



Impact of Residential Energy Retrofit on Energy Consumption and Carbon Emissions : An ex post analysis on a French panel of households

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Motivation

Global cost curve for greenhouse gas abatement measures beyond 'business as usual'; greenhouse gases measured in GtCO₂e¹

■ Approximate abatement required beyond 'business as usual,' 2030



GHG mitigation cost curve, McKinsey

It illustrates the « energy efficiency gap » assumption (Hirst & Brown, 1990)

Building Insulation is the most profitable operation according to McKinsey

Motivation

- EU directive : reducing by 32,5% the 2007 energy consumption by 2030 ;
 - In France several tools were implemented as energy efficiency public support policies.
 - Amongst them, an original scheme which is a mix of a tax and a grant, named « CEE » scheme, represents more than 3 billions € per year.
- Is the « energy efficiency gap » assumption verified ?
- Have Energy public grant policies a real impact ?
- Are these policies efficient to address climate change ?

Main results

We found that a 10,000 € **investment in energy retrofit**

- reduces the annual energy bill by **7.4% or 90€**
 - reduces the annual household carbon footprint by **13.4% or 400 kgCO₂**. = 2500 car-km saved (25% of average distance travelled by a French driver).
- **Energy retrofit sounds less efficient than McKinsey claims it to be !**

The profitability calculation remains to be done. Actually, there are two kinds of residential energy investments : equipment replacement and efficiency upgrading.

Literature

- Fowlie, Greenstone & Wolfram (2018) pointed out the overestimation of energy retrofit impact on residential consumption in Illinois, USA using an RCT ;
- UFE (2017) with an ex-ante analysis underlined the non-profitability of residential energy retrofit in France ;
- Raynaud (2014) did an ex-post analysis of the residential energy retrofit impact on consumption using small cross-section data in France ;
- **→ We did an ex-post analysis in France of energy retrofit impact on energy bills and carbon footprint using a 10,000 households panel data between 2000-2013.**

Outline

1. Data

- 2. Identification, Estimation and Results
- 3. Discussion and Further Steps

Data

- The dataset used is from « l'enquête Maîtrise de l'Energie « 10 000 ménages » » conducted by TNS-SOFRES for the ADEME ;

It is a French households panel :

- Interviewed each year from 2000 to 2013 about their energy behavior ;
 - 7100 to 8900 households each year ;
 - Each household is in average 6 years in the panel
- **Dependent variable** : residential energy bill & carbon footprint;
- **Variable of interest** : cumulative capital invested in energy retrofit.

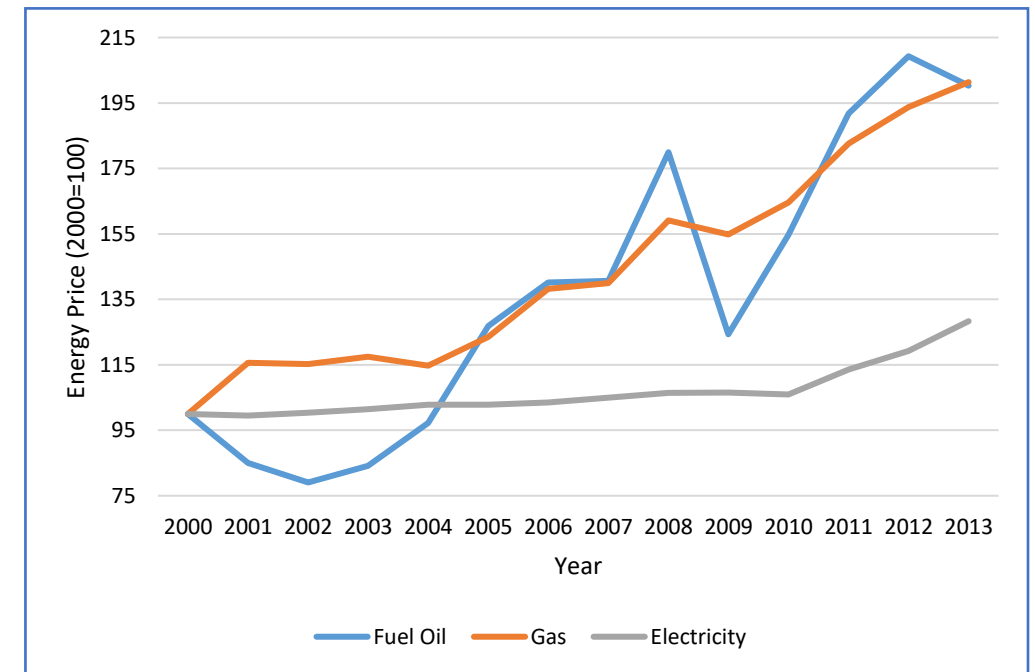
It enables the calculation of energy spending and carbon footprint before & after energy retrofitting

