Energy billing and heating externalities in multi-family housing

Dorothée Charlier, Louis-Gaëtan Giraudet

Switching to individual billing has proved an effective way to remove over-consumption incentives associated with utility-included contracts. Yet as heat can move across multi-family units, such an intervention gives rise to potential externalities, with occupants in one dwelling turning their thermostat down as they benefit from heat transfers from their neighbours, who in return turn their thermostat up. Using data from the 2013 French housing survey, we quantify the net effect of these conflicting incentives and their distributional impacts. We compare variations in energy use across floor designations and billing contracts with those arising in water use, which arguably is immune from uncontrolled transfers. We use the existence of an elevator as an instrument to address endogeneity between floor choice and consumption patterns. We find evidence of heating externalities in that energy use (but not water use) is significantly higher in intermediate-floor units than in ground- or top-floor ones (most subject to heat losses). Over-consumption in ground- and top-floor units, however, is economically smaller than that due to utility-included contracts (as opposed to individual billing). While confirming the net energy saving effect of switching to individual billing, our results point to equity concerns, as those dwellings most exposed to heating externalities tend to be occupied by poorer households.

Key-words : Energy efficiency; heating; externalities; Moral hazard; Endogeneity.

JEL CODES : D86; H23, Q41, C26

1/ Introduction

Energy use in multi-family dwellings results from a complex interplay between physics, technology, and contractual incentives. Heat can move across adjacent dwellings, chiefly along a vertical gradient and, to a lesser extent, a horizontal one, especially if control systems allow heating intensities to differ across dwellings. These physical and technological features create heating externalities – occupants in one dwelling turning down their thermostat as they benefit from heat transfers from adjacent dwellings, the occupant of which in turn turns their thermostat up. In equilibrium, this can result in excessive energy use at the building scale, as compared to a benchmark where heat is optimally distributed across dwellings so as to ensure the same level of comfort to all. Such a benchmark typically prevails when all building occupants share energy expenditure under a utility-included rental contract. By lowering the marginal cost of energy usage, howeversuch billing schemes create incentives to over-use (Gillingham et al. 2012; Levinson and Niemann 2004; Maruejols and Young 2011; Giraudet, 2020). Interventions substituting individual energy billing for utility-included contracts have proved effective at removing these distortions and thus reducing energy use (e.g., Elinder et al. 2017). Yet it is seldom noted that, by restoring price signals, such interventions can give rise to the aforementioned externalities if the physical structure of the building permits significant heat transfers.

To our knowledge, the economic significance of heating externalities, and the extent to which they can diminish the effectiveness of implementing individual billing, has never been assessed. These problems, however, have important policy implications. In France, multi-family dwellings represent 43,5% of the housing stock, 14% of which is covered by utility-included contracts (INSEE 2018). In the United States, 60% of housing rental contracts include at least one energy or water utility (Choi and Kim 2012). Substitutions of individual billing for utility-included contracts is increasingly becoming mandatory across Europe, as is the case in France since 2017 for multi-family buildings using more than 80 kWh/m² annually on heating (ADEME 2019). As of 2017, 1.8 million dwellings occupied by 6 million individuals were subject to this obligation.

In this paper, we ask: How big are heating externalities? Is induced over-consumption commensurate with that arising from different billing schemes? How does a household's exposure to these conflicting incentives vary across income and other socio-economic characteristics?

We examine these questions using data from the French housing survey of 2013. Our sample of interest contains 12,561 households living in multi-family units, with detailed information about their (income, rents, utility and home investment expenditure, loan repayments, etc.) and their dwelling's (location, size, solar input, energy efficiency equipment of the dwelling) characteristics. We quantify variations in energy expenditure across floor designations (which are subject to varying heat losses) and energy billing contracts and compare them with variations in water expenditure, which is plausibly not subject to uncontrolled physical transfers across dwellings. We use the existence of an elevator as an instrument to address endogeneity between floor choice and consumption patterns.

We find that energy expenditure is highest for those households living on the ground floor, followed by those from the top floor and those from intermediate floors. Living on intermediate floors decreases energy expenditure by 41% compared to living on the ground floor. In contrast, floor designation has no influence on water expenditure, as additional regressions indicate. This benchmark confirms the significance of heat transfers across dwellings from different floors. Over-heating seems necessary to maintain a desirable temperature in dwellings located on the ground floor, from which heat easily flows up. The same phenomenon applies to the top floor, though to a lesser extent, as top-floor dwellings plausibly benefit from heat input from lower floors. The most important marginal effects in explaining energy expenditure, however, are the impact of utility-included contracts, the presence of a heating control system, and the interaction between the two. Households that cannot control heating and enjoy utility-included contracts have 73% higher energy expenditure and 42% higher water expenditure. The moral hazard problem induced by not facing the marginal cost of water and energy therefore is substantial. The effect is robust to regressions ran by floor designation or on the smaller water sample. Our estimates of other parameters are consistent with those found in the literature, with positive but low income elasticity values and a positive association between the age of construction (until 1949) and energy expenditure.

Our results suggest that, as the distortions induced by utility-included contracts induce more energy over-use than do the heating externalities typically arising when switching to individual billing, the mandatory ban of utility-included contracts retains most of its benefits in terms of energy (and thus cost) savings. Yet descriptive statistics indicate that poorer households tend to occupy ground- and top-floor units with no elevator, which are particularly exposed to negative heating externalities. A policy solution to jointly address the two distortions is to promote two-part utility contracts in which a fixed part is designed to address externalities. In France, this fixed part is set to 30%. Whether this fraction is optimal is an interesting question for future research.

The rest of the paper is organized as follows. Section 2 presents the data. Section 3 details the empirical modelSection 5 discusses the results. Section 6 concludes.

2. Data and descriptive statistics

2.1 Data

We use data from the 2013 French housing survey (INSEE, 2013). Carried out every 7 years or so, this survey provides detailed information about the physical characteristics of the housing stock (size, comfort variables, heating equipment), housing conditions (location, solar input, noise exposure, characteristics of the neighbourhood), expenditure (rents, energy and water utilities, mortgage and other loan repayments, retrofit expenditure) and various sources of household income. The sample of multi-family dwellings we are interested in contains 12,561 observations. In the literature, it is commonly assumed that energy expenditure are explained by household characteristics on the one hand (socioeconomic characteristics, individual preferences, income, etc.), the characteristics of the building envelope and the appliance stock on the other. The number of occupants is known to have a positive impact on energy consumption (Leahy and Lyons 2010; Vaage 2000), with a cyclical effect based on the age of the reference person: energy consumption is comparatively higher for occupants aged 45-65 than for other age classes (Brounen and Kok 2011; Brounen et al. 2013). Consistently with the “normal good status” of energy consumption, income elasticity lies within 0.01 and 0.15. Positive elasticity may mainly involve the purchase of more energy-efficient appliances, which will induce lower energy consumption (Cayla et al. 2011; Labandeira et al. 2006) (Charlier and Kahouli 2019; Labandeira et al. 2017; Nesbakken 2001; Santamouris et al.

2007)1. Housing characteristics and localization (through climate in particular) typically account for more than half of the variability in energy use (Estiri 2015). Newer buildings tend to consume less energy, and housing type is an important variable (Nesbakken 2001; Santin 2011; Vaage 2000). Dwelling insulation (attic or cavity walls or global insulation) reduces energy consumption from -10% to -17% (Brounen et al. 2012). Finally, local climate also has an impact: in western countries, the longer the heating period is, the more energy a dwelling consumes (Kaza 2010).

