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How different are dwellings whose energy efficiency impacts price formation?

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Abstract. Housing energy-efficiency has become a relevant issue since it is mandatory to exhibit an Energy Performance Certificate (EPC) when transacting real estate in the European Union. A number of studies have focused on energy-efficiency marginal prices using hedonic models from cross-sectional and longitudinal perspectives. Some of them have found that the increase of relevance of EPC ranks (i.e. marginal prices) is not the same for all the A-G classes. This study aims to explore the differences in terms of architectonic and location attributes between the apartments depicting an increase of EPC ranking marginal prices regarding those where energy efficiency seems not to play a role in price formation. In doing so, a pooled spatial error hedonic model is done using selling information for multifamily housing in Barcelona for the years of 2014 and 2016. Furthermore, it is shown which EPC ranks do exhibit an increase in terms of marginal prices in the period studied. Finally, we compare the architectonic and locative attributes for the set of homes where the energy efficiency has increased in terms of price importance to the set of homes where it has not increased. The results suggest that dwellings with high and medium EPC ranks (e.g. A for 2014; and B, C and D for 2016) are more expensive, larger and boasting of better architectonic qualities than the rest of homes where EPC ranks failed to have a role in price formation. On the contrary, the location attributes are different: while A-ranked dwellings of 2014 are located on peripheries where new housing completions are placed; B, C and D-ranked homes of 2016 are located in more centric locations. These findings have implications for future analysis regarding the energy premium and energy poverty, since specific characteristics in different submarkets may have a different impact on housing prices.

1. Introduction

Since the energy consumption in the residential sector has accounted for 25% consumption of the whole world and 40% in Europe, the European Commission promulgated relevant energy directives since early 2000s. In the real estate market, the specific one is the Energy Performance of Buildings Directive. It recast in 2010 made it mandatory to exhibit Energy Performance Certificates (EPCs) when properties are rented or sold. This program aims at promoting the transparency of energy efficiency and breaking down the barriers of energy information asymmetries between buyers and sellers [1]. In Spain the transposition of such Directive has been introduced by the RD 235/2013, so as 1st of June 2013 it is also mandatory to show an EPC label on property advertisement [2].

A number of studies have researched the marginal price for energy efficiency, some of them have found that such energy premium is not the same when the market is segmented. Therefore, the concomitant architectonic and locative attributes contributing to this energy premium deserves special attention. In this regard, this paper aims to explore the differences in terms of architectonic and location attributes between the apartments depicting an increase of EPC ranking marginal prices regarding those where energy efficiency seems not to play a role in price formation. A spatial error hedonic model is applied in Barcelona Metropolitan Area in order to identify those homes where EPC labels produce an increase of price regarding those homes where such attribute plays a null role in price formation. Next, using an ANOVA test the significant attributes between both kind of homes are identified.

The results suggest that energy premiums are reserved for "A"-ranked homes in 2014 and "B,C,D"-ranked homes in 2016. So the first conclusion is that energy premium evolves in a sprawling fashion among high efficient energy classes. Nevertheless, the characteristics of homes which hedonic agenda does includes energy premiums are not the same that the remainder dwellings. Since such homes tend to be more expensive, larger and boast the best architectonic features. Interestingly, "A" ranked homes locate in peripheries where new completions are developed, meanwhile "B", "C" and "D" depict a more central location in neighborhoods of wealthy population. Such findings have relevant implications for market segmentations from energy efficiency perspective.

The remainder of this paper is organized as follows: after a short literature review, first, the scope, case study and models are detailed in the methodology section; followed by the results and discussion; and finally a brief conclusion is provided.