Energy bill & retrofit operation

- Each year 13,1% of households have energy-related operations in their home

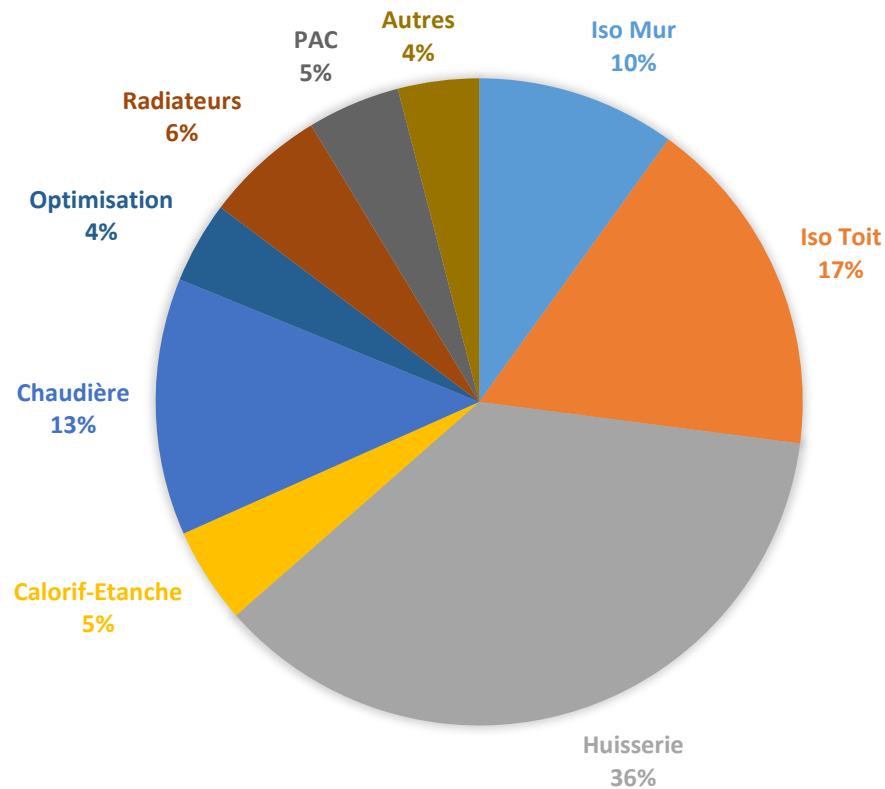
Variables	Mean	St-Error
Average operation cost	4239 €	4601 €
Average energy bill	1296 €	640 €
% electricity	55%	30%
% gas	27%	31%
% fuel oil	9%	23%