2. 2 Descriptive statistics

Main descriptive statistics are provided in Table 1 below.

Table 1: Descriptive statistics (based on 10,304 observations)

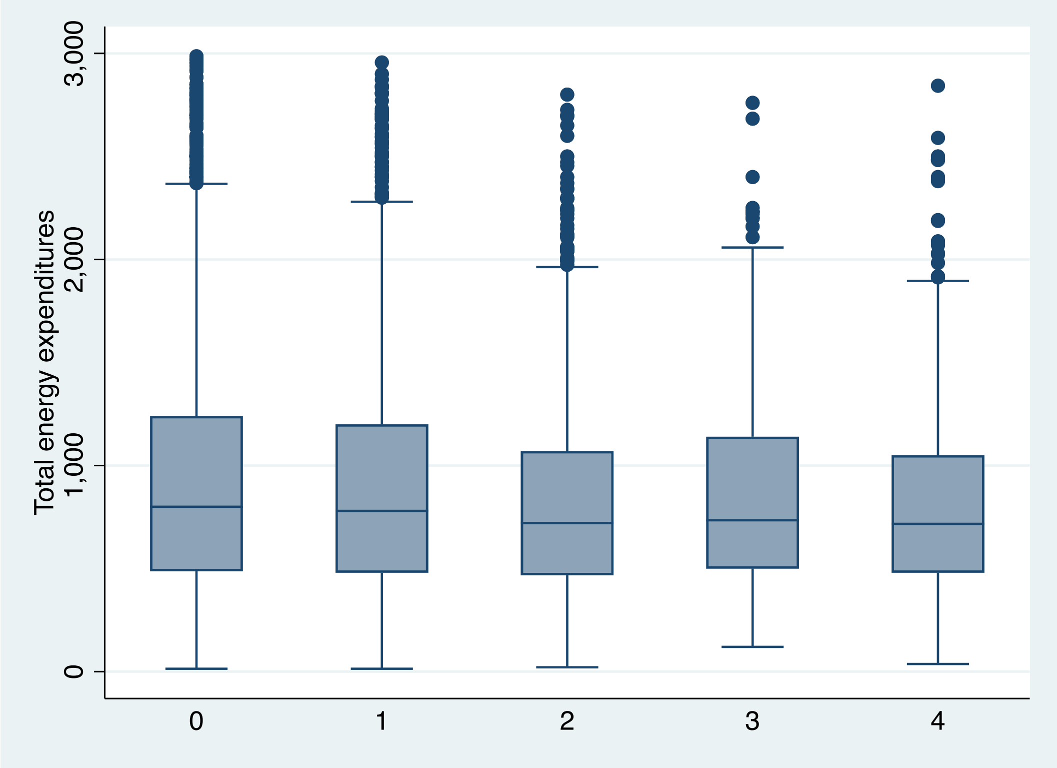
	Unit	Mean	Std. Dev.	Min	Max
Energy expenditure		954.658	575.939	14	4630
Water expenditure		90.95	179.784	0	1954
Income		33078.18	28555.59	3.667	389767
Man		0.524	0.499	0	1
Couple		0.429	0.495	0	1
Age		50.626	17.276	19	101
Nb children		0.616	1.05	0	8
Bac+2		0.107	0.309	0	1
Sup. Bac+2		0.207	0.405	0	1
Climate zone 4		0.097	0.297	0	1
Climate zone 3		0.084	0.277	0	1
Climate zone 2		0.592	0.491	0	1
Climate zone 1 (coldest)		0.227	0.419	0	1
Surface area		66.126	23.047	1	260
Double glazing		0.829	0.377	0	1
Constructed before 1949		0.177	0.382	0	1
Constructed 1949-1974		0.483	0.5	0	1
Constructed 1975-1981		0.135	0.341	0	1
Constructed 1982-1989		0.058	0.234	0	1
Constructed 1990-1998		0.073	0.259	0	1
After 1999		0.076	0.264	0	1
Heating Control		0.101	0.302	0	1
Heating expenditure included		0.138	0.345	0	1
Water expenditure included		0.232	0.422	0	1
Collective heating system – district heating or natural gas		0.425	0.494	0	1
Connected to the gas network		0.698	0.459	0	1
Paris Area		0.404	0.491	0	1
Ground floor		0.148	0.355	0	1

Intermediate floor	0.634	0.482	0	1
Last floor	0.218	0.413	0	1
Floor number	5.14	3.675	1	95

On average, households spend €955 on energy and € 91 on water[1]. Only 7,6% of dwellings where constructed before building codes tightened in 1999.[2] 42.5% of units are equipped with a collective heating system powered with district heating or natural gas. Among the 57.5% using an individual heating system, 26.1% used oil as principal heating fuel.

Comparing total energy expenditure across building code vintages (closely aligned with the construction period, except for building constructed after 1999), however, does not reveal important variation, probably because of a concomitant increase in energy prices over the period (see Figure 1 and Figure 2).

Figure 1: average energy expenditure across building code vintages.



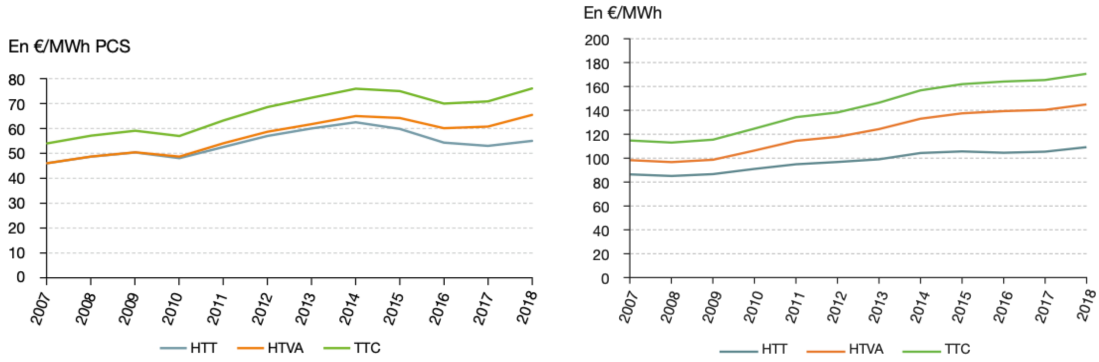
Note : 0 "No thermal regulation" 1 "Thermal regulation 1974" 2 "thermal reg ulation 1988" 3 "thermal regulation 2000" 4 "thermal regulation 2005 and 2012"

---

[1] There are a large number of zeros, so the regressions will be conducted on the 3,106 households that report non-zero spending.

[2] Tighter building codes were subsequently introduced in 2005 and 2013.

Figure 2: evolution of energy prices (gas and electricity) in France



Gas

Electricity

Source : *SDES, enquête transparence des prix du gaz et de l'électricité*

Source : *SDES, enquête transparence des prix du gaz et de l'électricité*

By cross-referencing information on housing costs, household income, and the type of floor they live on (Table 2), we find that the most expensive dwellings are located in the middle floors, which tend to be occupied by the wealthiest households. This suggests that the distribution of households across floors is not random but probably endogenous to their profile. 30,1% of households living in multi-family dwellings are homeowners, against 58% on average for the total building stock.