2. Literature review

Energy efficiency in the housing sector has become a concerning issue along with Energy Performance Certificates (EPCs) introduced by Energy Performance of Buildings Directives (EPBD) in 2002. Numerous studies have concluded the EPC impacts on housing prices by hedonic models. Brounen and Kok [3] indicated that there was an energy-efficiency premium of 3.6% with energy ranking increase in the Netherlands. Fuest et al. [4] found in England and Wales, an 11.8% housing premium increased when dwellings improved from ranking G to ranking A. Likewise, Hyland et al. [5] found the green premium was higher when selling in Ireland, rather than renting a house. Bottero and Bravi [6] indicated there was an increase of 26.44 euros per square in housing price along with each energy ranking improvement in Turin. De Ayala et al. [7] suggested that, in Spanish 5 cities, there was a green premium after asking for the opinion value using a survey applied to households. Marmolejo [8] suggested there was a 0.85% increase in housing prices around Metropolitan Barcelona Area (AMB) while in 2019, the premium increased to 1.4% with each energy ranking increase [9]. However, a few studies concluded that the impact of energy efficiency on housing prices was insignificant or even total inverse than what expected [10,11].

Considering the specific characteristics that contributed to price formation, Bourassa [12, 13] suggested the errors from the spatial dependence do matter on housing prices after using different spatial and statistical models in Auckland. Next, Hyland et al. [5] indicated that marginal impacts are different in various temporal submarkets, locations and dwelling typologies (e.g. the numbers of bedrooms) in Ireland. Also, Cerin et al. [14] estimated such marginal prices using the technical units of energy consumption (i.e. KWh/m^2). They pointed out that the dwellings with lower selling prices and older property age made negative contributions to energy saving. Subsequently, Fuerst et al. [4] classified the real estate market in England and Wales by buildings types and found the energy premium varies across these market segments. Olaussen et al. [15] and Jensen et al. [16] also found the marginal price by time-period groups in real estate markets of Oslo and Denmark. Likewise, Marmolejo and Chen [9, 17] found that the accuracy in the determination of such an energy premium is improved when controlling for the metropolitan area were the apartment is located.

In general, numerous studies have pointed out that energy label does matter on housing prices but these impacts on price formation vary widely, based on different real estate market conditions and socio-economic attributes in detail.

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3. Methodology and data

3.1. Study Area and Data

This study area is the functional Barcelona Metropolitan Areas (AMB) which is comprised of 164 municipalities and contributes a considerable number of energy-labelled dwellings in Spain. Habitaclia, one of the leading real estate websites in Catalonia, offers a sample of listing prices and characteristics of apartments in AMB. Also, the relevant data are derived from the 2001 Housing and Population Census (HPC), 2013 Cadastral Database, 2001 Mobility Metropolitan Survey. The HPC in 2011 is not reliable at census tract level since it was based in a restricted sample survey.

After depurating, the sample comprises 3,246 apartments for the year 2014, and the same number of apartments in 2016. As a result, the pooled sample is consist of 6,492 apartments. Table 1 exhibits the descriptive statistics of the primary variables organised in conceptual dimensions.

It is clear that an apartment sized with 84 m^2 in 2014 were asking for 162,851 Euros. It also consists of 1.3 bathrooms, 2.9 bedrooms, and its average height of the buildings where it is located is 2.1 stories with an average terrace area of 12 m^2. Regarding the amenities, 4% of apartments have swimming pools, 9% gardens and 46% lift service. The conditioning systems are also presented: 48% of the apartments have air conditioner while 68% central heating system

Concerning indictors of energy efficiency, the average ordinal EPC rank (G=1, A=7) is 2.7. Class "A" comprises only 3% of the sample, far less than Class "E" (49%) and class "G" (21%). It is noted that Class "B" in 2014 is not presented. In terms of the average location, 93% are located in municipalities with access to highway, and 50% are near to a railway station. The average density of population and employment are 21,935 residents/km^2 and 9,511 jobs/km^2 respectively which can be regarded as the proxy variables for the centrality and serviced zones. Also, 1.2% of the apartments have sea access within 200 meters which proxies for environmental quality.