Residential energy prices evolution in France in the period

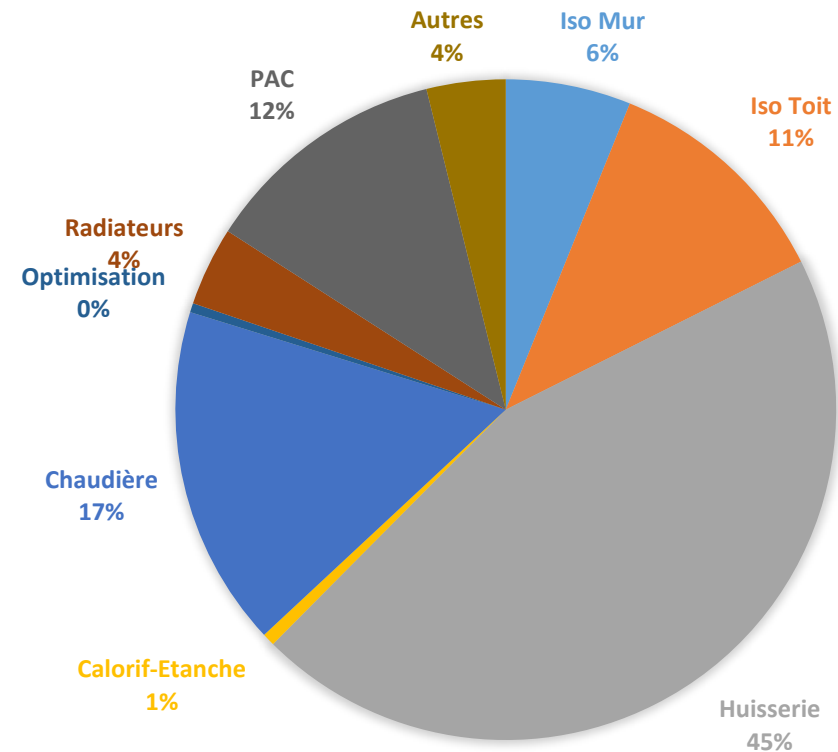


Type of investments

Type of Actions Shares in Numbers



Type of Actions Shares in Capital



→ Mainly insulation (as McKinsey curve advices) and windows operations (said inefficient)

Plan

1. Data

2. Identification, estimation and results

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Regression equation

- We use a fixed effect log-linear regression with instrumental variable
- We estimate the impact α of invested capital in energy retrofit operations on total energy bill with this equation:

$$\ln(Y_{it}) = \alpha * K_{it-1} + \beta * X_{it} + \delta_{r(i)t} + \gamma_{h(i)t} + \mu_i + \varepsilon_{it}$$

Y_{it} : household i energy bill or carbon footprint, year t ;

K_{it-1} : cumulative capital invested in energy retrofit operations by household i , year $t-1$;

X_{it} : control vector for the household i , year t ;