Table 2: Descriptive statistics by floor

Floor	Heating expenditure		Water expenditure		Dwelling price		Rent		Income	
	mean	Std. dev	mean	Std. dev	mean	Std. dev	mean	Std. dev	mean	Std. dev
First floor	996.85	585.64	127.83	195.47	185663	79256.	415.40	188.63	29781	22897
Intermediate floor	971.15	563.67	139.88	211.49	193773	117910	438.10	266.52	32532	27689
Last floor	939.16	577.27	110.09	209.83	243160	176989	452.67	279.02	34033	29943
obs	10,304		8,055		636		8,055		10,304	

At a glance, there is no significant difference in energy expenditure across floor designations. Nevertheless, households living on top floors are more likely to report overheating problems (see figure 3). Dependency tests reveal a dependency between (i) the floor and reporting cold or overheating issues (Pearson chi2(2) 5,21, p-value=0,072) and (ii) having a regulator and energy expenditure (Pearson chi2(2) =101,87, p-value =0) .

Figure 3: Households reporting overheating problem across floor designations

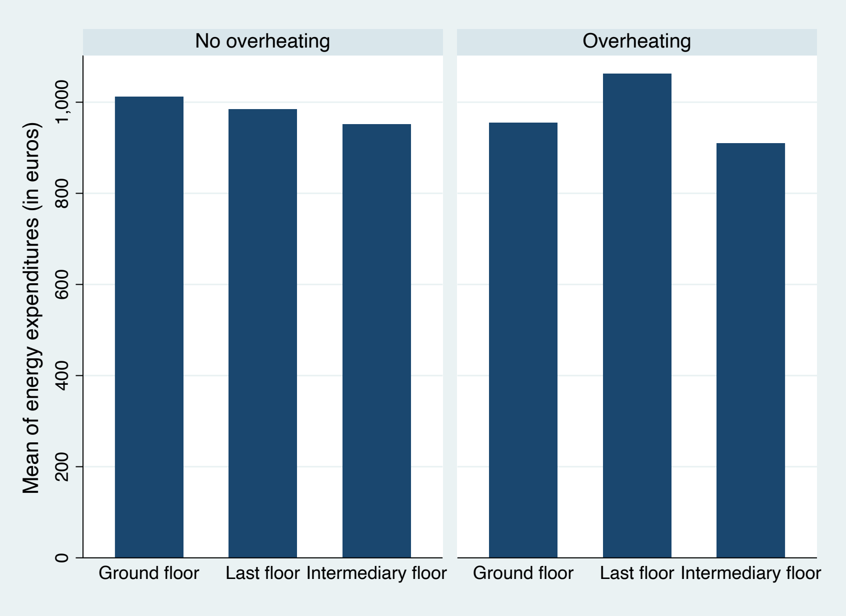
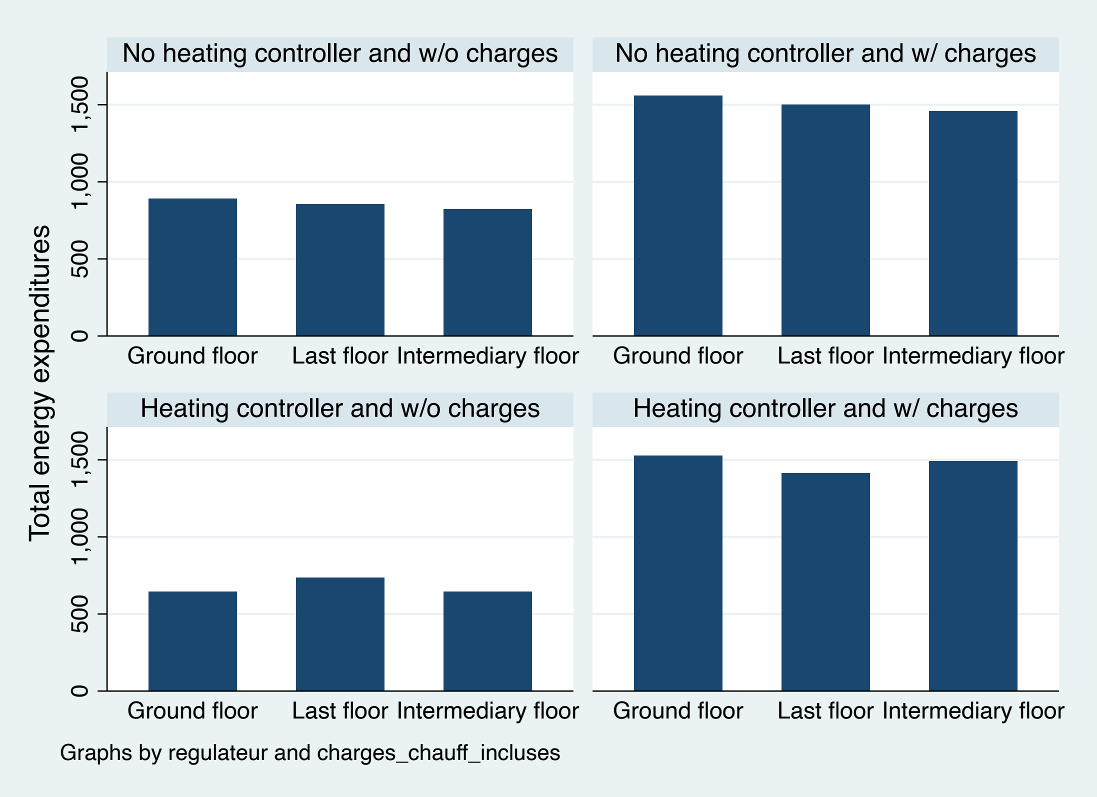


Table 3 : water and energy expenditure included in condominium fees

	Water included		
Heating included	No	Yes	
No	7,819	1,065	8,884
Yes	91	1,329	1,420
	7,910	2,394	10,304
Chi2 test of dependance	Pearson chi2(1) = 4,6+03	critical pvalue 0.0000	

There is also a strong dependency between inclusion of water and heating in utility bills. Only 11.2% of the sample have only one utility (water or heating) included. Overall, households have either all or no utility included. In multi-family dwellings with collective heating systems, some households have no control over heating. Over-consumption can therefore be expected. Looking at Figure 4, it is clear that households whose energy expenditure is included in condominium fees spend significantly more, whether or not they are regulated. It is also noticeable that households that are able to regulate their consumption spend less.

Figure 4: Having heating controller, charges and floor



3/ Model

Econometric analysis of household energy use has heavily relied on conditional demand analysis and the two-step discrete-continuous model first developed by Dubin and McFadden (1984). This framework genuinely links continuous energy use (or expenditure) to discrete investment choices (appliances, heating and cooling systems, insulation). As such, it allows one to address the endogeneity of energy use being determined directly through usage and indirectly through equipment choice (Bakaloglou and Charlier 2019; Dubin and McFadden 1984; Nesbakken 2001; Risch and Salmon 2017; Vaage 2000). It also addresses selectivity biases in data sets with endogenously partitioned observational units (Frondel et al. 2016).

We build on this framework and extend it to account for the fact that household characteristics determine energy expenditure not only through their effect on energy efficiency investment, but also through the floor the household chooses to live on. We thus face two endogeneity problems in the choice of a dwelling's thermal performance, one linked to the floor designation and the other to the heating system. We propose two instruments for each problem.

