De Ayala, A.; Galarraga, I.; Spadaro, J.V. 2016. The price of energy efficiency in the Spanish housing market. Energy Policy. 94. DOI (10.1016/j.enpol.2016.03.032).

The price of energy efficiency in the Spanish housing market

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Abstract: The housing sector is a substantial consumer of energy, and therefore a focus for energy savings efforts. The Energy Performance of Buildings Directive (EPBD), introduced in 2002 and revised in 2010, is a key instrument to increase the energy performance of buildings across the European Union. Following the implementation of the EPBD into Spanish law, all properties offered for sale or rented out in Spain are required to have an Energy Performance Certificate (EPC). Given that the implementation of the EPC scheme for new, existing and advertised properties is still very low in Spain, unlike other European housing markets, the Spanish one lacks market data on energy efficiency (EE) labels and their impact on housing price. To overcome this gap, we determine the EE ratings of a sample of 1,507 homes across Spain on the basis of information collected previously through household surveys. This allowed us to answer the question of whether or not, and to what extent, Spanish housing markets capitalise the value of EE. We apply the hedonic−price technique and observe that more energy efficient dwellings have a price−premium between 5.4% and 9.8% compared to those with the same characteristics but lower EE level.

JEL classification**:** C13, C21, Q40, Q48, Q54

Keywords**:** Energy, Housing, Energy Performance Certification, Spain, Hedonic pricing

1. Introduction

The primary driver of global Greenhouse Gas (GHG) emissions is the production and consumption of energy. Under the context of climate change and energy dependence, most developed countries are attempting to reduce fossil−fuel use in the different economic sectors, such as buildings, transportation and industry. Compared to baseline scenarios in which the global mean surface temperature increment is limited to 2°C by the end of the 21st century, global investments in energy efficiency (EE) in the buildings, transportation and industry sectors are expected to grow by a further $336 billion annually over the next two decades 2010−2029 (IPCC, 2014).

The building sector is a major contributor of GHG emissions. According to the IPCC (2014), when emissions from electricity and heat production are attributed to the sectors that use the final energy (i.e. indirect emissions), industry accounts for 32% of global GHG emissions, followed by Agriculture, Forestry and Other Land Use (AFOLU) emissions at 24.8%, building at 18.4%, while 14.3% and 11% is attributed to transportation and other energy, respectively. Throughout Europe, residential and commercial buildings are responsible for approximately 40% of the total energy consumption, and 36% of CO_2 emissions. In Spain, residences account for nearly 17% of the total final energy consumption, whereas buildings in the tertiary sector contribute 9% (IDAE, 2012b). Direct energy used in homes represents one fifth of the GHG emissions of Spain. Considering also the emissions arising from the construction process itself, the residential sector contributes one third of the total national GHG emissions (WWF, 2010).

Under the EU's targets for climate and energy[1] (20% improvement in EE and 20% GHG emissions reduction by 2020; 27% EE goal and 40% emission reduction by 2030), buildings have a large potential for cost−effective energy savings through effective EE measures. Some of these EE measures are informative and/or educative, some are mandatory, and some use financial incentives to promote EE behaviour (de la Rue du Can et al., 2011; Dixon et al., 2010; Geller et al., 2006; Markandya et al., 2015).

The Energy Performance of Buildings Directive (EPBD) (Directive 2002/91/EC)[2] is the main EU policy instrument to improve the energy performance of buildings, taking into account cost−effectiveness, and local conditions and requirements (Bio Intelligence Service et al., 2013). If fully and properly implemented, energy savings from implementation of the EPBD are expected to reduce final energy demand by 96 million tonnes of oil equivalent (Mtoe) in 2020, or 6.5% of EU final energy demand[3].

The EPBD ensures that when buildings are constructed, sold or rented out, an Energy Performance Certificate (EPC) is made available to the owner, or by the owner to the prospective buyer, or tenant. The EPC shows an EE rating for the energy performance of a home from A to G, where A is very efficient, and G is very inefficient. The idea is similar to the ratings currently applied to domestic appliances. In addition, EPCs must include information on the energy needs or consumption of a building including reference values, as well as recommendations for cost−effective improvement options to raise the rating of the building. The recast of the EPBD

[1] http://ec.europa.eu/clima/policies/strategies/index_en.htm
[2] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings
[3] Impact assessment document accompanying the Proposal for a recast of the EPBD (2002/91/EC). Consulted (April, 2015): http://www.buildup.eu/es/publications/1274

in 2010 (Directive 2010/31/EU)[4] clarified some aspects, promoted the role of the public sector, and reinforced the role of EPCs by demanding publication of the EPC at the time of advertising a building for sale or rental rather than at the time of signing a purchase agreement or rental contract.

The implementation and effectiveness of the EPBD in Europe vary from country to country and region to region depending on a range of factors including the local political and legal context, and the characteristics of the local housing market (Bio Intelligence Service et al., 2013). Arcipowska et al. (2014) provides an overview of EPC schemes across EU countries concerning the type of label (classes label vs. continuous scale), the EPC calculation methodology (calculated vs. actual energy consumption) and software (public vs. private), the requirements for qualified and/or accredited experts (registers, training courses, mandatory exam, periodic renewal of the license), as well as the quality control schemes (national vs. regional level) and bodies in charge (government bodies, professional associations or third parties). In addition, the Buildings Performance Institute Europe (BPIE) offers a public database containing EU country-specific information about the EPC scheme, including general information, training of experts, calculation methodology, procedure, as well as compliance, quality control and penalties[5]. As an example, the appendix of the paper presents a table summarising main features of the EPC scheme for buildings in some European countries.

