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Energy Efficiency Renovations in Residential Buildings: What Are the Key Variables in the Decision-Making? Evidence From France

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Abstract
The building sector is the most important energy consumer in many developed countries. But it also represents the greatest energy-saving potential through energy efficient renovations. To induce households to undertake energy efficient renovations it seems important to identify the key decision variables. In this paper, we analyse the renovation expenditures, using an econometric approach and with French data. We focus on the effect of households and dwelling characteristics as well as public policies. Our results thus show that, besides energy-savings, the increase in comfort appears as an important variable. To induce households to undertake renovations, it seems important that policy measures aimed at decreasing the cost of the renovation exist, this being through subsidies, and to inform households on energy-savings investments.

Keywords - Energy-efficiency renovations; Decision-making variables; Residential sector; Tobit model.

1. Introduction

The building sector is the most important energy consumer in many developed countries. The growth of the population, which has led to an increase in the number and the size of homes and an increase in electronic equipment, tends to expand energy needs. With regards to European countries, the European Commission stated, in the 2011 Energy Efficiency Plan that the greatest energy-saving potential lies in buildings. This is due to the improvements in efficiency of insulation or appliances. However, literature shows that households do not invest significantly in energy-saving

measures even if it is profitable in the long run (Brown, 2001; Jaffe and Stavins, 1994; Sanstad et al., 1995; Van Soest and Bulte, 2001). This is mainly because of market imperfection (i.e. uncertainty about energy prices or energy savings following a renovation and the irreversibility of the investment). To induce households to undertake energy-saving renovations it seems important to understand the key renovating decision variables. By subscribing to a multidisciplinary project, and associating researchers in economics and engineering sciences, the aim of this study is the preliminary analysis of the decision to undertake energy-efficiency renovations.

Our objective is to highlight the key variables that impact on the decision to renovate, including the effect of dwellings and of household characteristics, as well as the effect of public policies. At first, we focus on the motivation and also on the preference between energy-savings over improvement in comfort. The effect of the overall renovations on national energy consumption or greenhouse gas emissions will probably be lower than expected if households renovate in order to improve their comfort instead of to obtain energy-savings. Indeed, literature underlines the presence of a 'rebound effect': following an energy-saving investment, households may prefer to increase their comfort, through an increase in dwelling temperature for example (Groening et al., 2000). This way, real energy savings are much lower than initially expected. Second, we study the effectiveness of policy measures on the decision to renovate and the amounts invested. In European countries, several public policies have been introduced to offset market imperfections and induce households to undertake an energy-efficiency renovation. In France, this included (i) financial measures as a tax credit or a zero-rate bank loan. The tax credit was implemented in 2005, for all households, and allows a part of the expenses in energy saving renovations to be deducted from the household income tax (or refunded if the household pays no income tax). The zero rate bank loan, with no interest on the amount borrowed, is intended for homeowners who make several renovations or an energy-saving investment which significantly decreases housing energy consumption. A condition to benefit from these measures is that a qualified building professional must be hired to perform the renovation work. (ii) Informational measures, named "*espaces info-energie*", were initiated in 2001. It regroups 250 premises, where households can find all the information they need on energy consumption and energy saving investments. It was initiated to alert and inform households. Our results on the effectiveness of these measures will provide further guidance for policy makers. Finally, we underline the incentives and obstacles to undertake energy-efficiency renovations, by taking into account households characteristics (such as the income, or the number of persons in the households) and dwelling features (the age, the kind of housing: houses or apartment buildings, the surface area).

The impact of households and dwelling characteristics on residential energy consumption has largely been studied in the literature (Santin et al., 2009 for example). However, papers studying their effect on the decision-making to renovate are scarcer. Montgomery (1992) shows with US data that, as we can expect, the income to have a positive effect on renovation expenditures, as well as the dwelling age (as confirmed by Nair et al., 2010 and Cirman et al., 2013). On the contrary, the age of the homeowner has a negative effect. Concerning other households characteristics, the occupancy statute seems to be non-negligible. Indeed, split-incentives exist between owners and tenants (Phillips, 2012). The tenant has less incentive to make energy efficiency investments because he does not stay long enough in the dwelling to secure a return on the investment. On the contrary, the owners have more prone to renovate given that the renovations increase the value of the dwelling.

Some papers focus on the gains following the renovation but only a few pay attention to the arbitration between energy-savings and comfort. They show that the cost of the renovation and expected energy-savings are the main factors in the decision to renovate (Grösche and Vance, 2009; Banfi et al., 2008). However, the investment profitability is not sufficient to encourage households to renovate (Charlier, 2014; Nair et al., 2010).