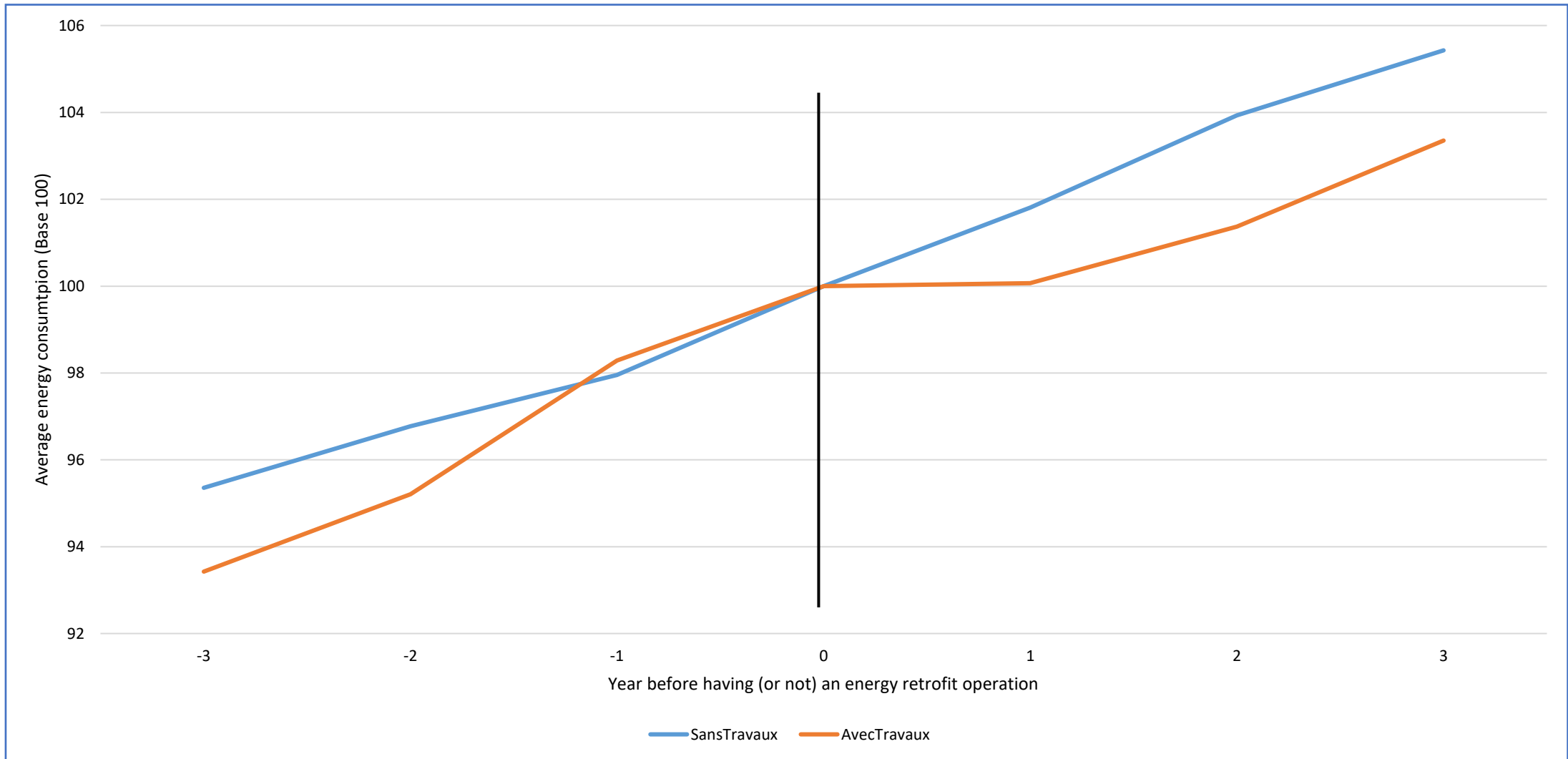
$\delta_{r(i)t}$: FE vector for the region $r(i)$, year t ;

$\gamma_{h(i)t}$: FE vector for the main heating source $h(i)$, year t ;

μ_i : FE vector for the household i ;

ε_{it} : error term for household i , year t .

Energy consumption trends before & after retrofitting



Endogeneity

- Our study includes a selection bias : people having energy retrofit are self-selected.
- Decision to have energy retrofit operation might be highly correlated with changes in energy consumption behavior :
 - Positively correlated with energy consumption : new baby or retirement.
 - Negatively correlated with energy consumption : people saw a documentary about global warming.
- We used the knowledge of public support policies as an IV to estimate the capital invested in energy renovation. It treats the positive correlation bias.

Detailed Results

VARIABLES	(1) Log (Energy Bill)	(2) IV Log (Energy Bill)	(3) Log(Carbon)
Cumulative capital in energy retrofit	-0.00200**	-0.00739**	-0.0134***
	(0.000822)	(0.00314)	(0.00462)
House surface	0.0468*** (0.00547)	0.0473*** (0.00548)	0.0650*** (0.00742)
Household size	0.0511*** (0.00645)	0.0508*** (0.00646)	0.0676*** (0.00943)
Underidentification KPW stats		280.12	
Weak KPW stats		172.83	
Observations	33,332	33,332	41,368
R-squared	0.108	0.173	0.108
Number of households	9,092	9,092	10,799
RegionYear FE	YES	YES	YES
RevenueFE	YES	YES	YES
MainHeatingSourceYear FE	YES	YES	YES

Main results

We found that a 10,000 € **investment in energy retrofit**

- reduces the annual energy bill by **7.4% or 90€**
- reduces the annual household carbon footprint by **13.4% or 400 kgCO₂**. = 2500 car-km saved (25% of average distance travelled by a French driver).