[4] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)
[5] http://www.buildingsdata.eu/data-search

In Spain, the EPBD 2002/91/EC was transposed into the Royal Decree 47/2007, requiring an EE certificate (in the form of an energy label) to be provided just for new buildings. The Royal Decree 235/2013 incorporated the 2010 EPBD recast and extended EPC scope to all buildings, including existing ones. Thus, onward from June 2013, all properties offered, promoted or advertised for sale, or rented out in Spain are required to have an EE certificate[6].

Informational failures seem to be pervasive and relevant to foster energy efficiency in the residential sector (Ramos et al., 2015). The EPC is designed to address both informational (asymmetric and/or incomplete information, principal-agent problems, transaction costs and uncertainty) and behavioural (decision-making heuristics and biases) failures (Linares and Labandeira, 2010; Ramos et al., 2015) so that individuals can make efficient decisions through the provision of direct, reliable and costless information that otherwise would not be available. Moreover, the information presented through the EPC can be seen as an incentive for builders and owners to invest in EE measures, as it can be hypothesised that the improvement of the energy performance of a building should then also lead to higher transaction prices and rents on the market. Much of the empirical research of the effect of EE ratings on building's prices is focused on commercial real estate markets (Eichholtz et al., 2013, 2010; Reichardt et al., 2012; Wiley et al., 2008). The literature on residential buildings is still limited but generally shows a

[6] According to the Spanish Royal Decree 235/2013, the EPC assessment should be carried out by an authorized technician. The technician collects information related to the building's physical characteristics (e.g. orientation, exterior exposure, window and door openings), and calculates the CO_2 emissions and the corresponding EE label by means of a computer software (known as CE3X) created by the Spanish Institute for Energy Diversification and Saving (*Instituto para la Diversificación y Ahorro de la Energía*, www.idae.es). A report presenting and assessing various recommendations for improvements along with the resulting EE letter grade (between A to G) is generated. The certificate is validated and registered by the competent Autonomous Administration, and an original copy will be delivered to the property owner to be kept on file for 10 years or until re−validated.

positive relation between EE ratings and home prices or rental rates. The EE influence is strongest in the sales segment (Brounen and Kok, 2011; Fuerst et al., 2015; Hyland et al., 2013).

This paper will focus just on residential sector. The implementation of the EPC scheme for new, existing and advertised properties is still very low in Spain, and therefore, the Spanish residential market, unlike other markets across Europe, lacks evidence on the EPC penetration rate. Empirical research on the existence and magnitude of the price effects of energy labelling in the residential market would be relevant in evaluating the potential effectiveness of this type of EE measure and helpful for proper design of the labelling system.

The main scope of this work is to carry out an estimation of the importance of EE in the Spanish residential market. This is done by estimating how much is actually paid in the market for EE attributes that could be represented by an energy label. This is usually interpreted in the literature as the actual willingness to pay (WPT). Many other studies have used energy labels as a good proxy to estimate the WTP for EE in the housing sector (Brounen and Kok, 2011; Hyland et al. 2013; Fuerst et al., 2015), private vehicles (Alberini et al., 2014; Galarraga et al., 2014) and household appliances (Galarraga et al., 2011b). As widespread availability and consumer experience on EE ratings is still very limited in the study area, we determine the energy ratings of a sample of 1,507 homes across Spain on the basis of information collected previously through household surveys, and using the CE3X software developed by the Spanish Institute for Energy Diversification and Saving (IDAE, 2012a). The marginal price differential due to improvements in EE is determined using a hedonic analysis. We also present potential energy savings from a switch to more efficient dwellings from less efficient ones.

The rest of the paper is structured as follows. Section 2 reviews the EE literature, and Section 3 presents the hedonic pricing method, the data used and the specified regression model for the estimation. Section 4 reports and discusses the main results arising from the estimation of the model, and Section 5 outlines the main conclusions of the study.

2. Literature review

Research on the understanding of consumer reactions to EE ratings in different markets has been growing over the last few years, largely due to implementation of EE labels, as well as growing environmental and climate change concerns. There is a rich literature of studies analysing the impact of EE labels in the appliances market, such as for washing−machines in Switzerland (Sammer and Wüstenhagen, 2006); air conditioners and refrigerators in China (Shen and Saijo, 2009); dishwashers and refrigerators in Spain (Galarraga et al., 2011a; 2011b); TVs and light bulbs in European markets (Langley et al., 2012); and refrigerators in the US (Houde, 2014; Ward et al., 2011). In the car market, studies analysing consumers' preferences for "cleaner" cars (Achtnicht, 2012; Baltas and Saridakis, 2013; Matas and Raymond, 2009) and concerning the EE or fuel economy of cars (Alberini et al., 2014; Allcott and Wozny, 2014; Chugh et al., 2011; Espey and Nair, 2005; Galarraga et al., 2014).

With regards to the impact of EE rating in the housing market, early studies have found a positive relation between EE improvements and the housing transaction prices in the US (Dinan and Miranowski, 1989; Laquatra, 1986; Longstreth, 1986), and between EE ratings and the search time of a house in Minnesota, US (Gilmer, 1989). A growing number of studies have been carried out in which market data have been mainly used. Table 1 presents the main findings of the following studies reviewed on EE effect in the housing market regarding different certification schemes, such as the European EPC, the ENERGY-STAR labelling in the US, or the Green Mark Certification in Singapore (see IEA, 2010 for their main characteristics).

In Europe, one of the earliest studies of the effects of EPC on house prices is provided by Brounen and Kok (2011) in the Netherlands. Based on a sample of energy certified dwellings (31,993), the authors estimated price−premiums of 10%, 5.5% and 2% for A, B and C rated homes (most energy efficient), respectively, compared to a D rated home but with similar characteristics. However, for homes rated E, F and G (least efficient), they identified discounts of 0.5%, 2.5% and 5%, respectively. Their hedonic regression model presented a broad range of control variables including dwelling size, insulation quality, central heating, and level of maintenance.