Finally, certains papers focus only on the impact of public policy on the decision to renovate and on the expenditures (Hasset and Metcalf, 1995; Dubin and Henson, 1988). Their results are mixed. This literature underlines the potential presence of free-riding, which may offset the impact of public measures (Grösche and Vance, 2009; Malm, 1996). Free-riders are households that would have made energy-efficiency investments even in the absence of public policy.

In this paper, we use French data from the ADEME-SOFRES Maitrise de l'energie survey over 6 years (2003, 2004, 2008, 2009, 2010 and 2011). This survey questions households about the undertaking or not of energy efficient renovations, the type of renovation (such as the improvement of the insulation or of the heating system, and the adoption of renewable energy) and the cost. It also provides information on households and dwelling characteristics.

We use an econometric approach and we focus on renovation expenditures of homeowners, in order to highlight the key variables in the decision to renovate. We show that both comfort, through indoor temperature, and energy-savings seem to be important in the decision-making. Informative measures have a significant and positive effect to induce households to undertake a renovation, as well as the tax credit which allows to increase renovation expenditures by about 19%.

We have organised the remainder of this paper as follows: In section 2 we present the data, in section 3 we discuss the method and present the results; finally we conclude in section 4.

2. Data and descriptive statistics

Let us recall that the aim of this study is to understand the key variables that impact on the decision to renovate, including the effect of public policies, of dwellings and of household characteristics. We also pay particular attention to the role of comfort through the indoor temperature, energy-savings, and the effect of public policies.

To do this, we use the *maitrise de l'energie* survey from ADEME-SOFRES (the French environment agency). We have data on 7,371 households and their main residence over 6 years (2003, 2004, 2008, 2009, 2010 and 2011). We do not observe all the households over the whole period: we observe only 189 households over the 6 years (see table A-1 in appendix).

However, the survey regroups information on (i) household characteristics and behaviour (their income, occupancy statute, the number of persons in the households and the indoor temperature for example), (ii) on their housing (such as the type of dwelling: individual houses or apartment buildings, the type of heating system, the year of construction) and (iii) the energy-efficiency renovations in terms of insulation, improvement of the heating system, or adoption of renewable energy. We also observe the renovation rate and renovation expenditures before and after the implementation of public policy: The tax credit[1] was introduced in 2005 and the zero rate bank loan[2] in 2009. We can therefore study the effect of public policy.

To this survey, we add unified degree-days at a regional level, from SOeS[3] (the statistics department of the Ministry of Environment) in order to

[1] The tax credit concerns only a range of specific renovations and the expenses deducted is limited to a certain amount, depending on the household characteristics. A deduction rate of up to 50% of the equipment costs depends on the kind of renovation carried out (e.g., change in heating system, improvement of the insulation) and the equipment chosen (e.g., adoption of renewable energy). The maximum amount of expenses deducted depends on the number of people in the household (the maximum deductible expense is €8,000 for a household with one person and €16,000 for a couple).

[2] This charges no interest on the amount of the bank loan. It concerns homeowners who make several renovations or an important energy saving investment. The amount of the loan depends on the renovation.

[3] The degree-days are calculated on the basis of data from INSEE (French national statistics institute) and Meteo France.

measure the impact of climate and its change over a year, on the decision-making of undertaking a renovation.

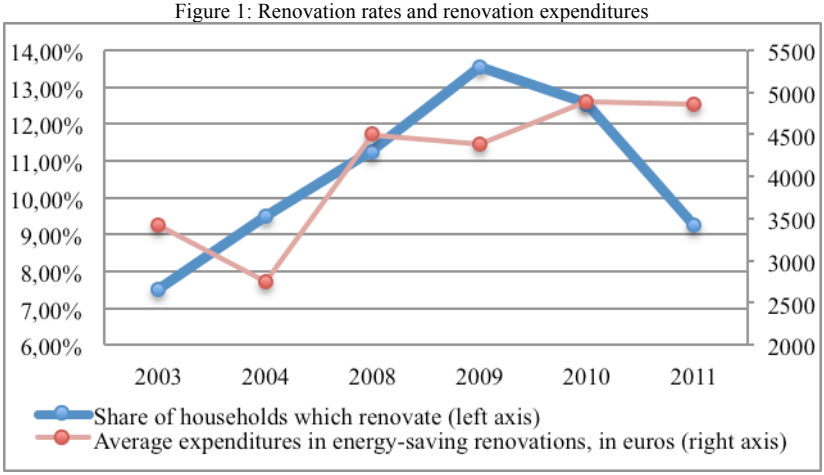
The sample is representative of French households, except that we observe a more important share of homeowners compared to the French population (69.51% on average over the whole period, against 57.70% in France according to INSEE - the French institute of statistics and economic studies) (see table A.2 in appendix).

