The structuring of air source heat pumps' prices in a retrofitting residential buildings market: what did I pay for?

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Abstract
The recent European energy proposals for the revision of the Energy Efficiency and the Energy Performance of Buildings Directives emphasize the importance to drive investments into the renovation of building stocks and to stimulate the refurbishment demand. Moreover, the challenge of acquiring data about retrofitting is reasserted because the lack of reliable data is detrimental to the perception of cost-effectiveness. Especially it is well known that refurbishment prices are, according to various papers, subject to large uncertainty and can sometimes be controversial even if public subsidies are available.

In this paper, we evaluate the main determinants of prices. Their structuring is a complex phenomenon blending technical, economical and organizational sides. For such purpose, we analyzed hundreds of invoices concerning the installation of heat pumps in existing buildings.

In order to model the influence of the different variables on the up-front cost paid by the households, we developed general linear statistical models (ANCOVA) blending qualitative and quantitative variables. The variables taken into account are:

- Technical: living area, type of building (multi or single family), coefficient of performance, installed power;
- and economic: company description (number of employees, main activity and sales network), average household's income linked to location, brand of equipment installed.

Our results confirm the importance of economic variables (such as brand or sales network) beside the technical variables in the explanation of prices. Our results also quantify the relative role of each variable. Half of the prices' variation is explained by the models and it is a huge step in the understanding of retrofit prices in order to better orientate the public subsidies.

Introduction
The renovation of the French housing stock is one of the objectives of the public authorities which has introduced a number of incentives (tax credit, Energy Performance Certificate, lower rate of VAT (Value Added Tax), Energy Efficiency Obligation (EEO), etc.) that are intended to make it possible to achieve these aims in terms of reducing carbon dioxide (CO_2) emissions through market forces rather than through the imposition of obligations (République Française, 2016; MEDDE, 2015).

Nevertheless, in order to have an effective retrofit market, it is necessary that the prices (representing an investment costs for the household) are understandable by the decision-maker, which is not the case today because of the differences observed in renovation prices (Laurent et al. 2011). The reasons for the differences in prices between quotations remain somewhat unclear to private individuals and sometimes even for professionals in the sector. However, a particular link has been observed between a high price paid for renovation work and the quality perceived by households meaning that a low price is associated with a poor quality (Stolyarova 2016) but the prices' difference between quotations cannot be helpful for the household to make a decision. Although this deviation may be due in part to techni-

Table 1. Characterisation of the two samples of ASHP studied.

Type of work	Sample	size	Median price of work (in € ex. VAT)	absolute maximum difference (AMD)	relative interquartile coefficient (RIC)
a-ASHP	main	7,181	3,733	10.9 %	1.11
	subsample	192	4,141		1.12
w-ASHP	main	1,720	13,211	0.3 %	0.49
	subsample	167	13,165		0.49

AMD=|(P_main-P_subsample)|/Min(P_main,P_subsample). The calculation of the maximum absolute difference maximises the error between the two estimates.

RIC: Since the majority of the observed prices had a log-normal distribution with positive asymmetry, the measure of the relative dispersion is based on the relative interquartile coefficient (RIC), which is more robust in the case of an asymmetric distribution.

cal reasons (complexity of a site) or economic reasons (quality of the products, company structure, etc.), it is currently poorly understood. There are therefore objective reasons (technical, etc.) and other more subjective reasons (brand image, etc.) that may be able to explain these differences. However, no study has yet made it possible to quantify the respective impacts of these two groups of causes. The public authorities have insisted on the need to study the level of knowledge concerning the cost of energy renovation work (Couriol & Fuk Chun Wing 2015).

As one area of study, we have analysed the installation of air-air source heat pumps (a-ASHP) and air-water source heat pumps (w-ASHP) during renovation work. As far as ASHP systems are concerned, the literature often analyses their technical and economic performance (Asaee 2017, Kelly et al. 2016, Torekov et al. 2007) but, to our knowledge, has devoted little attention to the observed price structures. The value chain for w-ASHP systems was analysed by (In Numeri, 2014) who found that in 2012, the observed price breakdown was approximately 29 % manufacturing cost, 23 % for the distributor, 22 % for the cost of installation, and a remaining 25 % of "unexplained" costs. Furthermore, recent ASHP-related studies have rather examined the difference between the estimated and real costs (Kelly & Cockroft 2011, Raynaud et al. 2016) or the potential for ASHP installation (Szekeres & Jeswiet 2016, Petrović et al. 2016, Gupta 2014).

Methodology

Based on invoices for renovation work in several residential areas, we produced statistical models combining both qualitative and quantitative variables in order to estimate the effect of different types of variables: technical data (COP, type of ASHP, m²…), macroeconomic data (regional added value, median income in the town …), and microeconomic data (brand of equipment, number of employees per company, economic activity …).

SAMPLING FOR THE ANALYSIS

Two complementary approaches were adopted to estimate the price of an ASHP because they provide different information: an initial approach involving the detailed analysis of invoices for work ("technical" subsample for approximately a hundred installations) and a less detailed approach involving, nevertheless, a larger volume (main, "economic" sample involving several thousand installations).

The work analysed in the present study was commissioned by residential customers, most of whom were owner-occupiers who financed the installation of an ASHP. It should be noted that the differences in the estimates (maximum absolute difference) of the median price (P) between the two samples of data used was less than approximately 10 %. The Euro prices ex. VAT[1] given in this document are for the supplied and fitted system (including labour and ancillary costs (Laurent et al. 2009)) and excluding any eventual trade discount (which is used as an explanatory variable).

