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Estimating the price premium of high energy-efficient washing-machines in Spain: A hedonic approach

Elena López-Bernabé[*a], Amaia de Ayala[a,b] and Ibon Galarraga[a,c]

Abstract

Household appliances account for a considerable proportion of residential electricity consumption, and are therefore an important focus for energy-saving efforts. Energy-efficiency labels for appliances are a key instrument in providing information on the energy-efficiency level of an appliance and promoting the purchase of the most energy-efficient ones. This paper applies the hedonic price method to estimate the price premium paid for energy efficiency in the washing machines market in Spain. We find that consumers actually pay a price premium of 11% for high energy-efficiency washing machines compared to machines with the same characteristics but lower energy efficiency. This accounts for about €67 in the average market price of washing machines in Spain. This price premium in Spain seems to have increased by more than 5% from 2012 to 2019. Our analysis also shows that other specific attributes such as brand, place sold, spin-drying performance and built-in washing machines are very important in purchasing decision-making.

Keywords: Hedonic price model; Energy-efficiency label; Household appliances (washing machine).

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1. Introduction

With rising living standards, the number of household appliances is growing rapidly, as is household electricity consumption (Wang et al., 2021). In the context of climate change and the plans of the European Union to transition to a clean, carbon-neutral economy by 2050 (EC, 2019), the household sector is one of those that needs to be addressed urgently. Household energy consumption accounts for around 26% of final energy consumption in Europe (Eurostat, 2021) and 17% in Spain (IDAE, 2021a). It also accounted for around 17% of global energy-related carbon dioxide emissions in 2019 (UN, 2020). More specifically, appliances represent one of the main sources of household energy consumption (IDAE, 2021b). In the EU, household appliances and lighting account for 57% of total residential end-use electricity consumption (Eurostat, 2019). In Spain the figure is about 62%[1]. They are therefore very important products for energy-saving efforts.

Energy Efficiency (EE) provides an opportunity to substantially reduce household energy consumption (Linares and Labandeira, 2010)[2]. Several studies have analysed the potential energy savings, avoided CO2 emissions and profitability of energy-efficiency investments in the household sector (Cattaneo, 2019; Ramos et al., 2016, 2015; Stieß and Dunkelberg, 2013).

However, despite the potentially significant monetary benefits and environmental advantages of EE, its adoption levels are generally low, as illustrated by the literature on the EE gap (Jaffe and Stavins, 1994; Linares and Labandeira, 2010; Shama, 1983). This gap can be explained by various failures and factors such as market failures (including information failures), behavioural failures and/or other factors (e.g. social norms, procrastination or personal experience) (Solà et al., 2020).

For the case of appliances, the fact that consumers do not observe the amount of electricity consumed by the appliance in question contributes to the EE gap. As a result, EE in the appliances market gives rise to several problems related to information, which is (i) frequently imperfect and asymmetric; (ii) almost always hard to obtain; and (iii) generally constrained for consumers to operating costs (Ramos et al., 2015; Solà et al., 2020).

The relevant literature has analysed several policy instruments for addressing these barriers (Cattaneo, 2019; Gillingham et al., 2009, 2006; Gillingham and Palmer, 2014; Labandeira et al., 2020; Ramos et al., 2016). The policy instrument most commonly used to reduce informational failures is the EE label[3]. These labels provide information on the energy consumption of energy-related products and on their EE levels, among other technical information (e.g. energy consumption, volume or capacity, noise level and water consumption). They are intended to provide consumers with the information that they need to make energy-efficient purchases.

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[1] The Institute for Diversification and Energy Saving in Spain (known by its Spanish acronym IDAE) classified electricity consumption into the following categories in 2019: appliances (62.8%), lighting (11.74%), cooking (9.29%), domestic hot water (7.47%), heating (7.37%) and air conditioning (2.33%).

[2] The Energy Efficiency Directive (2018/2002/EU) sets a target of at least 32.5% EE by 2030 and the Spanish National Energy and Climate Plan envisages a 39.5% improvement by 2030 (NECP, 2020).

[3] The energy-efficiency label for household appliances has been in place for almost 30 years at EU level, regulated by Directive 92/75/EEC(EEC, 1992). On that basis, the EU published implementing directives for refrigerators in 1994 (94/2/EC), washing machines in 1995 (95/12/EC), washing machines and washer dryers in 1996 (96/60/EC) and dishwashers in 1997 (97/17/EC).

With mandatory minimum standards for EE, energy labelling regulations encourage manufacturers to use more energy-efficient technologies. This effectively changes the distribution of household appliances with different energy consumption levels in the current market (Wang et al., 2021). However, there are still arguments as to the effectiveness of EE label policy for purchasing decision making on energy-efficient appliances, because of the EE gap mentioned above (Galarraga et al., 2011a; Wang et al., 2021).

This paper focuses on the EE label for washing machines in Spain. This market provides a very interesting case study due to the substantial electricity consumption of washing machines, which were ranked third among all the appliances used in 2019, accounting for around 11% of total energy demand from appliances[4].

The energy-efficiency label for washing machines provides standardised information on electricity use, on how energy-efficient a washing machine is and on other resource consumption such as water consumption, rated capacity, spin-drying efficiency class and noise level. Directive 95/12/EC(EC, 1995) on washing machines has been amended several times. For a more detailed explanation of the EU regulation on the energy performance of household appliances, see Schleich et al., (2021).

This paper estimates how much consumers actually pay on the washing machines market in Spain for the EE label. To that end, we use real purchase data for 2019 and apply the well-known hedonic price method to calculate the marginal price differential due to improvements in EE.

Estimating the price-premium is useful with a view to adequately designing the widely used rebate schemes that seek to support the purchase of high-efficiency appliances. Comparing those premiums over time could also provide an idea as to whether the actual willingness-to-pay (WTP) for EE is increasing or not. There are many factors that could explain an increase in the premium paid, such as policies and other efforts to promote EE. Apart from energy labels, those policies include smart meters and information feedback tools and energy audits (Cattaneo, 2019; Solà et al., 2020). Other factors refer to changes over time in the price of electricity and even supply-side factors such as standards for EE, technological progress and similar (e.g. encouraging manufacturers to drive technological innovation by using more energy-efficient technologies due to the mandatory minimum standards for EE) (Schleich et al., 2021). In any event, an increase in the EE premium can be interpreted as positive for the general goal of increasing the adoption of EE and reducing energy consumption.