Amongst households in our sample, around 50% have an income above 23,000 € a year and 58.5% live in a house. More than half (57%) of the dwellings were built before 1975 and 29% after 1982. The energy expenditures reach 2.59 euros per square meter and the average indoor temperature is 19.8°C (table A.3). It is mainly homeowners who undertake renovation: 14.1% of homeowners renovate their main dwelling over the period compared to only 2.78% of tenants. Renovations carried out by homeowners are also more significant: the cost of a renovation reaches on average 4,402 euros, with only 1,421 euros for tenants. These latter have less incentive to renovate taking into account that they do not stay long enough in a dwelling to make such an investment cost effective, and they cannot exploit the increase in the market value of the housing following the investment (Diaz-Rainey and Ashton, 2009). Given this, in the remainder of the study, we focus on the decision to renovate only for homeowners.

The following figure presents the renovation rate over the period observed, as well as renovation expenditures (including only households which renovate). The renovations we take into account concern the improvement of insulation (wall, roof, floor and windows), the modification of the heating system and the adoption of renewable energy. A more detailed list of renovations taken into account is in appendix (table A.4). On average, 10.7% of households (and 14.10% of owners) in the database renovate at least once during the period, the renovations have an average cost of 4,160 euros. Amongst households we observe over several years, 7.9% undertake renovations over several years over the period.

The renovation rate increased between 2003 and 2009 (to reach 13.5%) and decreased after (figure 1). The renovation rate was on average higher after the introduction of the tax credit in 2005, which aimed to induce households to undertake energy-efficient renovations (11.8% vs. 8.5% before). The zero-rate bank loan was implemented in 2009. The renovation expenditures increased on average over the period. This can be explained by the price increases (see figure B.1 in appendix), and by the type of renovation undertaken.

Figure 1: Renovation rates and renovation expenditures



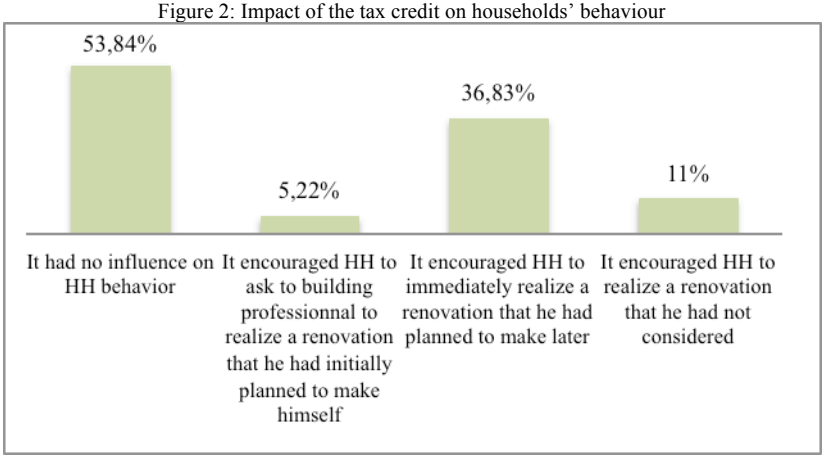
Source: ADEME SOFRES *maitrise de l'energie* survey – final sample.

The biggest proportion of renovation (73.8%) concerns the improvement of the housing insulation and 35.1% concerns the change of the equipment (such as the heating system) and the adoption of renewable energy.

Renovations are mainly carried out by building professionals (80% of renovations, and the remainder is done by the household itself). Households have to hire a building professional to undertake the renovation works, in order to benefit from the tax credit or the zero rate bank loan. We observe that about 61% of households which undertake a renovation after 2005 benefitted from the tax credit, and only 5.5% of households which renovate after 2009 benefited from the zero rate bank loan.

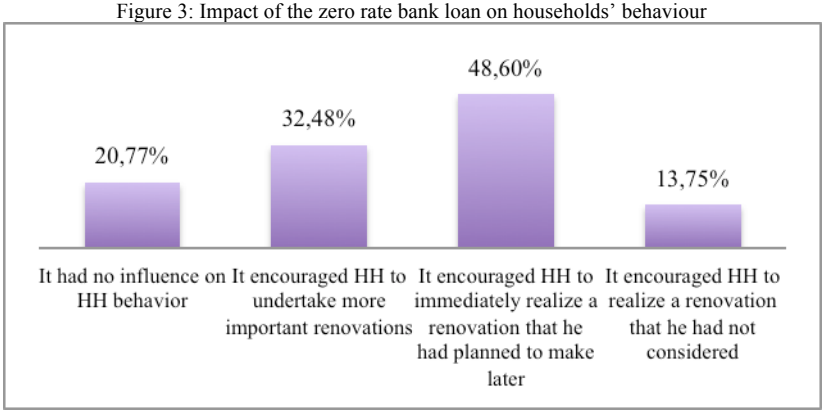
Amongst households which benefitted from the tax credit, almost 54% declare that the tax credit had no influence on their behaviour (figure 2). This means that more than half of the households receiving the tax credit would have carried out the renovation without this financial measure. Free-riding seems to be significant over the period, and fall in the range of the estimates from Grösche and Vance (2009). Free-riders are households that would have made energy-efficiency investments even in the absence of public policy. For its part, the zero rate bank loan seems to encourage households to undertake the renovation sooner than they planned (for almost 49% of households) or to carried out more important renovation works (for 32% of households). This measure targets homeowners who make an important energy-saving investment.