First, the choice of a heating system, which results from past decisions, will have a direct impact on heating costs in 2013. Upon choosing a dwelling, a household chooses a heating system from among mutually exclusive technologies (collective or individual heating system). Nesbakken (2001) instruments the choice of a heating technology through technical characteristics of the equipment, such as the rate of capital depreciation. Absent such kind of information, we use access to the natural gas network as an instrument. Indeed, using natural gas is only possible if the dwelling has access to the network, which in turn does not affect its performance. As natural gas networks are more common in urban areas, we focus on the Paris area.

Second, the choice of a heating technology is also simultaneous to that of the dwelling's floor. Upon choosing a dwelling, households might be aware of the horizontal and vertical heat transfers that occur within a building (Najjar et al. 2019). In essence, some unobserved preferences may lead a household to choose a dwelling located on the top floor (perhaps to enjoy a nice view) while another one will prefer an intermediate-floor dwelling (perhaps to benefit from heat transfers from neighboring units). To the best of our knowledge, the endogeneity of the floor choice has not been studied in the literature. Here, we address it using the existence of an elevator and the number of units in the building as instruments. The existence of an elevator makes it more convenient to live on a high floor, while involving higher condominium fees. These different arguments can explain the choice of living in a multi-family building with an elevator, without explaining a household's heating costs. In order to ensure the quality of identification, we use the number of units in the building as a second instrument. Specifically, we assume that the probability of living on an intermediate floor is higher in a building with more dwellings, and that this does not affect individual energy expenditure.

We use an extended regression model that allows us to simultaneously estimate a household's choice of a heating technology, a living floor and heating expenditure.[3]

Based on Bakaloglou and Charlier (2019), we specify a utility model such that a household's demand for a heating fuel R^* is determined by a stochastic indirect utility function, which we assume to be unobserved. Indirect utility V depends on income Y, household characteristics (including preferences) Z and building characteristics W. It is defined conditionally on the choice of a heating system and the floor designation:

$$R_{ij}^* = V_{ijf}[Y_i, Z_i, W_i] + v_{ijf} \tag{1}$$

where, for each individual $i = \{1, \dots N\}$, $j = \{0,1\}$ is the type of heating system (using natural gas from the network as the constant), $f = \{0, .., F\}$ is the floor the household lives on, and v_{ij} is the error term.

Once simplified, the energy demand of household i, conditional on a heating system j and a floor f reads:

$$q_{ijf} = \gamma_{ijf} z_{ijf} + \nu_{ijf} w_{ijf} + \alpha_{ijf} \widehat{Floor}_i + \beta_{ijf} \widehat{Heating}_i + \eta_{ij} \tag{2}$$

where q_{ij} is the quantity of energy consumed by household i using a heating system j in floor f, z_{ij} is a vector of household characteristics, $Floor_i$ is the floor designation, $Heating_i$ is the type of heating system, w_{ij} is a vector of building characteristics, γ_{ij} and ν_{ij} are vectors of the related parameters, and η_{ij} the error term considering the influence of unobservable parameters.

We compare two types of estimates, one associated with a dummy variable indicating living on the top floor and another one associated with an order variable representing the floor level (top, , intermediate , ground).[4]The latter is obtained with an ordered probit model(Cameron and Trivadi 2010). For individual i, we thus specify:

$$\widehat{Floor}_i = \gamma'_{ijf} z_{ijf} + \nu'_{ijf} w_{ijf} + \gamma 1_i Elevator_i + \gamma 2_i Nb\_units_i + \beta_{ijf} \widehat{Heating}_i + u_i$$

(3)

where $floor$ is a latent variable indicating the floor; the number of units (Nb_{units}) and the existence of an elevator ($Elevator$) are the instruments; z_{ijf} and w_{ijf} are the regressors.

---

[3] The most common alternative is to estimate the discrete and continuous choices separately, as in Dubin and McFadden (1984). Our simultaneous approach estimates parameters more efficiently, as is illustrated in Table A.2.1 (Appendix A.2) when comparing the predicted values of energy expenditure (in log) and standard deviation obtained with 2SLS and ERM.

[4] Further robustness checks could include using a continuous variable to describe floor level.

For an m-alternative ordered model (with $m = 3$ levels here), we define:

$$Floor_i = f \quad if \;\; \alpha_{j-1} < \widehat{Floor_i} \leq \alpha_j, \qquad f = 1, \ldots., m$$

$$\Pr(Floor_i = f) = \Pr\,(\alpha_{f-1} < \widehat{floor_i} \leq \alpha_f)$$

The regression parameters β and the $m - 1$ threshold parameters $\alpha_1, \ldots, \alpha_{m-1}$ are obtained by maximizing the log likelihood with $p_{if} = \Pr(floor_i = f)$.

We estimate the discrete choice of a heating system with a binary probit model:

$$\widehat{heating_i} = \gamma''_{ijf} z_{ijf} + \nu''_{ijf} w_{ijf} + \delta 1_i Gas\_network_i + \delta 2_i Paris_i + \widehat{Floor_i} + u'_i$$

(4)

where $heating$ indicates the type of heating system; having access to the natural gas network ($Gas\_network$) and living in Paris ($Paris$) are the instruments; z_{ijf} *and* w_{ijf} are the regressors.

Finally, we estimate total energy expenditure (in logarithm, conditional on the dwelling's heating system and floor and a set of control variables (income as well as other individual and housing characteristics).

Altogether, we have a system composed of a threesimultaneousequations(2) (3) and (4). We use extended regression models to simultaneously estimate the two endogenous discrete choices and use maximum likelihood to estimate the linear regression expenditure.[5]

4/ Results and discussion

4.1 Quality of instruments

A preliminary look at error correlation terms reveals significant correlations (see Table 5). This result confirms the endogeneity of a household's choice of aheating system and a living floor. The unobserved heterogeneity associated with energy expenditure is negatively

---

[5] Energy prices are missing from the dataset. Anyway, we do not find it relevant to include them in the estimation. One reason is that they are endogenous to energy expenditure. Another reason is that controlling for technology choice in the first stage (having access to the natural gas network) allows us to consider in cross-section the cost of energy by proxy of the fuel used over the year in question.

correlated with that associated with the choice of the last floor on the one hand, the choice of a heating system on the other.

To test the quality of our instruments – an inherently difficult task when the endogenous variable is discrete --, we proceed in two steps. First, we conduct a significance test (Table A.3 in appendix A) and a wald test (see Table 5).
Second, we use Lewbel (2012)'s estimator for linear regression models containing an endogenous binary regressor. Identification is achieved in this context by having regressors that are uncorrelated with the product of heteroskedastic errors, a common feature when error correlations are due to an unobserved common factor (Baum and Schaffer 2020).

Some authors have considered the method in empirical applications where an endogenous regressor is binary though without verifying if the assumptions is still valid (Le Moglie et al. 2015) but (Lewbel 2018) proofs the validity of the estimator when an endogenous regressor is binary. The estimator is also valid for simultaneous equation systems with more than one endogenous regressor.

