land

MDPI

Article

Are Cave Houses a Sustainable Real Estate Alternative?

Maria-Francisca Cespedes-Lopez * and Raul-Tomas Mora-Garcia *

Building Sciences and Urbanism Department, University of Alicante, 03690 San Vicente del Raspeig, Spain
* Correspondence: paqui.cespedes@ua.es (M.-F.C.-L.); rtmg@ua.es (R.-T.M.G.)

Abstract: The high level of energy consumption of buildings has outlined the need for more sustainable and environmentally friendly constructions, which has led to cave houses now being more highly valued. This study looks to study whether sustainable constructions, such as cave houses, have an economic impact with regard to other construction types in the real estate market in Granada. Moreover, this study looks to determine whether energy rating is a relevant characteristic for the price of cave houses and whether the price determinants vary according to whether the house in question is a cave house or a single-family one. To develop this study, a final sample of 61,573 properties was used. A regression model estimated by ordinary least squares was performed. This study shows that cave houses are being marketed at higher prices than single-family houses. It was noted that energy rating is not an important characteristic for estimating the price of a cave house. Finally, in this type of housing, refrigeration equipment is not one of the determining characteristics for the price.

Keywords: cave houses; hedonic regression model; house sale prices; price determinants; energy rating

Citation: Cespedes-Lopez, M.-F.; Mora-Garcia, R.-T. Are Cave Houses a Sustainable Real Estate Alternative? *Land* **2022**, *11*, 2185. https://doi.org/10.3390/land11122185

Academic Editor: Michelangelo Savino

Received: 12 November 2022
Accepted: 25 November 2022
Published: 1 December 2022

1. Introduction

In the history of architecture, caves were man's first refuge or house, and, despite now being in disuse, they were once one of the most widespread construction types in the world. Housing, since its beginnings, has been evolving and adapting throughout the centuries according to the human and social needs of the time; structures were made with local materials and techniques and were adapted to the local climate. Both the industrial revolution and the huge demographic explosion caused excessive urban development [1], which resulted in the current worldwide problem of high energy consumption in buildings, being above both the transport and industry sectors [2]. This consumption is mainly due to the demand for electricity needed for a heating, ventilation, and air-conditioning (HVAC) system and the use of household appliances [3].

The main result of this has been the implementation of politics that favor the improvement of energy efficiency in the European Union (EU) [4–7], which have been integrated into a series of decrees in Spain [8,9]. As a result, there is a need to look for more sustainable and environmentally friendly construction solutions.

Cave houses are considered to be a sustainable housing typology as they are built using a construction type that utilizes the thermal inertia of the land. As a result, the interior temperature of the house scarcely changes throughout the different seasons of the year, which allows for thermal comfort to be ensured in the interior of the house without the need for additional energy inputs (air-conditioning or heating) [10,11]. Cave houses are also considered sustainable because of the combination of social, economic, and cultural factors [12–14].

There are different studies on cave houses (Figure 1a) that address different lines of research, such as: (1) the importance of preserving and maintaining architectural heritage

[15,16]; (2) the importance of assessing the application of bioclimatic strategies used for cave houses in present-day constructions [17]; (3) the importance of analyzing thermal comfort or whether the ventilation in cave houses is adequate; [10,18–25]; and (4) the psychological and physiological problems associated with this type of construction [26,27].


(**a**) (**b**)

Figure 1. (**a**) Cave house in the Baza area. (**b**) Single-family houses in Guadix town. Source: own elaboration.

Moreover, several studies have been carried out in which it has been noted that the buyers of single-family houses (Figure 1b) are willing to pay more if a house is more efficient [28–42]. A broader overview regarding housing prices and energy ratings can be found in the work by [43,44].

Cave houses are excavated in the rock itself, normally with vaulted forms for a better transmission of the upper loads, and may or may not have attached constructions. They are made up of one or more cavities where the usual activities and living and sleeping are carried out. The walls and vaulted ceilings are finished with a lime coating and the most rustic pavements are made with the ground itself or with a layer of cement. As a consequence of the current housing needs, these constructions have been adapted and improved, increasing the number of interior spaces and improving the qualities and facilities.

The single-family houses are characterized by having a structure based on load-bearing walls or reinforced concrete structures. They are usually distributed in a living–dining room, kitchen, bathroom and bedrooms. The most common materials used are ceramic bricks covered with plaster for the vertical partitions; the floors are usually made of natural or artificial stone, ceramic tiles or wood; and the ceilings can be made of plaster or plasterboard.

Vernacular architecture is one of the most widespread types of architecture in Spain and is specifically used for housing. Authors such as [45–48] have confirmed that society has changed its attitude towards cave houses and considers this type of construction to be sustainable. However, has this change in attitude been reflected in the asking price of this type of construction? As far as the authors are aware, there have been no studies that analyze the prices of cave houses. The lack of results in the literature has resulted in new research questions. Firstly, as cave houses are considered sustainable, does this mean that they are marketed at higher prices than single-family houses? Secondly, is energy rating a relevant characteristic for cave houses? Thirdly, if the interior of a cave house is maintained at a constant temperature throughout the year, would an HVAC system be a price-determining feature?