Figure 2: Impact of the tax credit on households' behaviour



Note: 717 households benefitted from the tax credit between 2008 and 2011. Amongst them, 706 clarify the impact of this measure on their behaviour.

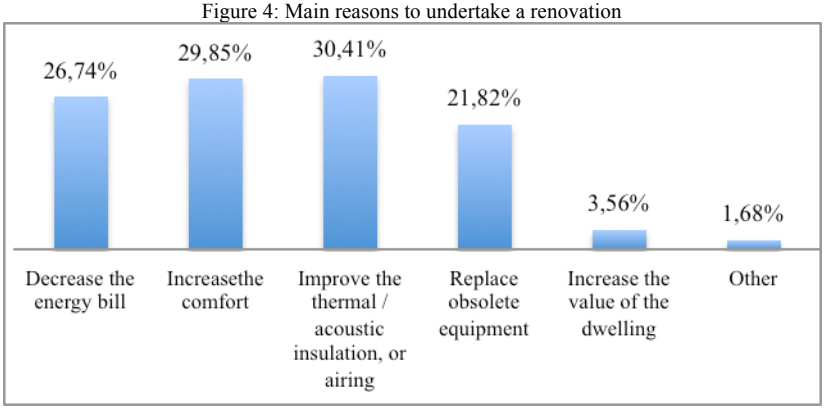
Figure 3: Impact of the zero rate bank loan on households' behaviour



Note: 48 households benefitted from the zero rate bank loan between 2009 and 2011. Amongst them, 48 clarify the impact of this measure on their behaviour.

We focus in this paper on the key variables in the decision to renovate. Amongst households which renovate, 53.7% undertook an energy efficient renovation mainly to reduce the energy bill and/or improve the comfort inside the dwelling (2,9% of households have the two incentives) (figure 4).

Figure 4: Main reasons to undertake a renovation



In the next section, we study the key variables on the decision to renovate, all things being equal.

3. Econometric model

We use an econometric analysis to explain the decision-making to undertake energy-efficiency renovations, and to underline the incentives and obstacles. We choose to study the renovation expenditures, in order to consider the decision to renovate and the amount invested.

First, we take into account in our model, the housing characteristics, such as the year of construction (which can be an indication of the housing quality), the surface area and the type of dwelling (individual houses or collective apartment buildings). We can expect that households are more motivated to renovate an old and poorly insulated building (Montgomery, 1992). Also in collective apartment buildings, some renovations cannot be decided at the household level but must be decided by the community of co-owners. Consequently, it may take more time to decide on a renovation.

Second, we consider the households characteristics: the income, and the access to the information on the type of renovation and on energy-savings (through the French "*espaces info energie*"). We take into account the implementation of financial support to households which decide to renovation (this means the tax credit and the zero rate bank loan).

Third, we pay a particular attention to household behaviour through the temperature inside the dwelling and to the energy bills. Our objective is to understand the motivation of households and to study if households have a preference for comfort or for energy-savings. Through public policies, the objective of the government is to significantly decrease the energy consumption of the residential sector. However, if households undertake a

renovation to increase their comfort, the energy-savings will be alleviated and the effect of renovations on the national energy consumption will be lower than expected. Consequently the efficiency of public policy will be also lessened. We considered in the model the energy bills and the temperature in the dwelling, both lagged by one year, to have this information before the potential renovation.

Finally, we take into account in the model the location of the housing, through the type of agglomeration as an indicator of supply saturation: In some French town, we observe that suppliers cannot meet all the demand (Moussaoui, 2008). Indeed, energy-saving renovation requires specific knowledge. It exists a label to certify that building professionals have the skills needed to realize energy-saving renovations. We also consider the unified degree-days by region to study the impact of climate on the incentives to renovate. We take this variable lagged by one year.

A list and a description of variables used in the model are available in appendix (table C.1).