Bio Intelligence Service et al. (2013) explored the effect that EPC had on the purchase or rental prices in several EU Member countries (Austria, Belgium, France, Ireland, and the UK) and regions. The hedonic regression model showed that a one−letter improvement in EPC translated to to a price−premium, *ceteris paribus*, of 8% and 4.4%, respectively, in the sales and rentals markets in Austria. The estimates for Brussels (Belgium) showed a price−premium of almost 3% (sales) and 2.2% (rentals). In France, a one−letter improvement in EPC was associated with a 4.3% and 3.2% higher price in the sales market of Marseille and Lille, respectively. Ireland presented a price−premium of 2.8% in the sales market and 1.4% in the lettings market. Oxford (UK) was the only sales market where a negative relation between EE and price was found (price−discount of 4%). According to the authors, this could be due to the small sample available and/or the omission of the dwelling's age as an independent variable.

Cajias and Piazolo (2013) quantified the energy price−premium in the German residential market based on a continuous scale based considering 2,630 building observations from 2008 to 2010. According to their estimated hedonic datasets, a 1% increase in energy conservation produced a 0.45% increase in market value and 0.08% increase in rental price after controlling for regional, geographical and building−specific factors. Hyland et al. (2013) provided the first set of estimates for Ireland of the value of increased EE in domestic buildings. The Heckman procedure was adopted to control for selection bias given that only 5% of homes for sale and 2.3% for rent have an EE rating. For a sample of 15,060 dwellings on the sales market between 2008 and 2012, they found price−premiums for A, B and C rated dwellings (9.3%, 5.5% and 1.7%, respectively) and price−discounts for E and F/G ratings (0.4% and 10−6%, respectively), *ceteris paribus*. For the rental market (sample of 20,825), price−premiums were found for A and B labels (1.8% and 3.9%, respectively), whereas price−discounts were observed for C, E and F/G ratings (0.6%, 1.9% and 3.9%, respectively). The same study also noted that the effect of EE rating was generally stronger where market conditions were worse.

A significant positive impact of EE on housing prices was also observed in the residential market in England (Fuerst et al., 2015). The work considered 333,095 dwellings sold at least twice between 1995 and 2012. Applying the hedonic−price model, significant positive premiums were estimated for dwellings rated A/B (5%) and C (1.8%) compared to D rated dwellings. For homes rated E and F statistically significant discounts were found (0.7% and 0.9%, respectively). There was considerable variation by region and property types.

Concerning empirical evidence from outside Europe, one of the first studies was carried out by the Australian Bureau of Statistics (2008). They used a hedonic−price model applied to residential sales in the Australian Capital Territory (ACT) for years 2005 and 2006. The EE rating was measured as a continuous variable, and the authors found, *ceteris paribus*, a price−premium of 1.23% in 2005 for every 0.5 increase on the energy rating qualitative scale (which ranges from 0 to 6). The price−premium increased to approximately 2% in 2006. These magnitudes, however, decreased when the EE label and EE features of the house were accounted for separately. In the pooled sample (2005−2006 data), the EE label was treated as a categorical variable, and price−premiums of 1.6% (EE rating 1), 3% (EE rating 2), 5.9% (EE rating 3), 6.3% (EE rating 4) and 6.1% (EE rating 5 and 6) were estimated (relative to EE rating 0). Bloom et al. (2011) compared original sale prices between ENERGY STAR qualified homes and non−ENERGY STAR rated homes in Fort Collins (Colorado, US) using hedonic regression analysis. Their results indicated that ENERGY STAR homes sold for $8.7 more per square foot than comparable non−ENERGY STAR homes. Similarly, Kok and Kahn (2012) found that homes labelled by ENERGY STAR in California, LEED for Homes and Green−Point− rated sold for 9% more than comparable non−labelled homes.

One of the first analyses of the economics of energy efficient dwellings in Asia was carried out in Singapore by Addae−Dapaah and Chieh (2011). The Green Mark Certification (GMC) programme of Singapore is categorised into four quality levels (from most to least energy efficient): Platinum, Gold Plus, Gold and Certified. The results of the hedonic model showed that the premium ranged from an average of 9% for both Gold Plus and Gold, 13% for Certified, to 28% for Platinum when compared to non−GMC rated home. Another experience in Singapore also supported the same conclusion. The two−stage hedonic pricing model of Deng et al. (2012) estimated a 15% average price−premium for dwellings with GMC compared to non−GMC rated ones.

Zheng et al. (2012) developed a “Green Index” using Google search to rank housing complexes in Beijing (China) with respect to their “marketing greenness” (depending on the green, energy−saving and environment−friendly technologies). Their hedonic−price estimations suggested that, holding other factors constant, houses that score high on this “Green Index” presented a price−premium at the presale stage (17.7%), but subsequently resold and leased at a price−discount of 11% and 8.5% compared with the complexes with zero Google Green Index, respectively (i.e. a 30% value loss when moving from the presale to the resale stage). This might be due to the perception that Green homes have higher maintenance costs.

Contrary to the positive relationship between EE and house prices generally found in the previous studies, Yoshida and Sugiura (2010) concluded that “green” condominiums (Tokyo Green Building Program) transacted for about 5.6% lower prices in Tokyo. The authors highlighted that this negative relation might be due to the perception of higher future maintenance costs, the uncertainty about the quality of materials/systems, and omitted variables bias. Eventually, Amecke (2012) observed that EE is a purchasing criterion of only minor importance based on a web−based survey on house purchasing criteria to German property owners. Location, price, outdoor spaces, and the conditions of a dwelling were found to be the most important ones. The study highlighted that the effectiveness of energy rating will increase with the new mandatory EU legislation in 2013 (EPBD).