The main objective of this study was to determine the economic impact that cave houses have with regard to single-family houses in the real estate market in the province of Granada (Spain). The secondary objective of this study was to understand whether energy rating and HVAC systems are relevant characteristics when determining the price of a cave house.

The first hypothesis that was put forward for the study (H_1) was that cave houses are being marketed at higher prices than single-family houses. The second hypothesis that was proposed (H_2) was that energy ratings for cave houses are a relevant characteristic. The third hypothesis generated (H_3) was that the availability of an HVAC system is not a determining characteristic for the price of cave houses. However, it is for single-family houses.

The estimates made from the regression model showed that cave houses are marketed at higher prices than single-family houses. It was also observed that energy ratings and the availability of air-conditioning are not determining characteristics for the price of cave houses.

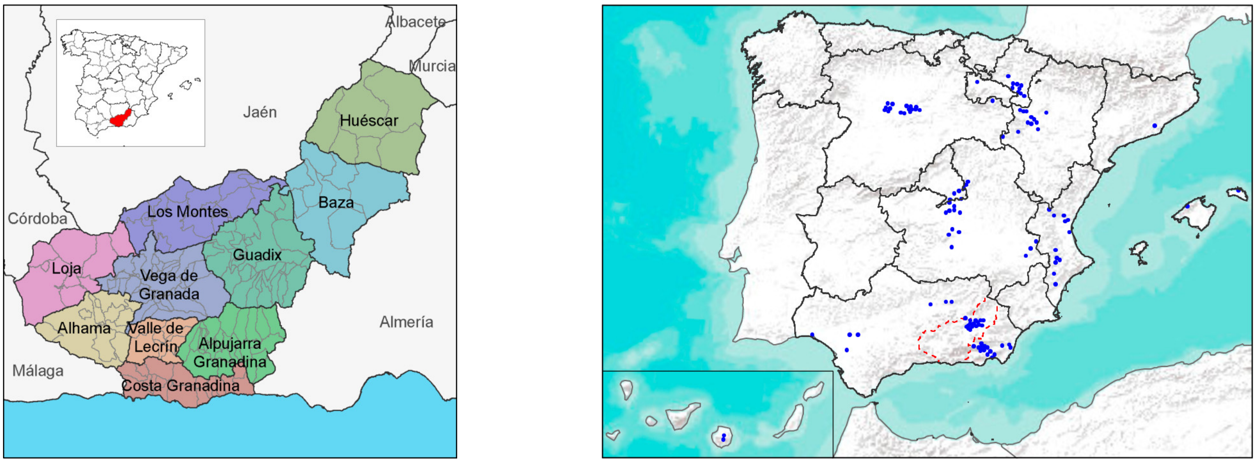
This document is organized as follows: the first section includes the introduction, objectives and hypotheses. The second section denotes the materials and the methods used, outlining the sources that were employed and the database generated. The third section details the results. The fourth section denotes the discussion, and finally, Section 5 explains the conclusions obtained.

2. Materials and Methods

To understand what characteristics determine the asking price of a house, an ordinary least squares (OLS) hedonic regression model was performed. This type of analysis began to be used with the "New Consumer Theory" developed by Lancaster [49]. Later, Ridker and Henning [50] used the regression model in the housing market for the first time. Authors such as Zietz et al. [51] noted that a hedonic regression analysis is typically used to identify the marginal effect that a set of characteristics has on housing prices. In terms of heterogeneous goods such as housing, the hedonic methodology allows for the effect of each characteristic on the price to be estimated [52]. Currently, this is one of the most used methodologies for determining the economic premium generated by different characteristics.

2.1. Population and Sample

The database consisted of cave houses and single-family houses offered for sale in the province of Granada (Andalusia). This province is located in the south of Spain and has 10 regions or *comarcas* [1] (Figure 2a).



(**a**) (**b**)

Figure 2. (**a**) Map of the Granada province with the delimitation of the *comarcas* and municipalities (own elaboration); (**b**) Towns with cave dwellings in Spain, own elaboration based on [12] (p. 3, Figure 2).

The interest and selection criteria for this territory were due to the fact that cave houses are a traditional construction in Spain. The province of Granada and the province of Almería have the highest concentration of cave houses and have developed them the most in the country [45,53] (Figure 2b).

The representativeness of the sample was verified using the equation for large or infinite populations when the exact size of the component units is unknown [54]. Using a confidence level of 95% ($z_{\alpha/2} = 1.96$), a probability level of $p = 0.50$ and a sample size of

N = 61,573, a maximum error of 0.39% (0.0039) was estimated, which guaranteed a high statistical precision of the sample.

The main information sources were two real estate portals. The first was *idealista*, which was used between June 2017 and March 2018, and the second was *habitaclia*, which was used between June 2019 and January 2021. During these time periods, information on the houses offered was collected, and data about the characteristics of the houses were extracted. A geographic information system (GIS) was then used to provide the location and neighborhood information from other sources of information. Data from the population and housing census tract by the National Institute of Statistics were used [55]. Each house was assigned information about the type of occupation (vacant, main residence and second residence) as well as the socio-demographic characteristics of the population (dependency, aging, foreign population and level of education).