The paper is organised as follows: Section 2 reviews the existing literature on energy-efficiency label premiums for household appliances. Section 3 explains the hedonic price method, the data used and the regression model specified for the estimation. Section 4 presents and discusses the main results and Section 5 concludes.

[4] The distribution of electricity consumption by appliances in Spain in 2019 was the following: refrigerators (30.6%), TVs (12.2%), washing machines (11.8%), stand-by (10.7%), ovens (8.3%), computers (7.4%), dishwashers (6.1%), freezers (6.1%), dryers (3.3%) and other equipment (3.5%) (IDAE, 2021b).

2. Review of the literature

Research into understanding consumer reactions to EE improvements in different markets has been growing in recent years, due to both the implementation of EE labels and growing concern for the envi-

Table 1. Research on EE label premiums for household appliances in different countries

Appliance type	Country	EE price premium	Method	Year	Reference
Washing machine	Spain	4.15% (19.79€)	Hedonic price model	2012	(Lucas and Galarraga, 2015)
	China	15.9% (424.76 RMB)	Discrete-choice experiment	2017	(Zha et al., 2020)
	Switzerland	30% (455€)	Discrete-choice experiment	2004	(Sammer and Wüstenhagen, 2006)
Dishwasher	Spain	4% (19.28€)	Hedonic price model	2012	(Lucas and Galarraga, 2015)
		15% (80€)	Hedonic price model	2009	(Galarraga et al., 2011a)
Refrigerator	Spain	12.6% (86.18€)	Hedonic price model	2012	(Lucas and Galarraga, 2015)
		8.9% (58.56€)	Hedonic price model	2009	(Galarraga et al., 2011b)
	China	28.1% (1162RMB)	Hedonic price model	2018	(Zhang and Tao, 2020)
		21.63% (757 RMB)	Discrete-choice experiment	2006	(Shen and Saijo, 2009)
		23.09% (731.16 RMB)	Discrete-choice experiment	2017	(Zha et al., 2020)
	United States	26.17%-36.60% ($249.82-$349.30)	Discrete-choice experiment	2009	(Ward et al., 2011)
		6.66%-10.66% ($95-$152)	Structural demand model	2008	(Houde, 2014)
		Over 28% (Over $200)	Discrete-choice experiment	2009	(Li et al., 2016)
	India	35% ($100)	Discrete-choice experiment	2015	(Jain et al., 2018a)
Air conditioner	China	12.4% Around (703RMB)	Hedonic price model	2018	(Zhang et al., 2021)
		8.12% (276 RMB)	Discrete-choice experiment	2006	(Shen and Saijo, 2009)
		9.4% (400RMB)	Discrete-choice experiment	2013	(Zhou and Bukenya, 2016)
	India	24% ($126.24)	Discrete-choice experiment	2015	(Jain et al., 2018a)
		36% ($137)	Discrete-choice experiment	2015	(Jain et al., 2018b)
Air purifier	Korea	9.1% (40,000 KRW)	Discrete-choice experiment	2018	(Kim et al., 2019)
Television	Korea	19.1% (359.27€) No premium after using difference-in-differences and fixed-effect models.	a. Hedonic price model b. Discrete-choice experiment	2012	(Park, 2017)
	Germany	15.8% (150€)	Discrete-choice experiment	2009	(Heinzle and Wüstenhagen, 2012)

Source: Own work.
Notes:
€: Euro, the official currency of 19 of the 27 member states of the European Union. This group of states is known as the Eurozone.
$: United States dollar, the official currency of the United States and several other countries.
RMB: Renmimbi, the currency of the Republic of China.
KRW: Korean Republic won, the official currency of South Korea.

ronment and climate change. There are several studies that analyse the effectiveness of EE labels in different product markets such as appliances (Faure et al., 2021; Galarraga et al., 2011b, 2011a; Lucas and Galarraga, 2015; Schleich et al., 2021; Zhang et al., 2021), dwellings (Brounen and Kok, 2011; Copiello and Donati, 2021; de Ayala et al., 2016; Fuerst and Warren-Myers, 2018; Walls et al., 2017), and cars (Alberini et al., 2014; Arawomo and Osigwe, 2016; Galarraga et al., 2020, 2014).

For the appliances market, there is a substantial body of research analysing the effect of EE levels on purchasing decisions for different appliances (washing machines, refrigerators, dishwashers, air conditioners, air purifiers and TVs) and in several countries (e.g. Spain, Germany, Switzerland, China, South Korea, the United States and India). Table 1 provides an overview of these empirical studies organised by types of appliance, country and method.

For the specific case of washing machines, research on EE label premiums has been carried out in different countries. For instance, Lucas and Galarraga (2015) use the hedonic price method to calculate the premium for the most energy-efficient washing machines in Spain. They find that those with the highest energy–efficiency label (A+++) had a premium of 4.15% compared to those with lower EE in 2012. Results from other studies that conduct DCEs in other countries find, for instance, that the premium on A-level energy-efficiency washing machines was about 30% compared to C-level washing machines in Switzerland in 2004 (Sammer and Wüstenhagen, 2006). Zha et al.(2020) show that the price premium paid by Chinese consumers for each increase in the energy-efficiency level of washing machines was 15.9% of the mean prices in 2017.

In Spain, several studies have used the hedonic price model to calculate the price premium on different appliances. In addition to the specific research on washing machines market mentioned before, Galarraga et al. (2011a) and Lucas and Galarraga (2015) also analyse the dishwashers market and find that the premium paid for energy-efficiency was 15% in 2012 and 4% in 2009. Galarraga et al. (2011b) and Lucas and Galarraga(2015) conduct a similar investigation for refrigerators and find that those with the highest energy-efficiency label had a premium of 8.9% in 2012 and 12.6% in 2009.