For the overall analysis, the information collected, irrespective of the nature of the work, was: the amount in € ex. VAT of the work without distinguishing between the work eligible for EEO and any other associated work not admissible for EEO, location (zip code), type of dwelling (single-family house – SFH, multi-family house – MFH), company's SIREN[2] code and the membership in a commercial network (here, we considered company networks, not networks of energy providers). Despite this, filtering on the number of operations conferring entitlement to EEO does not guarantee that the overall cost of any given operation conferring entitlement to EEO might not contain other work not eligible for EEO but which might be listed in the invoice and therefore included in the analysis. This partly explains the presence of work with very high costs and the removal of these values from the analysis.

The "technical" approach (subsample) permitted a detailed analysis of the work performed in combination with the additional technical data collected, such as the living area covered (m²), the performance (COP[3]), the installed power (kW) and the brand of the installed heating system. To provide further input into the price-of-work databases, we used also other sources of information which were joined together on the basis of the INSEE[4] code, the SIREN code or the region (8 areas):

- Number of RGE (Guaranteed Environmental Quality) small businesses[5] per region (ADEME, 2016).

1. ex-VAT : excluding Value Added Tax.

2. SIREN: national system of identification and register of companies (Système national d'identification et du répertoire des entreprises).

3. Coefficient of Performance.

4. The INSEE code is the numerical code (alike ZIP code), elaborated by the National Institute of Statistics and Economic Studies (INSEE), to register the french municipalities.

5. RGE – Reconnu Garant de l'Environnement (Guaranteed Environmental Quality): the customers of businesses accredited with this quality label are able to benefit from support for their energy renovation projects (MEEM, 2016a).

- Number of employees and company's NACE[6] activity code (INSEE, 2016a), median income in the town (commune)[7], regional Added Value (AV) of the construction sector (INSEE, 2016b).

STATISTICAL ANALYSIS

Due to the nature of the data to be processed, we prepared this prior to the statistical analysis in order to improve the models. Outlying values were removed and the explained variable was log-transformed. The type of statistical modelling chosen was an analysis of covariance[8] (ANCOVA) using the ordinary least square procedure. This has the particular property of combining quantitative and qualitative variables. The obtained model is of the type:

$$\begin{aligned} &ln(explained\ variable) \\ &= cst + \sum_{j=1}^{N_j} a_j * \ln(quantitative\ variable)_j \\ &+ \sum_{k=1}^{N_k}\sum_{l=1}^{m_l} b_{kl} * qualitative\ variable_k\ modality_l + \varepsilon \quad (1) \end{aligned}$$

The use of the logarithm corresponds to multiplicative relations of type:

$$\begin{aligned} &explained\ variable = e^{cst} * quantative\ variable^{a} \\ &* e^{qualitative\ variable^{b}} \quad (2) \end{aligned}$$

The selection of the explanatory variables in the ANCOVA models were made according to the stepwise procedure (entry probability: 0,05 / deleting probability: 0.1) and the reference for the qualitative data: $\sum(b_{kl})=0$, where $l=1,\ldots,m_l$. This means that we compared the effect of a variable with the mean of the modalities and not with a reference modality (such as $b_{k1}=0$) of the qualitative variable under study.

It should be noted that certain statistical models do not respect all the assumptions (homoscedasticity, normal distribution of residuals) for the linear regression model and in particular the normal distribution of residuals. However, if the aim is simply to estimate the parameters of the model and the size of their effect on one another, this latter assumption can be disregarded. However, the model cannot be used predictively (presence of bias) (D.N.Gujarati, 2004). In addition, the statistical models do not exhibit a high level of multicollinearity (VIF[9] max <2.2 et VIFmean <1.3).

The table of standardised coefficients (also known as beta coefficients) makes it possible to compare the relative weight of the variables. The higher the absolute value of a coefficient is, the greater the weight of the corresponding variable. Due to the limitations of certain models, it is this latter analysis that we will consider here.

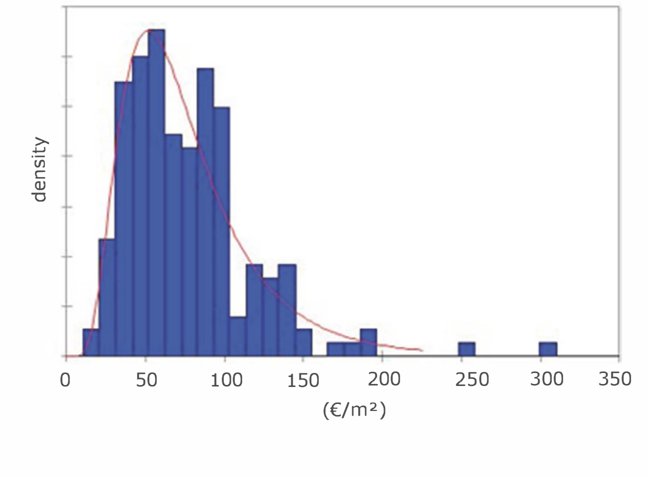

Figure 1: Distribution of total price per square metre (€/m²) for the installation of an a-ASHP [mode = €51 ex-VAT/m² mean = €76 ex-VAT/m², median = €70 ex-VAT/m²].

Results

AIR/AIR SOURCE HEAT PUMPS

Technical subsample

The sample consists mainly of work in Single Family Houses (SFH) (86 %) in climatic zone[10] H3[11] (42 %) with a monosplit (54 %). The analysis makes it possible to calculate a mean total cost of €5,300 ex VAT (€4,141 ex VAT as the median value) for a mean covered living area of 71 m² (i.e. a median price per square metre of €70 ex VAT and a mean price of €76 ex VAT/m²).