In terms of the socioeconomic level of the zones where the apartments are located, 7% of the neighbouring housing has doorman service as an average and 11% of households hold a university degree. Considering the possibility of collinearity from such variables, a factor analysis has been used including job positions and education level. As a result, there are two principal components: PC1-High Income proxies for high-income job positions/high education level with an average -0.11 scores where the lower its value, the lower the proportion of neighbours in managerial, professional and specialised technical job positions as well as the lower the education level. PC2-Med Income proxies for medium income level, incorporating clerks, service vendors or qualified manufacturing positions.

In 2016, the physical and locational quality of the apartments show superior performance and higher prices. Compared to 2014, the apartments in 2016 are: more expensive, larger, best equipped (*i.e.* air conditioner, heating and lift, swimming pool and garden), more efficient in energy performance terms, and located in centralized and well-connected zones. Since 2014 year is still in the period of real estate crisis in Spain, owners of properties with better qualities and locations are willing to transact them during the economic recovery period for better price quotations. Therefore, it is clear that the characteristics performance of homes in 2016 is better than that in 2014.

Table 1. Descriptive statistics for the 2014 & 2016 depurated sample and selected variables

	2014 Sample (N=3,246)				2016 Sample (N=3,246)			
	Min	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**
Architectonic Attributes								
Total price (Euros)	34,000	715,000	162,851	88,957	48,000	830,000	229,507	153,812
Unitary price (Euro/m^2)	845	3,542	1,914	661	602	10,172	2,592	1,295
Area (m^2)	25	234	84	28	20	380	87	32
Number of bathrooms	-	4	1.3	1	-	4	1.4	1
Number of bedrooms	-	15	2.9	1	-	10	2.9	1
Ration bathroom/bedroom	-	2	0.5	0	-	2	0.5	0
Level of the apartment	-	13	2.1	2	-	19	2.2	2
Terrace (m^2)	-	256	9.5	14	-	240	9.5	21
Living room area (m^2)	-	90	12	10	-	102	12	12
Large terrace (Dummy)	0	1	7%		0	1	13%	
Air conditioner (Dummy)	0	1	31%		0	1	48%	
Central heating (Dummy)	0	1	43%		0	1	68%	
Retrofited apartment (Dummy)	0	1	11%		0	1	19%	
Swiming pool (Dummy)	0	1	4%		0	1	11%	
Garden (Dummy)	0	1	9%		0	1	16%	
Lift (Dummy)	0	1	46%		0	1	67%	
Building age	0	104	45	18	0	326	46	25
Energy Performance Class								
Energy class (ordinal)	1	7	2.70		1	7	2.84	
Energy class G (Dummy)	0	1	21%		0	1	19%	
Energy class F (Dummy)	0	1	14%		0	1	13%	
Energy class E (Dummy)	0	1	49%		0	1	50%	
Energy class D (Dummy)	0	1	10%		0	1	11%	
Energy class C (Dummy)	0	1	4%		0	1	3%	
Energy class B (Dummy)	na	na	na	na	0	1	1%	
Energy class A (Dummy)	0	1	2%		0	1	3%	
Accessibility Attributes								
Commuting time (minutes)	12.9	41.0	24.0	4.5	12.9	41.4	24.6	3.9
Highway ramp (Dummy)	0	1	93%	26%	0	1	94%	23%
<800 m from railway station (Dummy)	0	1	50%	50%	0	1	56%	50%
Pop. density (residents/km^2)	11	144,421	21,935	22,700	16	152,596	24,262	23,273
Employment density (jobs/km^2)	5	56,454	9,511	9,738	7	73,563	10,548	10,078
Centrality index	3.5	20.5	11.4	2.4	4.7	20.5	12.0	2.7
Average gross area floor ratio (m^2/m^2)	0.2	6.0	2.0	1.3	0.2	6.0	2.3	1.6
<200m from sea shore (Dummy)	0	1	1.2%		0	1	3.9%	
Socioeconomic Attributes								
Doorman (%)	0%	72%	7%	10%	0%	94%	10%	14%
People with university degree (%)	1%	44%	11%	8%	1%	47%	14%	10%
Managers (%)	1%	34%	8%	4%	1%	32%	10%	5%
Professionals (%)	1%	45%	11%	8%	1%	44%	14%	10%
Technicians (%)	3%	25%	13%	4%	2%	25%	14%	4%
Clerks (%)	3%	21%	11%	3%	3%	21%	11%	3%
Service vendors (%)	3%	29%	15%	3%	5%	33%	15%	4%
Agriculture (%)	0%	8%	1%	1%	0%	10%	1%	1%
Craft & qualified manufacture (%)	2%	39%	17%	6%	1%	37%	15%	7%
Manufacturing (%)	1%	40%	13%	6%	1%	36%	11%	6%
Non qualified jobs (%)	2%	32%	10%	4%	1%	32%	9%	5%
PC1 High income	- 2.15	3.86	- 0.11	0.81	- 2.15	3.76	0.16	1.03
PC2 Med income	- 3.14	2.51	- 0.24	0.96	- 3.14	2.62	0.02	0.93

