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The correct price or the fair price? A quali-quantitative analysis of the formation of price for energy retrofit works in the residential sector in France

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ABSTRACT

This paper tackles the crucial issue of price structure in the energy retrofit market of the private residential sector. It is based on a quantitative study of retrofit prices in France (1,000+ invoices) and a qualitative sociological survey of installers (25 open-ended interviews). We show a strong dispersion of prices within single retrofit-work categories (e.g. boiler, insulation). Half of the dispersion is explained by technical and economic reasons (brand and quality of product, housing size, type of company, discount…). This means that from a technical standpoint, the price is correct. Other components of the price are revealed by the qualitative survey.

On the customer side, the refurbishment market is marked by a strong uncertainty. It is technically complex and there is a concern about poor workmanship, hence the role of reputation and trust. These are factored in the price as a "confidence premium" which makes the price fair from the customers' point of view.

On the installer side, the price is formed at the crossroads of three characteristics: the perception of the household willingness to pay, the management practices of the company (profit margin calculation, load plan) and an adjustment to current local market prices. The fair price from the installer point of view is the price that allows his company to survive or make profit and to win new contracts. However, a determining factor of the price lies in the installer's recommendation of exactly which work to do and with which material or equipment. For a given energy performance, several technical solutions exist that impact the final price.

To conclude, we note that observed prices may differ from the technically "correct" price but this doesn't mean that prices are inaccurate. Prices incorporate qualitative dimensions such as the accessibility of the site or the work quality of the company (being on-schedule, cleanliness of the work, etc.) that make them "fair" in practice. As a policy consequence, rather than a direct intervention on prices which is complex, governmental action might focus on standardizing the presentation of quotation, craftsmen company management and on assisting customers in their choices.

Introduction

France has made a commitment to cut its greenhouse gas emissions by 75% by 2050. In France, buildings are one of the levers identified in government policies to reach this objective, since they are the

major energy-consuming sector in France and one of the largest emitters of greenhouse gases (ADEME 2013). Renovating existing buildings is a priority for reducing fuel consumption to an acceptable level; but the diffuse nature of the residential sector complicates identifying what mechanisms to implement to promote successful, large-scale renovation.

This fact is well known to the public authorities which have, in recent years, set ambitious targets and implemented measures to refurbish housing. One objective laid out in the Law on Energy Transition for green Growth (2015) is to of renovate 500,000 homes per year from 2017, of which 380,000 are private housing units. In order to achieve these objectives, public authorities have chosen to encourage households to carry out retrofits through subsidies (tax credits, energy efficiency obligation, etc.). More recently, more restrictive standards on energy performance have been passed in the thermal regulation in existing buildings (2017), particularly thresholds for components used in renovation such as windows or insulation materials.

This has been accompanied by inflationary price trends (INSEE 2017) in a sector in which prices and margins are already nebulous and controversial (Baulinet *et al.* 2014, Chesnay and Bourcier 2016). The question of fair pricing for refurbishments is crucial to secure the market's dynamics and consequently to increase the number of successful renovations undertaken. Whereas the profession considers that "*there is no standard price... because prices depend not only on the performance and the quality of the products or equipment that are used but also on the actual situation of the dwelling and people's lifestyles*" (Batirama 2016a), consumer associations point to a "*stagnation of the market [due] to a lack of consumer confidence*" (Batirama 2016b).

The price appears as a central but under-researched issue in the energy efficiency retrofit debate of the private residential sector. As mentioned above, the level and breakdown of prices, margins and the distribution of value within the sector are not only notoriously poorly understood but also subject to controversy. It is this lack of knowledge that this article intends to remedy, thus helping to inform the debate. More precisely, this article tackles the issue of price dispersion in energy efficiency retrofits. Indeed, one of the major characteristics of this market is the wide price dispersion, for a given type of work. The aim of this article is not to study the level of renovation prices but to analyse the reasons for their wide dispersion, a phenomenon that is even more nebulous than price levels themselves and more interesting in terms of potential recommendations for widespread expansion of the market.

