.Err.	p value	Coef.	St.Err.	p value
Electricity price	1.821	0.328	***	0.938	0.293	***
Gas price	1.860	1.024	*	5.793	0.906	***
Interaction parameter	0.997	5.949		-19.134	5.285	***
Dark dwelling	0.308	0.030	***	0.185	0.027	***
Other control variables	Yes			Yes		
Constant	-7.877	0.388	***	-4.527	0.339	***
Observations		219,404	***			
Wald test	chi2(4) = 247.62 p= 0.0000			chi2(4) = 198.44 p= 0.0000		
LR test	chi2(3) = 120.62 p= 0.0000			chi2(3) = 143.45 p= 0.0000		
Percent correctly predicted	87.2%			86.7%		

Sargan-Hansen statistic 5.550 Chi-sq(3) P-value = 0.1357

*** *p<0.01*, ** *p<0.05*, * *p<0.1* - Bootstrap 5000 replications

	Initial conditions	With only state dependence	*With state dependence and endogeneity*
To be in bad health (in lag)		1.611***	1.609***
		(0.0328)	(0.0328)
Fuel poor 10%	0.252***	0.198***	
	(0.0332)	(0.0630)	
Number of children	0.0824***	0.0353***	0.0188**
	(0.0127)	(0.0118)	(0.00857)
Unified Degree Day (log)	0.0527	0.0306	-0.0280
	(0.0466)	(0.0361)	(0.0371)
Age	0.0529***	0.0216***	0.00139
	(0.00100)	(0.00651)	(0.00272)
Pollution problem	0.186***	0.142***	0.0202
	(0.0247)	(0.0515)	(0.0273)
Undergraduate diploma	-0.365***	-0.186***	0.0287
	(0.0469)	(0.0718)	(0.0397)
Homeowner	-0.642***	-0.281***	-0.0208
	(0.0274)	(0.0915)	(0.0392)
Mills		-0.0219	-0.836***
		(0.293)	(0.119)
Predicted Fuel poor 10%			21.39***
			(3.357)
Constant	-5.568***	-3.068***	-0.242
	(0.362)	(0.828)	(0.431)
Observations	173,88	122,362	122,347

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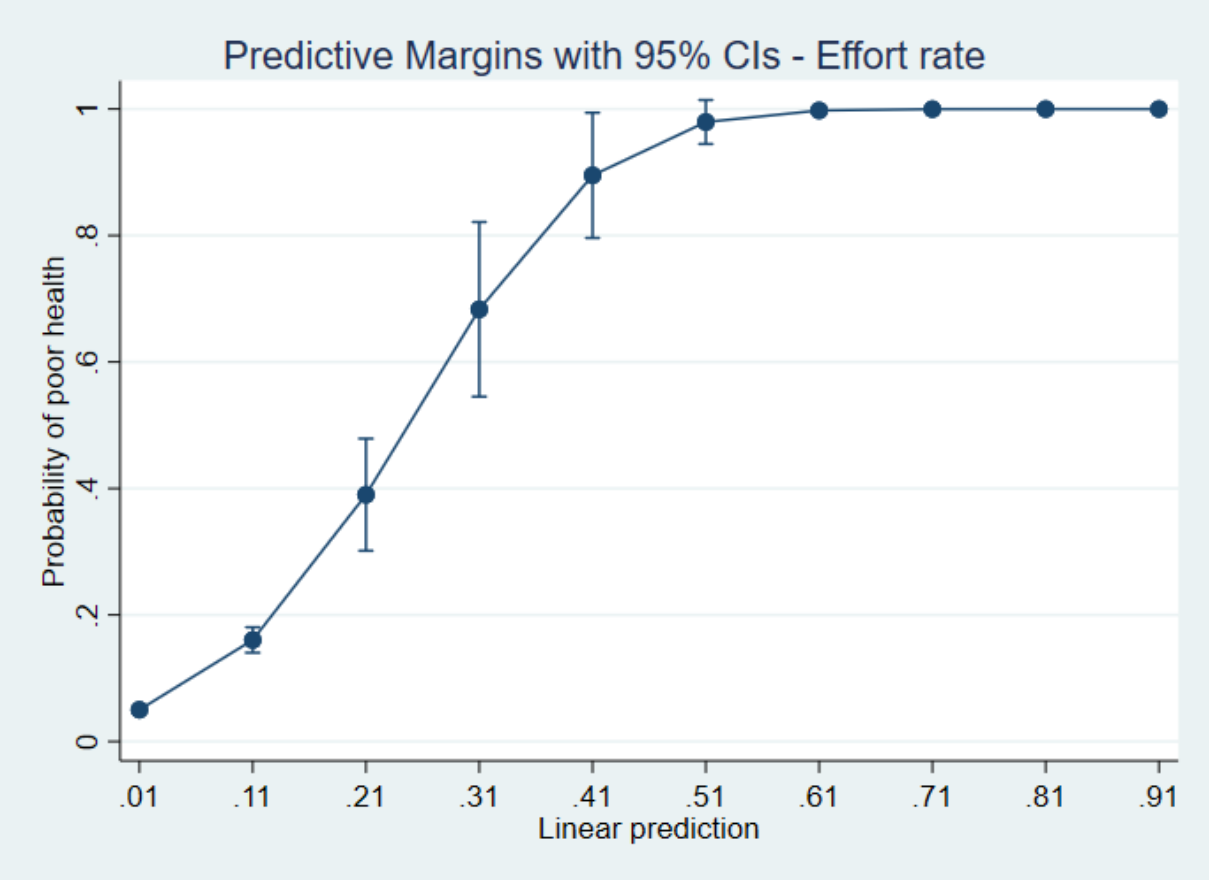
Predictive margins for effort rate – linear prediction