Results are also compared with methods that consider the endogenous regressor as continuous. Results stay valid and are presented in the Table 4 below.
Tests are performed with and without correction for heterosckedascitiy problem.
In a first step, we perform test that determine whether endogenous regressors in the model are in fact exogenous:
-Durbin and Wu-Hausman score test of endogeneity. The Durbin (Durbin 1954) and Wu–Hausman (Hausman 1978; Wu 1974) tests assume that the error term is i.i.d.;
-2SLS estimation with an adjusted VCE, Wooldridge (1995)'s score test and a robust regression-based test for estimations corrected for heteroskedasticity.
In all cases, if the test statistic is significant, then the variables being tested must be treated as endogenous. In case it cannot be assumed that errors are i.i.d, the more general estimator based on GMM will produce consistent and efficient estimates. After GMM estimation, the test for exogeneity is the difference-in-Sargan Statistic, also called C statistic.
The underidentification test indicates whether the equation is identified, i.e, whether the excluded instruments are relevant and thus correlated with the endogenous regressors. Rejection of the null hypothesis implies that the model is identified. The rk statistic reported

in Table X is that obtained in the case of robust standard errors. In all cases, our model is identified.

Weak identification tests indicate whether excluded instruments are correlated with endogenous regressors weakly or not. If instruments are weak, such as LIML, estimators can perform poorly and different estimators can be more robust. The estimate reports robust Kleibergen-Paap Wald rk F statistic. The instruments are weak if the 10% maximal IV size exceeds the critical value or different estimators should be prefered. The identification test shows that our instruments are not weak except for the last regression with two endogenous regressors. This result suggests that an extended regression model is more relevant than a two-stage least-square method.

Finally, we perform tests of overidentifying restrictions using a Sargan's and Basman's score tests with and without correction of heteroskedasticity (Sargan 1958). If we used an IV-GMM estimator, the test of overidentifying restrictions is the Hansen J statistic (Hansen 1982). Non-rejection of the null hypothesis of the Sargan-Hansen test builds confidence about the validity of instruments. Tests of overidentifying restrictions actually test two different things simultaneously – whether the instruments are uncorrelated with the error term on the one hand, whether one or more of the excluded exogenous variables are missing from the structural equation on the other. A non-significant test statistic could therefore represent either valid instruments or a correctly specified structural equation. Our tests being non-significant in all cases, we conclude that our instruments are valid.

	Endogeneity on last floor only	Endoneity on floor (3 modalities[a])	Endogeneity on floor (floor number)	Endogeneity on heating system on	Endogeneity on last floor and heating system
Tests of endogeneity H0: variables are exogenous					
Durbin (score) test	chi2(1) = 91.5512 (p = 0.0000)	chi2(1) = 70.0104 (p = 0.0000)	chi2(1) = 47.2317 (p = 0.0000)	chi2(1) = 182.758 (p = 0.0000)	chi2(2) = 265.488 (p = 0.0000)
Wu-Hausman test	F(1,10280) = 92.1568 (p = 0.0000)	F(1,10280) = 70.3251 (p = 0.0000)	F(1,10280) = 47.3387 (p = 0.0000)	F(1,10280) = 185.625 (p = 0.0000)	F(2,10279) = 135.924 (p = 0.0000)
Wooldridge's robust score test	chi2(1) = 89.5308 (p = 0.0000)	chi2(1) = 67.1703 (p = 0.0000)	F(1,10280) = 44.0227 (p = 0.0000)	chi2(1) = 175.578 (p = 0.0000)	chi2(2) = 257.768 (p = 0.0000)
Robust regression-based test	F(1,10280) = 88.8426 (p = 0.0000)	F(1,10280) = 67.447 (p = 0.0000)	chi2(1) = 44.8822 (p = 0.0000)	F(1,10280) = 183.13 (p = 0.0000)	F(2,10279) = 138.163 (p = 0.0000)
C statistic - Difference-in-Sargan Statistic – GMM model	chi2(1) = 89.325 (p = 0.0000)	chi2(1) = 67.3459 (p = 0.0000)	chi2(1) = 5.57754 (p = 0.0182)	chi2(1) = 175.34 (p = 0.0000)	chi2(2) = 256.716 (p = 0.0000)
Test of underidentification H0: the model is underidentified					
Kleibergen-Paap rk LM statistic	105.854 Chi-sq(2) P-val= 0.0000	241.223 Chi-sq(2) P-val = 0.0000	689.564 Chi-sq(2) P-val = 0.0000	28.060 Chi-sq(1) P-val = 0.0000	9.676 Chi-sq(2) P-val = 0.0079
Weak identification test – the instruments are weak is the 10% maximal IV size exceed the critical value					
Kleibergen-Paap rk Wald F statistic					
Critical value	46.280	123.228	437.931	28.060	3.279
10% maximal IV size	19.93	19.93	19.93	16.38	13.43
Test of overidentifying restrictions H0: instruments are valid					
Sargan's score test	chi2(1) = .13201 (p = 0.7164)	chi2(1) = .006965 (p = 0.9335)	chi2(1) = .51849 (p = 0.4715)	chi2(1) = .21497 (p = 0.6429)	chi2(2) = .63383 (p = 0.7284)
Basman's test	chi2(1) = .131705 (p = 0.7167)	chi2(1) = .006948 (p = 0.9336)	chi2(1) = .517308 (p = 0.4720)	chi2(1) = .214474 (p = 0.6433)	chi2(2) = .632331 (p = 0.7289)
Wooldridge's robust score test	chi2(1) = .167125 (p = 0.6827)	chi2(1) = .007903 (p = 0.9292)	chi2(1) = .594744 (p = 0.4406)	chi2(1) = .207865 (p = 0.6484)	chi2(2) = .646353 (p = 0.7238)
Hansen J test	chi2(1) = .167125 (p = 0.6827)	chi2(1) = .007903 (p = 0.9292)	chi2(1) = .3548 (p = 0.5514)	chi2(1) = .207865 (p = 0.6484)	chi2(2) = .646353 (p = 0.7238)

Note: [a]. 0 ground floor (ref), 1 last floor, 2 intermediary floor

Control variables: Income (log), Man,Couple,Age,Nb children,Bac+2,Sup. Bac+2,Climate zone 4,Climate zone 3,Climate zone 2,,Surface area,Double glazing,constructed 1949-1974,Constructed 1975-1981, Constructed 1982-1989, Constructed 1990-1998,After 1999, Heating Controller,Heating expenditures included, Included heating expenditures#Heating controller

4.2 Empirical results

Table 5: empirical results

VARIABLES	(1)	(2)	(3)	(4)	(5)
Heating control	-0.0572**	-0.0559**	-0.0538**	-0.0519**	0.0153
	(0.0159)	(0.0158)	(0.0157)	(0.0157)	(0.0443)
Heating expenditure included	0.728***	0.733***	0.734***	0.737***	
	(0.0159)	(0.0158)	(0.0157)	(0.0157)	
Heating expenditure included#Heating control	0.0741**	0.0721**	0.0763**	0.0751**	
	(0.0368)	(0.0366)	(0.0363)	(0.0361)	
Heating system	-0.437***	-0.429***	-0.0949***	-0.0849***	0.116
	(0.0132)	(0.0133)	(0.0282)	(0.0280)	(0.0957)
Ground floor				REF	REF
Top floor	0.0129	0.290***	0.285***	-0.200***	-0.00726
	(0.0126)	(0.0294)	(0.0296)	(0.0219)	(0.0676)
Intermediate floor				-0.410***	-0.0873
				(0.0401)	(0.133)
Water expenditure included					0.420***
					(0.0863)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	10,304	10,304	10,304	10,304	3,106
R-squared	0.352				
Cut 1				-0.7525	-0.6666
				0.0209	0.0321
Cut 2				-0.0080	0 .1501
				0.0203	0.0311
Correlation error terms					
Floor and energy expenditure (or water expenditure)		-0.3055***	-0.2736***	0.2475***	0.0311
Heating sytem and energy expenditure			-0.3801***	-0.3748***	0 .099
Heating system and floor			-0.0519***	0.0777***	0.0871***
Wald Test					
Chi2		299.98	1235.23	1544.05	382.72
P-value		0.000	0.000	0.000	0.000

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; (1) OLS, (2) control for one endogeneity source on top floor, (3) control for two endogeneities sources (top floor and the type of heating system), (4) control for two endogeneities sources (floor as an ordered variable and type of heating system) and (5) control for two endogeneities sources (floor as an ordered variable and the type of heating system), control regression for water expenditure

By comparing our results with a simple OLS model, we see that ignoring endogeneity concerns leads us to miss the impact floor designation has on energy expenditure and overestimate that of the heating system (see Table 5). Detailed results and results for instrumental equations are provided in appendix A.3.