From our literature review we conclude that a more energy efficient home carries a price−premium, although such a price differential may vary depending on context. Given that each country operates its own specific EPC scheme, cross−country comparisons should be made with caution. For the case of Spain, there are no studies on the impact of EE label so far. To our knowledge, ours is the first of a kind. A recent study in Spain focused on the socio−economic and attitudinal factors that affect sectors EE related decisions in homes (Ramos et al., 2015). Based on a household survey, the authors generally found, among other findings, a positive relation between eco−friendly behaviours and EE supporting decisions.

[Table 1: Summary of literature review on EE ratings effect in the residential sector]

3. Estimation

3.1. Hedonic price method

Nearly all studies reviewed in Section 2 have applied a version of Rosen's (1974) hedonic model to estimate the price effect of an energy label in the residential sector. Hedonic price technique is commonly used to estimate the value of individual attributes of a given property type whose prices are not directly observed (e.g. Alberini et al., 2014; Fuerst et al., 2015; Galarraga et al., 2011a; 2011b; 2014; Palmquist, 1984), and is “the most widely accepted empirical approach” (Markandya et al., 1992). The method assumes that different goods are differentiated by the number of characteristics (attributes) they pose. At the market equilibrium, the price is a mixture of demand side and supply side attributes that can be analysed with the method. A complete description of this technique can be found in Braden and Kolstad (1991).

3.2. Data description

Data were obtained through a survey of randomly selected 1,507 primary urban residences across Spain. The survey was conducted in early 2013 and the representation by region is as follows: (i) Northeast Spain (498 surveys in Bilbao and Vitoria); (ii) Central Spain (504 surveys in Madrid); and (iii) South Spain (505 surveys in Seville and Malaga)[7]. The survey sample involves housing flats or apartments building (86%) as well as detached houses (14%) of families living there at least one year under tenure of property (82%), rental (17%) and cession (1%).

The survey consists of three main parts: (i) socio−economic data of the interviewed household (and the household head); (ii) energy characteristics of the residence; and (iii) energy consumption of the dwelling. On average, a household is formed by three members, and at least one of them is employed. The most common structure of the household is couples with children. The majority of household heads (almost 64%) are men with a mean age of 49 years old.

The survey collected the relevant information needed to run the CE3X software which was used to determine the EE rating of the dwelling (IDAE, 2012a). This software involves three steps. In the first step, the program constructs a fictitious building from the technical characteristics of

[7] The survey was done under the PURGE project (Gran Agreement No. 265325) of the 7th Framework Programme of the European Commission.

the dwelling. In the second step, the programme compares the information of the fictitious building with other constructions within a large data base in order to determine the theoretical energy demand for heating and cooling. The third step, and final step, consists of defining the total CO_2 emissions and the EE rating of the house by combing the energy necessities with the fuels and appliances used in heating, cooling, and Domestic Hot Water (DHW). The software also presents a number of intervention measures to improve EE. The overall rating of the building (from A to G) is expressed in terms of carbon dioxide emissions ($kgCO_2/m_2$) from dwelling energy consumption.

CE3X requires a large set of data to carry out its calculations, and demands expert knowledge on the technical characteristics of the building. In order to obtain a reliable CO_2 emission level and EE label, the survey asks easily answered questions to accurately capture the technical features of the dwelling. The following variables for the estimation of residential CO_2 emissions were selected: the zip code of the dwelling, the age of the building (or last major reform), living area of the dwelling, whether the dwelling is part of a flat/apartment building, whether it is in the top floor, access to solar energy, the use of air conditioning and heating, and main appliances and fuels used to provide heating and DHW. Regarding the main façade, information about orientation, surface, shading, type (and percentage) of glass and material of window frames was obtained.

The predominant energy sources for heating and DHW in our sample are electricity and natural gas, the latter dominating consumption in the North and Central regions. Electricity is the fuel of choice in the South. While every home has DHW, 10.6% of the surveyed sample has no heating (most of these dwellings are located in the South of Spain). Data on energy consumption were collected from 2012 bills: kilowatt hour (kWh) consumption, the variable and fixed costs per kWh, and the net amount paid in euros. On average, a household consumes 2,800 kWh of electricity and 2,200 kWh of natural gas.

Respondents were also asked to state the perceived value of their home. The stated price ranges from €25,000 to €1,025,000 with a mean equal to €212,100. Finally, the survey data were supplemented by collecting socio−demographic variables of the township where the dwelling is located, such as population density, ageing index, life quality index, and distance to the main infrastructures such as highways, schools, hospitals, and secondary roads (see Table 2).

3.3. The regression model

A semi−log hedonic price regression model was estimated. This is the usual specification as it allows a rather simple interpretation of the estimated coefficients (see Alberini et al., 2014). While transaction prices are preferable as the dependent variable, this information, unfortunately, is not available. Instead, we use the respondent's stated housing price as a surrogate of the market price. The log of the home price for the hedonic−price equation is expressed as a function of the independent variables as indicated in Eq. [1]:

$$\begin{aligned} Ln\,(price_i) = {} & \alpha + \beta_1 Label\ ABC_i + \beta_2 Before\,2007_i + \beta_3 Last_i + \beta_4 m_i^2 + \beta_5 Rooms_i + \beta_6 Air_i + \\ & + \beta_7 Bilbao_i + \beta_8 Vitoria_i + \beta_9 Malaga_i + \beta_{10} Seville_i + \beta_{11} Density_i + \beta_{12} Ageing\ Index_i + \\ & + \beta_{13} Secondary_i + \beta_{14} Life\ Quality_i + \beta_{15} City_i + \beta_{16} Distance\ Highway_i + \varepsilon_i , \end{aligned} \quad [1]$$

where, i refers to the household number, α is a constant term, $\beta_1,...,\beta_{16}$ are the housing coefficients to be estimated, and ε is the error term. The explanatory variables we selected can be grouped into: (i) dwelling's variables (*Label ABC, Before 2007, Last, m^2, Rooms, Air*); (ii) geographical variables (*Bilbao, Vitoria, Malaga, Seville*); and (iii) socio−demographic variables (*Density*, *Ageing Index*, *Secondary*, *Life Quality*, *City, Distance Highway*). Table 2 provides the description of each of the variables included in Eq. [1] together with summary statistics.