Other studies quantifying the energy-efficiency price premium differ in terms of the appliances and countries covered. For example, the EE price premium for refrigerators is found to range from 22% to 28% in China (Shen and Saijo, 2009; Zha et al., 2020; Zhang and Tao, 2020), from 7% to 37% in the United States (Houde, 2014; Li et al., 2016; Ward et al., 2011) and to be close to 35% in India (Jain et al., 2021, 2018a). For air conditioners a price premium ranging from 9% to 12% is found in China (Shen and Saijo, 2009; Zhang et al., 2018; Zhou and Bukenya, 2016) and close to €110 in India (Jain et al., 2018a). In Korea, Kim et al. (2019) estimate a price premium of 9% for air purifiers in 2018. Park (2017) uses a hedonic price model analysis and finds a 19% premium for TVs in Korea. However, no premium is found when a discrete-choice experiment is used. Finally, Heinzle and Wüstenhagen (2012) find a price premium of 19% for the highest energy-efficiency TV on the EU label scale (A to G) in 2012 in Germany.

As can be seen from this literature review, the studies considered all generally find a positive price premium for EE but its extent varies across countries, product categories and years and depending on how EE is measured.

3. Methodology

3.1. The hedonic price method

As can be seen from Table 1, the literature uses either the DCE methodology or the hedonic price method to estimate the price premiums for EE. DCEs are based on subjective data as they enable hypothetical decisions on appliance choice to be estimated (McFadden, 1974; Theil, 1970). A major drawback, however, is that there could be a gap between consumers' WTP and the actual prices they accept because data do not come from a real purchase situation (Zhang et al., 2021). In comparison, the hedonic price model relies on observed market data or on household surveys in which participants are asked to report their past appliance purchase decisions (Schleich et al., 2021). The price premiums considered therefore reflect what consumers actually pay in the market for the EE attribute.

The hedonic price technique is commonly used to estimate how much of the price of a good is explained by each different attribute of that good (Rosen, 1974). This method enables the relationship between a product's price and its different attributes to be analysed by generating a bundle of implicit prices for all attributes. In other words, by using this method the price of a good can be broken down into the prices of its different attributes (Ankamah-Yeboah et al., 2016; Bockstael and McConnell, 2007; Schamel, 2012; Soler et al., 2019). The method assumes that different goods are differentiated by the number of characteristics (attributes) that they have. It enables the price difference between two goods of different EE levels to be estimated *ceteris paribus*, i.e. while controlling the rest of the attributes (Galarraga et al., 2011a). It is usually interpreted in the literature as the price premium of the EE attribute or the actual WTP of consumers for EE when they purchase an appliance (Galarraga et al., 2011a). Thus, the WTP for (or actual cost of) the EE attribute reflects the preference for or degree of recognition of that attribute (Fernández et al., 2019; He et al., 2019; Zhang et al., 2021).

In this paper we estimate how much consumers actually pay on the washing machine market for the EE attribute in Spain. A complete description of this technique can be found in Braden and Kolstad (1991) and Rosen (1974).

The hedonic price method has been widely applied to analyse the effects of product attributes on product prices in the housing (Copiello and Donati, 2021; de Ayala et al., 2016), car (Galarraga et al., 2014) and appliances markets (see Section 2), among others.

3.2. Data

Data were collected online in Spain by a specialist polling company (CPS[5]) between June 2018 and May 2019. They cover market prices and related product-attribute information on 322 washing-machine models from 18 different brands. Data were collected from online catalogues (18%) and the websites of various stores (82%).

[5] *CPS is a market research and opinion polling company that collects market and consumer information in Spain (https://www.cps2000.com/)*

The period when the largest number of price observations were made was May 2019[6] (19% from June 2018, 27% from November 2018, 24% from January 2019 and 30% from May 2019). Given that the 322 washing-machine models were sold on more than one store's website, the final number of market price observations was 739, distributed as follows: *catalogue* (107 observations), *El Corte Ingles* (224 observations), *Mediamarkt* (104 observations), *Carrefour* supermarkets (232 observations)

Table 2. Variables selected and summary statistics

Variable	Codification	Description	Obs.	Mean (Std. dev)	Range [Min; Max]
Dependent variable					
Ln (price)	Quantitative	Log of the market price of the washing-machine	739	612.60 (290.18)	[206; 2,349]
Independent variables					
EE level					
High energy-efficient level	Dummy	Whether label is A+++ and a reduction of energy consumption from 10% to 70%	739	0.55 (0.50)	[0; 1]
Store					
Catalogue	Dummy	Whether the store is Catalogue	739	0.14 (0.35)	[0; 1]
El Corte Inglés	Dummy	Whether the store is El Corte Inglés	739	0.30 (0.46)	[0; 1]
Supermarkets	Dummy	Whether the store is Eroski and Carrefour	739	0.41 (0.49)	[0; 1]
Technical attributes					
Spin-drying efficiency performance A	Dummy	Whether spin-drying performance of the washing machine is A	739	0.16 (0.37)	[0; 1]
Spin-drying efficiency performance B	Dummy	Whether spin-drying performance of the washing machine is B	739	0.67 (0.47)	[0; 1]
Spin-drying efficiency performance C	Dummy	Whether spin-drying performance of the washing machine is C	739	0.12 (0.33)	[0; 1]
Width	Quantitative	The width of the washing machine measured in millimetres	739	581.09 (59.62)	[400; 850]
Depth	Quantitative	The depth of the washing machine measured in millimetres	739	577.55 (49.11)	[340;850]
Height	Quantitative	The height of the washing machine measured in millimetres	739	849.29 (31.03)	[550; 990]
Water consumption	Quantitative	Weighted annual water consumption of the washing machine measured in litres per year	734	10,145 (1,182)	[6,400; 17,000]
Colour	Dummy	Whether the washing machine is white	739	0.81 (0.40)	[0; 1]
Capacity	Quantitative	The capacity of the washing machine measured in kilogramme	738	7.98 (1.34)	[4; 17]
Load type	Dummy	Whether the washing machine has front-load type	739	0.93 (0.26)	[0; 1]
Noise speed spin	Quantitative	The noise speed spin of the washing machine measured in decibels	730	74.55 (2.77)	[66; 82]
Built-in	Dummy	Whether the washing machine can be integrated into the wall	739	0.06 (0.23)	[0; 1]

Notes:
Obs.: Observations.
For dummy variables, a value of 1 is assigned if the feature was present and 0 otherwise.