A closer look at the results (Table 5) indicates that living on the top floor increases expenditure by 28.5% compared to other floors. Expenditure, however, are highest on the ground floor and lowest on intermediate floors (41% less than on the ground floor).

In contrast, additional regressions indicate that the floor designation has no influence on water expenditure. This benchmark confirms the significance of heat transfers across dwellings from different floors. Over-heating seems necessary to maintain a desirable temperature in dwellings located on the ground floor. The same phenomenon plausibly applies to the top floor, which is particularly subject to heat losses.

The most important marginal effect in explaining energy expenditure is the impact of utility-included contracts, the presence of a heating control system, and the interaction between the two. Households that cannot control heating and enjoy utility-included contracts have a 73% higher energy expenditure and a 42% higher water expenditure. The moral hazard problem induced by not facing the marginal cost of water and energy therefore is substantial. The magnitude of the effect is little affected in regressions ran by floor designation or on a smaller sample (66% in the water sample) as demonstrated in appendix B (Table B.2 and B.3).

The moral hazard problem therefore seems to occur irrespective of the floor households live on. The effect is amplified when occupants have control over heating, which reduces energy expenditure by 5% under individual billing but only 0.96% under utility-included contracts. Moreover, regressions by floor designation (see appendix B, Table B.1) indicate that the effect of a control system is more pronounced for those people living on ground and intermediate floors; under utility-included contracts, in contrast, expenditure increases by 1.7%.

Finally, our estimates of other parameters are consistent with those found in the literature. Income elasticities are positive and low (0.035), which is consistent with the normal good status (Bakaloglou and Charlier 2019; Cayla et al. 2011).

Living with a partner and having children are positively associated with energy expenditure. Specifcally, an additional child in the household is associated with a 7% higher energy expenditure, an estimate close to what is otherwise found in the literature (Leahy and Lyons 2010; Vaage 2000)., but there is not a cyclical effect based on the age of the reference person contrary to Brounen and Kok (2011) and Brounen et al. (2013). Newer building (especially those built after 1949) and building located in warmer zones tend to use less energy, a finding consistent with Nesbakken (2001).

5/ Conclusion

Our paper proposes an original instrumental-variable approach to quantify a little discussed problem: heating externalities in multi-family dwellings. We find a significant variation in energy use across floor designations, with intermediate floor using relatively little energy, arguably because they benefit from heat transfers from adjacent dwellings. Albeit significant, the effect is not so large as to offset the energy savings induced by substituting individual energy billing for utility-included contracts. It does however imply that some households – particularly those living on ground floors, who tend to be poorer – may be hurt by such an intervention.

Acknowledgment

Dorothée Charlier would like to thank INTERREG for funding the PACs-CAD project.

References

ADEME 'Individualisation des frais de chauffage dans les logements collectifs.'.
Bakaloglou, Salomé and Charlier, Dorothée (2019), 'Energy Consumption in the French Residential Sector: How Much do Individual Preferences Matter?', *Energy Journal* 40 (3).
Baum, Christopher and Schaffer, Mark (2020), 'IVREG2H: Stata module to perform instrumental variables estimation using heteroskedasticity-based instruments'.
Brounen, Dirk and Kok, Nils (2011), 'On the economics of energy labels in the housing market', *Journal of Environmental Economics and Management,* 62 (2), 166-79.
Brounen, Dirk, Kok, Nils, and Quigley, John M. (2012), 'Residential energy use and conservation: Economics and demographics', *European Economic Review,* 56 (5), 931-45.
--- (2013), 'Energy literacy, awareness, and conservation behavior of residential households', *Energy Economics,* 38 (0), 42-50.
Cameron, Colin A. and Trivadi, Pravin K. (2010), *Microeconometrics Using Stata* (Stata Press, Revisited Version).
Cayla, Jean-Michel, Maizi, Nadia, and Marchand, Christophe (2011), 'The role of income in energy consumption behaviour: Evidence from French households data', *Energy Policy,* 39 (12), 7874-83.
Charlier, Dorothée and Kahouli, Sondès (2019), 'From Residential Energy Demand to Fuel Poverty: Income-induced Non-linearities in the Reactions of Households to Energy Price Fluctuations.', *Energy Journal,* 40 (2), 101-37.
Choi, Seok Joon and Kim, Sangsin (2012), 'Why Do Landlords Include Utilities in Rent? Evidence from the 2000 Housing Discrimination Study (HDS) and the 2002 American Housing Survey (AHS)', *Journal of Housing Economics,* 21 (1), 28-40.
Dubin, Jeffrey A. and McFadden, Daniel L. (1984), 'An econometric analysis of residential electric appliance holdings and consumption', *Econometrica,* 52 (2), 345-62.
Durbin, J. (1954), 'Errors in variables', *Review of the International Statistical Institute,* 22, 23-32.
Elinder, Mikael, Escobar, S., and PetrÈ, I. (2017), 'Consequences of a price incentive on free riding and electric energy consumption', *Proceedings of the National Academy of Sciences,* 114, 3091 - 96.
Estiri, Hossein (2015), 'The indirect role of households in shaping US residential energy demand patterns', *Energy Policy,* 86, 585-94.
Frondel, Samuel, Flores, Fernanda Martínez , and Vance, Colin (2016), 'Heterogeneous Rebound Effects: Comparing Estimates from Discrete-Continuous Models', *USAEE Working Paper 16* (Ruhr Economic Papers: RWI - Leibniz-Institut für Wirtschaftsforschung, Ruhr-University Bochum, TU Dortmund University, University of Duisburg-Essen).
Gillingham, Kenneth, Harding, Matthew, and Rapson, David (2012), 'Split Incentives in Residential Energy Consumption', *The Energy Journal,* 33 (2), 37-62.
Giraudet, L.G and Houde, Sebastien (2018), 'Moral Hazard and the Energy Efficiency Gap: Theory and Evidence', *Journal of the Association of Environmental and Resource Economics,* 5 (4), 755-90.

Hansen, L. P. (1982), 'Large sample properties of generalized method of moments estimators', *Econometrica,* 50, 1029-54.

Hausman, J. A (1978), ' Specification tests in econometrics', *Econometrica,* 46 (1251–1271).

INSEE (2018), 'Le parc de logements en France au 1er janvier 2018', *Céline Arnold, division Logement,,* Insee Focus N°16.

Kaza, Nikhil (2010), 'Understanding the spectrum of residential energy consumption: A quantile regression approach', *Energy Policy,* 38 (11), 6574-85.