Notes: Energy class B in 2014 is null after depurating data. Source: Own elaboration.

3.2. Methods

The primary method used is the hedonic model [18]. However, it has been found that apartments' prices do not only respond to their locative and architectonic attributes, but also the price of nearby apartments (*i.e.* spatial dependence). According to Ord [19], the best way to correct the spatial dependence issue is

Spatial Error Model (SEM) where the largest and most significant value of the following Lagrange Multiplier Diagnostics should be used to diagnosis the spatial dependence. In our case, the Lagrange Multiplier (error) approach resulted in the largest value equivalent to 981.38 (sig=0.00). According to the Moran's I, the spatial autocorrelation of error from the OLS model is 0.22 (sig=0.00). The omission of this issue might lead to biased coefficients. For this reason, a pooled spatial error hedonic model has been implemented as the following equation (1):

$$\ln(P) = c + \sum_{i=1}^{n} X_i A_i + XE + \sum_{i=1}^{n} X_i B_i + \sum_{i=1}^{n} X_i L_i + \sum_{i=1}^{n} X_i S_i + c'2016 + XE_{2016} + \varepsilon \quad (1)$$

Being $\varepsilon = \lambda W \varepsilon + u$

Where
P is the asking selling price
X_i is the coefficient for each of the variables expressed as price semi-elasticities
A is a set of apartment's i architectonic attributes
E is the apartment's energy rank derived from EPC
B is a set of i facilities and amenities of the buildings where the apartment is located
L is a set of locative i attributes regarding transport and environmental quality of the site where the apartment is located
S is a set of socioeconomic attributes of the population living around the apartment
2016 is a year dummy variable equal to one if the dwelling comes from the 2016 dataset and zero otherwise
E_{2016} is an interaction term between the E energy rank and the dummy variable 2016. In the absence of an increase of the impact of energy rankings on housing prices the associated coefficient of this variable will appear as statistically insignificant
ε is the error term
λ is the autoregressive coefficient
W is the spatial matrix (in this case calculated following rook contiguity criteria)
u is the uncorrected error term

This approach helps to identify which energy classes for each of the years do produce an impact on property prices, and thus to segment those homes whose price is positively impacted by energy efficiency from these where energy labels play a null role in prince formation. Subsequently, using an ANOVA test it is possible to test significant differences, in terms of architectonic and locative attributes, between the aforementioned segments.

4. Results and discussions

4.1. Pooled estimation of EPC impacts on housing prices

Table 2 contains the results for the best model coming from the calibration of equation 1 in GeoDa. In such a table, it is possible to see that the average increase in terms of asking prices has been 4.1% for the period studied (1st Nov 2014-1st April 2016).

According to the multiplicative-interaction terms built from energy ranks and the Year 2016, the impact of more efficient ranks has increased in a monotonic coherent fashion: 10.7%; 10,6% and 10,5% for ranks "B", "C", and "D" respectively. As a matter of fact, the increment of the impact of ranked "A" apartments is also positive but fails to meet the 90% confidence criteria. On the contrary, energy efficient dwellings in 2014 almost fail to show significant impacts on housing prices, but "A"-ranked homes do matter with an 8.6% increase, compared to "G"-ranked ones.