[6] *This increase in the number of price observations may be due to two reasons: (i) some brands could be offering their models to more stores than previously; and/or (ii) the stores themselves may have decided to put more models of washing machines on sale.*

and *Eroski* supermarkets (72 observations). The average washing machine price was €612.60[7]. The data also contained related product-attribute information such as *EE level, brand* and other specific technical characteristics such as weighted water consumption in litres per year *(water consumption)*, rated capacity in kilograms *(capacity)*, spin-drying efficiency class (*Spin-drying efficiency performance A, B or C)* and airborne noise emissions during the washing and spinning phases expressed in decibels (*noise speed spin*). Table 2 describes each of the variables used in our hedonic model together and their summary statistics.

EE in our database is represented on a scale ranging from A+++ (the most efficient) to D (the least efficient) based on the EU Energy Labelling Directive (2010/30/EU) for household appliances in force at that time. The database includes information on higher energy-efficiency levels based on extra information on reductions in energy consumption of between 10% and 70% compared to A+++ energy-efficiency level, divided into the following levels: 70%; 60%; 55%; 50%; 40%; 30%; 20%; and 10%. This information on energy consumption reduction is added to the mandatory energy label at points of sale, e.g. A+++ level minus 10% energy consumption, or A+++ level minus 20% energy consumption, etc.

90.39% of the sample is accounted for by A+++ level products, 7.98% by A++ and 1.62% by A+. The high proportion of A+++ washing machines in the sample led us to decide to focus our analysis on the most energy-efficient washing machines in the sample, i.e. those classed as A+++ with a reduction in energy consumption of 10% to 70% in KWh (*high energy-efficient level*). These machines account for 54.67% of the total sample (see Figure 1).

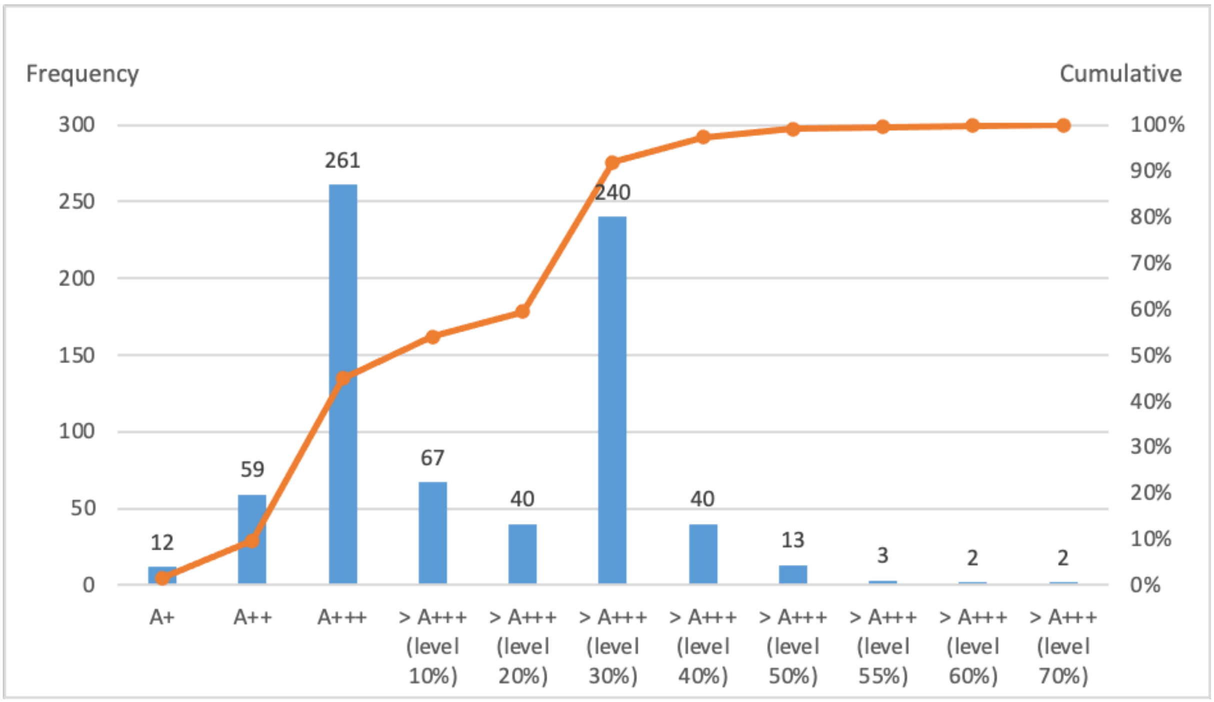

Figure 1. EE label distribution. The rating > A+++ with different % levels refers to higher energy-efficiency levels based on extra information about reductions in energy consumption from 10% to 70% compared to A+++ energy-efficiency level.

[7] *The average washing machine price differs from one store to another. Specifically, washing machines from Catalogue were on average 18% more expensive than washing machines from El Corte Ingles (€833.36 compared to €638.42). The average washing machine price at Carrefour was €489.79 and that of Eroski was €578.68. And the average price at Mediamarkt was €530.40.*

Regarding the *brand* attribute, half the washing machines belong to the following brands: *SIEMENS* (14%), *BALAY* (13%), *AEG* (8%), *SAMSUNG* (8%) and LG (7%). The other half is accounted for by the remaining brands (*WHIRPOOL, ZANUSSI, INDESIT, BEKO, MIELE, SMEG, CANDY, HAIER, TEKA, HOOVER* and *CORBERO*). We consider each of the 17 brands as a dummy variable, given that it represents numerous factors such as design, reputation and reliability[8] (Galarraga et al., 2011a, 2011b; Lucas and Galarraga, 2015). The 17 different brands of washing machines included in this study are listed separately in Table 3 together with their summary statistics.