→ **Energy retrofit sounds less efficient than McKinsey claims it to be !**

→ **ADEME calculation** : windows related operations, achieve 250€ of energy bill reduction for 10000€ invested !

Discussion (1)

- The impact on carbon footprint is higher than on energy bill :
 - Bills have a fixed part ;
 - Households with fuel oil or gas as heating source renovate more than those using electricity;
 - Post-renovation heating source switching from fuel oil to electricity/gas.
- Why do households invest in non-profitable operations ?
 - Only 28% of households having retrofit operations explained they were motivated by economics reasons
 - In contrast, 29% of households they were looking for an increased comfort which might cause a rebound effect.
- Windows-related retrofit operations represents 30% of our dataset mix. They are said very ineffective and they are less popular nowadays.

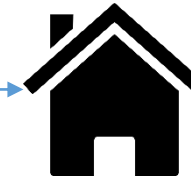
External validity ?

2000-2013



Same houses ?

2020



Same households ?



Same operations ?



Plan

1. White certificates scheme and data
2. Identification, estimation and results
- 3. Conclusion and further steps**

Policy implications

- We do not mean energy retrofit is useless, **our study does not measure improved comfort for households !**
- But energy retrofit is not very efficient in order to address energy efficiency targets and climate change issues.

We strongly advocate :

- The achievement of more energy efficiency ex-post impact analysis in a context where most of the energy retrofit public support policies are ex-ante based ones ;
- The focusing on ex-ante advices for relevant households retrofit decisions and ex-post quality checks of the operations done.

Further steps

In this paper :

- Data cleaning in order to solve the 2003 & 2007 problems ;
- Robustness checks ;

In this field during my PhD :

- Theoretical analysis of public support policies for energy efficiency ;
- Focus on the main public tool in France, the CEE « scheme » which mixes tax & grant and involves several market problematics.

Questions ?

Data

- **Energy relative data** : residential bill in € for each energy source, dummy for the heating main source ;
- **Energy retrofit data** : € yearly invested in energy renovation projects, 21 categories of project, dummy for benefiting from public policy ;
- **Personal data** : house/flat, ownership, living space, household size, region, revenues etc...

CO₂ data

- The initial dataset does not contain real energy consumption and carbon footprint ;
- ADEME's Base Carbone data to access carbon footprint of each energy source ;
- CRE's data on energy fixed and variable price subscription.

- $$C_{i,j,t} = \frac{(E_{i,j,t} - F_{j,t})}{V_{j,t}} * c_{j,t}$$

$C_{i,j,t}$: carbon footprint of household i, energy source j, year t ;

$E_{i,j,t}$: energy bill of household i, energy source j, year t ;

$F_{j,t}$: Price fixed part of energy source j, year t ;

$V_{j,t}$: Price variable part of energy source j, year t ;

$c_{j,t}$: Carbon footprint of energy source j, year t ;