The socio−demographic variables of the township where the household is located are based on official statistics. For measuring the life quality of the township (*Life Quality*), we used a synthetic index based on Value Efficiency Analysis (VEA) created by González et al. (2011). In order to represent the relevant dimensions of quality of life in Spanish municipalities, the index covers aspects related to consumption, social services, housing, transport, environment, labour market, health, culture and leisure, education, and security. The distances to the main infrastructures (school, hospital, highway and secondary road) were obtained from the postcodes of the surveyed dwellings using GIS mapping. Only the distance from the centre of the postcode to the closest highway (*Distance Highway*) was found to be significant in the estimation stage.

[Table 2: Variables and summary statistics]

4. Results and discussion

Based on the available survey data, EE labels were calculated for 1,489 dwellings. Fig. 1 shows the resulting EE labels distribution by area (north, centre and south). Homes labelled A, B and C account for less than 10% of the housing stock. In fact, there are only three houses with A rating, 23 with B and 82 with C. Most of households in the sample (52%) are E rated. F and G rated residences account for almost 25% of the sample. As can be seen, there are considerable opportunities to increase the energy performance of Spanish housing stock, particularly in the Southern region of Spain.

[Fig. 1. EE labels distribution by region]

We evaluate the EE label impact on housing price estimating the hedonic−price Eq. [1] by ordinary least squares (OLS) with robust standard errors (for our calculations we have used the STATA software, Ver. 13). Table 3 presents the estimated coefficients along with their 95% confidence intervals. A, B or C dwellings are valued at a price premium of 9.8% compared to homes of similar characteristics but lower energy efficiency. The average price premium is €20,800 (9.8% of the average home price of €212,100). We have also explored a second hedonic−price model with an alternative grouping of EE labels. For this second specification, we define a variable *Label ABCD* which takes on the value 1 if the house is rated A, B, C, or D, and 0 otherwise. All other explanatory variables are unchanged. The results of the second alternative are presented in Table 4. The price premium is 5.4%, or equivalent to an additional cost of €11,450 compared to less efficient homes with ratings E, F, or G (*ceteris paribus*). The most energy efficient homes in Spain, therefore, have a price premium between 5.4% and 9.8% relative to less efficient homes of comparable characteristics. Our range is consistent with empirical evidence from other European countries (see Table 1).

Our results also reveal that homes located in the north of Spain (Bilbao and Vitoria) are valued on average more than those in the centre (Madrid) or in the south (Malaga and Seville), *ceteris paribus*. Turning to the characteristics of the residence, we find a positive relationship between buildings built before 2007 and price. As one would expect, dwellings located on the last floor, the living area, the number of rooms and having air conditioning all have a positive impact on the price of the house. With regards to socio−demographic variables, the population density of the township where the residence is located has a positive, albeit very small, effect on the price. The share of housing stock classified as secondary in the municipality and the quality life of the township are estimated to have a positive impact on the price, while the ageing index seems to have a negative influence. The effect of the distance from the centre of the postcode to the main infrastructures was tested, and only the proximity to a main highway was found to have a significant, positive effect on price (which is likely related to insufficient information on postcodes).

[Table 3: Estimated model I – *Label ABC*]

[Table 4: Estimated model II – *Label ABCD*]

Moreover, we calculate the energy savings from improving the EE rating of a typical house of our sample due to the implementation of certain EE improvement measures using the CE3X software. Table 5 shows the assessment of energy savings for a typical house of 80 m^2 when moving from an E (initial situation) to a D (measure I) and C (measure I + measure II) EE rating. As indicated in Table 5, improving EE rating delivers substantial energy savings, as well as significant reductions of CO_2 emissions.

Installing a high efficiency condensing boiler (measure I), for example, in a house that is currently rated E will improve its rating to D, with a corresponding reduction in annual energy consumption equal to 24 kWh/m^2. For an average dwelling of 80 m^2, the anticipated annual energy savings reach €228 (or €19 per month). If, in addition, we upgrade the exterior insulation of the same dwelling (measure II), the EE rating improves to C (starting initially from E), and the annual energy savings realised are t €826 (or €69 per month). Meanwhile, the two step transition (from E to C) reduces carbon emissions each year by 13.2 $kgCO_2$ per m^2 (or 1,054 $kgCO_2$ per year per household). Assuming this change applies, on average, to the Spanish housing stock (17.4 million households), the aggregate CO_2 emission reductions equal 18.4 $MtCO_2$, or about 35% of the annual emissions (direct only) from the whole Spanish housing sector.