We estimate the following model:

$$y_{it}^{*} = \alpha_i + \beta x_{it}' + \varepsilon_{it} \quad (1)$$

with y the renovation expenditures, α a constant, x the vector of explanatory variables (including dwellings and households characteristics and other variables listed above or in table C.1), ε an error term, i the households and t the years observed (2003, 2004, 2008, 2009, 2010 or 2011).
The renovation expenditures can be observed only partially. Indeed we know the expenses only for households which undertake a renovation, and we do not know how many households that have not renovated would have spent if they had undertaken a renovation. This leads to a censorship problem, since we have:

$$y_{it} = \begin{cases} y_{it}^{*} \text{ if } y_{it}^{*} > 0 \\ 0 \text{ if } y_{it}^{*} \leq 0 \end{cases} \quad (2)$$

y^{*} is the latent variable, this means it is the renovation expenditures which is not directly observable because of the censorship problem.

To take this problem into account, we use a Tobit model to estimate the renovation expenditures and to measure the key variables in the decision-making. The Tobit model is currently used to estimate the goods consumption. It provides unbiased results in the case of censorship in an explained variable, and estimates each result all things being equal (this means, the result isolates the effect of one variable on renovation expenditures considering all other variables from the model as constant).

4. Results

The results are presented in table D.1 in appendix. We estimated the model only for homeowners. This table presents (i) the marginal effect, this means the effect in percentage of a variable on the renovation expenditures[4], (ii) the standard error (or the deviation to the mean) which allows to estimate the significance of the results. The significance of the results is estimated with a Student test (if the results are not significant, this means that the variable has no effect on the renovation expenditures; if the results are significant at 1%, this means we take a risk of 1% to consider that the coefficients have an effect different from zero whereas they equal zero).

Variables concerning dwelling characteristics all have a significant effect. As expected, living in a house (compared to an apartment building) increases the renovation expenditures by 35.32% ceteris paribus. As already mentioned, the adoption of some renovations in collective apartment buildings is more difficult because the decision must be taken by the majority of co-owners. The construction period also has a significant effect. Living in a dwelling built before 1982 increases the renovation expenditures compared to a dwelling built after 1982. For poorly insulated and very old buildings, it is sometimes cheaper to demolish the building in order to build a new one, rather than renovate it. This may explained that the marginal effect is less important for dwellings built before 1948 than dwellings built between 1975 and 1981. Finally the surface area has a significant effect on amounts invested.

Household income also has a significant effect on renovation. Having an income of between 23000 € and 36600 € or higher than 36600 € increases renovation expenditures by 30.66% and 32.45% respectively, compared to households with an income below 12000 € a year, all things being equal. There is an income threshold (around 23000 € a year) under which the household hardly renovate. The inactivity of the head of household (unemployed, student or inactive) also has a significant and negative effect on renovation expenditures. The households undertake more renovation works in the years following their move. Moving into the housing less than five years ago increases the renovation expenditures by 24.44% ceteris paribus. Conversely, the number of persons in the household has no significant effect, as well as the age of the head.

The temperature inside the dwelling has a significant impact on renovations: if the temperature decreases by one percent, the renovation expenditures increase by 3.6% during the following year. The comfort

[4] All continuous variables are in logarithms (including the renovation expenditures), in order to express the results in percentage.

seems to have a significant part in the decision-making. It is also the case for energy-savings. An increase in the energy bill by 1% leads to an increase in renovation expenditures by 15.7% ceteris paribus.

The effect of public policies is mixed. Informative measures, such as the knowledge of the existence of "espaces info-energie", seems to increases renovation expenditures by 19.3%.

The effect is lower concerning financial measures. The zero rate bank loan has no effect on renovation expenditures. This means that a household which can benefit from the zero rate bank loan is not more prone to undertaking energy efficiency renovations. The tax credit is most efficient, because this subsidy allows to increases renovation expenditures by 19.3%, ceteris paribus. The tax credit is very popular. From 2005 to 2008, 4.2 million French households received the tax credit (Clerc and Mauroux, 2010); this represents a significant cost for the government: The public cost reached €7.8 billion during this period and €4.2 billion during 2009–2010. This result suggests that an efficient measure to increase the renovation rate is to diminish the cost of the renovation.

5. Conclusion

We has chosen to study the renovation expenditures with a French dataset, which provides information on the energy-saving renovations undertaken over five years. An econometric analysis was used to underline the incentives and obstacles to undertake energy-efficient renovations. We focus in this study o homeowners.