In fact, from the point of view of economics, the price of renovation work has very distinctive characteristics. Energy efficiency retrofits can be considered as a "*belief and trust purchase*" whose quality is unknown at the time of purchase and may become apparent only through usage (Giraudet *et al.* 2015), which has consequences for the price (in particular, on the willingness of households to pay). Also, to analyse the prices of the renovation, it is advisable to appeal not only to economics as a science but also to economic sociology. The latter considers that markets are not interfaces between supply and demand in which the outcome of the balance of power is the economically rational constitution of a price. If prices are indeed at the heart of markets, they are shaped by social dynamics that go beyond the simple economic balance between supply and demand (Beunza *et al.* 2006; Callon 2017). From this point of view, therefore, price analysis involves analysing the context of the market in which they are shaped, taking into account dynamics and factors other than those conventionally considered by economic analysis.

That is why this article intends to remedy the lack of knowledge on the dispersion of renovation prices by implementing a dual approach: technical-economic and sociological. The quantified investigation of the price structuring of the renovation market is complemented by a qualitative field survey on the actual practices of the actors in order to be able to understand and interpret the quantified results in a sensible way. The objective of this study is not to give *THE PRICE* of energy efficiency refurbishment work, which, we will see later, is illusory, but to understand how the prices vary and the reasons for these variations. Our choice of a mixed approach (quantitative and qualitative) to a problem that is notoriously little addressed and controversial is original to this paper.

The first part of the paper is a techno-economic quantitative analysis of the prices of energy retrofit works in the diffuse (owner-occupied) residential sector in France. It focuses on the breakdown and heterogeneities of prices in that market. The second part of the paper proposes a qualitative sociological analysis centered on the role of the intermediaries (installers) in the sector and on the socio-economic mechanisms of pricing to supplement and clarify the quantitative analysis. Finally, we conclude on the potential implications on energy policies that our results suggest.

Quantitative analysis

Methodology

This section presents the data and methodologies used to analyse the observed price structure of energy efficiency retrofit in the scattered residential sector. Two complementary approaches, both based on invoice analysis, have been implemented to estimate the variations in the price of work because they offer different information. A first approach analyses the invoices for the work carried out in detail[1], the so-called "technical" approach on a hundred of renovation work. The second approach uses a less detailed[2] approach but more consistent in terms of volume, the so-called "main sample" approach on several thousand of invoices. The items of work studied concerned both the insulation of the building shell (roofs, walls, windows) and heating systems (condensing boiler, air/water and air/air heat pump (HP)) for one and the same year. Prices are analysed separately for each type of works, even when several works are jointly done. However no distinction from the two samples (“technical” and “main”) are presented because the results are similar or complementary.

The statistic models were based on analysis of covariance (ANCOVA: generalised multiple linear regression for quantitative and qualitative variables). For more details and explanations about these quantitative analyses, see (Osso *et al.* 2017). This method was selected because it enables to assess the relative effect of each qualitative or quantitative variable tested on the explained variable and to distinguish the effects of variables that can be correlated.

Table 1: target prices (€ excluding VAT) of various types of work (main samples).

Type of work (unit)	Average price	Median price	Relative interquartile range**	Share of Labour costs*	Share of ancillary costs*
Air/air HP (€)	4,767	3,733	0.69	20%	9%
Air/water HP (€)	14,300	13,211	1.11	12%	7%
Domestic heating boiler (€)	4,400	3,864	0.58	17%	15%
Attic (€/m²)	55	47	0.61	26%	22%
Internal wall insulation (€/m²)	80	67	0.50	30%	58%
External wall insulation (€/m²)	174	159		30%	35%
Window (€/unit)	1,343	1,131	0.73	18%	-

* Data from technical sub-sample: labour cost and ancillary costs are not cumulative.

**The greater is the relative interquartile range, the greater the dispersion.

[1] The invoice provides several technical information, beyond the efficiency of the measure, like area (m²), power (kW), the type of equipment installed (e.g. brand). The invoices analysed are from 2012.

[2] Less detailed means that the technical information available are limited.

The prices of residential retrofits in the residential sector (i.e. for the samples analysed: mostly works in single-family homes decided by owner-occupiers) presented a large price dispersion (see relative interquartile range[3] in Table 1) that was difficult to explain at first, even for fairly similar projects (e.g. boiler, insulation of attic spaces). We must noticed that we only studied efficient work (i.e. eligible for the French EEO[4] and tax credit schemes) with relatively small performance differences between the different measures of the same type (e.g. small efficiency difference between the condensing boilers installed).