The research had several limitations. Firstly, a limitation was the lack of information from official sources about the real transaction prices and housing characteristics. Another limitation was the possible errors in the information or the omission of information on the prices and/or characteristics of the houses that were offered on the two real estate portals.

With regard to the first limitation, authors such as [56–59] suggest that real estate asking prices are an adequate substitute for transaction prices. Moreover, there are studies that analyze the effect of the housing characteristics on the price, using listing price information from real estate portals due to the lack of information from other official sources [35,39,60–64].

In terms of the second limitation, the data was preprocessed so that properties with missing data could be identified and discarded. As a result, 3030 properties were discarded. To identify the atypical values in the quantitative variables, a limit of three standard deviations was established for the set of values [65,66]. As a result, 595 properties were discarded. The final sample consisted of 61,573 properties.

2.2. Data

To identify the most important variables in the estimate of the single-family house prices, a literature review was carried out, which is shown in Table 1.

Table 1. Variables used by other authors for the determination of single-family house prices.

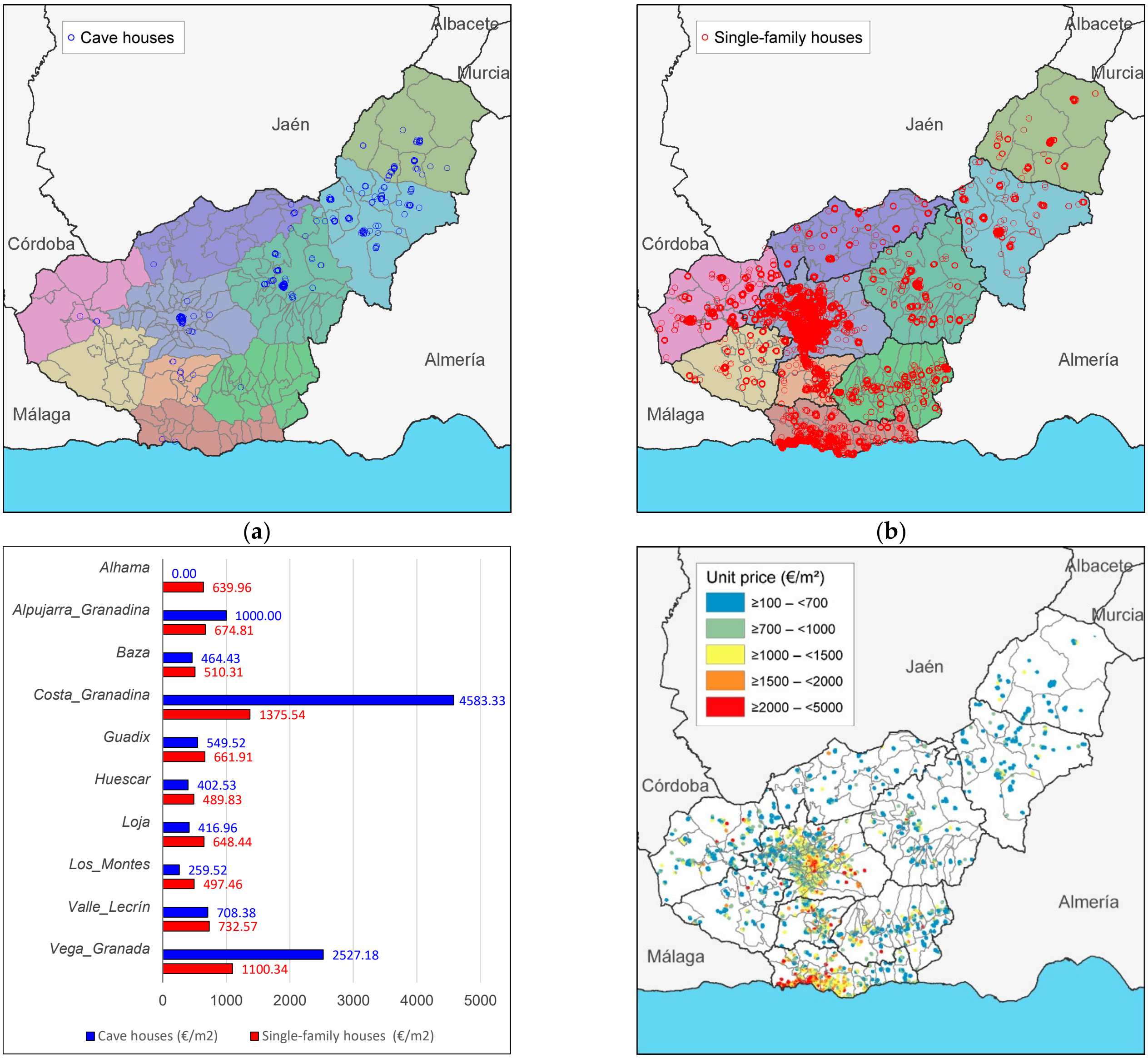
Category	Characteristics	References
House characteristics	*House surface area*	[51,67–74]
	Number of bedrooms	[70,71,75,76]
	Number of bathrooms or toilets	[69–72,76,77]
	Availability of air conditioning	[51,69,70]
	Availability of heating	[69,76–79]
	Availability of fireplace	[71,72,76,77,80]
	Availability of built-in closets	[81,82]
	Availability of furniture	-
	Newly built housing	[83–85]
	House typology	[71,74,75,86,87]
	Parking	[70,76,77,80]
	Garden	[51,67,68]
	Swimming pool	[51,69,74,77,80,84]
	Energy rating	[34,38,41,75,86,88]
Location characteristics	*Location within the territory or the city*	[67,68,74–77,86]
Neighborhood characteristics	*Age of the population*	[37,89,90]
	Number of foreigners	[87,89,91]
	Level of studies	[79,87,92]
	Type of house occupancy	[71,72,79]