In terms of household characteristics, having a high income and moving into the dwelling less than five years ago, significantly increases the renovation expenditures. Dwelling characteristics are also important (such as the year of construction and the type of dwelling: house or apartment building for example). We show that the implementation of the tax credit has a significant and positive effect on renovation expenditures, ceteris paribus, as well as policies having an informative role (as "*Espaces Info Energie"*). Through public policies, the objective of the government is to significantly decrease the energy consumption of the residential sector. However, literature underlines the presence of a rebound effect and shows that following an energy-saving investment, households may prefer to increase their comfort, through an increase in dwelling temperature for example (Groening et al., 2000). Our results show that, besides energy-savings, the increase in comfort also appears as an important variable. This can at least partially offset the beneficial effects of the renovation.

This research is the first step of a multidisciplinary project, which includes researchers in economics and engineering sciences. The knowledge obtained will be used to build a decision-making tool in order to rank the best options in terms of renovation. The objective is to help the owner to take the decision to renovate his house, and to undertake measures that are energy-efficient. This tool will be designed using the MACBETH approach (Measuring Attractiveness by a Categorical Based Evaluation Technique) (Bana e Costa et al., 2012), which is a multicriteria decision analysis approach and allows to rank the options. Then, in the next step of the project, we will analyse the decision to undertake energy-efficiency renovations in a different context: for the manager of several social housings. Managers have to allocate the budget between several housings, and we need to understand their decision-making to help them to choose the most efficient energy-saving renovations.

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Appendix

Appendix A: Data

Table A.1: Presentation of the sample

Number of years observed	Number of households	Share of households which renovate	Renovation expenditures (average amongst households which renovate) – in €
6	189	10.23 %	4,638.67
5	310	12.14 %	3,939.57
4	665	10.86 %	4,756.99
3	1054	11.25 %	4,099.70
2	1943	9.79 %	3,925.40
1	3210	10.56 %	3,936.63
Total	7,371 households 15,602 observations	10.65 %	4,160.31

Notes: Renovation rates and renovation expenditures are independent of the number of years we observe households.

Table A.2: Representativity of our sample

	Statistics from our sample – on average through the period observed	French statistics from INSEE – in 2006, for main residences
Homeowners	69.5%	57.7%
Housing built		
before 1948	25.8%	25.5%
between 1949 and 1974	31.2%	30.7%
between 1975 and 1981	14.01%	13.3%
after 1982	29.07%	30.5%
Houses	58.5%	56.4%
Surface area (in m2)	96.9	91.6

Nb of persons in the household:		
1	33.5%	33.1%
2	36.0%	32.7%
3	13.2%	14.9%
4 or more	17.4%	17.3%
Inactive persons	45.6%	43.9%

Table A.3: Variables and descriptive statistics

Variables	All the sample		Homeowners	
	Mean	Std. dev.	Mean	Std. dev.
Renovations				
Renovation rate	0.1065	0.3085	0.1411	0.3481
Renovation expenditures	4,160	4,620	4,402	4,672
Households characteristics				
Homeowner	0.6951	0.4604	-	-
Income :				
below 12000 € / year	0.1102	0.3132	0.0622	0.2416
between 12000 € and 15700 € / year	0.0944	0.2923	0.0757	0.2645
between 15700 € and 19000 € / year	0.1109	0.3140	0.0959	0.2945
between 19000 € and 23000 € / year	0.1463	0.3534	0.1449	0.3520
between 23000 € and 36600 € / year	0.3210	0.4669	0.3526	0.4778
more than 36600 € / year	0.1825	0.3863	0.2237	0.4167
Head of the household younger than 35	0.1129	0.3165	0.0712	0.2572
Head of household inactive	0.4564	0.4981	0.4906	0.4999
Households with one person	0.3347	0.4719	0.2748	0.4465
two persons	0.3596	0.4799	0.3928	0.4884
three persons	0.1319	0.3384	0.1320	0.3385
four persons or more	0.1738	0.3790	0.2004	0.4003
Moving into the housing less than 5 years ago	0.2188	0.4134	0.1655	0.3717
Temperature in the dwelling (the year preceding the survey)	19.77	1.32	19.79	1.24
Dwelling characteristics				
Houses	0.5845	0.4928	0.7294	0.4442
Year of construction :				
before 1948	0.2576	0.4373	0.2627	0.4401
between 1949 and 1974	0.3116	0.4631	0.2896	0.4536
between 1975 and 1981	0.1401	0.3471	0.1432	0.3503
after 1982	0.2907	0.4541	0.3044	0.4602
Energy expenses in euros per m2 (the year preceding the survey)	2.59	0.45	2.58	0.4357
Surface area	96.88	46.01	106.49	46.17
Location:				
Unified degree-days by region (the year	1,953	347	1,973	341

preceding the survey) Rural agglomeration	0.2316	0.4219	0.2721	0.4451
Public policies				
Possibility of access to the tax credit	0.6523	0.4763	0.6556	0.4752
Possibility of access to a zero rate bank loan	0.4584	0.4983	0.4678	0.4990
Knowledge of the existence of "*espace info energie"*	0.2233	0.4165	0.2428	0.4288
Number of households	7,371		5,470	
Number of observations	15,602		11,744	