Overall, these results suggest that in a short period, energy efficiency in Barcelona has gained importance in terms of residential prices. It is worth noting that the dwellings with high and medium

EPC rankings (ranked "A" in 2014 while "B", "C" and "D" in 2016) have a significant impact on housing price formation.

Table 2. Spatial Error Estimation Results

Spatial Error Model - Maximum Likelihood Estimation				
R Square	0.764	Log-likelihood	-928	
Sigma Square	0.075	AIC	1917	
S.E of regression	0.274			
		Coefficients		
	B	Std. Error	Z-Value	Prob.
Lambda	0.462	0.016	28.317	-
(Constant)	10.125	0.056	182.398	-
Year 2016	0.041	0.015	2.684	0.007
Structural architectonic characteristics of apartments and buildings				
Area	0.015	0.000	37.546	-
Area^2	- 0.000	0.000	- 19.709	-
Number of bathrooms	0.098	0.008	11.842	-
Air conditioner	0.074	0.008	8.905	-
Central heating	0.041	0.009	4.686	-
Retrofitted apartment	0.034	0.010	3.437	0.001
Swimming pool	0.186	0.015	11.976	-
Lift	0.089	0.008	10.452	-
Inverse of building age	0.238	0.045	5.340	-
Energy performance of apartments				
Energy class A	0.086	0.034	2.492	0.013
Energy class C	- 0.011	0.029	- 0.375	0.708
Energy class D	0.000	0.019	0.020	0.984
Energy class E	0.007	0.013	0.572	0.567
Energy class F	0.019	0.016	1.132	0.258
Energy class A * Year 2016	0.067	0.044	1.515	0.130
Energy class B * Year 2016	0.107	0.041	2.619	0.009
Energy class C * Year 2016	0.106	0.041	2.597	0.009
Energy class D * Year 2016	0.105	0.026	4.071	-
Energy class E * Year 2016	0.008	0.018	0.462	0.644
Energy class F * Year 2016	- 0.033	0.024	- 1.386	0.166
Locative attributes (transport, centrality and amenities)				
Commuting time	0.004	0.001	2.597	0.009
<200m from sea shore	0.131	0.029	4.532	-
Highway ramp	0.081	0.022	3.712	-
<800 m from railway station	0.033	0.011	3.120	0.002
Centrality index	0.025	0.003	8.680	-
Average gross area floor ratio	0.048	0.005	9.029	-
Socio-economic attributes				
PC1 High income	0.104	0.006	17.356	-
PC2 Med income	0.072	0.007	10.979	-

Note: independent variables/covariates are introduced using the stepwise method. Energy class G is the controlled group. '–' indicated the significant is less than 0.000. Variables with grey colour are insignificant at 90% of confidence. Source: Own elaboration.

4.2. How different are the dwellings which energy efficiency gains relevance in price formation?

In order to explore significant differences in terms of achitectonic and locative attributes first the 6,492 aparments are clustered in 4 groups. Group 1 (N = 73) is for the energy-labelled dwellings (ranking A) which impact significantly on housing prices in 2014 while the others are for Group 2 (N = 3,167) where no impact was found in the same year. Dwellings in the 2016 dataset are groupped in the same way, resulting in Group 3 (ranking B, C, D) where EPC ranking was found to have an impact on price formation and Group 4 where no impact was found- Each of such gropus are formed by 485 and 2,718 apartments respectively. Next, an ANOVA test (at 90% confidence level) is implemented among these groups) for each of the architectonic and locative attributes.