Results

The ANCOVA analyses based on the technical and main samples show that the price dispersion was partly explained by technical reasons (complexity of a renovation project) and/or economic reasons (product quality, organisational structures). Other reasons may also have come, among others, from the brand of products, the local competitive situation and the ability of households to pay.

Effects of technical variables

The statistical analyses showed that extensive technical variables (e.g. surface treated, number of windows) were the main reasons for the price variation in absolute terms (i.e. in € excluding VAT). Since we only studied efficient work (i.e. eligible for the French EEO and tax credit schemes) with relatively small performance differences, the energy performance variables (e.g., heat pumps' coefficient of performance – or thermal resistance) were considered as significantly explanatory of the price variation only for the modelling of external insulation works and the installation of an air/water HP.

Once the extensive technical dimensions[5] had been neutralized via the price per unit for surfaces (in € excluding VAT /m²), the main variables that explained the price variations remained technical:

- Installed power (boilers and heat pumps) density, i.e. per heated floor area (kW/m²), surface treated (m²) for insulation (scale effect). The installed surface power density (kW/m²) is usually linked to the design depending on the energy needs of the dwelling. The greater the installed power per unit area, the higher the price. For insulation, as the area increased, the price per square meter decreased non-linearly due to the effect of fixed and variable costs (surface treated).
- Individual technical characteristics (e.g. multi-split air/air heat pump, external wall insulation, etc.).

Economic effects

We studied socio-economic components impacting price changes with economic effects. For all the works, the geoclimatic zone[6] (H1, H2 or H3) impacted the price of the works. Energy efficiency retrofit works had a higher price in zone H1 than in zone H3. Zone H2 is between these two extremes or close to zone H1. It was difficult to interpret the origin of this gap easily but we must noticed that the effect of the climatic zone can be distinguished from other correlated variables (e.g. the installed power of heating systems in colder zone is likely higher than in warmer zone – see above). A possible explanation could be the willingness of households to pay that would be greater in areas with a harsher climate (zone H1) because heating costs are a proportionately larger share of the energy bill.

[3] The relative interquartile range is equal to the difference between 75th (Q3) and 25th (Q1) percentiles divided by the median value.

[4] EEO: Energy Efficiency Obligation.

[5] We must noticed that for some equipment (e.g. boiler) there is no sizing as the power installed is generally in the order of 23 to 25 kW due to sanitary water heating (at the exception of 30 kW for larger houses).

[6] H1: coldest climatic zone in France (mostly North and East of France); H2: West of France, H3: warmest climatic zone (mostly South-East of France).

Indeed, the potential income effect related to climatic zones should be captured at least partly by the variable "town's household income" but its effect remained small. The problem of competition between professionals and the types of work could not explain the existence of the gaps between climatic zones. Indeed, local wealth (identified through the town's household income (INSEE, 2016) as proxy for the income level of the household financing the works) had a small but positive significant effect on the price of works.

Another notable economic effect concerned the brands of heating systems. Name of brands of the installed equipment were available for thermal systems (HP, boilers) but could not be acquired for insulation work. The effect of brand alone accounted for one-third of the variance in the installation cost of a condensing boiler. As there is significant uncertainty associated with the effects of each brand, we are not really able to differentiate all brands beyond two groups of brands that are more or less expensive than the average. Moreover, some brands present no effect meaning that they are close to the average market price.

The effect of the commercial network[7] to which the installer belonged (or did not) was variable and depended on the network itself, some having a positive impact on prices and others a negative effect. Membership in a commercial network therefore did not guarantee a lower price level than with an unaffiliated company; however non-affiliated companies were still the majority in the sample and in the market.

The increasing number of a company's employees is related to a higher price, with the exception of businesses without employees or very large companies (> 100 employees). The impact of the company's workforce seemed to have an upward effect on prices, with businesses with more workers having a higher price. Individual entrepreneurs formed an outlier as their prices were higher than these of slightly larger companies (1 to 6 employees). It was difficult to get comprehensive knowledge of companies without any employees. We should therefore be cautious about the generalization of our observations. Nevertheless, the upward effect of company size on the price could be explained by higher structural and management costs that might not compensate for possible bargaining power for lower equipment prices from wholesalers.