Based on the information received, 40 variables were obtained, as summarized in Table 2. The variables were ordered according to three categories. House characteristics (A); Location characteristics (B); and Neighborhood characteristics (C). The unit with which each variable was measured, a brief description of the variable and the descriptive statistics are indicated.

Table 2. Set of variables that make up the study, with their units, description and descriptive statistics.

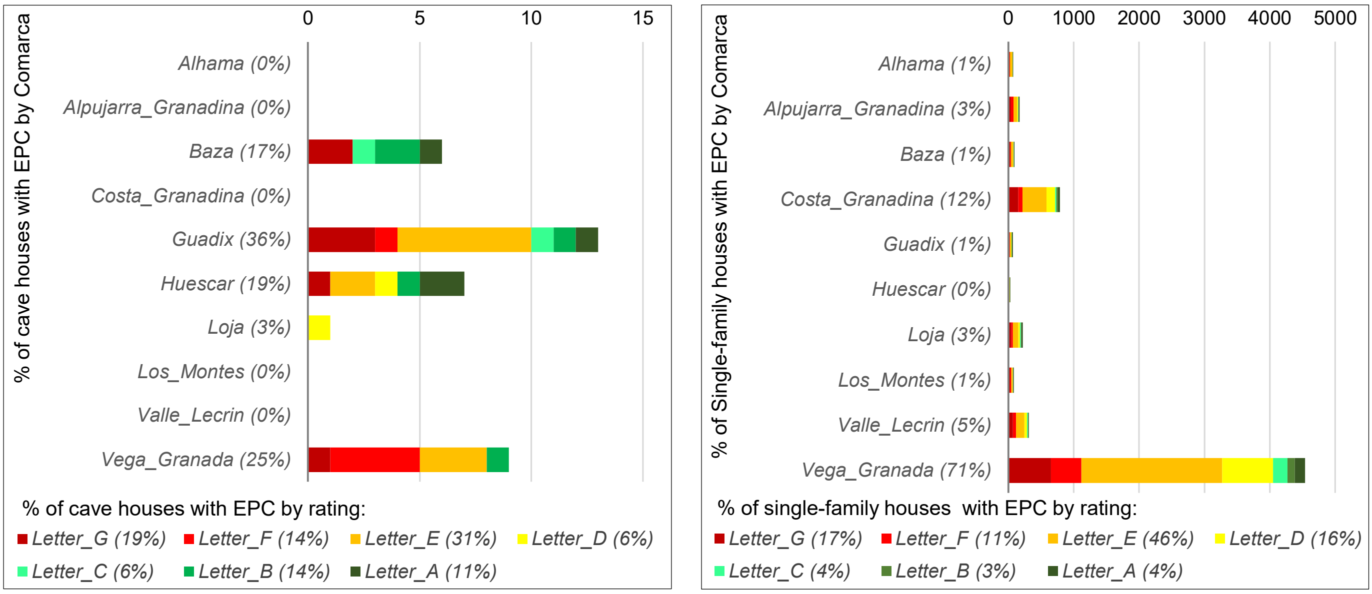
Category	Variable	Unit	Variable Description	Continuous Variables				Dummies Variables		
				Mean	*SD*	Min.	Max.	Coding.	Freq.	%
	Ln_Price	numerical	Dependent variable. The natural log of the property price offered by the seller (in EUR).	12.105	0.668	9.2	14.8			
House characteristics (A)	*Area_m2*	numerical	Built area of the house (sqm), gross square meters of the house.	214.854	111.884	20.0	1746.0			
	Bedrooms	numerical	Number of bedrooms in the house.	3.806	1.375	1.0	29.0			
	Bathrooms	numerical	Number of bathrooms.	2.348	1.023	0.0	11.0			
	Toilets	numerical	Number of toilets.	0.193	0.456	0.0	10.0			
	Air_cond	dummy	Availability of air conditioning (=1).					(1) With	21,005	34.1
	Heating	dummy	Availability of heating (=1).					(1) With	24,170	39.3
	Fireplace	dummy	Availability of fireplace (=1).					(1) With	2080	3.4
	Closet	dummy	Availability of built-in closets (=1).					(1) With	5458	8.9
	Furnished_house	dummy	Availability of furniture (=1).					(1) With	3768	6.1
	New_construction	dummy	Newly built housing that can be: a project, under construction, or less than 3 years old (=1).					(1) With	343	0.6
	Cave_house	dummy	Indicates whether the property has this typology (=1).					(1) With	440	0.7
	Parking	dummy	Availability of garage slot (=1).					(1) With	37,618	61.1
	Garden	dummy	Availability of garden (=1).					(1) With	6219	10.1
	Pool	dummy	Availability of swimming pool (=1).					(1) With	22,482	36.5
	Letter_A	dummy	Indicates if the dwelling has an energy rating: letters A, B, C, D, E, F or G, or has no energy rating label.					(1) With	285	0.5
	Letter_B	dummy						(1) With	166	0.3
	Letter_C	dummy						(1) With	279	0.5
	Letter_D	dummy						(1) With	1021	1.7
	Letter_E	dummy						(1) With	2923	4.7
	Letter_F	dummy						(1) With	684	1.1
	Letter_G	dummy						(1) With	1066	1.7
	Not_EPC	dummy						(1) With	55,149	89.6
Location characteristics (B)	*Alhama*	dummy	Identifier of the *comarca*: *Alhama, Alpujarra Granadina, Baza, Costa Granadina, Guadix, Huéscar, Loja, Los Montes, Valle de Lecrín* and *Vega de Granada*.					(1) With	520	0.8
	Alpujarra_Granadina	dummy						(1) With	886	1.4
	Baza	dummy						(1) With	651	1.1
	Costa_Granadina	dummy						(1) With	5137	8.3
	Guadix	dummy						(1) With	603	1.0
	Huescar	dummy						(1) With	230	0.4
	Loja	dummy						(1) With	1073	1.7
	Los_Montes	dummy						(1) With	462	0.7
	Valle_Lecrin	dummy						(1) With	2240	3.6
	Vega_Granada (Ref.)	dummy						(1) With	49,771	80.8
Neighborhood characteristics (C)	*Dependency_ratio*	numerical	Dependency ratio (sum of the population aged >64 and <16/population aged 16–64).	0.474	0.133	0.0	1.8			
	Elderly_index	numerical	Aging index (population aged >64/population aged 0–15).	0.836	0.863	0.0	11.5			
	Foreigners_pct	numerical	Percentage of foreign population.	6.152	7.183	0.0	52.6			
	No_studies_pct	numerical	Percentage of population without education.	8.449	6.620	0.0	44.8			
	University_pct	numerical	Percentage of the population with university studies.	18.780	10.822	0.0	58.5			
	Secondary_pct	numerical	Percentage of vacant dwellings and secondary.	12.537	14.273	0.0	81.9			
	Vacant_pct	numerical		18.058	9.711	0.0	75.7			