4.2.1. The specific characteristic performance in year periods. According to the first column of table 3, in the 2014 dataset all the architectonic attributes (excluded the number of bedrooms) are significantly different between homes clustered in Group 1 and 2. Conversely, in the remainder of accessibility and socioeconomic dimensions just the centrality index, population density and employment show significant differences. The average unit price for an "A"-ranked dwelling with a 90 square meters' size is 2,208 euros per square meter in 2014, 300 euros more per square meter than that in Group 2. Similarly, physical attributes (e.g. number of bathrooms, area of outdoor spaces and living room) and amenities (e.g. air conditioning and heating) are more present in Group 1 where the probability to find a heated dwelling doubles in Group 2 in relation to Group 1. Regarding the accessibility and socioeconomic dimensions, the "A"- ranked dwellings in 2014 are located in metropolitan peripheries where the average centrality index is 10.73, less than the referenced Group 2. The same is true for population and employment densities. All in all, energy-efficient homes in 2014 are basically located at peripheral zones where buildings are constructed under newer construction codes requiring efficient thermal performances.

Table 3. Statistical Description for the groups in 2014 and 2016

Variables	2014				2016			
	Group 1 (N=73)	Group 2 (N=3,167)	ANOVA TEST F	Sig.	Group 3 (N=485)	Group 4 (N=2,718)	ANOVA TEST F	Sig.
Architectonic Attributes								
Total_price	197,784	162,047	11.55	0.001	275,192	221,404	51.58	0.000
Unit_price	2,209	1,908	14.87	0.000	3,029	2,514	67.04	0.000
Superficie	89.84	83.94	3.20	0.074	90.64	86.40	7.37	0.007
No_bedrooms	2.89	2.92	0.06	0.801	2.82	2.89	2.21	0.137
No_bathrooms	1.52	1.29	14.82	0.000	1.50	1.33	38.34	0.000
Dum_air_conditioning	0.67	0.30	47.38	0.000	0.60	0.45	37.82	0.000
Dum_heat	0.92	0.42	75.30	0.000	0.81	0.66	41.27	0.000
Dum_reform	0.30	0.10	30.71	0.000	0.28	0.18	30.19	0.000
Dum_lift	0.86	0.46	48.34	0.000	0.79	0.65	36.59	0.000
Ages of buildings	30.84	45.55	49.25	0.000	40.70	46.45	21.66	0.000
Construction_before 1981	0.51	0.84	57.91	0.000	0.62	0.77	48.44	0.000
Construction_between 1982-2006	0.25	0.12	11.16	0.001	0.21	0.17	4.35	0.037
Construction_after 2007	0.25	0.04	68.77	0.000	0.17	0.06	69.12	0.000
Storied	2.47	2.14	2.82	0.093	2.11	2.19	0.46	0.497
Areas_outdoor	12.60	9.40	3.63	0.057	9.71	9.45	0.06	0.800
Areas_living	15.18	12.11	6.75	0.009	13.19	11.69	6.18	0.013
Dum_grand_terrance	0.18	0.07	13.35	0.000	0.12	0.14	0.48	0.487
Dum_swim_pool	0.08	0.04	3.02	0.082	0.15	0.10	8.03	0.005
Dum_gard	0.27	0.09	30.77	0.000	0.20	0.15	7.17	0.007
Accessibility Attributes								
Time_commuting	24.61	24.00	1.32	0.250	24.57	24.65	0.19	0.666
Dum_sea (in 200 meters)	0.03	0.01	1.49	0.223	0.04	0.04	0.26	0.608
Dum_highway	0.96	0.93	1.18	0.278	0.94	0.94	0.10	0.758
Dum_trans_stations	0.53	0.50	0.36	0.547	0.57	0.56	0.33	0.568
Index_Central	10.73	11.39	5.52	0.019	12.47	11.94	16.39	0.000
Ratio_floor_areas	1.84	1.99	0.87	0.350	2.43	2.33	1.54	0.214
Socioeconomic Attributes								
Proportion of university degree	9.77	10.88	1.49	0.222	15.85	14.21	11.75	0.001
Density of population	16,884	22,051	3.70	0.054	21,623	24,730	7.42	0.006
Density of employment	7,021	9,569	4.89	0.027	9,456	10,742	6.77	0.009
PCA High income	-0.23	-0.11	1.64	0.201	0.32	0.13	13.32	0.000
PCA Med income	-0.22	-0.24	0.03	0.865	0.05	0.01	0.73	0.393
Pr_Manager	7.28	7.90	1.40	0.237	10.26	9.39	10.92	0.001
Pr_professiones	9.95	11.01	1.33	0.249	15.67	14.14	10.55	0.001
Pr_technics	13.31	13.29	0.00	0.974	14.97	14.35	9.60	0.002
Pr_admin	11.14	10.98	0.25	0.614	11.32	11.31	0.01	0.935
Pr_commer	15.20	15.05	0.15	0.702	14.21	14.77	8.48	0.004
Pr_agricultura_fisher	0.67	0.75	0.64	0.425	0.67	0.69	0.33	0.568
Pr_craftman	18.06	17.47	0.62	0.430	13.69	14.82	11.51	0.001
Pr_operation	13.73	13.28	0.38	0.535	10.22	10.88	4.69	0.030
Pr_unquality	10.61	10.17	0.68	0.408	8.89	9.55	8.54	0.004