[Table 5: Energy savings calculation (CE3X)]

5. Conclusions and policy implications

The building sector has a key role to play in climate and energy policies. The main legislative instrument affecting energy use in buildings in Europe is the 2002 EPBD, and its 2010 recast. The EPC scheme addresses both informational and behavioural failures to provide better information to individuals and enable them to adopt the most efficient decisions, contributing to reduce the energy efficiency gap (Ramos et al., 2015). The EPC also includes recommendations for cost−effective improvement options to raise the rating of a building. Its implementation has been gradual across the EU Member States. In the case of Spain, EPC became mandatory in 2013, and has since been applied to both new and existing buildings. A key assumption behind this policy instrument is that if informational and behavioural failures are reduced, and improvements in EE are capitalised in the housing market, this will translate into greater demand and supply of new and refurbished energy efficient homes. In this context, this study provides preliminary empirical evidence of the price−premium of energy efficient homes in Spain.

Using a survey on housing characteristics and stated home prices, we determine the corresponding EE rating of each surveyed home by means of IDAE's software CE3X (IDAE, 2012a), and provide a first set of estimates of the value of increasing housing EE grades. Our hedonic pricing estimations show that, all else being equal, homes labelled A, B or C are valued at a 9.8% higher price compared to D, E, F or G rated homes, while dwellings with an A, B, C or D grade have a 5.4% price−premium compared to homes with E, F or G ratings. According to the results of the CE3X software, for a typical home in Spain, an improvement in energy efficiency from an E to a C rating can reduce the household annual energy demand by 86 kWh/m^2, in addition to lowering CO_2 emissions by 13 kgCO_2/m^2. This is equivalent to a savings of €826 per year, assuming a typical home size of 80 m^2, and an average energy cost of €0.12 per kWh.

This study has some caveats generated namely by the current inability to obtain data on housing market transactions with EPCs in Spain. First, we have assumed that the stated price in the survey is a proxy of the market transaction cost. Second, given that the initial focus of the survey was on collecting the energy characteristics of the houses, additional housing features are lacking in order to better explain the variability of the data (e.g. the existence of a lift in an apartment, terrace, garden, specific location of the house). Third, time series data are not available. Since the EPBD recast seeks to improve this situation (by making the display of EPC in property advertisements obligatory), future studies will be better able to assess the influence of the EPC on the decision to buy/rent a property with a higher/lower energy rating.

Meanwhile, Member States should be encouraged to (or continue to) focus on quality assurance of the EPC, making the EPC better available, and providing improved and trustworthy information on the label. For doing this, the reports of Arcipowska et al. (2014) and Tigchelaar et al. (2011) present a range of specific recommendations, such as; training and harmonised accreditation schemes for certifiers, enforcing the penalty of non-compliance, use of plain language and layout, and providing homeowners with the information they are interested in regarding home purchasing (e.g. potential costs and savings, where to go and whom to consult for further information and advice; either on the EPC or online). As pointed out by Ramos et al. (2015), energy certificates can be effective if they are properly designed.

In fact, in order to achieve a successful EPC, homeowners should be aware of its existence; understand the information on it; trust the information on it; find the information useful; and be motivated to implement recommendations to improve EE in their homes (Tigchelaar et al., 2011). The values presented in this study offer some information in this regard as they provide a first estimate of the WTP for energy efficient homes in Spanish households, which can assist EPBD in making EPCs more effective in influencing individual' decisions.

At the same time, this work contributes to a growing European literature examining the price−premium for energy efficient durables that can assist the design of EU energy and climate policies. Particularly, as Europe moves towards Nearly Zero Energy Buildings, EPCs (including energy ratings, recommendations for improvement and price-premiums) can play a relevant role in encouraging property developers and the rest of the market (including the financial market) to move in this direction. However, since EPC schemes are not fully implemented in all Member States nor sufficiently enforced yet (Arcipowska et al., 2014), further research is still needed to guide future revisions of EE labelling directives towards improving the quality, credibility and usefulness of EPCs.

Acknowledgements

The authors acknowledge the PURGE Project (Gran Agreement No. 265325) of the 7th Framework Programme of the European Commission for financial support in carrying out the survey work. Additionally, Ibon Galarraga wishes to recognise the support of the Ministerio de Economía y Competitividad, Government of Spain (project ECO2013−41183−P: *Economía de la Eficiencia Energética en el Sector Residencial y de Transporte en España*).

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TABLES

Table 1. Summary of literature review on EE ratings effect in the residential sector

Reference	Country	Dependent variable	Main finding
Brounen and Kok (2011)	Netherlands	Trans. price \$/m² (sales)	EPC price–premiums compared to D rated homes: A = 10%; B = 5.5%; C = 2%; E = −0.5%; F= −2.5%; G = −5%
Bio Intelligence Service et al. (2013)	Some EU countries	Trans. price € (sales and rentals)	One–letter improvement in EPC carried a price–premium (except in Oxford): Austria = 8% (sales), 4.4% (rentals) Belgium: Flanders = 4.3% (sales), 3.2% (rentals); Wallonia = 5.4% (sales), 1.5% (rentals); Brussels = 2.9% (sales), 2.2% (rentals) France: Marseille = 4.3% (sales); Lille = 3.2% (sales) Ireland = 2.8% (sales), 1.4% (rentals) Oxford (UK) = −4% (sales)
Caijas and Piazolo (2013)	Germany	Market value and €/m² (sales and rentals)	A 1% increase in energy saving increased market values by 0.45% and rent prices by 0.08%
Hyland et al. (2013)	Ireland	Listed price \$ (sales and rentals)	EPC price–premiums compared to D rated homes: A = 9.3% (sales), 1.8% (rentals); B = 5.5% (sales), 3.9% (rentals); C = 1.7% (sales), −0.6% (rentals); E = −0.4% (sales), −1.9% (rentals); F/G = −10.6% (sales), −3.2% (rentals)
Fuerst et al. (2015)	England	Trans. price £/m² (sales)	EPC price–premiums compared to D rated homes: A/B = 5%; C = 1.8%; E = −0.7%; F = −0.9%
Australian Bureau of Statistics (2008)	ACT	Trans. price \$ (sales)	Price–premiums of 1.23% (2005) and 2% (2006) for an increment of 0.5 on the EE rating scale
Bloom et al. (2011)	Colorado (US)	Trans. price \$/ft² (sales)	ENERGY STAR labelled homes sold for \$8.7 per square foot more than non–ENERGY STAR homes
Kok and Kahn (2012)	California (US)	Trans. price \$ (sales)	ENERGY STAR labelled homes sold for 9% more than non–labelled homes
Addae–Dapaah and Chieh (2011)	Singapore	Trans. price \$ (sales)	GMC homes presented a price–premium compared to non–GMC rated ones (e.g. 13% for Certified)
Deng et al. (2012)	Singapore	Trans. price \$/m² (sales)	GMC homes presented a price–premium compared to non–GMC rated ones: 15% on average
Zheng et al. (2012)	Beijing (China)	Trans. price yuan/m² (sales and rentals)	"Green" indexed houses presented an initial sales price–premium (17.7%), but resold and leased at a price discount (11% and 8.5%, respectively) compared with non–"green" homes
Yoshida and Sugiura (2010)	Tokyo (Japan)	Trans. price yen/m² (sales)	"Green" condominiums trade at a price discount of 5.6% compared with non–"green" homes