The statistical model possesses moderate explanatory power (adjusted $R^2 = 0.52$).[12] All other things being equal, the variance in the price per square metre (in € ex VAT/m²) of an a-ASHP is explained by (Figure 2):

- Technical considerations:
  - The installed output per square metre (kW/m²). As expected, the higher the installed output per unit of surface area is, the higher the price.
  - The type of a-ASHP: a multisplit system is more expensive than a simple monosplit.
- The socio-economic characteristics:

6. Economic Activities in the European Community (commonly referred to as NACE for the French term "nomenclature statistique des activités économiques dans la Communauté européenne"), is the industry standard classification system used in the European Union (Eurostat, 2008).

7. Expressed in €/UC (unit of consumption): 1 UC for the first adult in the household; 0.5 UC for the other persons aged 14 years or more and 0.3 UC for children aged less than 14 years (INSEE, 2016b).

8. Generalisation of a multiple linear regression to the quantitative and qualitative variables.

9. VIF: *variance inflation factor*.

10. Mainland France is subdivided into three climatic zones: H1 (North and East); H2 (West); H3 (South).

11. Then with an equivalent distribution between zones H1 and H2 (27 % and 31 %, respectively).

12. Table 2: RMSE: Root-Mean-Square Error.

- The geoclimatic zone. In zone H3, where the majority of a-ASHP are installed, the price is lower than the national average. By contrast, the price is higher in zone H1.
- The brand. Some brands are differentiated on the market and this has an impact on the final price. However, there are considerable uncertainties concerning the effect and this means that differentiation on the basis of brand is inconclusive. Only the C brands are differentiated from the A and B brands, which are themselves differentiated from the other brands (6 other non-significant brands in the model).
- Income in the commune: counter-intuitively, prices are lower in communes with high median income. It should be noted that the level of uncertainty is high for this variable but in the opposite direction from that observed for other types of work. It is therefore prudent not to consider this variable.
- A discount on the initial quotation (18 % of invoices for a mean amount of €13 ex VAT/m²) finally resulted in a price that does not differ from the mean. It should be noted that we are studying the supplied and fitted price before any discount. In this case, the initial quotation is higher when there is a discount and this results in a final price that does not differ from the other invoices. The presence of a considerable discount thus points to an initial overestimate.

We can also model the total price of installing an a-ASHP (in EUR ex. VAT) using explanatory variables similar to those in the preceding model but with the covered living area added. We find the same conclusions as previously.

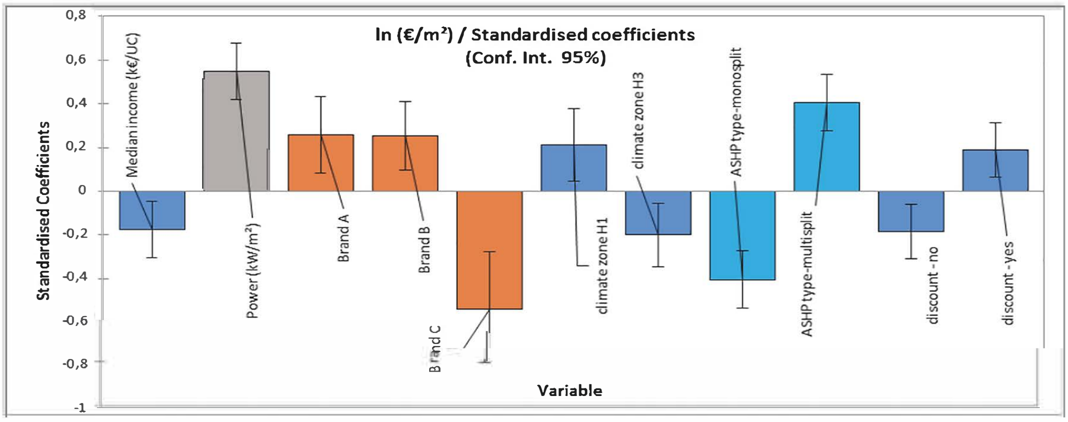

Figure 2. standardised coefficients of the model of the price per square metre (in € ex VAT/m^2) of an a-ASHP. (Significant modalities only).

Table 2. ANCOVA model of the price per square metre (in € ex VAT/m^2) of an a-ASHP. (Significant modalities only).

Variable = ln(€ ex VAT/m²)	Sample =131		F = 11.065		RMSE1 = 0.361	
	R² adjusted =0.52		(Pr > F) < 0.0001		VIFmax=1.216 - VIFmean=1.103	
Source	Value	Standard error	t	Pr > |t|	Lower cut-off (95%)	Upper cut-off (95%)
Constant	4.216	0.284	14.821	< 0.0001	3.653	4.780
Median income (€k/UC)	-0.039	0.014	-2.710	0.008	-0.067	-0.010
kW/m²	6.333	0.757	8.368	< 0.0001	4.834	7.832
Brand-A	0.239	0.081	2.931	0.004	0.077	0.400
Brand-B	0.327	0.103	3.175	0.002	0.123	0.531
Brand-C	-0.323	0.159	-2.033	0.044	-0.637	-0.008
Climate zone-H1	0.139	0.055	2.521	0.013	0.030	0.249
Climate zone-H3	-0.132	0.046	-2.859	0.005	-0.224	-0.041
Type-monosplit	-0.211	0.034	-6.141	< 0.0001	-0.279	-0.143
Type-multisplit	0.211	0.034	6.141	< 0.0001	0.143	0.279
Discount (y/n)-no	-0.126	0.042	-2.980	0.004	-0.209	-0.042
Discount (y/n)yes	0.126	0.042	2.980	0.004	0.042	0.209

Standardised residuals: Shapiro-Wilk test: p-value = 0.059.