Notes: Variables with grey colour are insignificant at 90% of confidence. Source: Own elaboration.

In the 2016 dataset for Groups 3 and 4, the same significant differences in the "architectonic attributes dimension" which are found in 2014, are identified but the number of storey, area of outdoor spaces and the presence of large terraces (more than 20 m2). In Group 3, the average unit price in 2016 is 3,029 euros per square meter for a "B", "C" or "D"-ranked dwelling with 91 square meters where the probability of amenities (e.g. air conditioning, heating and lift) is 15% larger than that in group 4. Unlike the result in 2014, almost all the socioeconomic attributes show significant differences between groups. The proportion of households holding a university degree as well as the proportion of high-level positions (e.g. managers, professionals) are higher in Group 3. All in all:

- There is a clear correlation between the impact of EPC rankings on housing prices and the quality of apartments. Namely, those energy-labelled dwellings that have a significant impact on housing prices are more expensive, larger and boast the best architectonic attributes. Homes where EPC rankings have found to be significant on price formation are newer than other, although half of them were constructed before 1981 when non construction code with thermal implications existed in Spain.
- Also, the location of homes where EPC rankings have found to be impacting prices are different for the 2 analysed years. In 2014 A-ranked apartments (Group 1) were located in peripheries, conversely in 2016 "B","C" and "D"-ranked apartments (Group 2) were located in more centric locations. Such different location is reflected in the centrality index as well as urban densities. Differences in locations explain why gardened (i.e. outdoor spaces) and terraced apartments are identified in 2014 as those being impacted by energy efficiency and not in 2016 where more centric locations imply less outdoor areas.
- Finally, the different locational patterns are also reflected in the socioeconomic profile of areas: more central zones are characteised, in the case study, by an important presence of well-educated population holding privilegied job positions, which in turns proxies for large income.

4.2.2 Evolution of characteristics between housing groups where EPC rankings have found to be significant in price formation in 2014 and 2016. As stated the recast EPBD requires that the energy label information to be exhibited in the advertisement of real estate, in Spain such obligation was introduced by the transposition of the Directive in 2013. In order to explore the differences of characteristics in homes where EPC rankings have found to be relevant to the price formation, an ANOVA test has been used. The results are exhibited in table 4.