In the final model, being fuel poor increases the risk of bad health by a factor 7 if previously in bad health, and 2 if previously in good health.

The risk of declaring a chronic disease increases by a factor of 4.38 for a healthy person

- **There is a clear impact of fuel poverty on self-reported health**
- Nature of the health variable as well as its trajectory are important
- Neglecting FP's endogeneity = **significant underestimation** of its impact on health
- **Spillover effect** in public policies (Green et Gilbertson, 2008)
- Need for **anticipation** from energy-transition policies to avoid hidden economic and social costs (Penot-Antoniou, 2010)

Thank you for your attention !

Marginal effect of fuel poverty (LIHC) on poor health

	LIHC	
Model 1	0.02***	
	Good health in t-1	Poor health in t-1
Model 2	0.02***	0.09***
Model 3	2.30***	8.89***
Model 4	4.38***	5.62***

In the final model, being fuel poor increases the risk of bad health by a factor 9 if previously in bad health, and 2 if previously in good health.

Modèles	Equations
Spécification 1 (Probit, RE)	$y_{it}^* = \alpha P_{it} + X_{it}\beta + u_i + v_{it}$ $i = 1, \dots, N \; et \; t = 1, \dots, T$ $y_{it} = 1$ if $y_{it}^* > 0$ et 0 sinon
Spécification 2 (Probit dynamique avec CI, RE)	$y_{i0}{}^* = \gamma Z_{i0} + \theta u_i + \varepsilon_i$ (Orme, 1996; Contoyannis *et al.*, 2004; Carro et Traferri, 2014). $\boldsymbol{y_{it}^* = \delta y_{it-1} + \alpha P_{it} + X_{it}\beta + \sigma E[u_i \mid y_{i0}] + u_i^* + v_{it}}$
Spécification 3 (Probit dyn. avec CI et PE, RE)	$P_{it}^* = X_{it}\beta + Gas\_p_{it} + Elec\_p_{it} + GasElec\_p_{it} + D_{it} + u_i' + v_{it}'$ Avec $p_{it} = 1$ si $p_{it}^* > 0$ et 0 sinon (Heckman, 1979; Charlier et Kahouli, 2019). $\boldsymbol{y_{it}^* = \delta y_{it-1} + \alpha \widehat{P_{it}} + X_{it}\beta + \sigma E[u_i \mid y_{i0}] + u_i^* + v_{it}}$ (Churchill et Smith, 2018)
Spécification 4 (Maladie chronique)	$\boldsymbol{w_{it}^* = \delta w_{it-1} + \alpha \widehat{P_{it}} + X_{it}\beta + \sigma E[u_i \mid w_{i0}] + u_i^* + v_{it}}$

Descriptive statistics (1/3)

Variable		Mean	Std Dev	Min	Max	Observations
Poor health	overall	0.084	0.277	0.000	1.000	N = 187817
	between		0.246	0.000	1.000	n = 53430
	within		0.166	-0.805	0.972	
Chronic disease	overall	0.372	0.483	0.000	1.000	N = 187803
	between		0.423	0.000	1.000	n = 53438
	within		0.264	-0.516	1.261	
Fuel poverty 10%	overall	0.048	0.213	0.000	1.000	N = 239477
	between		0.178	0.000	1.000	n = 67030
	within		0.137	-0.841	0.937	
Fuel poverty LIHC	overall	0.057	0.233	0.000	1.000	N = 239477
	between		0.197	0.000	1.000	n = 67030
	within		0.153	-0.832	0.946	

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Descriptive statistics (2/3)