Amecke (2012)	Germany	Purchasing criteria (sales)	The effectiveness of EPCs is limited on purchasing decisions

Notes:
ACT: Australian Capital Territory.
EPC: Energy Performance Certification.
GMC: Green Mark Certification.
Trans. price is the home transaction price, normalized per unit area when divided by m^2 (square meter) or ft^2 (square foot).

Table 2. Variables and summary statistics

Variable	Codification	Description	Obs.	Mean (Std. Dev.)	Range [Min Max]
Dependent variable					
Ln (price)	Quantitative	Log of the price of the house	1,499	12.15 (0.47)	[10.13 13.84]
Dwelling's independent variables					
Label ABC	Dummy	Whether the dwelling is rated an A, B or C	1,489	0.07 (0.26)	[0 1]
Before 2007	Dummy	Whether the building is constructed, or has had the latest major refurbishment, before 2007	1,501	0.91 (0.29)	[0 1]
Last	Dummy	Whether the dwelling is in the last floor of the flat/apartment building	1,507	0.14 (0.35)	[0 1]
m^2	Quantitative	Total living area (m^2)	1,498	87.00 (32.81)	[23 500]
Rooms	Quantitative	Number of rooms (excluding kitchens, bathrooms, corridors, halls and terraces)	1,506	4.67 (1.49)	[1 12]
Air	Dummy	Whether the dwelling has air conditioning or not	1,488	0.43 (0.50)	[0 1]
Geographical independent variables					
Bilbao	Dummy	Whether the dwelling is located in Bilbao area	1,507	0.17 (0.37)	[0 1]
Vitoria	Dummy	Whether the dwelling is located in Vitoria area	1,507	0.16 (0.37)	[0 1]
Malaga	Dummy	Whether the dwelling is located in Malaga area	1,507	0.16 (0.37)	[0 1]
Seville	Dummy	Whether the dwelling is located in Seville area	1,507	0.17 (0.38)	[0 1]
Socio–demographic independent variables					
Density	Quantitative	Inhabitants/km^2	1,498	3,684 (2,564)	[9.44 14,970]
Ageing Index	Quantitative	% inhabitants > 65 years old	1,498	17.20 (3.76)	[3.52 29.21]
Secondary	Quantitative	% of housing stock in the municipality classified as secondary (i.e. not primary residence)	1,485	4.48 (3.96)	[0.70 32.18]
Life Quality	Quantitative	Index of the life quality of the municipality (González et al., 2011)	1,498	0.91 (0.05)	[0.76 1.13]

Variable	Codification	Description	Obs.	Mean (Std. Dev.)	Range [Min Max]
City	Dummy	Whether the dwelling is located in a municipality with more than 10,000 inhabitants (considered as a city)	1,498	0.95 (0.21)	[0 1]
Distance Highway	Quantitative	Distance (meters) from the centre of the postcode to the closest highway	1,507	1,478 (1,961)	[10.27 18,637]

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

Table 3. Estimated model I – *Label ABC*

Variable	Coefficient	Std. Error	95% confidence interval
Label ABC	0.098**	(0.045)	[0.011 0.186]
Before 2007	0.110***	(0.035)	[0.040 0.179]
Last	0.065**	(0.027)	[0.011 0.119]
m^2	0.006***	(0.0006)	[0.005 0.007]
Rooms	0.050***	(0.009)	[0.031 0.068]
Air	0.114***	(0.027)	[0.061 0.168]
Bilbao	0.361***	(0.037)	[0.288 0.435]
Vitoria	0.133**	(0.057)	[0.020 0.245]
Malaga	−0.274***	(0.044)	[−0.360 −0.188]
Seville	−0.252***	(0.032)	[−0.316 −0.188]
Density	0.000016*	(≈0)	[≈0 0.00003]
Ageing Index	−0.008*	(0.004)	[−0.016 0.0006]
Secondary	0.009***	(0.003)	[0.003 0.015]
Life Quality	0.641***	(0.239)	[0.172 1.109]
City	0.281***	(0.064)	[0.155 0.408]
Distance Highway	0.000016**	(≈0)	[≈0 0.000028]
Constant	10.384***	(0.226)	[9.939 10.828]
Observations		1,443	
R^2		0.4272	
Log−likelihood		−569.107	
AIC		1,172.215	
BIC		1,261.881	