Labandeira, Xavier, Labeaga, JosÃ© M., and Rodriguez, Miguel (2006), 'A residential energy demand system for Spain (English)', *The Energy journal* 27 (2), 87-111.

Labandeira, Xavier, Labeaga, José M., and López-Otero, Xiral (2017), 'A meta-analysis on the price elasticity of energy demand', *Energy Policy,* 102, 549-68.

Le Moglie, Marco, Mencarini, Letizia, and Rapallini, Chiara (2015), 'Is it just a matter of personality? On the role of subjective well-being in childbearing behavior', *Journal of Economic Behavior & Organization,* 117, 453-75.

Leahy, Eimear and Lyons, Sean (2010), 'Energy use and appliance ownership in Ireland', *Energy Policy,* 38 (8), 4265-79.

Levinson, Arik and Niemann, Scott (2004), 'Energy use by apartment tenants when landlords pay for utilities', *Resource & Energy Economics,* 26 (1), 51.

Lewbel, Arthur (2012), 'Using Heteroscedasticity to Identify and Estimate Mismeasured and Endogenous Regressor Models', *Journal of Business & Economic Statistics,* 30 (1), 67-80.

--- (2018), 'Identification and estimation using heteroscedasticity without instruments: The binary endogenous regressor case', *Economics Letters,* 165, 10-12.

Maruejols, Lucie and Young, Denise (2011), 'Split incentives and energy efficiency in Canadian multi-family dwellings', *Energy Policy,* 39 (6), 3655-68.

Najjar, Mohammad K., et al. (2019), 'A framework to estimate heat energy loss in building operation', *Journal of Cleaner Production,* 235, 789-800.

Nesbakken, Runa (2001), 'Energy Consumption for Space Heating: A Discrete-Continuous Approach', *Scandinavian Journal of Economics,* 103 (1), 165–84.

Risch, Anna and Salmon, Claire (2017), 'What matters in residential energy consumption: evidence from France', *International Journal of Global Energy Issues,* 40 (1-2), 79-115.

Santamouris, M., et al. (2007), 'On the relation between the energy and social characteristics of the residential sector', *Energy and Buildings,* 39 (8), 893-905.

Santin, O-G (2011), 'Behavioural patterns and user profiles related to energy consumption for heating', *Energy and Buildings,* 43 (2262-2672).

Sargan, J.D (1958), 'The estimation of economic relationships using instrumental variables', *Econometrica,* 26, 393–415.

Vaage, Kjell (2000), 'Heating technology and energy use: a discrete/continuous choice approach to Norwegian household', *Energy Economics,* 22 (6), 649.

Wooldridge, J. M. (1995), 'Score diagnostics for linear models estimated by two stage least squares.', *In Advances in Econometrics and Quantitative Economics: Essays in Honor of Professor C. R. Rao, ed. G. S. Maddala, P. C. B. Phillips, and T. N. Srinivasan,* (Oxford: Blackwell), 66-87.

Wu, D.-M. (1974), 'Alternative tests of independence between stochastic regressors and disturbances: Finite sample results.', *Econometrica,* 42, 529-46.

Appendix A – Results for estimations

Table A.1 Predicted values for energy expenditures in (log)

Energy expenditures (log)	Mean	Std. Deviation
Predicted value with 2SLS	2.545	1.022
Predicted value with ERM	6.672	0.392
Observed value	6.671	0.655

Table A.2 Detailed results

VARIABLES	(1)	(2)	(3)	(4)	(5)
Income (log)	0.0366***	0.0377***	0.0343***	0.0359***	0.0506***
	(0.00837)	(0.00840)	(0.00836)	(0.00840)	(0.0176)
Man	-0.00958	-0.00934	-0.00700	-0.00714	-0.0231
	(0.0118)	(0.0118)	(0.0117)	(0.0117)	(0.0235)
Couple	0.150***	0.150***	0.147***	0.146***	0.287***
	(0.0136)	(0.0136)	(0.0135)	(0.0135)	(0.0267)
Age	-4.08e-05	9.32e-05	-9.26e-05	-3.64e-05	-0.00160**
	(0.000365)	(0.000366)	(0.000366)	(0.000364)	(0.000699)
Nb children	0.0701***	0.0699***	0.0682***	0.0680***	0.155***
	(0.00562)	(0.00561)	(0.00558)	(0.00556)	(0.0118)
Bac+2	-0.0123	-0.0121	-0.00967	-0.00698	-0.0242
	(0.0169)	(0.0168)	(0.0167)	(0.0166)	(0.0366)
Sup. Bac+2	-0.0440***	-0.0395***	-0.0356**	-0.0291**	-0.104***
	(0.0142)	(0.0141)	(0.0141)	(0.0141)	(0.0376)
Climate zone 4	0.00175	0.00302	0.00472	0.00771	0.103***
	(0.0196)	(0.0195)	(0.0195)	(0.0194)	(0.0339)
Climate zone 3	-0.0285**	-0.0235*	-0.0502***	-0.0440***	0.0222
	(0.0138)	(0.0137)	(0.0140)	(0.0139)	(0.0263)
Climate zone 2	-0.0935***	-0.0941***	-0.0976***	-0.0981***	-0.105***
	(0.0208)	(0.0208)	(0.0208)	(0.0207)	(0.0329)
Surface area	0.00698***	0.00700***	0.00683***	0.00693***	0.00447***
	(0.000288)	(0.000288)	(0.000288)	(0.000288)	(0.000596)
Double glazing	0.00838	0.00577	0.00390	0.00159	-0.00620
	(0.0147)	(0.0147)	(0.0146)	(0.0146)	(0.0332)
Construction period 2	-0.119***	-0.112***	-0.120***	-0.114***	0.0616**
	(0.0162)	(0.0161)	(0.0162)	(0.0162)	(0.0309)
Construction period 3	-0.156***	-0.144***	-0.135***	-0.126***	0.0495
	(0.0201)	(0.0201)	(0.0200)	(0.0200)	(0.0435)
Construction period 4	-0.0856***	-0.0757***	-0.0545**	-0.0497**	0.00806
	(0.0253)	(0.0253)	(0.0253)	(0.0251)	(0.0539)
Conbstruction period 5	-0.0836***	-0.0714***	-0.0484**	-0.0425*	0.0178
	(0.0223)	(0.0223)	(0.0223)	(0.0223)	(0.0502)
Construction period 6	-0.114***	-0.100***	-0.0718***	-0.0703***	0.0447
	(0.0209)	(0.0209)	(0.0210)	(0.0213)	(0.0421)
Heating controller	-0.0572**	-0.0559**	-0.0538**	-0.0519**	0.0153
	(0.0237)	(0.0237)	(0.0234)	(0.0234)	(0.0443)
Included heating expenditures	0.728***	0.733***	0.734***	0.737***	