The impact of the business trades (NACE[8] segment) was complex to study because companies only report in the INSEE database their main activity (or their historical activity) and it may have had nothing to do with the activity we were studying[9]. In addition, because of the diversity of business segments (several dozen) and the sometimes similar effects, it is difficult to draw general conclusions about a particular sector. Nevertheless, certain business segments that seemed to be the least directly connected to renovation activity (services, wholesale trade, holding activities, home sales, etc.) had an upward effects on prices. Similarly, in certain types of work, there may have been be an upward effect on the price when the company was identified as performing work outside of a different category from the one studied (e.g. carpentry work for the installation of a heat pump, electrical installation for the installation of windows, etc.). This can be interpreted as risk hedging (the company adding an extra margin to carry out work it is not used to). There is also a difference between insulation work and thermal system work. These last cases were for the majority carried out in a single activity (NACE 4322B) corresponding closely to the works involved. On the other hand, for insulation work, there was a greater spread in the NACE activities identified, possibly due to the lower technical requirements.

[7] Franchise network, craftsman affiliated to a brand…

[8] Economic Activities in the European Community (Eurostat, 2008).

[9] For example, a craftsman of which the main activity is windows installer (declared NACE 4332A - Carpentry and PVC work) could also install internal wall insulation (NACE 4329A - Insulation work) which is not his declared activity.

Table 2: direction of effects (increasing: + ; decreasing: -) explanatory variables on the variation of the price of the retrofit in the "main sample" statistical models.

Type of work (unit)	adjusted R^2	Technical variables		Economic variables					
		Extensive*	Performance	H1 climatic zone	H3 climatic zone	Business segment	Trade network	Town's household income	number of employees
Air/air HP (€)	0.70	+		+	-	+/-	+/-	+	+
Air/water HP (€)	0.40	+	-	+	-	+/-	+/-		+/-
Domestic heating boiler (€)	0.32	+	n/a	+	-	+	-		+/-
Attic insulation (€/m²)	0.36	-	n/a	+	-	+/-	+/-	+	+
Internal/external wall insulation (€/m²)	0.51	-	n/a	+	-	+/-	+/-		
Window (€/unit)	0.12	-	n/a	+	-	+/-	+/-	+	+

n/a: information not available. m² of insulated area. *Equipment size / extent of the works.

In conclusion, it should be emphasized that it is difficult to understand the price changes of the residential renovation. At best, we can explain half of the variations by statistical models (see R^2 adj. in the Table 2 generally lowest than 0.5). This means that we were not able to capture enough information from those involved in price setting to explain all of it. However, for one of the best case (Figure 1) the coefficient of determination[10] (R^2_{adj}) shows that half of the prices variation is explained with the available data. According to the statistical procedure[11], the main explaining variables are technical (blue ones) followed by economic variables (yellow and green ones).

Figure 1: Change in the coefficient of determination (R^2_{adj} = 0.52) according to the variable selected (stepwise procedure) for the air/air HP "technical sample" (price in €/m² excluding VAT). The segments show the coefficient of determination increase by the cumulative addition of a new variable.

If we were able to record the technical data of the energy efficiency operation studied or the financial information from the professional performing the work (retrofit supply side), the information

[10] The R^2 adjusted (goodness of fit) is the proportion of the variance in the dependent variable that is predictable from the independent variables and penalized the statistic as extra variables are included in the model (Wikipedia).
[11] The stepwise procedure is a method of fitting regression models in which the choice of predictive variables is carried out by an automatic procedure. In each step, a variable is considered for addition (forward selection) from the set of explanatory variables, adding the variable (if any) whose inclusion gives the most statistically significant improvement of the fit, and repeating this process until none improves the model to a statistically significant extent (Wikipedia).

concerning the client (demand side) was not accessible. An unexplained part of price changes could therefore be sought from the household demand side or any other information not available in the quantitative study. This is why the qualitative study aimed at explaining in other ways the origins of the price variations that remained inaccessible for the moment.