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

Table 4. Estimated model II – *Label ABCD*

Variable	Coefficient	Std. Error	95% confidence interval
Label ABCD	0.054**	(0.028)	[≈0 0.109]
Before 2007	0.093***	(0.034)	[0.026 0.160]
Last	0.071**	(0.028)	[0.016 0.126]
m^2	0.006***	(0.0006)	[0.005 0.007]
Rooms	0.050***	(0.009)	[0.031 0.068]
Air	0.113***	(0.027)	[0.060 0.166]
Bilbao	0.366***	(0.038)	[0.292 0.440]
Vitoria	0.131***	(0.058)	[0.018 0.245]
Malaga	−0.273***	(0.044)	[−0.359 −0.186]
Seville	−0.247***	(0.033)	[−0.311 −0.182]
Density	0.000016*	(≈0)	[≈0 0.00003]
Ageing Index	−0.007**	(0.004)	[−0.016 0.001]
Secondary	0.010***	(0.003)	[0.004 0.016]
Life Quality	0.610***	(0.239)	[0.140 1.080]
City	0.277***	(0.064)	[0.151 0.403]
Distance Highway	0.000015**	(≈0)	[≈0 0.000028]
Constant	10.42***	(0.228)	[9.971 10.866]
Observations		1,443	
R^2		0.4268	
Log−likelihood		−569.599	
AIC		1,173.198	
BIC		1,262.864	

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

Table 5. Energy savings calculation (*CE3X*)

Situation	Amount	Grade
Initial energy rating (total emissions)	24.20 $kgCO_2/(m^2$ year)	E
Initial energy consumption	167.7 kWh/(m^2 year)	
Measure I (switch to condensing boiler):		
Energy rating (total emissions)	19.40 $kgCO_2/(m^2$ year)	D
Energy consumption	143.91 kWh/(m^2 year)	
Energy savings E → D:	23.79 kWh/(m^2 year)	
For a 80 m^2 typical house (in kWh)	1,903 kWh/year	
For a 80 m^2 typical house (in €)[1]	€228/year (€19/month)	
Measure I + Measure II (exterior wall insulation):		
Energy rating (total emissions)	11.03 $kgCO_2/(m^2$ year)	C
Energy consumption	81.69 kWh/(m^2 year)	
Energy savings E → C:	86.01 kWh/(m^2 year)	
For a 80 m^2 typical house (in kWh)	6,881 kWh/year	
For a 80 m^2 typical house (in €)[1]	€826/year (€69/month)	

[1] Assuming €0.12 per kWh (this number is the household weighted cost of electricity and gas consumption in Spain).

FIGURE

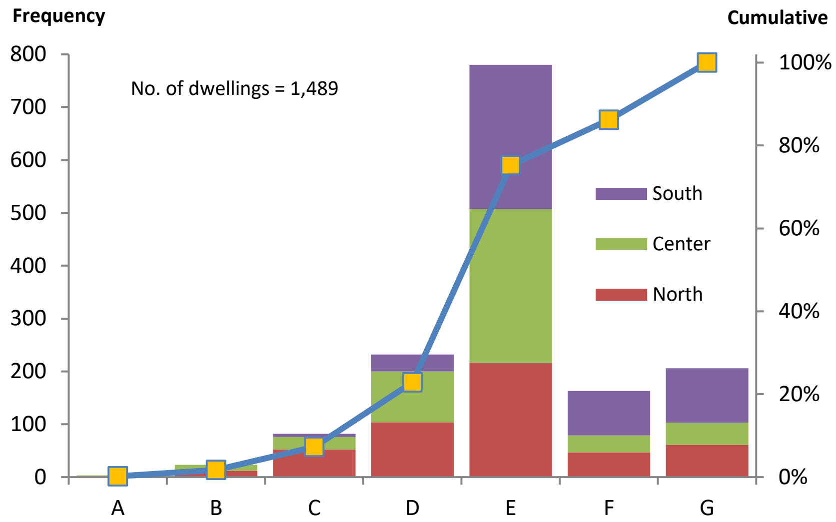

Fig. 1. EE labels distribution by region

Appenidx - EU EPC scheme for buildings: An overview of some EU countries

Table A1

Country	Methodology [a]	Software	Type of label	Unit	Range	Quality checks
Spain	Asset rating	Private and public	Classes label	$kgCO2/m^2$ per year	A to G [b]	Regional governmental body
Austria	Asset rating	Private	Classes label	kWh/m^2 per year	A++ (<10) to G (≥250)	Regional governmental body
France	Asset and operational rating	Private	Classes label	kWh/m^2 per year	A (<50) to G (≥450)	Third party body
Germany	Asset and operational rating	Private	Continuous scale Additional classes label for residential buildings (since 2014)	kWh/m^2 per year	From 0 to >400 A+ (<30) to H (≥250)	Central and regional governmental body
Ireland	Asset rating	Private and public	Classes label	kWh/m^2 per year	A1 (<25) to G (≥450)	Central governmental body
Slovenia	Asset rating (residential buildings) and operational rating (non-residential buildings)	Private	Classes label	kWh/m^2 per year	A1 (<10) to G (≥210)	Central governmental body

Source: Arcipowska et al. (2014) and http://www.buildingsdata.eu/data-search (accessed 19.12.15)

Notes:

[a] While the asset rating methodology based on calculate energy consumption takes into account the primary energy needs of the buildings without taking into account all the losses derived from the production of energy, the operational rating methodology focused on actual energy consumption is generally based on the energy delivered to the buildings and therefore includes users' behaviours and the potential malfunctioning of some equipment (thus might not necessary reflect the typical use). In some cases, both the actual and calculated energy consumptions are foreseen depending on the building type or building age.

[b] The ranges depends on the type of building (housing flat vs apartment building) and the climatic zone.

More country