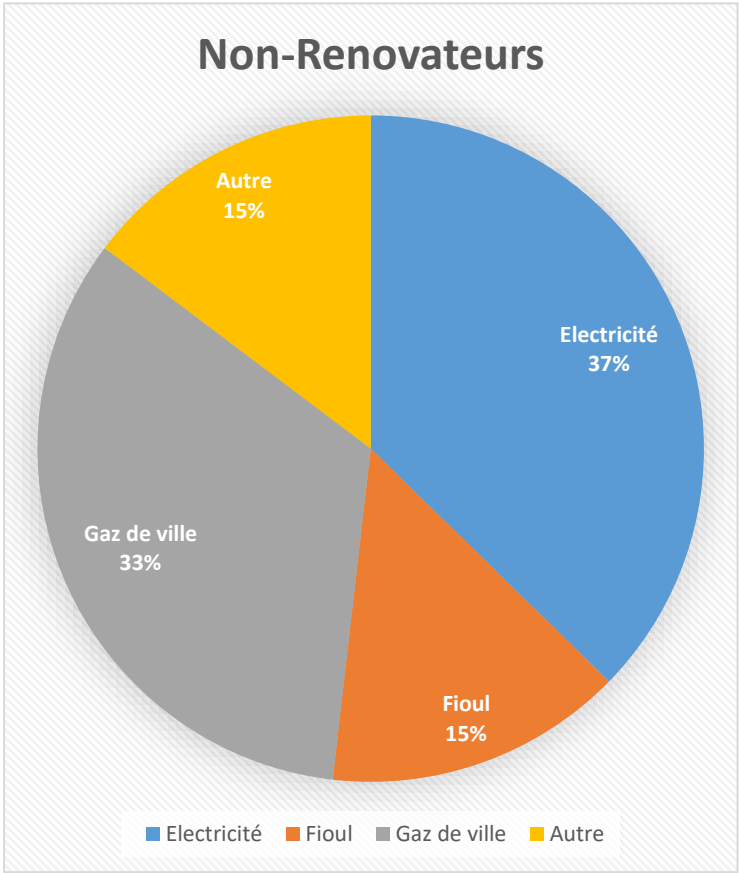
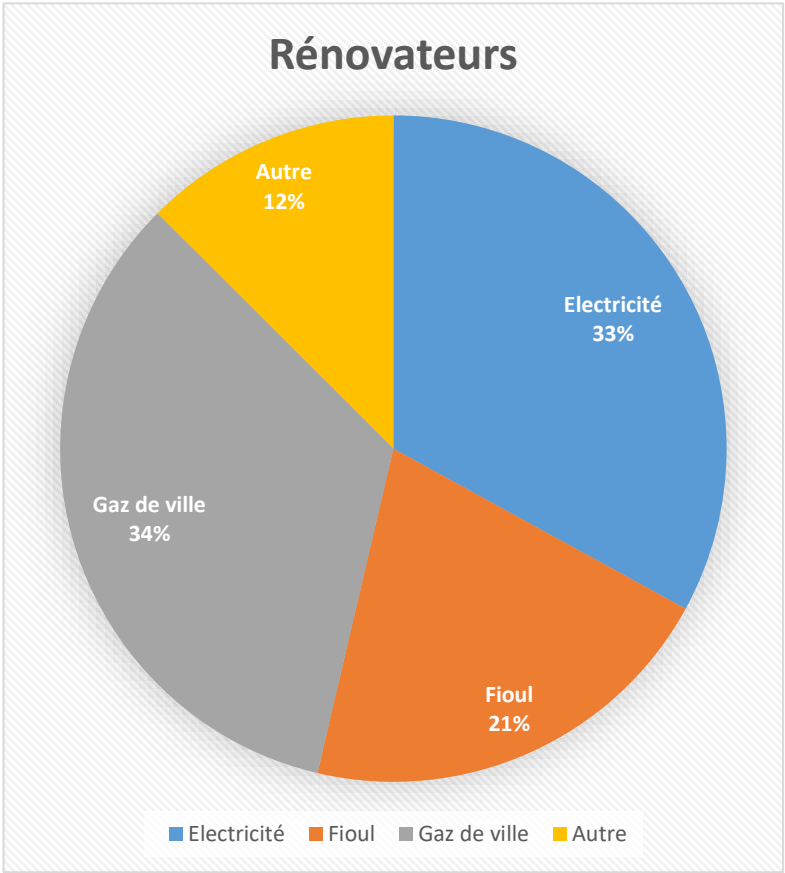
Detailed Results