Note: Statistics are weights to be representative of French households

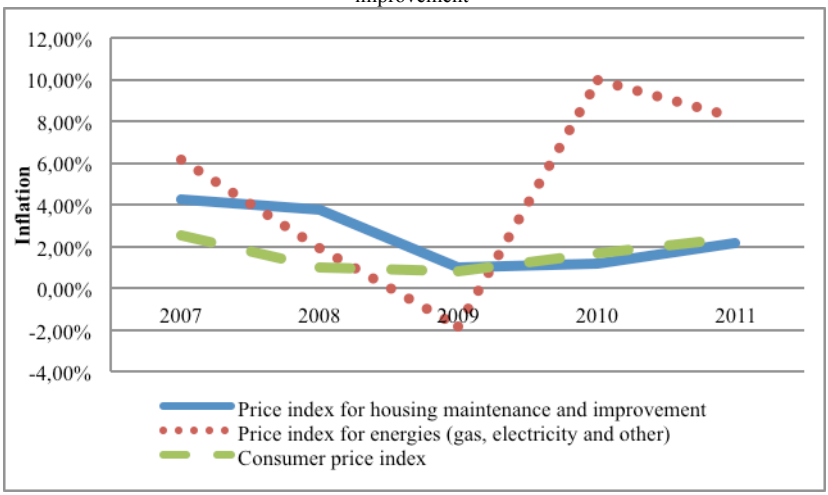
Table A.4: List of renovations

Notes: 281 households do not give information on the type of renovation undertaken.

Type of renovations	Share of households which undertaken the renovation
Renovations to reduce heat losses	**6.83%**
Wall insulation (from indoor or outdoor)	1.01%
Roof or attic insulation	1.66%
Floor insulation	0.21%
Insulation of pipes	0.05%
Caulking, joints	0.28%
Change of windows (with or without double glazing)	3.93%
Double glazing without a change of windows	0.23%
Change or installation of shutters	1.28%
Others	0.07%
Renovations to improve the equipment	**3.20%**
Installation of a boiler or water heater (including solar water heater)	0.13%
Change of a boiler with or without a fuel change	1.23%
Fuel change without the change of the boiler	0.01%
Change to burner	0.06%
Installation of a fireplace insert or a closed fireplace	0.25%
Installation of an ambient thermostat	0.13%
Installation of a programme	0.10%
Installation of a heating cost allocator	0.03%
Installation or replacement of one or more radiators	0.75%
Installation or replacement of thermostatic valves	0.17%
Installation or renovation of a ventilation system	0.18%
Others	0.51%
Number of observations	**15,321**

Appendix B: Price index

Figure B.1: Evolution of energy price and price index for housing maintenance and improvement



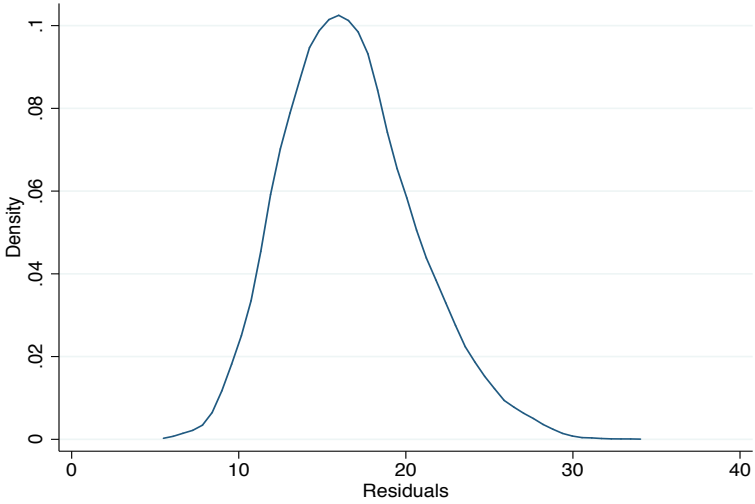
Appendix C: The model

Table C.1: Variables in the model

Variables	Description
Dwelling characteristics	
Houses	=1 if the household live in a house, =0 if the household live in an apartment building
Year of construction : before 1948	=1 if the dwelling was built before 1948
between 1949 and 1974	=1 if the dwelling was built between 1949 and 1974
between 1975 and 1981	=1 if the dwelling was built between 1975 and 1981
after 1982	=1 if the dwellng was built after 1982
Energy expenses in euros per m^2 (the year preceding the survey)	Energy bill in euros lagged by one year
Surface area	Surface area per square meter
Unified degree-days by region (the year preceding the survey)	Unified degree-days from SOeS (the statistics department of the Ministry of Environment)