Table 3. ANCOVA model of the price (in € ex VAT) of an a-ASHP. (Significant modalities only).

Variable = ln(in € ex VAT)	Sample = 131 R^2 adjusted = 0.701		F = 22.217 (Pr > F) < 0.0001		RMSE = 0.357 VIF_{max}=1.828 - VIF_{mean}=1.217	
Source	Value	Standard error	t	Pr > |t|	Lower cut-off (95%)	Upper cut-off (95%)
Constant	7.215	0.445	16.200	< 0.0001	6.332	8.097
Median income (€k/UC)	-0.040	0.014	-2.799	0.006	-0.068	-0.012
ln(m²)	0.328	0.082	3.990	0.000	0.165	0.491
Output (kW)	0.069	0.011	6.500	< 0.0001	0.048	0.090
Climate zone-H1	0.141	0.055	2.581	0.011	0.033	0.249
Climate zone-H3	-0.132	0.046	-2.859	0.005	-0.224	-0.041
Type-monosplit	-0.226	0.037	-6.049	< 0.0001	-0.300	-0.152
Type-multisplit	0.226	0.037	6.049	< 0.0001	0.152	0.300
Brand-A	0.242	0.080	3.012	0.003	0.083	0.402
Brand-B	0.359	0.102	3.531	0.001	0.158	0.560
Brand-D	0.193	0.085	2.278	0.025	0.025	0.361
Brand-C	-0.413	0.165	-2.499	0.014	-0.741	-0.086
Discount (y/n)-no	-0.099	0.042	-2.343	0.021	-0.183	-0.015
Discount (y/n)yes	0.099	0.042	2.343	0.021	0.015	0.183

Standardised residuals: Shapiro-Wilk test: p-value=0.103.

Main sample

Here again, the greatest number of a-ASHP were installed in SFH (80 %), with a difference in price between installations in Multi Family Houses (MFH) and SFH of approximately 50 %, primarily due to the higher mean living area covered in SFH[13]. The H3 zone was overrepresented (54 %).

The available "economic" sample does not directly indicate the covered living area but does enable us to estimate this surface area by segment by modulating[14] the EEO sheet (MEEM 2016b). We are therefore obliged to estimate only the absolute price of the work (in € ex VAT/dwelling) and not the price per square metre as was possible for the technical subsample. The main modalities of the quantitative variables in the sample were as follows: company with fewer than 10 employees for 68 % of the sites [3 modalities present] with the company's main activity being the installation of heating and air conditioning equipment (NACE 4322B) in 58 % of cases [48 modalities] and the company not being a member of a commercial network in 42 % of cases [8 modalities].

The obtained statistical model possesses moderate explanatory power (adjusted R^2 = 0.53). The variations in the price of installation of an a-ASHP are explained by similar variables to those found in the previous models, together with microeconomic variables that were not available for the "technical" subsample. Thus, the number of employees in the company performing the work had an impact on the observed prices with the price being higher in the case of large companies (>50 employees). Similarly, the company's sector of activity, which has a clear upward effect on price for companies whose main sector of activity is not installing heat pumps (construction, insulation, etc.). Finally, we observe upward or downward price effects for certain commercial networks although coupled with a high level of uncertainty. As far as the median communal income variable is concerned, the positive effect, although small, is opposite to that observed for the technical subsample. For this variable, the uncertainty of the effect is lower in this latter model than in the previous one and acts in the same direction as has been observed for other types of work (Osso & Laurent 2016). It should be noted that the "living area covered" technical variable is the variable that explains the greatest part of the price variations (first variable adopted in the stepwise procedure with an adjusted R^2 of 0.442 for a total adjusted R^2 of 0.533).

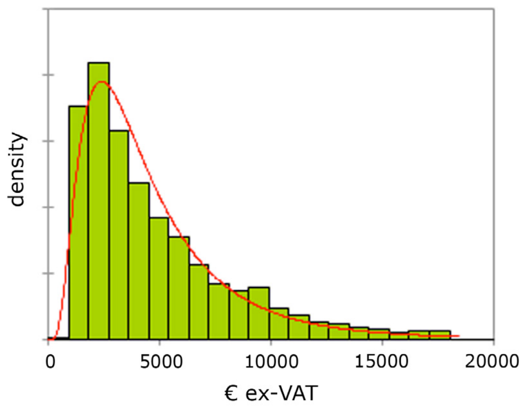

Figure 3. Distribution of the total price for installing an a-ASHP [mode = €2,387 ex VAT, mean = €4,767 ex VAT, median = €3,786 ex VAT].

13. When compared on the basis of similar surface areas (60-80 m^2), the mean price is slightly different: €4,157 ex VAT for a MFH and €4,708 ex VAT for a SFH.