Qualitative analysis

Methodology

The objective of the qualitative analysis was to understand the mechanisms for setting prices as they are practiced by professionals. In other words, it was about understanding how craftsmen make their estimates. Knowledge of the renovation companies' real-life practitioners made it possible to complement the quantitative technical and economic analyses. The methodology used was based on two field surveys conducted in 2017 through semi-structured interviews (duration: 1 to 2 hours) with professionals of the renovation works. In detail, these surveys consisted of:

- 16 interviews with retrofit professionals in Brittany and the *Pays de la Loire* region, North-West of France (plumber-heating specialists, electricians, roofers, insulation specialists, plasterers, carpenters, masons, interior fitters). Ages of the companies: from a few months to 36 years. Size: from a single craftsman working alone up to the commercial enterprise of 21 people with turnovers ranging from €70,000 to €1.8 million/a.
- 20 interviews with 15 companies in *Alsace* region (*Bas-Rhin*, North-East of France) with a focus on two main crafts: façades and space heating/electricity. Ages of the companies: from a few months to more than 100 years (mostly: over 10 years) and sizes: from a single craftsman working alone, to a company of 40 people with turnovers ranging from €150,000 to €3 million/a.

Most of the companies interviewed were involved in several markets: new constructions and renovations (energy-related or not), for individuals, architects, individual house builders, etc. Companies were very diverse with different "business models", stages of development and different outlooks, etc. Given this diversity, it is assumed that the sample is representative of the diversity of the companies active on the renovation markets.

The field survey of 31 building companies helped to understand professional pricing practices. Companies were asked about their search for clients, their site visits, estimate procedures and the prices charged. As a result of this investigation, we identified three additional explanations for the dispersion of renovation prices, thus complementing the quantitative analysis. In the next three subsections, we discuss each of these explanations in more detail: singularity of the project, characteristics of the customer as perceived by installers, and economic health of the company. Of course, in practice, these three aspects are much more interrelated than the presentation below might suggest. When preparing a cost estimate, the professional takes into account and constantly cross-references the job's characteristics. We propose this division for analytical purposes.

The singularity of the project

The singularity of the project means that each project has unique characteristics, which differentiated it from other projects and led craftsman to adjusting the price compared to the standard price. A first qualitative reason for price dispersion or variations is thus that renovation projects are not standard. Indeed, one of the major characteristics of private residential renovation is that each house, and therefore each renovation project, is unique: differences in construction methods (type of materials and implementation), size and accessibility, amenities, and work already done. The "technical" characteristics of the house, are complemented by the characteristics of the "buyer": their need, their

project, their budget. Renovation remained up to now a "tailor-made" service[12]: tailor-made for the house and tailor-made for the client. Finding and visiting the site was therefore crucial: the professionals we met never made a commercial proposal without being on site.

The on-site visit was essential because it allowed: identification of its accessibility, taking measurements, evaluating the complexity of the retrofit project, and identifying specific needs which could be transformed into ancillary services. It was also necessary to "understand" the house: the layout of rooms, where ducts could be laid, how to insulate the roof, how the house could develop (new living spaces in the attic or in the basement). This was reflected in the detail of the cost estimate, which according to the professionals, took on the shape of an actual technical study (energy audit) (particularly true in the case of the complete installation of a heating system, less true in the case of a simple change of boiler). The more complex the project, the more difficult it would be to prepare the cost estimate (it was not uncommon for it to take several hours). The detailed estimate was, beyond the cost justification (quantification), the formalization of the expertise of the craftsman through a technical study: assessing the house to suggesting solutions. In some cases, and especially when the professional feared the customer might share a cost estimate with competitors (see next section), the estimates were deliberately not very detailed.

Appraisal of the client

Appraisal of the client means here the “quality” of the client perceived by the craftsman on the basis of the maturity of its technical and financial project (which influenced the probability and timeliness of contract signature) and the cordial relations between the client and the professional (which may have had an impact on the margin and reputation of the professional).