Figure 3 shows the location of the cave houses (Figure 3a) and single-family houses (Figure 3b) analyzed within the territory. Regarding the distribution of prices, it can be noted that in the center of Granada and on the coast, unit prices (€/m²) are higher than in the rest of the regions of the province (Figure 3c,d). At the same time, it can also be noted that there is a higher percentage of cave houses with high ratings (letters A, B and C) with respect to the sample of single-family houses (Figure 3e,f).



(**a**) (**b**)

(**c**) (**d**)



(**e**) (**f**)

Figure 3. (**a**) Spatial distribution of cave houses; (**b**) Spatial distribution of single-family houses; (**c**) Bar chart with unit prices according to house typology and *comarca*; (**d**) Kernel density map with unit prices of the complete sample of houses (euros/m²); (**e**) Chart of the energy rating distribution of cave houses by *comarca*; (**f**) Chart of the energy rating distribution of single-family houses by *comarca*.

2.3. Methodology

The regression model was estimated by ordinary least squares (OLS) with a semi-logarithmic functional form, as this facilitated the interpretation of the coefficients as average percentage premiums. Moreover, this reduced problems of heteroscedasticity and improved the goodness of fit of the data [58,93]. The model used had the following expression:

$$ln(P_i) = \alpha + \sum_{j=1}^{n} \beta_j X_{ij} + \sum_{k=1}^{m} \gamma_k D_{ik} + \varepsilon_i \quad (1)$$

where:

$ln\ (P_i)$ is the natural logarithm of the advertised asking price for the house "i";
α is the fixed component, it does not depend on the market;
β_j is the parameter to estimate related to the characteristic "j";
X_{ij} is the continuous variable that collects the characteristic "j" of the observation "i";
γ_k is the parameter to estimate related to the characteristic "k";
D_{ik} is the dummy variable that collects the characteristic "k" of the observation "i";
ε_i is the error term in the observation "i".