14. Segmentation of the different living areas covered as a function of the type of dwelling (SFH, MFH).

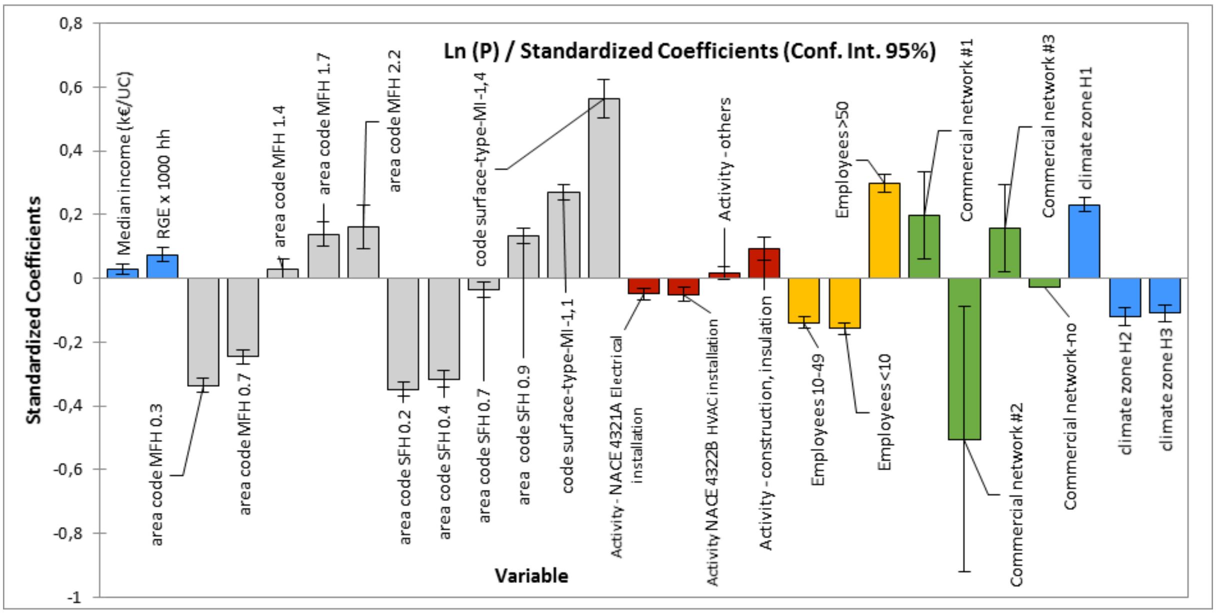

Figure 4. standardised coefficients of the ANCOVA model of the price (in € ex VAT) of installing an a-ASHP.

AIR/WATER SOURCE HEAT PUMPS

Technical subsample

The analysed sample consisted of installations of w-ASHP performed exclusively in SFH in the H1 zone, at a mean price of €14,300 ex VAT per SFH, i.e a price per square metre of €114 ex VAT/m² of covered living area.

According to the statistical model, the price per square metre (in € ex VAT/m²) is explained, all other things being equal, by:

- Technical considerations: The installed output per square metre (kW/m²), which increases the price.
- Microeconomic variables:
  - The product brand, even if, among the 16 brands observed, only 5 were considered significant and this with a high level of uncertainty. Instead, it is necessary to consider three brands that are less expensive and two brands that are more expensive than the observed market mean.
  - A considerable discount on the initial quotation (16 % of invoices for a mean amount of €2,700 ex VAT) finally resulted in a price that does not differ from the mean for the sample.

Main sample

The mean price for the installation of a w-ASHP is €14,271 ex VAT (median €13,404 ex VAT) and such installations are primarily found in houses with a large surface area (>130 m²: 41 %; 100 to 130 m²: 35 %) located in zone H1 (49 %) and H2 (39 %). It should be noted that there are significant geographical price disparities between regions.

In the absence of microeconomic data on the companies, the statistical model has low explanatory power ($R^2<0.2$). When the economic (NACE, workforce) and geographical data is added, the main modalities of the qualitative variables are as follows:

- For the geoclimatic zones: H1 at 54 % and H2 at 36 %.
- For the number of employees: between 10 and 19 employees for 19 % of the sites [8 modalities in all].
- For NACE code 4322B for the company's activity – Installation of heating and air conditioning equipment 55 % [24 modalities in all].
- Non-membership of a commercial network at 63 % [6 modalities for membership of a network, with "non-membership" being the modality of most of the companies in question].
- A large living area (>130 m²) for 40 % of the sites [7 modalities].
- The installation of a w-ASHP with a COP>4 for 54 % [2 modalities COP < or > 4].

All other things being equal, the price per square metre (in € ex VAT/m²) is thus explained by:

- Technical considerations: the performance of the system (i.e. the COP) with a lower price for the more powerful equipment (COP>4).
- Microeconomic variables:
  - The number of employees, with increasing numbers of employees being associated with higher prices.
  - The company's activity, with activities less associated with heat pump installation (e.g. insulation) being associated with higher prices.
  - The company's commercial network: membership of a commercial network may have a positive or negative impact on the final price depending on the type of commercial network.
- Macro-economic variables:

Table 4. ANCOVA model of the price (in € ex VAT) of an a-ASHP. (Significant modalities only).