The following variables representing technical characteristics were included in the model: *Spin-drying efficiency performance (sdp)* level *(ranging from the most efficient level, A, to the least, C), Depth* (in millimetres), *Height* (in millimetres), *Water consumption* (in litres per year), *Colour* (white or non-white), *Capacity* (in kilogrammes), *load type* (front-load or top-load), *High-speed spin noise* (in decibels) and Built-in[9].

Table 3. Brands and summary statistics

Variable	Codification	Description	Obs.	Mean (Std. dev)	Range [Min; Max]
AEG	Dummy	Whether the brand is AEG	739	0.77 (0.27)	[0; 1]
BALAY	Dummy	Whether the brand is BALAY	739	0.13 (0.33)	[0; 1]
BEKO	Dummy	Whether the brand is BEKO	739	0.35 (0.18)	[0; 1]
CANDY	Dummy	Whether the brand is CANDY	739	0.02 (0.15)	[0; 1]
CORBERO	Dummy	Whether the brand is CORBERO	739	0.01 (0.10)	[0; 1]
HAIER	Dummy	Whether the brand is HAIER	739	0.02 (0.14)	[0; 1]
HISENSE	Dummy	Whether the brand is HISENSE	739	0.01 (0.08)	[0; 1]
HOOVER	Dummy	Whether the brand is HOOVER	739	0.01 (0.12)	[0; 1]
INDESIT	Dummy	Whether the brand is INDESIT	739	0.05 (0.21)	[0; 1]
LG	Dummy	Whether the brand is LG	739	0.07 (0.25)	[0; 1]
MIELE	Dummy	Whether the brand is MIELE	739	0.03 (0.18)	[0; 1]
SAMSUNG	Dummy	Whether the brand is SAMSUNG	739	0.08 (0.26)	[0; 1]
SIEMENS	Dummy	Whether the brand is SIEMENS	739	0.14 (0.35)	[0; 1]
SMEG	Dummy	Whether the brand is SMEG	739	0.03 (0.16)	[0; 1]
TEKA	Dummy	Whether the brand is TEKA	739	0.16 (0.13)	[0; 1]
WHIRPOOL	Dummy	Whether the brand is WHIRPOOL	739	0.06 (0.24)	[0; 1]
ZANUSSI	Dummy	Whether the brand is ZANUSSI	739	0.05 (0.22)	[0; 1]

Notes:
Obs.: Observations.
For dummy variables, a value of 1 is assigned if the feature was present and 0 otherwise.

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[8] *A preliminary test was conducted with brands into low, medium and advanced according to durability in the product ranking offered by the OCU (Spanish Organization of Consumers and Users). However, this classification was not included in the final version because "brand" is not just durability but also the sum of numerous factors such as design, reputation and reliability. Accordingly, the seventeen brands included in this study are coded as dummy variables.*

[9] *The dataset contained other valuable information such as extra-silent motor, extra rinse, Sensofresh technology, start/pause or home connect arrangements, among others, which however were not reported for many of the models and were therefore discarded from the analysis.*

16% of the washing machines in the sample are in the highest-efficiency class (A) in *spin-drying efficiency performance (sdp)*, 67% are in class B and 12% in class C. The average *width*, *depth* and *height* are 581, 578 and 849 millimetres respectively. The average water consumption is 10.145 litres per annum and the *high-speed spin noise* level is 74.55 decibels. As many as 92.56% of the washing machines currently on the market are *front-load*. *White* washing machines account for 80.65% of the total. The *Capacity* of washing machines ranges from 1 to 17kg., with 7, 8, 8.5 and 9 kg models accounting for more than 84%. *Built-in* washing machines account for only 5.82%.

3.3. The regression model

A logarithmic transformation of the original prices (*lnprice*) is used as the dependent variable and regressed on different explanatory variables referring to different attributes. The log-linear function is chosen for different reasons. First, it is appropriate in view of the dichotomous nature of most of our explanatory variables (Galarraga et al., 2011a). Second, many other research studies in different fields use this function (Zhang et al., 2021). And third, it gives a useful explanation of the regression coefficient of independent variable, i.e. the percentage change in price when the independent variable increases by one (Galarraga et al., 2011a; Wooldridge, 2008; Zhang et al., 2021).

The general specification of the simple semi-log-linear model estimated is indicated in Eq. (1):

$$lprice_i = \propto + \beta \sum x_i + \varepsilon_i \tag{1}$$

where $lprice$ is the logarithm of the washing machine price, $\propto$ is a constant, x_i is the vector containing the attributes and technical characteristics of the washing machine. The vector of coefficients associated with the explanatory variables is β and the error ε is assumed to be uncorrelated with x_i.

The estimated hedonic-price equation applied can be expressed as follows:

$$\begin{aligned} lprice_i = \propto &+ \beta_1 HighEElevell_i + \beta_2 Catalogue_i + \beta_3 El\ Corte\ Ingles_i \\ &+ \beta_4 Supermarkets_i + \beta_5 Brand_i + \beta_6 sdpA_i + \beta_7 sdpB_i + \beta_8 sdpC_i \\ &+ \beta_9 Depth_i + \beta_{10} Height_i + \beta_{11} Water\ Consumption_i + \beta_{12} Colour_i \\ &+ \beta_{13} Capacity_i + \beta_{14} Load\ type_i + \beta_{15} Noise\ speed\ spin_i \\ &+ \beta_{16} Built-in_i + \varepsilon_i, \end{aligned} \tag{2}$$

where the vector x_i contains explanatory variables related to (i) stores (*Catalogue, El Corte Ingles, Supermarkets*); (ii) Brand (AEG, BALAY, ..., ZANUSSI)[10]; (iii) EE level (*high energy-efficiency level*); and (iv) technical attributes (*sdpA, sdpB, sdpC*, *Depth, Height, Water Consumption, Colour, Capacity, Load type, High-speed spin noise, Built-in*) (see Table 2 and Table 3). Using this model, it is possible to estimate how much consumers actually pay for the washing machine with the highest EE level (i.e. *high energy-efficiency level)*. Note that the prices analysed include demand side and supply side factors because they are the equilibrium prices, i.e. the prices at which a consumer can buy a certain appliance.