Rural agglomeration	=1 if household live in a rural agglomeration
Households characteristics	
Income : below 12000 € / year	=1 if the income of households is below 12000 € / year
between 12000 € and 15700 € / year	=1 if the income of households is between 12000 € and 15700 € / year
between 15700 € and 19000 € / year	=1 if the income of households is between 15700 € and 19000 € / year
between 19000 € and 23000 € / year	=1 if the income of households is between 19000 € and 23000 € / year
between 23000 € and 36600 € / year	=1 if the income of households is between 23000 € and 36600 € / year
more than 36600 € / year	=1 if the income of households is higher than 36600 € / year
Head of the household younger than 35	=1 if the head of the household is younger than 35
Head of household inactive	=1 if the head of household inactive (mainly retired, unemployed, student)
Households with one person	=1 if the number of person in the householsq equals one
two persons	=1 if the number of person in the householsq equals two
three persons	=1 if the number of person in the householsq equals three
four persons or more	=1 if the number of person in the householsq equals four or more
Moving into the housing less than 5 years ago	=1 if the household moved into the housing less than 5 years ago
Temperature in the dwelling (the year preceding the survey)	The temperature in the dwelling (the year preceding the survey) in Celsius degree
Public policy	
Possibility of access to the tax credit (i.e. households in the survey in 2005 and after)	=1 if the household is in the survey in 2005 and after
Possibility of access to a zero rate bank loan (i.e. households in the survey in 2009 and after)	=1 if the homeowner is in the survey in 2009 and after
Knowledge of the existence of *espace info energie*	=1 if the household is aware about the existence of *espace info energie*

Figure C.1: Distribution of residuals



Appendix D: The results

Table 1: Estimation of renovation expenditures on the basis of a tobit model – Results for homeowners

		Marginal effects E(y*|y>0)	Standard errors	
Dwelling characteristics				
houses		0.3532	0.0568	***
year of construction :	before 1948 (1)	0.5186	0.0857	***
	between 1949 and 1974	0.7821	0.0952	***
	between 1975 and 1981	0.5190	0.1068	***
	between 1982 and 1988	0.3532	0.0568	***
	after 1989	ref		
energy expenses per m^2 (in log) (2)		0.1573	0.0639	**
surface area (in log)		0.3598	0.0763	***
Households characteristics				
Income :	below 12000 € / year	ref		
	between 12000 € and 15700 € / year	0.1681	0.1352	
	between 15700 € and 19000 € / year	0.1442	0.1223	
	between 19000 € and 23000 € / year	0.1602	0.1113	
	between 23000 € and 36600 € / year	0.3066	0.0958	***
	more than 36600 € / year	0.3245	0.1109	***
head of the household younger than 35		0.1599	0.1169	
head of household inactive		-0.2135	0.0653	***

households with	one person	0.1520	0.0997	
	two persons	0.1115	0.0782	
	three persons	0.1267	0.0941	
	four persons or more	ref		
moving into the housing less than 5 years ago		0.2444	0.0819	***
temperature in the dwelling		-0.0359	0.0199	*
Localisation of the dwelling				
unified degree-days by region		-0.0001	0.0001	
rural agglomeration		0.0072	0.0510	
Public policies				
after the introduction of the tax credit		0.1934	0.0572	***
after the introduction of the zero rate bank loan		0.0593	0.0588	
knowledge of the existence of *espace info energie*		0.2101	0.0612	***
number of years we observed the households		0.0322	0.0144	**
Number of observations		11,744		
Log likelihood		-8275.7891		

Note: *** Significant at 1%, ** significant at 5%, * significant at 10%. The table presents bootstrapped standard errors, obtained after 500 replications, to limit heteroskedasticity bias. Concerning the goodness of fit of the model, the Wald Chi2 equals 214.59 (with a degree of freedom equal to 24) and this indicates that the model is globally significant. Moreover, we conduct a graphical analysis of the residual distribution and the normality assumption seems to be respected (see appendix C, figure C.1).

Results interpretation: REF, means reference variable: All the effects are expressed compared to the reference variable in categorical variables. In continuous variable, the effects are given for an increase of 1% of the independent variable.

(1) Living in a dwelling built before 1948 increases the renovation expenditures by 51.86% compared to a dwelling built after 1982, all things being equal.

(2) An increase in the energy bill by 1% leads to an increase in renovation expenditures by 15.73% *ceteris paribus*.