VARIABLES	(1) Huisseries Log (Energy Bill)	(2) Isolation Log (Energy Bill)	(3) Equipement Log(Energy Bill)
Cumulative capital in energy retrofit	-0.00529	-0.00378*	-0.00407
	(0.00401)	(0.00218)	(0.00250)
House surface		0.0485*** (0.00536)	
Household size		0.0538*** (0.00639)	
Underidentification KPW stats		182	
Weak KPW stats		32.59	
Observations		33,830	
R-squared		0.177	
Number of households		9,181	
RegionYear FE		YES	
RevenuFE		YES	
MainHeatingSourceYear FE		YES	

Dataset description : main heating source switching matrix

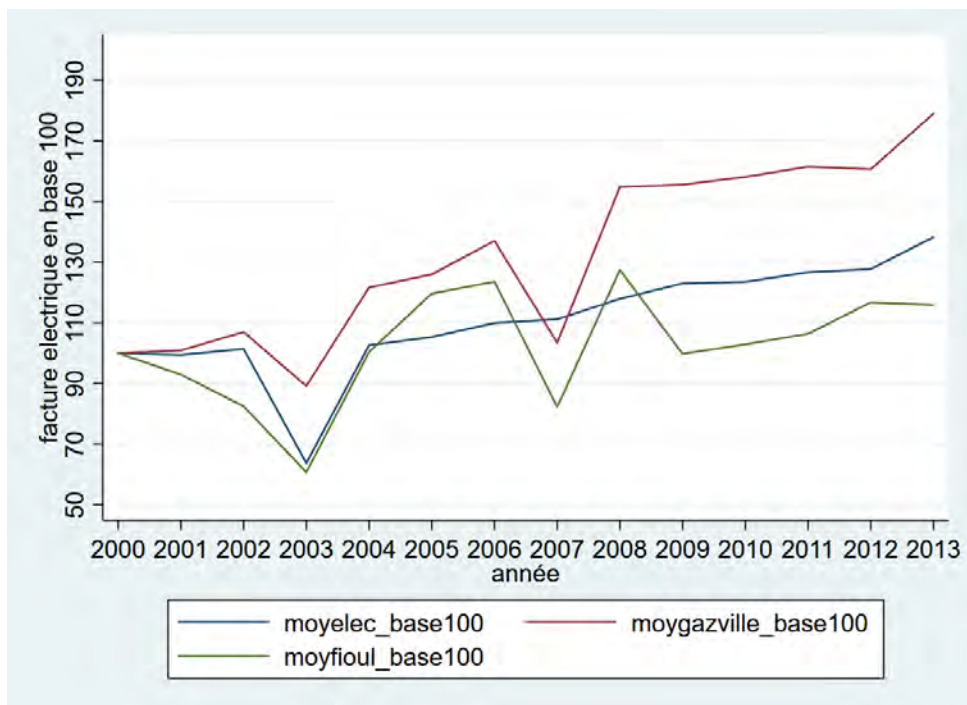
Energie d'arrivée Energie de départ	Electricité	Fioul	Gaz de Ville	Propane	Petrole	Charbon	Bois	Vapeur	Total	Nouveaux arrivants
Electricité		613	1000	164	40	22	411	589	2839	83
Fioul	707		100	25	2	2	67	134	1037	-145
Gaz de Ville	961	52		12	5	1	37	315	1383	108
Propane	183	28	28		2	0	22	8	271	-32
Petrole	40	1	5	6		0	1	1	54	-2
Charbon	38	5	2	0	0		8	0	53	-21
Bois	368	51	40	17	1	7		7	491	63
Vapeur	625	142	316	15	2	0	8		1108	-54
Total	2922	892	1491	239	52	32	554	1054		

Who is renovating ?