In 2016, there are 485 homes (Group 3) where EPC rankings play a role in price formation, around seven times than the corresponding cluster (Group 1) in 2014. Such divergence in group size is explained because in 2014 only "A"-ranked homes form Group 1, while in 2016 Group 3 is formed by "B", "C" and "D"-ranked apartments. According to table 4, three variables show significant differences in architectonic attributes between the two groups. The probability to find a heated home decreases from 92% in 2014 to 81% in 2016. Perhaps it is reflecting a correlation between energy class and quality. Also, by the fact that 62% of Group 3 homes was constructed before 1981while in Group 1 only 51% was built before any thermal building regulation came into force. Also, the centrality index which proxies for well-located apartments is larger, and the floor area ratio also increases up to 2.43. Finally, the proportion of households holding a university degree, the population and employment densities and the proportion of professional positions (e.g. managers, professions and technicians) shows a considerably superior performance in 2016. It is noted that in 2016 the proportion of household holding university degrees increases up to 15.85%, which is roughly the double than that in 2014.

- There are more homes with energy rankings playing an important role in housing prices after the mandatory of EPC on advertising in 2013. In other words, a larger number of homes with various energy rankings is introduced in Barcelona Metropolitan market and does matter on housing prices.

- Also, there is a worse performance on architectonic attributes of energy labelled homes related to housing prices. Namely, the qualities of physical features of energy-efficient homes impacting on housing prices are lower along with the evolution of the EPC program. Generally, it is supposed that the correlation between the physical quality of dwellings and the energy ranking is positive. Therefore, it is explicable regarding this "Worse Performance" change, considering more homes with lower energy rankings introduced.
- Finally, energy-efficient homes related to housing prices are located in a central area where the proportion of household holding a university degree and the density of population is higher. It is noted that in 2014, the homes relevant to housing prices are located in a peripheral area although they are labelled as A rank.

Table 4. Statistical Description for the groups in 2014 and 2016

Variables	Group 1 in 2014 (N=73)	Group 3 in 2016 (N=485)	ANOVA	
			F	Sig.
Architectonic Attributes				
Dum_heat	0.92	0.81	5.45	0.020
Ages of buildings	30.84	40.70	8.01	0.005
Construction_before 1981	0.51	0.62	3.26	0.071
Accessibility Attributes				
Index_Central	10.73	12.47	27.86	0.000
Ratio_floor_areas	1.84	2.43	8.01	0.005
Socioeconomic Attributes				
Proportion of university degree	9.77	15.85	24.25	0.000
Density of population	16,884	21,623	2.98	0.085
Density of employment	7,021	9,456	4.21	0.041
PCA High income	-0.23	0.32	18.34	0.000
PCA Med income	-0.22	0.05	5.65	0.018
Pr_Manager	7.28	10.26	19.92	0.000
Pr_professiones	9.95	15.67	22.83	0.000
Pr_technics	13.31	14.97	11.19	0.001
Pr_commer	15.20	14.21	3.86	0.050
Pr_craftman	18.06	13.69	27.99	0.000
Pr_operation	13.73	10.22	19.16	0.000
Pr_unquality	10.61	8.89	8.80	0.003

Notes: Variables with grey colour are insignificant at 90% of confidence. Source: Own elaboration.

5. Conclusions

Housing energy-efficiency has become a relevant issue in the Spanish residential sector since in 2013 it was made mandatory to exhibit a label coming from an energy performance certificate (EPC) when transacting real estate. As stated, many studies have identified the impact of such EPC labels on housing prices. However, few studies focus on the differences of homes where the EPC rankings are found to be important in price formation in relation to those which energy performance plays a null role. This paper, using a spatial error hedonic approach, explores this issue using listing prices for apartments located at Metropolitan Barcelona.

Results suggest that A-labelled homes do impact on housing prices in 2014, while B/C/D-labelled ones in 2016. In average, an energy performance improvement from G class to A class brings in a growth 8.6% of housing prices in 2014, and an increase of 10.6% from class G to class B in 2016. After comparing with the specific characteristics for homes related to energy premium, we find that more homes with various energy rankings are introduced in real estate market and they are located in more central areas in 2016, instead of peripheral area in 2014. It is noted that the physical features show worse performances in 2016 since more ancient dwellings are present in the B/C/D Group.

These findings have implications for future analysis regarding energy premium and energy poverty, since specific characteristics in different submarkets may have a different impact on housing prices.

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