[10] Table 3 provides a description of each brand included in Eq. (2) together with summary statistics.

4. Results and discussion

The hedonic price method enables us to estimate, *ceteris paribus (*i.e. when all other attributes and technical characteristics remain the same), the price premium of washing machines with the highest energy efficiency level. This is done by estimating Eq. 1 by ordinary least squares (OLS) with robust standard errors using STATA software (Ver.13.1). The regression results for the hedonic price model are shown

Table 4. Results of hedonic price model

Variable	Coefficient	Std. error	P>|z|
EE level			
High energy-efficient level	0.110***	0.023	0.000
Stores			
Catalogue	0.183***	0.028	0.000
El corte ingles	0.154***	0.023	0.000
Supermarkets	-0.061***	0.023	0.007
Brand			
Aeg	0.108***	0.033	0.001
Balay	-0.115	0.027	0.000
Beko	-0.271***	0.043	0.000
Candy	-0.105*	0.059	0.076
Corbero	-0.256***	0.078	0.001
Haier	-0.278***	0.055	0.000
Hisense	-	-	-
Hoover	-0.125*	0.070	0.074
Indesit	-0.185***	0.045	0.000
Lg	-0.252***	0.039	0.000
Miele	0.495***	0.048	0.000
Samsung	-0.001	0.047	0.983
Siemens	0.062**	0.027	0.021
Smeg	0.364***	0.051	0.000
Teka	-0.088	0.063	0.157
Whirpool	-0.103***	0.038	0.008
Zanussi	0.056	0.044	0.196
Technical attributes			
sdpA	0.327***	0.051	0.000
sdpB	0.100**	0.043	0.021
sdpC	0.015	0.045	0.738
Width	-0.000	0.000	0.197
Depth	0.001***	0.000	0.000
Height	0.001***	0.000	0.001
Water consumption	0.000	0.000	0.101
Colour	-0.155***	0.020	0.000
Capacity	0.081***	0.012	0.000
Load type	0.010	0.054	0.855
Noise spin speed	-0.032***	0.004	0.000
Built-in	0.310***	0.041	0.000

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

in Table 4[11]. The adjusted R-squares value of almost 0.8 suggests that the model fits the data well and explains a large proportion of the variation in price[12].

The results show a significant, positive effect of *high energy-efficiency level* on price, i.e. the *highest energy-efficiency level* of washing machines (A+++ label with extra information about energy consumption savings between 10% and 70%) is valued at a price premium of 11% compared to washing machines with the same characteristics but lower EE levels (A+++, A++, A+). That is, *ceteris paribus*, the price of washing machines is 11% higher when the highest level of EE is included. This is equivalent to €67 out of the average washing machine price of €612.60.

Our price premium estimate is consistent with the previous literature, where a positive price premium for EE is found in all cases with some differences in size depending on type of appliance, country and year analysed, as reviewed in Section 2. Moreover, it is important to bear in mind that the EE attribute does not represent the same EE level in all studies, so comparisons should be made with caution. Figure 2 shows the price-premium for EE (in percentages) of different household appliances in several countries and different years.

Recall that Lucas and Galarraga (2015) find that in 2012 washing machines with the highest energy–efficiency label (in this case A+++) in Spain were sold with a price premium of 4.15% (€19.79) compared to those with lower EE. Changes in the design of the label prevent a direct, straightforward comparison from being made but one could argue that the price premium for high energy-efficiency washing machines in Spain has increased, as the new estimate is more than double the previous one. This apparent increase in the premium may be explained by three reasons: (1) efforts to enhance information and raise awareness with respect to EE and climate change may have proved effective and significantly increased consumers' WTP for EE (Ramos et al., 2015); (2) the EE label is now well-known and more highly rated as an instrument for providing information about the EE level of washing machines and thus promoting energy-efficient choices (de Ayala et al., 2020); and (3) changes driven by technological progress, standards for EE and increases in electricity prices may also have encouraged investment in energy efficient appliances (Schleich et al., 2021).

The price premium estimated in other countries for high energy-efficiency washing machines is greater than that estimated in Spain. Sammer and Wüstenhagen (2006) estimate a price premium of 30% for A level energy-efficient washing machines in Switzerland in 2004. This difference can perhaps be explained by standards of living and by the price of electricity in Switzerland. Zha et al. (2020) show that the average WTP of Chinese consumers for each increase in the energy-efficiency level of washing machines was 16% in 2017.

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[11] *We also explored a second hedonic-price model considering discounts in prices which vary depending on different factors, e.g. stock available in store. All other explanatory variables are unchanged. In this case, the price premium for high energy-efficient washing machines was found to be insignificant. This could be because discounts on price prevail in purchasing decisions, so that energy efficiency and rest of the attributes and technical characteristics are no longer significant. The full set of estimates is available from the authors upon request.*

[12] *A multicollinearity analysis is conducted and no multicollinearity problem is found among the selected explanatory variables. The minimum variance inflation factor (VIF) for all variables is 1.19 and the maximum is 8.46. The mean VIF in the model is lower than 10. Thus, the assumption of collinearity between variables is rejected.*

A comparison of our estimate with those for other types of appliance reveals that the price premium trend for EE in washing machines is in general systematically lower than for refrigerators and TVs[13]. This may be explained by the fact that although washing machines are among the most important appliances in the home (de Ayala et al., 2020) they may be less used than others such as refrigerators or TVs (IDAE, 2021b). In fact, refrigerators were ranked first in Spain out of all the appliances used in 2019, followed by TVs and washing machines (IDAE, 2021b). This might be because refrigerators are used 24/7 all year round (Zha et al., 2020), so there is more incentive to invest in EE (del Mar Solà et al., 2021). EE seems to be key for energy savings in the case of refrigerators, while energy use in the home may be more important for reducing the energy consumption of washing machines (de Ayala et al., 2020; del Mar Solà et al., 2021; Pollitt and Shaorshadze, 2011; Trotta, 2018).