Variable = ln(in € ex VAT)	Sample = 7,181	F = 293.462			RMSE = 0.462	
	R^2 adjusted = 0.533	(Pr > F) < 0.0001			VIF_{max}=2.172 - VIF_{mean}=1.145	
Source	Value	Standard error	t	Pr > |t|	Lower cut-off (95 %)	Upper cut-off (95 %)
Constant	8.193	0.075	109.593	< 0.0001	8.047	8.340
Median income (k€/UC)	0.006	0.002	3.373	0.001	0.003	0.009
RGE (/1,000 hh)	0.288	0.044	6.535	< 0.0001	0.202	0.375
Area code-MFH-0.3	-0.781	0.026	-29.593	< 0.0001	-0.832	-0.729
Area code-MFH-0.7	-0.478	0.022	-21.551	< 0.0001	-0.521	-0.434
Area code-MFH-1.4	0.099	0.050	1.975	0.048	0.001	0.197
Area code-MFH-1.7	0.489	0.070	6.980	< 0.0001	0.352	0.626
Area code-MFH-2.2	0.603	0.128	4.701	< 0.0001	0.351	0.854
Area code-SFH-0.2	-0.749	0.024	-30.834	< 0.0001	-0.797	-0.701
Area code-SFH-0.4	-0.445	0.018	-24.677	< 0.0001	-0.480	-0.410
Area code-SFH-0.7	-0.055	0.019	-2.905	0.004	-0.093	-0.018
Area code-SFH-0.9	0.221	0.020	11.120	< 0.0001	0.182	0.260
Area code-SFH-1.1	0.462	0.020	22.755	< 0.0001	0.422	0.502
Area code-SFH-1.4	0.665	0.032	21.000	< 0.0001	0.603	0.727
Activity – Electrical installation (NACE 4321A)	-0.085	0.016	-5.242	< 0.0001	-0.117	-0.053
Activity –HVAC installation (NACE 4322B)	-0.062	0.013	-4.834	< 0.0001	-0.088	-0.037
Activity – construction, insulation (gathered NACE)	0.146	0.029	5.062	< 0.0001	0.090	0.203
Employees: 10–49	-0.182	0.012	-15.640	< 0.0001	-0.205	-0.159
Employees: <10	-0.182	0.011	-17.189	< 0.0001	-0.203	-0.161
Employees: >50	0.364	0.017	20.833	< 0.0001	0.330	0.399
Commercial network-#1	0.160	0.057	2.795	0.005	0.048	0.272
Commercial network-#2	-0.691	0.290	-2.383	0.017	-1.259	-0.122
Commercial network-#3	0.128	0.057	2.234	0.026	0.016	0.240
Commercial network-no	0.158	0.057	2.780	0.005	0.047	0.270
Climate zone-H1	0.221	0.011	19.348	< 0.0001	0.199	0.244
Climate zone-H2	-0.090	0.010	-8.826	< 0.0001	-0.110	-0.070
Climate zone-H3	-0.132	0.011	-12.140	< 0.0001	-0.153	-0.110

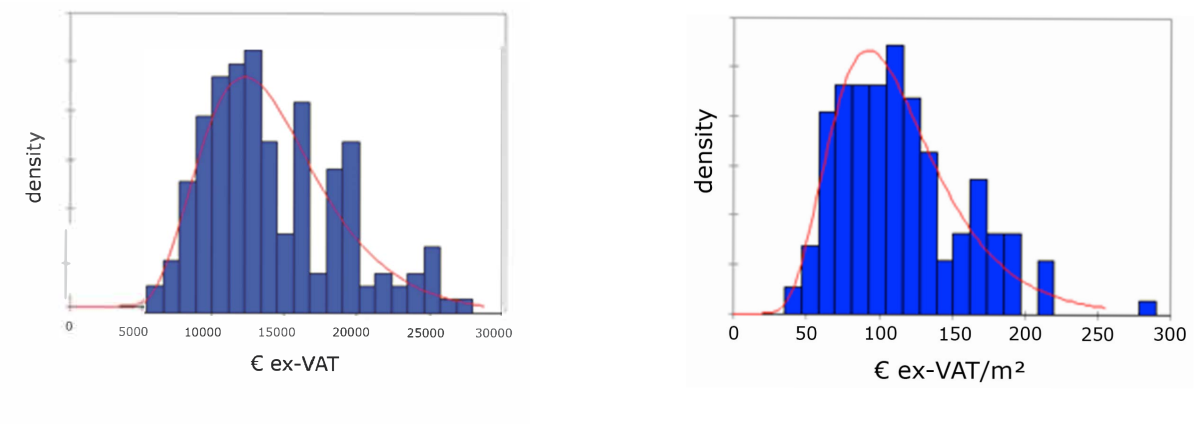

Figure 5. Distribution of total price [mode =€12,271 ex VAT] and price per square metre [mode = €92 ex VAT/m²] for a w-ASHP.

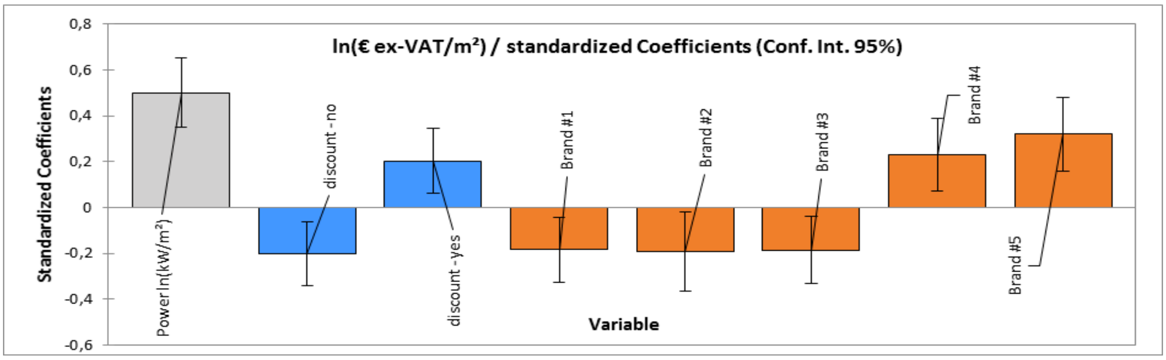

Figure 6. Standardised coefficients of the model of the price per square metre (in € ex VAT/m²) for the installation of a w-ASHP.