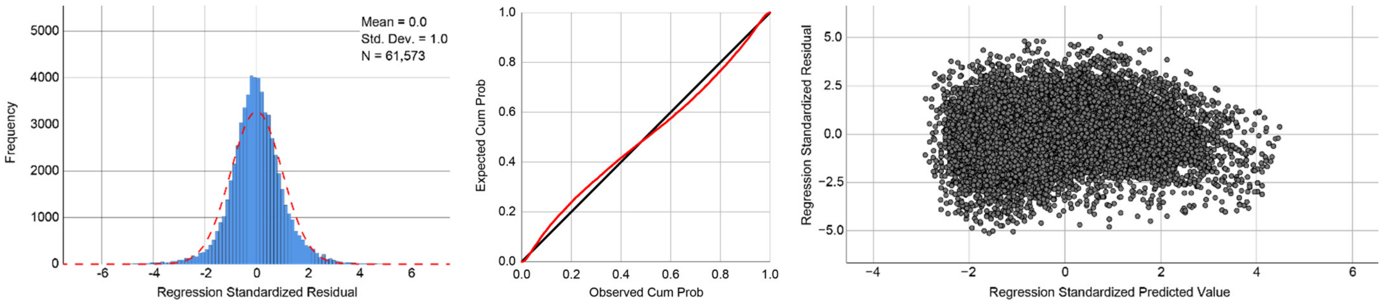
The model was estimated three times. The first estimate was for the complete set of observations. The other two estimates corresponded to the subsamples according to whether the houses were cave houses or single-family houses. This was in such a way that the results obtained made it possible to compare the determining characteristics for each group. The SPSS for Windows version 26 IBM Corp. statistical package [94] was used to perform this analysis, using the listwise deletion method.

3. Results

Regression Analysis

To determine whether the estimates reach the adequate level of quality, the following checks were carried out: the normality of the population; ensuring that there are no specification problems in the estimates (no multicollinearity, heteroscedasticity or autocorrelation); the statistical significance of the estimates; and, finally, whether the proportion of variance estimated is high (R^2).

The normality of the population was tested through the use of a histogram (Figure 4a) and a normality plot of the residuals (Figure 4b), which showed that the sample is a normal distribution. Multicollinearity was verified by using the VIF statistic (variance inflation factor). Many authors suggest that collinearity problems exist if any VIF is greater than 10 [95,96]. In the three estimates carried out, the majority of the VIF values are found to be between 1 and 3.5, which leads to the conclusion that there are no problems due to multicollinearity. Heteroscedasticity is analyzed with a scatter plot of the residuals (Figure 4c), and no serious problems of heteroscedasticity are found, showing a random distribution of the residuals. The existence of autocorrelation is checked with the Durbin–Watson statistic, obtaining the closest values to two in all the estimates, suggesting the absence of autocorrelation in the residuals [97,98]. The significance of each estimate is measured with the Snedecor's F test and is statistically significant. The coefficient of determination (adjusted R^2) of the estimates is shown in Table 3. and an explanatory power of 69% is obtained for estimates 1 and 3 and 81% for estimate 2. In summary, it can be said that the estimates reach a sufficient level of robustness and statistical significance to make them acceptable for inference.



(**a**) (**b**) (c)

Figure 4. Graphs of the estimate 1: (**a**) Histogram and normal curve of the standardized residual error; (**b**) Normal P-P plot of regression standardized residual; (**c**) Scatter plot of the predicted values and standardized errors.

The results of the different estimates of the regression model are shown in Table 3. The results obtained for estimate 1 of the model are described, as they correspond to the complete sample. With respect to the housing characteristics, the model estimates that increasing one square meter of floor space leads to a price increase of 0.2%, while the inclusion of an additional bedroom, bathroom or toilet leads to an increase of 2.6%, 15.7% and 10.8%, respectively. The average price impact of a house including extras such as air-conditioning, heating, built-in closets or being sold furnished was estimated by the model as having an increase of 5.3%, 11.4%, 6.7% and 7.1%, respectively. A house being a new construction (less than 3 years) leads to an increase in the price of 6.9%. The values obtained in the estimate of the parameters related to other characteristics, such as a house having a garage, garden or pool, lead to an average price increase of 8.1%, 9.7% and 19.8%, respectively. If the house is a cave house, the average asking price is 5.3% higher than that of a single-family house.

With regard to energy rating, houses with an E letter rating are taken as a reference. The results show that houses with a high letter rating (letters A and B) have higher economic premiums than other houses with worse ratings or those that do not advertise them (with some of these coefficients being non-significant).

Regarding location, the estimated impact for the price of the houses located in the Costa Granadina *comarca* is an increase of 21.1% in relation to the reference region, which is the Vega de Granada *comarca*. For the other *comarcas*, the model estimates a decrease in the asking prices offered, reaching reductions of between 17.4% and 54.5% with respect to the Vega de Granada *comarca*.

In terms of the neighborhood characteristics, a 1% increase in the dependency ratio and aging ratio leads to a price increase of 0.15% and 0.04%. Regarding the percentage of foreigners or people with university-level studies, the model estimated that an increase of 1% in these variables leads to a price increase of 0.7% and 1.8%, respectively. On the contrary, an increase in the percentage of uneducated people leads to a reduction of 0.3%.

Regarding the type of housing occupancy, the model shows price reductions of 0.1% and 0.04% respectively, in areas with a higher percentage of secondary residences or vacant houses.

In the estimates of the subsamples (estimates 2 and 3), some differences are observed (Figure 5 and Table 3). In the estimate of subsample 2 (cave houses), with regard to the characteristics of the house, only surface area, number of bedrooms and bathrooms, availability of heating, fireplace, furniture in the house and parking have positive and significant premiums. Other variables are not significant, such as the number of toilets, the availability of air-conditioning, built-in closets, a garden and a swimming pool. With regard to the energy rating, all the variables are non-significant, which may highlight that this characteristic is not relevant in this market segment. In terms of location, there are four *comarcas* that do not have a sufficient number of observations and are consequently discarded from the estimate. Using the Vega de Granada *comarca* as a reference, the houses situated in Baza, Guadix and Huéscar have an average price reduction of between 46.4% and 77.9%. In terms of the neighborhood characteristics, only the variables regarding the aging index, foreigners and those with university studies are significant. Finally, the occupation-type variables are not significant.