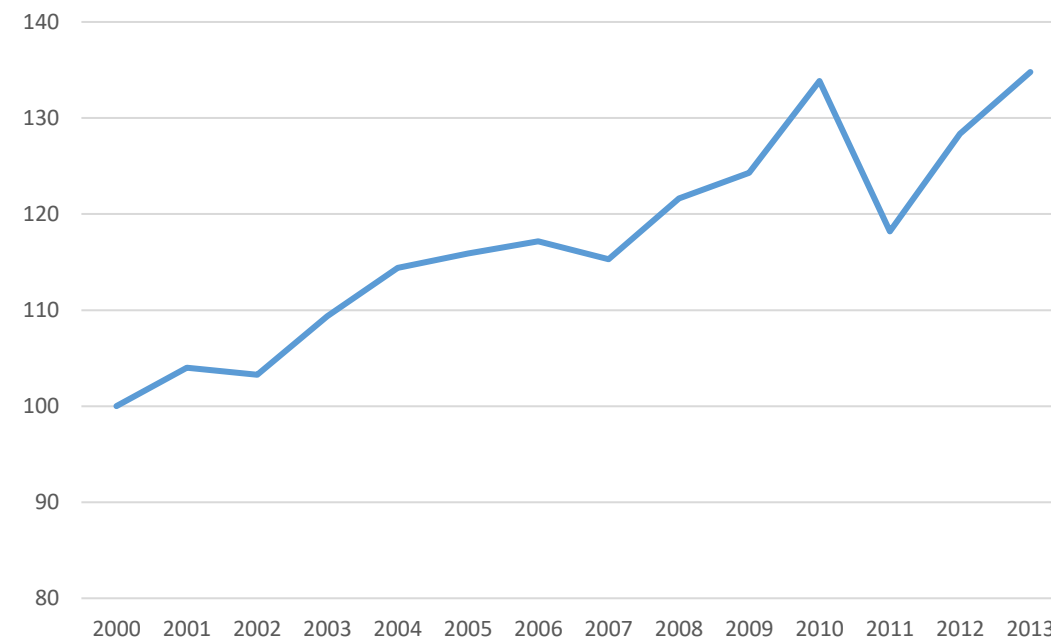


Revenue	Retrofit	Non-Retrofit
<16k€	16,1 %	22,17 %
<23k€	25,58 %	25,66 %
<32k€	30,72 %	27,2 %
>32k€	27,62 %	24,98 %

Data : total energy bill evolution



Dataset Average Total Energy Consumption



Official French Household Electricity
Consumption Evolution 2000-2013 (2000=100),
INSEE

→ 2003 & 2007 are really problematic... We have to find a method to correct them.

Further steps in external validity

- Assumption that household behaviors and French housing stock have not fundamentally changed.

However,

- Heating sources and retrofit operations type are very likely to have changed since 2020 :
 - Switching from fuel oil to gas/electricity ;
 - Windows-linked operations represent 1/3 of the dataset. Today, they have become rarer.
- Households and houses doing energy retrofit operations might have changed :
 - A new government policy in 2018 has made energy retrofit affordable to the poorest households.
- In order to go further in our analysis we must :
 - Compare our data with more recent one produced in France ;
 - Identify the characteristics of households having retrofit operations ;
 - Find ponderations in order to match our data with the more recent ones.

Endogeneity

- Decide to have energy retrofit operation might be highly correlated with changes in energy consumption behavior :
 - Positively correlated with energy consumption : new baby or retirement.
 - Negatively correlated with energy consumption : people saw a documentary about global warming.
 - We create a dummy $Z_{i,t}$ which is 1 in year t if
 - the household i had declared an intention to have energy retrofit operation in t-1 or t-2 or
 - the household i had declared to know at least two public support policies.
 - Our IVs are $\sum_0^t Z_{i,t}$ and $\sum_0^t Z_{i,t}^2$
- Instruments mainly treat the positive correlation but seem to amplify the negative one.

Discussion (2)

- Why do households invest in non-profitable operations ?
 - Only 28% of households having retrofit operations explained they were motivated by economics reasons
 - In contrast, 29% of households they were looking for an increased comfort which might cause a rebound effect.
 - Windows-related retrofit operations represents 30% of our dataset mix. They are said very ineffective and they are less popular nowadays.
- For the next steps, we must run an analysis per operation but it is likely not to be significantly different from 0.