Table 5. ANCOVA model of the price per square metre (in € ex VAT/m²) for the installation of a w-ASHP. (significant modalities only).

Variable = ln(€ ex VAT/m²)	Sample = 134 R² adjusted = 0.450		F = 7.396 (Pr > F) < 0.0001		RMSE = 0.263 VIF_{max}=1.438 - VIF_{mean}=1.076	
Source	Value	Standard error	t	Pr > |t|	Lower cut-off (95 %)	Upper cut-off (95 %)
Constant	6.185	0.239	25.881	< 0.0001	5.712	6.659
Power [ln(kW/m²)]	0.657	0.101	6.494	< 0.0001	0.456	0.857
Discount – no	-0.090	0.032	-2.854	0.005	-0.153	-0.028
Discount – yes	0.090	0.032	2.854	0.005	0.028	0.153
Brand-1	-0.310	0.120	-2.579	0.011	-0.549	-0.072
Brand-2	-0.559	0.251	-2.227	0.028	-1.056	-0.062
Brand-3	-0.381	0.150	-2.537	0.012	-0.679	-0.084
Brand-4	0.218	0.075	2.905	0.004	0.069	0.366
Brand-5	0.333	0.084	3.951	0.000	0.166	0.500

Standardised residuals: Shapiro-Wilk test: p-value=0.063.

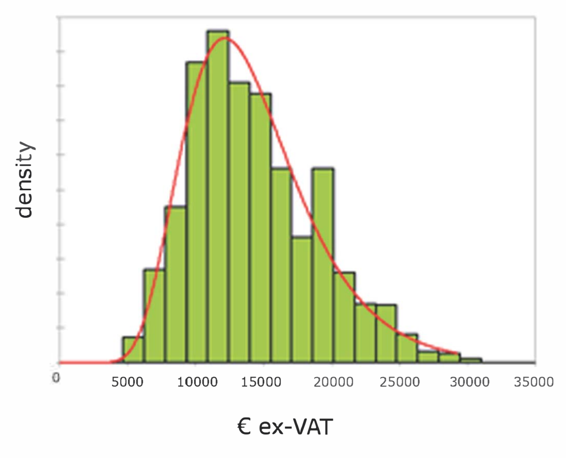

Figure 7. Distribution of installation prices (in € ex VAT) for a w-ASHP.

– The climatic zone, with work being more expensive in zone H1 than in zone H2 or H3. The regional added value in the construction sector per household, which has a downward effect on prices.

Conclusions

To explain these variations in the price of renovations in varied residential environments is a difficult task which our models are only partially successful in achieving. This means that, on the basis of our samples, we are not able to obtain sufficient quantities of the information that contributes to the determination of prices. There may be other technical reasons that we have not listed above. One of the reasons lies in our lack of knowledge about the households making the decisions concerning the work. While we are able to collect the technical data concerning the studied energy efficiency operations or the economic information concerning the professionals undertaking the work, no information relating to their customers is available to us.

Despite these limitations, this study allows us to reveal a range of reliable observations concerning the composition of renovation prices. First of all, the wide range of technical

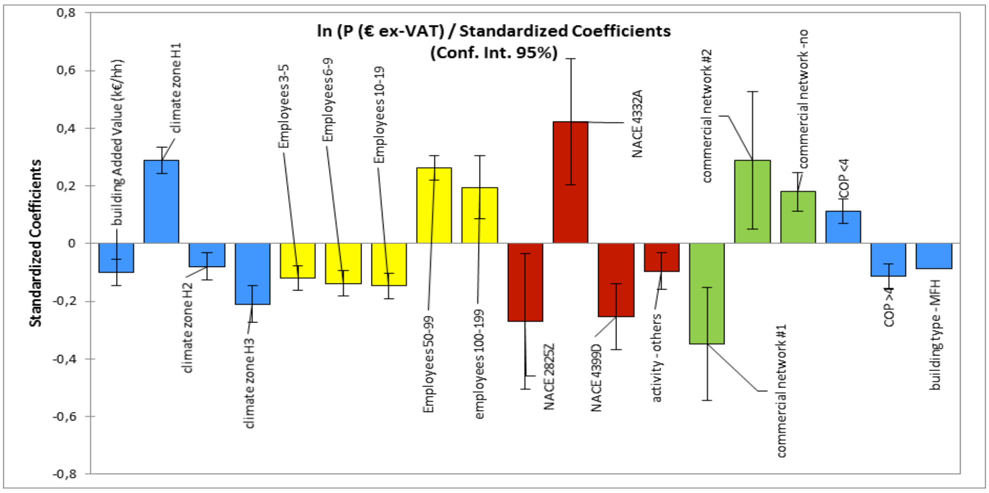

Figure 8. standardised coefficients of the model of the price (in € ex VAT) of installing a w-ASHP.

Table 6. ANCOVA model of the price (in € ex-VAT) for the installation of a w-ASHP. (significant modalities only).