Variable		Mean	Std Dev	Min	Max	Observations
Pollution	overall	0.121	0.326	0.000	1.000	N = 239477
	between		0.273	0.000	1.000	n = 67030
	within		0.213	-0.768	1.010	
Number of children	overall	1.282	1.298	0.000	11.000	N = 239475
	between		1.290	0.000	11.000	n = 67030
	within		0.297	-2.718	4.949	
Age	overall	40.507	23.586	0.000	102.000	N = 239475
	between		23.840	0.000	101.000	n = 67030
	within		1.565	13.507	54.507	
Undergraduate degree	overall	0.082	0.274	0.000	1.000	N = 239477
	between		0.257	0.000	1.000	n = 67030
	within		0.099	-0.807	0.971	
Homeowner	overall	0.676	0.468	0.000	1.000	N = 239477
	between		0.463	0.000	1.000	n = 67030
	within		0.138	-0.213	1.564	
Unified degree days	overall	1928	355	1054	2683	N = 219431
	between		297	1054	2683	n = 61324
	within		214	906	2904	

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Descriptive statistics (3/3)

Variable		Mean	Std Dev	Min	Max	Observations
Medical density	overall	302.65	39.64	243.70	403.00	N = 239477
	between		38.77	243.70	403.00	n = 67030
	within		10.50	203.73	392.98	
Dark dwelling	overall	0.077	0.267	0.000	1.000	N = 239452
	between		0.232	0.000	1.000	n = 67026
	within		0.166	-0.812	0.966	
Electricity price	overall	0.162	0.035	0.000	0.200	N = 239477
	between		0.028	0.000	0.200	n = 67030
	within		0.025	0.007	0.329	
Gas price	overall	0.051	0.037	0.000	0.130	N = 239477
	between		0.033	0.000	0.130	n = 67030
	within		0.021	-0.054	0.165	

	Fuel poverty 10%			Fuel poverty LIHC		
	Coef.	St.Err.	p value	Coef.	St.Err.	p value
Number of Children	-0.156	0.012	***	0.049	0.010	***
UDD (log)	0.511	0.050	***	0.183	0.044	***
Age	0.014	0.001	***	0.005	0.001	***
Pollution problem	-0.075	0.028	***	-0.028	0.024	
Undergraduate degree	-0.446	0.047	***	-0.498	0.044	***
Homeowner	-0.020	0.026		-0.417	0.022	***
Dark dwelling	0.308	0.030	***	0.185	0.027	***
Electricity price	1.821	0.328	***	0.938	0.293	***
Gas price	1.860	1.024	*	5.793	0.906	***
Interaction parameter	0.997	5.949		-19.134	5.285	***
Constant	-7.877	0.388	***	-4.527	0.339	***
Observations		219,404	***			
Wald test		chi2(4) = 247.62 p=	0.0000		chi2(4) = 198.44 p=	0.0000
LR test		chi2(3) = 120.62 p=	0.0000		chi2(3) = 143.45 p=	0.0000
Percent correctly predicted		87.2%			86.7%	

	Model 1	*Model 2*	*Model 3*	*Model 4*
To be in bad health (in lag)		1.611***	1.609***	
		(0.0328)	(0.0328)	
Fuel poor 10%	0.252***	0.198***		
	(0.0332)	(0.0630)		
Number of children	0.0824***	0.0353***	0.0188**	0.00461
	(0.0127)	(0.0118)	(0.00857)	(0.00607)
Unified Degree Day (log)	0.0527	0.0306	-0.0280	-0.0823***
	(0.0466)	(0.0361)	(0.0371)	(0.0252)
Age	0.0529***	0.0216***	0.00139	-0.000319
	(0.00100)	(0.00651)	(0.00272)	(0.00190)
Pollution problem	0.186***	0.142***	0.0202	0.0708***
	(0.0247)	(0.0515)	(0.0273)	(0.0179)
Undergraduate diploma	-0.365***	-0.186***	0.0287	0.0160
	(0.0469)	(0.0718)	(0.0397)	(0.0176)
Homeowner	-0.642***	-0.281***	-0.0208	0.00102
	(0.0274)	(0.0915)	(0.0392)	(0.0158)
Mills		-0.0219	-0.836***	-0.895***
		(0.293)	(0.119)	(0.0994)
Predicted Fuel poor 10%			21.39***	25.15***
			(3.357)	(2.964)
Existence of a chronic disease (Lag)				1.548***
				(0.0210)
Constant	-5.568***	-3.068***	-0.242	0.526*
	(0.362)	(0.828)	(0.431)	(0.286)
Observations	173,88	122,362	122,347	122,32
Number of idind	49,422	37,855	37,855	37,861

Results with predicted effort rate

Poor health (lag)	1.613***
	(0.0329)
Predicted effort rate	5.505***
	(1.522)
Number of children	0.0158*
	(0.00936)
Unified Degree Days (log)	-0.0245
	(0.0408)
Age	0.00172
	(0.00370)
Pollution problem	0.0203
	(0.0334)
Undergraduate degree	0.0514
	(0.0482)
Homeowner	-0.0560
	(0.0537)
Mills' ratio	-0.853***
	(0.165)
Panel-level variance (log)	-1.727***
	(0.132)
Constant	-0.433
	(0.526)
Observations	122,345
Number of individuals	37,855

*** *p<0.01*, ** *p<0.05*, * *p<0.1* - Bootstrap 5000 replications