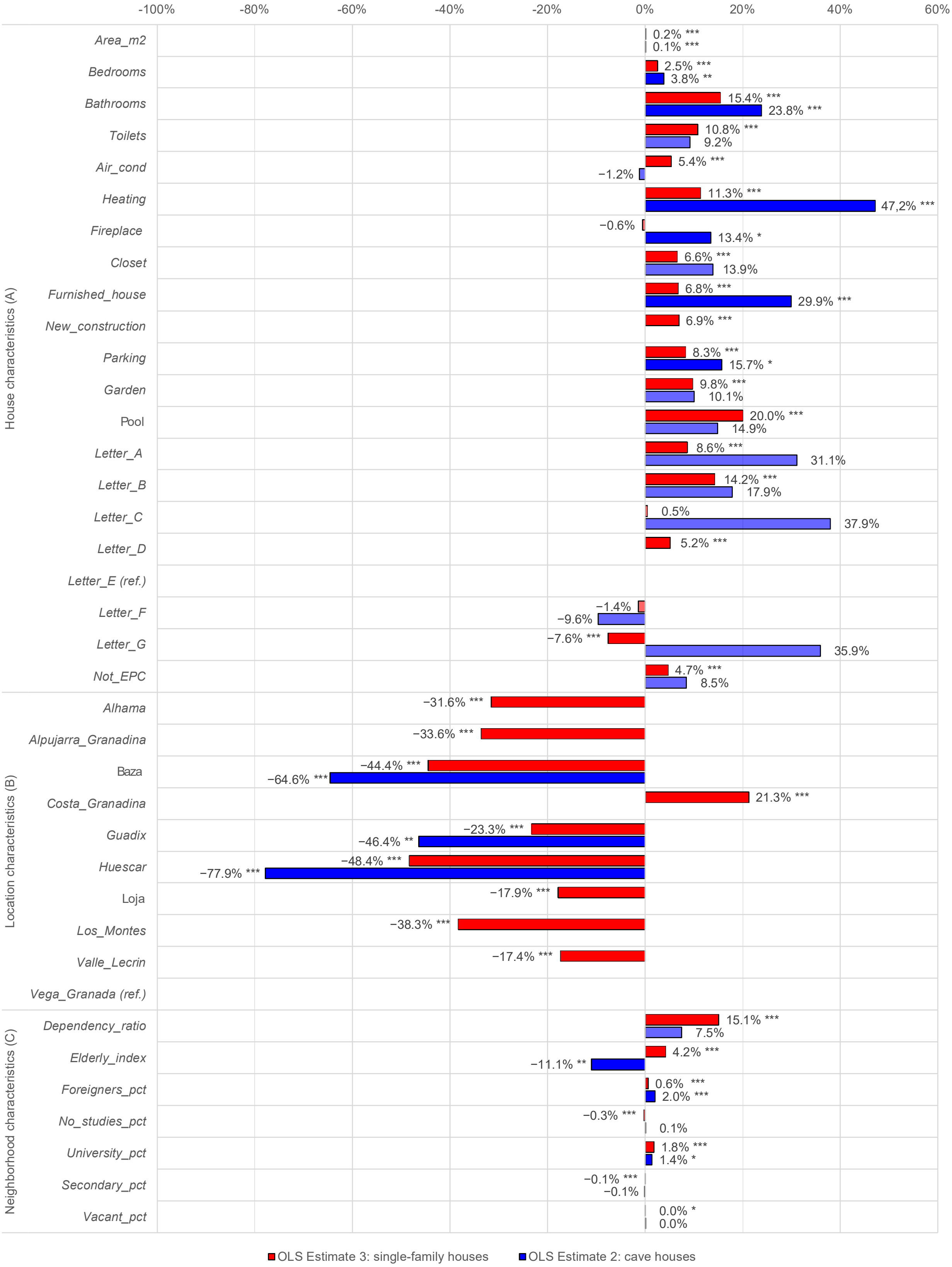


Figure 5. Bar chart with the regression coefficients (in %) of estimate 2 (sample of cave houses) and estimate 3 (sample of single-family houses). Notes: dependent variable *Ln_price*; signification: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 3. OLS model results for the different estimates depending on the selected sample (Estimate 1: full sample; Estimate 2: cave houses and Estimate 3: single-family houses).