VARIABLES	(1)	(2)	(3)	(4)	(5)
	(0.0159)	(0.0158)	(0.0157)	(0.0157)	
Included heating expenditures#Heating controller	0.0741**	0.0721**	0.0763**	0.0751**	
	(0.0368)	(0.0366)	(0.0363)	(0.0361)	
Heating system	-0.437***	-0.429***	-0.0949***	-0.0849***	0.116
	(0.0132)	(0.0133)	(0.0282)	(0.0280)	(0.0957)
Ground floor	0.0129	0.290***	0.285***	REF	
	(0.0126)	(0.0294)	(0.0296)		
Last floor	0.0129	0.290***	0.285***	-0.200***	-0.00726
	(0.0126)	(0.0294)	(0.0296)	(0.0219)	(0.0676)
Intermediary floor				-0.410***	-0.0873
				(0.0401)	(0.133)
Included water expenditures					0.420***
					(0.0863)
Constant	5.951***	5.858***	5.787***	6.114***	4.558***
	(0.0801)	(0.0812)	(0.0813)	(0.0832)	(0.181)
Observations	10,304	10,304	10,304	10,304	3,106
R-squared	0.352				
Cut 1				-0.7525	-0.6666
				0.0209	0.0321
Cut 2				-0.0080	0 .1501
				0.0203	0.0311
Correlation error terms					
Floor and energy expenditures (or water expenditures)		-0.3055***	-0.2736***	0.2475***	0.0311
Heating sytem and energy expenditures			-0.3801***	-0.3748***	0 .099
Heating system and floor			-0.0519***	0.0777***	0.0871***

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; (1) OLS, (2) control for one endogeneity source on last floor,, (3) control for two endogeneities sources: on last floor and on type of heating system, (4) control for two endogeneities sources: floors and on type of heating system, floors are an ordered equation and (5) control for two endogeneities sources: floors and on type of heating system, floors are an ordered equation – control regression for water expenditures

A. 3 Results for instrumental equations

	Energy					Water	
	(1)	(2)		(3)		(4)	
	Last Floor	Last floor	Heating system	Floor	Heating system	Floor	Heating system
Elevator	-0.419***	-0.405***		0.559***		0.609***	
	(0.0345)	(0.0338)		(0.0295)		(0.0505)	
Nb of dwellings	-0.0026***	-0.0025***		0.0031***		0.0046***	
	(0.000861)	(0.000844)		(0.000739)		(0.00103)	
To be connected to the gas			0.840***		0.833***		0.855***
			(0.0280)		(0.0281)		(0.0609)
Living zone :Paris			0.320***		0.319***		0.213**
			(0.0254)		(0.0254)		(0.0950)

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; (1) control for one endogeneity source on last floor,, (2) control for two endogeneities sources: on last floor and on type of heating system, (3) control for two endogeneities sources: floors and on type of heating system, floors are an ordered equation and (4) Control for two endogeneities sources: floors and on type of heating system, floors are an ordered equation – control regression for water expenditures

B Robustness checks

Table B.1 Robustness check – water sample (2,534 observations)

VARIABLES	(1)	(2)	(3)	(4)	(5)
Expenditures (log)	Energy				Water
Heating Controller	0.0451	0.0324	0.0228	0.0482	0.0319
	(0.0500)	(0.0493)	(0.0532)	(0.0603)	(0.0703)
Heating expenditures included	0.740***	0.715***	0.705***	0.774***	
	(0.0411)	(0.0445)	(0.0500)	(0.0514)	
Collective heating system – urban or gaz	-0.495***	-0.472***	-0.451***	-0.435***	0.0520
	(0.0282)	(0.0306)	(0.0617)	(0.0584)	(0.103)
Included heating expenditures#Heating controller	-0.0682	-0.0533	-0.0421	-0.0790	
	(0.0871)	(0.0913)	(0.0947)	(0.0989)	
Last floor	-0.0119	0.374***	0.375***	REF	
	(0.0237)	(0.106)	(0.107)		
Intermediary floor				-0.534***	-0.188*
				(0.112)	(0.112)
First floor				-0.970***	-0.318
				(0.227)	(0.220)
Included water expenditures					0.375***
					(0.0726)
Other control variables	Yes	Yes	Yes	Yes	Yes
Constant	5.475***	5.339***	5.343***	6.077***	4.730***
	(0.175)	(0.187)	(0.181)	(0.232)	(0.272)
Observations	2,534	2,534	2,534	2,534	2,534
R-squared	0.347				
Cut 1				-0.84746***	-1.01541**
				(0.140595)	(0.37852)
Cut 2				0.70955***	0.541594*
				(0.140098)	(0.378802)
Correlation error terms					
Floor and energy expenditures (or water expenditures)		-0.43143***	-0.43057***	-0.07861	-0.05493
Heating sytem and energy expenditures			-0.02236	0.56061***	0.20155
Heating system and floor			-0.08163***	-0.07271**	-0.04513

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; 1) control for one endogeneity source on last floor, (2) control for two endogeneities sources: on last floor and on type of heating system, (3) control for two endogeneities sources: floors and on type of heating system, floors are an ordered equation and (4) control for two endogeneities sources: floors and on type of heating system, floors are an ordered equation – control regression for water expenditures

Table B.2 Robustness check – by floor

VARIABLES	Last floor	Intermediate floor	First floor
Energy expenditures (log)			
Heating Controller	-0.0545	-0.148***	-0.279***
	(0.0563)	(0.0317)	(0.0717)
Heating expenditures included	0.669***	0.657***	0.662***
	(0.0374)	(0.0218)	(0.0532)
Collective heating system – urban or gaz	-0.295***	-0.175***	-0.309***
	(0.0506)	(0.0417)	(0.0633)
Included heating expenditures#Heating controller	0.0551	0.154***	0.296***
	(0.0865)	(0.0438)	(0.0972)
Constant	6.074***	5.816***	5.578***
	(0.181)	(0.108)	(0.192)
Other control variables	Yes	Yes	Yes
Observations	2,289	6,712	1,568
Correlation error terms	-0.157***	-0.273***	-0.227***
	(0.0470)	(0.0428)	(0.0548)

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$;

Table B.3 Robustness test – with the number of the floor

VARIABLES	(1)	(2)	(3)	(4)
Expenditures (log)	Energy			Water
Heating controller	-0.0619***	-0.0640***	-0.147***	0.0268
	(0.0234)	(0.0235)	(0.0255)	(0.0687)
Included heating expenditures	0.729***	0.735***	0.671***	
	(0.0158)	(0.0161)	(0.0178)	
Heating system	-0.419***	-0.391***	-0.187***	0.0443
	(0.0131)	(0.0143)	(0.0286)	(0.102)
Included heating expenditures#Heating controller	0.0785**	0.0752**	0.135***	
	(0.0364)	(0.0372)	(0.0370)	
Level of floor	-0.0300***	-0.0573***	-0.0577***	-0.0150
	(0.00425)	(0.00619)	(0.00619)	(0.0168)
Level of floor (square)	0.00118***	0.000890**	0.000978***	0.000872
	(0.000349)	(0.000351)	(0.000353)	(0.00116)
Included water expenditures				0.375***
				(0.0706)
Constant	5.986***	6.012***	5.919***	4.558***
	(0.0796)	(0.0808)	(0.0850)	(0.243)
Other control variables	Yes	Yes	Yes	Yes
Observations	10,569	10,569	10,569	2,534
R-squared	0.355			
Correlation error terms				
Floor ratio and energy expenditures (or water expenditures)		0.155***	0.160***	0.0364
Heating sytem and energy expenditures			-0.234***	-0.0415
Heating system and floor ratio			-0.0925***	0.0897***

Note: In this step, in order to consider the size of the building, we introduce a quadratic term.
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; 1 OLS, 2) control for one endogeneity source on floor number, (3) control for two endogeneities sources: on floor ratio and on type of heating system, (4) control for two endogeneities sources: on floor ratio and on type of heating system, water expenditures