Variable = ln(ex VAT)	Sample = 1,720 R² adjusted = 0.355		F = 29.707 (Pr > F) < 0.0001		RMSE = 0.266 VIFmax=2.165 - VIFmean=1.274	
Source	Value	Standard error	t	Pr > |t|	Lower cut-off (95 %)	Upper cut-off (95 %)
Constant	9.684	0.084	115.777	< 0.0001	9.520	9.848
Added Value (€/hh)	0.000	0.000	-4.350	< 0.0001	0.000	0.000
Climate zone-H1	0.141	0.011	12.324	< 0.0001	0.119	0.164
Climate zone-H2	-0.042	0.012	-3.348	0.001	-0.066	-0.017
Climate zone-H3	-0.100	0.016	-6.092	< 0.0001	-0.132	-0.068
Employees: 3–5	-0.121	0.021	-5.642	< 0.0001	-0.163	-0.079
Employees: 6–9	-0.103	0.017	-6.145	< 0.0001	-0.136	-0.070
Employees: 10–19	-0.117	0.018	-6.653	< 0.0001	-0.152	-0.083
Employees: 50–99	0.288	0.024	12.073	< 0.0001	0.241	0.335
Reduced activity code-2825Z – Production of industrial aeraulic and refrigeration equipment	-0.232	0.103	-2.258	0.024	-0.434	-0.031
Reduced activity code-4332A – Wood and PVC joinery	0.362	0.096	3.786	0.000	0.174	0.549
Reduced activity code-4399D – Other specialised construction work	-0.201	0.046	-4.371	< 0.0001	-0.291	-0.111
Reduced activity code-Other	-0.068	0.026	-2.657	0.008	-0.118	-0.018
Commercial network-#1	-0.198	0.057	-3.499	0.000	-0.310	-0.087
Commercial network-#2	0.126	0.053	2.386	0.017	0.022	0.229
Commercial network-no	0.139	0.051	2.723	0.007	0.039	0.239
w-ASHP COP <4	0.037	0.007	5.249	< 0.0001	0.023	0.051
w-ASHP COP >4	-0.037	0.007	-5.249	< 0.0001	-0.051	-0.023
MFH type-yes	-0.293	0.080	-3.671	0.000	-0.449	-0.136

variables (e.g. living area covered) has been identified as the main reason for the variation in absolute price (i.e. (in € ex VAT). Since we studied only high-performance installations (i.e. those eligible for EEO) with relatively small differences in performance, the technical variables associated with this performance (e.g. COP) were significant only for the installation of a w-ASHP.

Once the extensive technical dimensions have been neutralised by considering the price per square metre (in €/m²), the main variables explaining the price variations are still technical:

- The installed output per square metre: kW/m², the living area covered (scale effect). This means that a part of the fixed costs (integrated in the HP installation price) could be reduced with a complete refurbishment in one stage instead of many ones (e.g. room by room insulation). The question of a large up-front cost payment in the complete retrofit could be tackled through dedicated soft loans over a long period.

- The specific technical characteristics (e.g. a-ASHP multi-split with more components vs. mono-split) that have an upward effect on prices.

The socioeconomic components that have an effect on price variations, including macroeconomic effects such as:

- Geoclimatic zones (H1, H2 or H3). Overall, energy renovation work, irrespective of its nature, is more expensive in zone H1 than in zone H3. Zone H2 is either between these two extremes or close to zone H1. It is, however, difficult to find an easy interpretation for this difference. Indeed, the effect of potential income associated with the climatic zones should be at least partly captured by the variable median income of town, the effect of which is, nevertheless, weak. The question of competition between professionals and the types of work cannot explain why the differences between zones always point in the same direction. We could explain the price difference between geoclimatic zones as a willingness to pay to decrease energy bill which is more important in zone H1 than in zone H3.
- Regional economic activity (income in commune, percentage of RGE-qualified businesses, households, added value, etc.), the effects of which are very small and which may have a positive or negative impact depending on the type of work. It is again difficult to interpret these effects.

And microeconomic effects:

- First and foremost, the effect of certain brands of studied heating systems. The question of public subsidizing marketing position of companies through financial incentive is point out. This question was already tackled and a conditional subsidy scheme was proposed (Laurent et al., 2011).
- The effect of commercial network is variable: some have an upward effect on prices and others a downward effect. Membership of a commercial network does not therefore guarantee that prices will be lower than they are in the case of companies that do not belong to such a network. It should be noted that most of the companies did not belong to a commercial network.
- The effect of the company workforce seems to have an upward effect on prices with the largest establishments tending to have the highest prices. We should point out that this effect represents the balance between two opposing impacts on price: one, the organisation costs, exerting upward pressure; and the other, the greater negotiating power with equipment suppliers (dealers, for example), exerting downward pressure.
- The effect of sector of activity is difficult to study because companies declare their main activity (or the traditional activity of their organisation which may no longer have anything to do with the activity that we studied here). Furthermore, due to the diversity of the sectors of activity (several dozens) and effects that were sometimes of the same size, it is difficult to draw conclusions about any specific sector. Despite this, we can note the upward effect on prices of companies practising an activity other than the one under study (e.g. joinery activities for companies installing an ASHP). This can be interpreted as the inclusion of risk cover in the proposed price (e.g. potential subsequent technical problem to be resolved (Renauld-Giard, 2016)).

We can draw some preliminary conclusions in order to limit the public and consumer expenses (better allocation of energy efficiency incentives) and to develop the quality of retrofitting (better efficiency of retrofit). First of all, the extremes of the price distribution should be explained in order to better understand the reasons of them:

- Low prices: low quality, investment costs adapted to low income households, efficient structure of company or business model …
- High prices: overcharging and marketing position, complex retrofit or inadequate business model …

Finally, as numerous statistically observed effects are not totally explained, especially the type of commercial network associated with the lower prices, further study in order to explain the observed downward effects should be realised.

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