When meeting customers, professionals seek to understand their personality, their need (that was not necessarily energy-related), the maturity of their project and their budget. An important point concerned the financing of the project (cash or on credit) because its maximum amount impacted the craftsman's future suggestions. The source of the customer contact was also important to determine if the customer was more focused on quality (local network, reputational effect leading to a “confidence premium”) or on minimising costs (Internet, advertising). In the latter case, the customer tended to create a lot more competition between competing craftsmen, especially through the existence of digital intermediaries. Finally, the cordiality of the knotted relationship allowed the craftsman to anticipate the conduct of the project. A customer with whom contact is pleasant and who is not suspicious, but understanding, and who is in agreement with the professional's recommendations for the works is a guarantee of good progress on the renovation project. On-site "surprises" would not lead to unpleasant situations: the customer was likely to accept last-minute changes due to the actual conditions of the work or the professional adding materials not planned without recharging the customer. This aspect was doubly important for the work of the professional: not only during the work on site but also for their reputation, which in this market, was the main source of generating sales. Finally, the craftsman could decide to "ranking" their customers, which manifested itself in particular by sending cost estimates that were more or less detailed.

Understanding the singularity of the renovation project and assessing the client's worthiness led the professional to recommend a technical solution which, as we saw in the quantitative analysis, had a significant impact on the final price and not necessarily on energy performance. Indeed, several technical solutions could meet the same requirement: insulation under the roof, outside roof insulation (i.e. sarking), in attic spaces, etc. Or on a heating issue: condensing boiler, heat pump, biomass pellet boiler, etc. The craftsman therefore did not stipulate a single price but recommended or suggested a solution

[12] Even if there are initiatives such as Energiesprong under development in the Netherlands, UK and France to standardize retrofit measures (http://energiesprong.eu). However, Energiesprong addresses buildings and types of works that are prone to standardization which is not representative of the private residential building stock in France.

that corresponded to a certain budget for the work. The quote might include options like a type of paint but not two widely different options like natural vs synthetic insulation materials. The price line began to be developed at the time of the on-site visit, with the idea of a service that would allow a greater or smaller margin.

The economic health of the company

The economic health of the firm means here the greater or lesser need of the company to secure the contract, to adjust to market prices and the rigour of its management. This economic health, the dynamics of the market at the time of the site visit, and the local competitive pressure were all reasons which explained price variations. Indeed, even companies with high degrees of professionalism, that is to say, those organised (functional specialization) and using management tools, reported a variation in prices throughout the year. The same company would therefore charge different prices for comparable renovation projects depending on the season. In high season, when renovation projects were plentiful and the company had no trouble completing its workload schedule, prices would be higher (within the limit allowed by competitive pressure: a price that really was too high compared to competitors' offers would not "pass"). On the other hand, in the low season the company was ready to review its prices to ensure it won a job that it needed. The company's economic health played a similar role. A company facing economic challenges, which needed to get contracts to pay its employees, would be ready to reduce its margin to get a job. The quality of the company's management was also important. A company well equipped with management tools, which knew its costs, adjusted its margin but did not work at a loss. Some companies worked at a loss on some sites, and only discovered the problem at the end of the year, when they found themselves in deficit.

All these aspects had repercussions on the prices charged and the level of margins. Craftsmen approached their activity through their workload schedule ("have a good year") either by an empirical estimate of the number of renovation projects to be carried out or items of equipment to sell or on the basis of financial calculation via software tools and dashboards (annual turnover target). Except for some well-equipped and structured companies, two ways of calculating margins on materials and equipment were at work. The first way "started" with the cost of purchasing materials to which was added a margin that was standard for the trade, with "detailed" technical studies during the quoting process for complex services and detailed cost estimates. The second way "started" with the final selling price (selling price - gross margin = margin as a % of the selling price) which was standard for the trade that calculated per square meter with more standard services and simpler cost estimates.

Sometimes the initial quote included a percentage discount in the quotation (about 5%). This was regularly the case for the companies interviewed in the East of France and more rarely the case for the companies interviewed in the West of France (only for very standardised work and companies of a certain size with a dedicated sales department). This illustrated the role of local competitive pressure: prices were adjusted to what was done locally.

However, there was still the problem of including all the on-site risks, making the customers accept them and then charging them. The price did not include all the items to be taken into account: adjustment work that was not re-invoiced, undeclared work, any DIY[13] work. Finally, the price and the margin varied depending on the season and the workload schedule, the customer, the supply costs, the site's accessibility. This is illustrated in the figure 2 below.

[13] Do It Yourself, the part of retrofit supported by the household to reduce the retrofit cost.