The price-premium estimates for dishwashers and air purifiers are in the range of washing machines (between 4% and 15% for dishwashers and 9.1% for air purifiers). However, for air conditioners price premiums vary substantially (between 8% and 36%) depending on the country and year analysed.

Our results also show that product prices may vary substantially from one point of sale to another. In particular, *ceteris paribus*, washing machines bought via an online *catalogue* or at *El Corte Ingles* website are 18% and 15% more expensive, respectively. This last price premium is in line with Lucas and Galarraga (2015), who find that the *El Corte Ingles* website sells washing machines at higher prices (14%). However, washing machines sold on *supermarket* websites cost 6% less than at the other stores analysed.

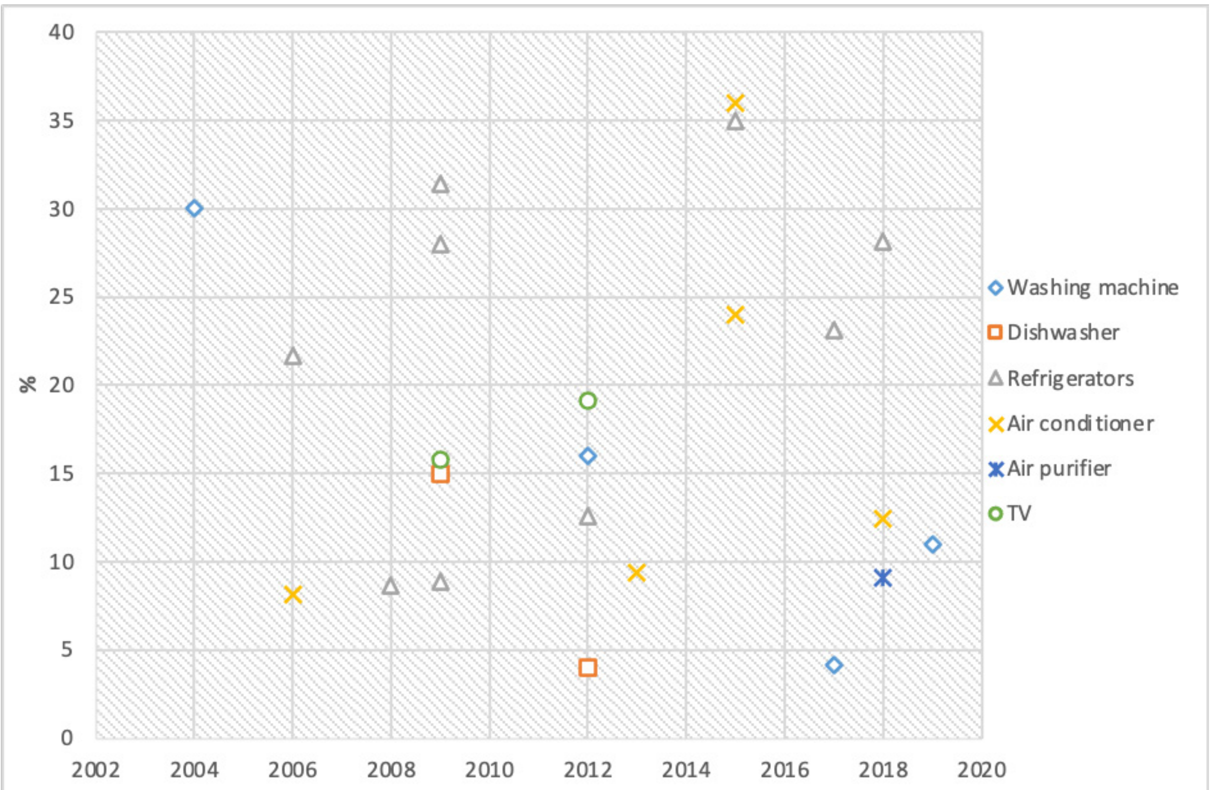

Figure 2: Price premiums (%) for high energy-efficiency level estimated for different types of household appliance.

[13] *There is an exception of three cases in which the price-premium estimates for refrigerators are similar to our price premium estimation for washing machines: 8.66% on average in the United States in 2008 (Houde, 2014); 8.9% in Spain in 2009 and 12.6% in Spain in 2012 (Galarraga et al., 2011b; Lucas and Galarraga, 2015).*

Brand has the highest price premium. We find that, all else being equal, customers who buy the *MIELE* brand (considered as an advanced brand according to average product prices) are willing to pay a premium of 49%, followed by *SMEG (36%), AEG* (11%) and *SIEMENS* (6%). However, *BEKO, HAIER, CORBERO, INDESIT, HOOVER, WHIRPOOL* and *CANDY* are considered as low-prestige brands (OCU, 2021), and have a negative effect on prices (ranging from 10% to 27%) all else being equal. These price premiums for brands are in line with a study conducted in Spain in 2012 (Lucas and Galarraga, 2015) (for a more detailed comparison of brand-based price premiums in Spain, see appendix A). In this regard, Sammer and Wüstenhagen (2006) estimate that customers are willing to pay a premium of 86% for the most popular brands (VZug and Miele) compared with no-name washing machines. Finally, literature analysing other appliances in other countries finds that prices of foreign products are much higher than those of domestic products (Zhang et al., 2021; Zhang and Tao, 2020). Specifically, Zhang et al.(2021) show that the price of foreign-brand air conditioners is 47% higher than that of Chinese-made units. Zhang and Tao (2020) reveal that foreign refrigerator prices are 71% higher than those of domestic Chinese products and that the prices of low, medium, and advanced brand refrigerators increase by around 63% with increases in market positioning.

In terms of technical attributes of washing machines, class A *spin drying performance* (*sdpA*) has a significant positive effect on price. Prices for machines with high drying efficiency (class A spin drying efficiency) are around 33% higher than for classes B and C, *ceteris paribus*. For washing machines with class B spin drying efficiency the proportion of the price explained is 10%. These results are compatible with those of Lucas and Galarraga (2015), who find that washing machines with *sdpA* cost more than the others in Spain (*sdB* or *sdpC*). *Width* seems not to be an important attribute for buyers of washing machines, while *depth* and *height* have a positive, albeit very small, effect on price. One possible reason is that most washing machines that cannot be built into the wall tend to have standard dimensions. *Water consumption* does not seem to be a major factor in purchases either. The literature seems to be inconclusive with respect to the significance of this attribute. For example, Sammer and Wüstenhagen (2006) estimate a negative impact of water consumption on the purchase of high energy-efficiency washing machines, but Lucas and Galarraga (2015) and Zha et al. (2020) find no significant effects for this attribute.

However, built-in washing machines are 31% more expensive that non-built in units with all else being equal. Also, white washing machines cost 15.5% less than non-white ones, all else being equal. Washing machines with a higher *capacity* seem to be more expensive (8.1%). A similar result was found for washing machines in Spain in 2012 (Lucas and Galarraga, 2015) and elsewhere in 2017 (Zha et al., 2020). *High-speed spin noise* has a negative effect consistent with the fact that noiseless washing machines tend to be more slightly more expensive (3.2%). Finally, l*oading type* seems not to be an important attribute.

5. Conclusions and policy implications

Household appliances in Spain accounted for about 62% of residential electricity consumption in 2019 so there is a need to improve their EE. EE provides an opportunity to substantially reduce household energy consumption and to meet the substantial energy-saving targets that authorities worldwide are aiming for. In this context, many countries have introduced EE labels as a key policy for attaining energy and climate policy targets. This policy instrument is expected to induce consumers to purchase more energy-efficient products through the provision of observable, consistent, credible information.

Using market data for 2019 in Spain, this study estimates how much consumers actually pay for the EE attribute, with all other attributes of appliances assumed to remain the same. To that end, we apply the hedonic price method, which enables us to calculate the marginal price differential due to improvements in EE. Our findings provide some insights into the effectiveness of EE labels for washing machines in recent years compared with the price premium estimated previously in Spain for the same appliances. We also compare our findings with similar studies analysing different appliances in different countries and years.

The hedonic method suggests that the price premium paid in the market for washing machines with the highest energy-efficiency level is 11% of the final price, i.e. €67 out of the estimated average price for washing machines on the Spanish market. Changes in the design of the EE label and the fact that EE levels are not exactly the same prevent a direct, straightforward comparison from being made, but our figure is much higher than the price premium estimated in 2012.

In most countries the price premium for EE on washing machines is systematically lower than for refrigerators, but for other appliances (e.g. air conditioners, air purifiers and TVs) it is slightly higher. This makes perfect sense, as consumers may have more incentive (and therefore be more willing) to pay more for EE in appliances which are used more frequently.

The information obtained with respect to WTP for different attributes may be also useful to appliance manufacturers. We find that brand reputation has the highest premium (49%), but brands considered as low-prestige negatively affect prices. This is in line with the previous literature, which suggests that the price premium of a specific appliance increases as the market positioning of the brand increases.

Specific technical characteristics also have significant effects. Attributes such as high *spin drying performance* (*sdpA*), *Built-in* and *higher capacity* seem to have a significant positive effect on the price of washing machines (33%, 31% and 8.1%, respectively), whereas white machines and *high-speed spin noise* have negative impacts of 15.5% and 3.2%, respectively.

Our findings have clear policy implications. First, knowing the precise premium paid on the market for the EE attribute is useful in designing the subsidy and rebate schemes widely used to encourage the purchase of efficient appliances. In addition, one similar studies could be run every few years to learn how the price premium is evolving and see what kind of measures and policies have been taken during that time. This is part of the information needed to understand whether policies and other efforts to promote EE are proving effective or not. Secondly, the increase in the price premium for high-energy efficiency washing machines in Spain (roughly estimated at 5%) suggests that efforts to enhance information and raise awareness with respect to EE and climate change may have become effective and significantly increased consumers' willingness to pay for EE. Moreover, the EE label for appliances is widely established in the appliances market, consumers are aware of it and take it more and more into account when buying. Of course, many other supply-side factors (such as new standards for EE and technological progress) and electricity prices may also explain this increase. In any case, the figures estimated are consistent with most research on price premiums for EE. All studies tend to find a positive premium in all cases but with some differences in size depending on the type of appliance, country and year analysed. These differences in the price premium are likely to reflect differences in national policies promoting the dissemination of energy-efficient appliances, such as information and awareness campaigns, rebates and taxes, plus other supply side factors such as technological progress and standards for EE. Likewise, electricity price differences may lead to different financial incentives to adopt more EE appliances across countries. Finally, the estimated differences in price premiums across countries suggest that cultural and environmental factors may also play an important role in purchasing decision-making by consumers.

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6. Appendix A

Brands	Coefficient (Lucas and Galarraga, 2015)	Coefficient of this research
AEG		+0.11
BALAY	-0.08***	-0.11
BEKO	-0.24***	-0.27
BOSCH	+0.05*	
CANDY	-0.11***	-0.10
CORBERO	-0.13***	-0.25
HAIER	-0.24***	-0.27
HOOVER		-0.13
INDESIT	-0.19***	-0.18
LG		-0.25
MIELE	+0.74***	+0.49
SAMSUNG	-0.12***	
SIEMENS	+0.13***	+0.06
SMEG		+0.36
TEKA	-0.08*	
WHIRPOOL	-0.09***	-0.10
ZANUSSI	-0.14***	

Note: ***, ** and * indicate significance at 1%, 5% and 10% level, respectively.

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