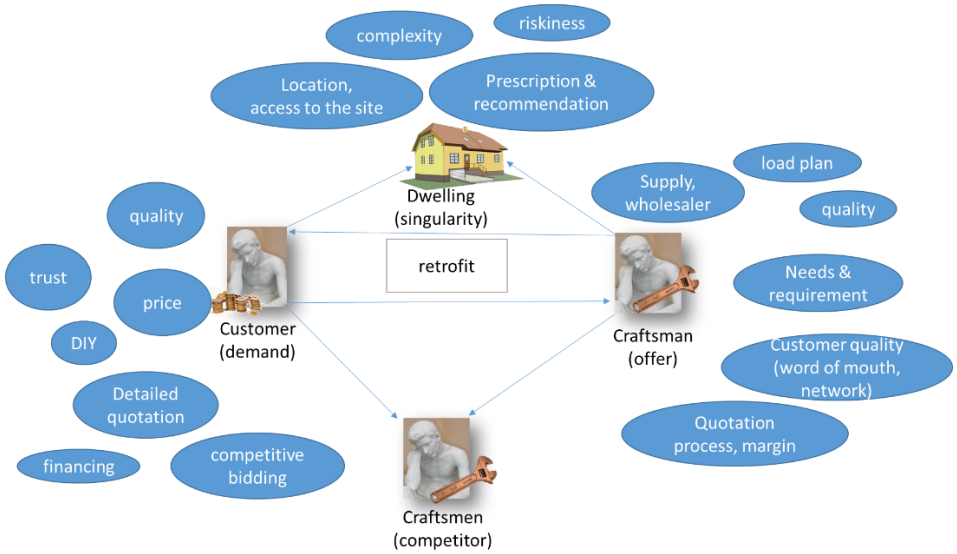

Figure 2: the difficulty of fixing the price of renovation works.

In conclusion of the qualitative analysis, the sociological study has shown three additional explanations of the price variation of energy retrofit works (Figure 2). First, part of the price variation is due to the singularity of the project that is the unique characteristics of a project, which differentiated it from other projects and led craftsman to adjusting the price compared to the standard price. Second, we have shown that price variation also depended on the characteristics of the customer as perceived by installers: the maturity of the customer's project and the cordial relations between the client and the professional (which may have had an impact on the margin and reputation of the professional). A third explanation of price change is the economic health of the firm and the local competitive pressure, that is to say, the greater or lesser need of the company to secure the contract, to adjust to market prices and the rigour of its management.

Conclusion: the variability of the price reflects the diversity of companies and works

The joint quantitative and qualitative study of renovation bills allowed us to show the reasons for the great variability of the prices observed in the field. The results of the statistical study and the sociological study are complementary.

From a technical point of view, prices were explainable in large part, even if the local competitive dynamics, climatic zone and other conditions impact the price. Thus, 50% at best of the variability could be explained by (Table 4):

- technical reasons: product quality, dwelling size,
- economic reasons: type of business,
- marketing variables: brand name,
- and climatic zone.

The quantitative analysis explained some types of work (heat pump, roof insulation and condensing boilers) properly, but others less well (windows, external insulation) (i.e. a low R^2). We could hypothesize that when actions involved equipment that was insensitive to the singularity of the housing, prices were less variable and the model of construction of the price had little influence (margin on the material or project management margin). Products and activities that were not standardised, such as

windows (often tailor-made) or external insulation (a variable part linked to irregularities in the house and ancillary services) introduced more unexplained variability. Conversely, for more standard products such as boilers and attic insulation, the variability of unexplained ground conditions is smaller.

A determining factor in the price of the work lies in the installer's recommendations: what work should be done and with what material or equipment? With equal energy performance, these recommendations also have an effect on prices.

From the customer's point of view, the renovation market is marked by high uncertainty: technically complex, committing (substantial budget) and worrying (potential design defect or poor execution). Reputation and confidence are key. These points are taken into account in the price as a "confidence premium[14]". The unexplained part of price setting could also be due to the supply characteristics that are not present in the invoice database, such as the "off invoice" (DIY) part.

On the installers' side, the price is fixed at the intersection of the perception of the appraisal of the customer, the management practices of the company (profit margin, workload schedule), and the adjustment to the local market price (Table 4). A good price from the installer's point of view is therefore the price that allows their company to survive or make profits and win new contracts (reputation effect).

In conclusion, observed prices may differ from the price that is objectively considered "correct" (i.e. on a purely technical basis) but this does not mean that prices are "unreasonable". Prices include qualitative dimensions: site accessibility, quality of work (meeting deadlines, cleanliness, etc.) that make them "fair" in practice. These dimension are not explicitly written on the quotation but are hidden behind technical items (e.g. larger margin on equipment) increasing price dispersion. Thus a merely technical reference price is not enough to determine the likely price of the renovation work.

Table 4: identified effects impacting the price of renovation works.

Effect	Impact on price	Statistical quantification (yes/no)	Comment/ example
Recommendation	+/-	yes	Technical solution implemented (e.g. Internal vs. External insulation)
Equipment size / extent of the works	+	yes	Installed power
performance	+/-	yes	Installed thermal resistance
Accessibility, location	+	no	Ease of access or not of the site
Climatic zone	+/-	yes	Cold zone more expensive
NACE business segment	+/-	yes	Type of building trades
Trade network	+/-	yes	Difficult explanation
Town's household income	+	yes	Household wealth
Workforce size	+/-	yes	Structural and management cost
Reputation	+	no	Word of mouth (confidence premium) vs. Internet
Interactions with other craftsman	+	no	Organizing time
DIY share	-	no	Part of retrofit supported by the household
Detailed cost estimate	+	no	Quotation writing time
Project risks	+	no	Risk hedging
Supplier relationship	+/-	no	
Annual activity management	+/-	no	

[14] The price of trust (via word of mouth) would be a premium of 15% to 20% of the amount of the retrofit (Travauxlib, 2017).

Outlook: what growth pathways?

What are the implications of the dispersion of renovation prices, observed and explained in this article, with regard to the widespread expansion of energy efficiency retrofit? These implications are twofold.

In the first place, this article has shown that price dispersion is inherent in the current non-standardization of private housing projects and that price dispersion has some objective reasons (i.e. technical). Other reasons that are not objective (i.e. explained by social factors) but understandable exist also.

This does not mean, however, that the whole price dispersion must be accepted and will lead to a status quo. We have indeed shown that there is room for rationalisation in the price of renovation that would certainly be likely to boost the market. Indeed, part of price dispersion is explained by the professional's perception of the customer's quality and the company's economic health.

These are two potential levers for price rationalization. On the one hand, by introducing systems that accelerate the client's project maturing, and informing and training the client about the energy efficiency retrofit (i.e. helping customers to better express their needs and understand the options recommended by the craftsmen; improving conditions for ensuring confidence between customers and craftsmen). On the other, helping professionals to better manage their businesses. One assumption could be that a customer that is better informed can better negotiate with a craftsman that have a good insight of his business to rationale his quotation.

In addition, to reduce the cost of work, studies on the energy renovation value chain and supply chain are necessary because some of the margins do not depend on the craftsman but to other entities (i.e. wholesaler, distributor and manufacturer).

As a result, price dispersion is not necessarily an absolute obstacle to the expansion of renovation but a currently unavoidable reality. In this case as a first step, it is more a question of working on the financing of the works than on their price. However, through standardization of practices and better business management, prices could be decreased but that is unfortunately not the current situation of the French retrofit market.

Lessons learnt from the study presented in this paper are very informative for the new plan for energy renovation recently released by the French Ministry (MTES, 2018). This plan indeed includes some actions in line with the findings from the study. For example, actions n°4 and 11 of this plan aim at increasing the confidence that owners can have in the offers of renovation works, by promoting a single quality brand and by reinforcing and complementing the existing labelling and training schemes. The plan also announced the establishment of a national observatory of energy renovations. One of its missions will be to improve the knowledge of the renovations markets, and particularly offers of renovation works. One of the specific tasks mentioned in the plan is to build indicators of average prices per type of works. Findings from our study show that this task could be challenging.

In conclusion, it should be noted that the research described in this article did not address the issue from the clients' point of view: how do they choose their professionals? What is their propensity to pay more for a promise of quality? Bridging this knowledge gap would complement our analysis of the factors behind the dispersion of renovation prices and suggest additional ways of optimizing the market.

Disclaimer

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of their affiliations.

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