Category	Variable	Estimate 1: Full Sample	Estimate 2: Cave Houses	Estimate 3: Single-Family Houses
	Intercept	10.536 *** (0.011)	10.633 *** (0.304)	10.539 *** (0.011)
House characteristics (A)	*Area_m2*	0.002 *** (0.000)	0.001 *** (0.000)	0.002 *** (0.000)
	Bedrooms	0.026 *** (0.001)	0.038 ** (0.014)	0.025 *** (0.001)
	Bathrooms	0.157 *** (0.002)	0.238 *** (0.025)	0.154 *** (0.002)
	Toilets	0.108 *** (0.004)	0.092 (0.065)	0.108 *** (0.004)
	Air_cond	0.053 *** (0.003)	–0.012 (0.067)	0.054 *** (0.003)
	Heating	0.114 *** (0.004)	0.472 *** (0.079)	0.113 *** (0.004)
	Fireplace	–0.004 (0.009)	0.134 * (0.067)	–0.006 (0.009)
	Closet	0.067 *** (0.006)	0.139 (0.084)	0.066 *** (0.006)
	Furnished_house	0.071 *** (0.006)	0.299 *** (0.086)	0.068 *** (0.006)
	New_construction	0.069 *** (0.020)	—	0.069 *** (0.020)
	Cave_house	0.053 ** (0.019)	—	—
	Parking	0.081 *** (0.003)	0.157 * (0.062)	0.083 *** (0.003)
	Garden	0.097 *** (0.006)	0.101 (0.086)	0.098 *** (0.006)
	Pool	0.198 *** (0.004)	0.149 (0.101)	0.200 *** (0.004)
	Letter_A	0.090 *** (0.023)	0.311 (0.275)	0.086 *** (0.023)
	Letter_B	0.139 *** (0.030)	0.179 (0.259)	0.142 *** (0.030)
	Letter_C	0.006 (0.024)	0.379 (0.364)	0.005 (0.023)
	Letter_D	0.052 *** (0.014)	—	0.052 *** (0.014)
	Letter_E	Ref.	Ref.	Ref.
	Letter_F	–0.011 (0.016)	–0.096 (0.263)	–0.014 (0.016)
	Letter_G	–0.073 *** (0.013)	0.359 (0.233)	–0.076 *** (0.013)
	Not_EPC	0.047 *** (0.007)	0.085 (0.147)	0.047 *** (0.007)
Location characteristics (B)	*Alhama*	–0.315 *** (0.017)	—	–0.316 *** (0.017)
	Alpujarra_Granadina	–0.337 *** (0.014)	—	–0.336 *** (0.014)
	Baza	–0.472 *** (0.016)	–0.646 *** (0.167)	–0.444 *** (0.017)
	Costa_Granadina	0.211 *** (0.007)	—	0.213 *** (0.007)
	Guadix	–0.262 *** (0.016)	–0.464 ** (0.164)	–0.233 *** (0.017)
	Huescar	–0.545 *** (0.026)	–0.779 *** (0.183)	–0.484 *** (0.028)
	Loja	–0.179 *** (0.013)	—	–0.179 *** (0.013)
	Los_Montes	–0.394 *** (0.019)	—	–0.383 *** (0.019)
	Valle_Lecrin	–0.174 *** (0.009)	—	–0.174 *** (0.009)
	Vega_Granada	Ref.	Ref.	Ref.
Neighborhood characteristics (C)	*Dependency_ratio*	0.146 *** (0.013)	0.075 (0.243)	0.151 *** (0.013)
	Elderly_index	0.041 *** (0.002)	–0.111 ** (0.038)	0.042 *** (0.002)
	Foreigners_pct	0.007 *** (0.000)	0.020 *** (0.005)	0.006 *** (0.000)
	No_studies_pct	–0.003 *** (0.000)	0.001 (0.006)	–0.003 *** (0.000)
	University_pct	0.018 *** (0.000)	0.014 * (0.006)	0.018 *** (0.000)
	Secondary_pct	–0.001 *** (0.000)	–0.001 (0.003)	–0.001 *** (0.000)
	Vacant_pct	–0.0004 * (0.0002)	0.0002 (0.0027)	–0.0004 * (0.0002)
	N	61,573	413	61,133
	R^2	0.686	0.822	0.685
	adj. R^2	0.685	0.809	0.685
	Std. Error	0.375	0.460	0.373
	F (*sig.*)	3625.41 (0.000)	63.23 (0.000)	3586.14 (0.000)
	Durbin-Watson	1.806	1.859	1.803

Notes: dependent variable *Ln_price*; signification: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; Standard errors in parentheses.

4. Discussion and Conclusions

Regarding the first objective, the aim is to determine the economic impact of cave houses, as opposed to single-family houses, and, as such, the first hypothesis—H1—is proposed. Estimate 1 confirms this hypothesis since cave houses are marketed 5.3% more expensive than single-family houses. This may be due to several factors. It is possible that this is due to a greater interest in exploiting these houses for short-term rental, as can be seen in platforms such as Booking or Airbnb, with a high supply of these homes and tourist resorts in prominent areas such as Huéscar, Guadix, Baza or Granada. This tourist interest was already highlighted by Urdiales [45] in 2003, being a movement initiated in the 1990s and mainly led by foreign promoters. Another main factor may be a consequence of foreign buyers who want to establish their residence in Spain. As can be seen in estimate 2, the incidence of the percentage of foreigners in the price of cave houses is higher than in estimate 3 for single-family houses. This suggests that there is a positive relationship between the price of cave housing, the existence of cave house offers and the presence of a higher foreign population.

In addition to the above factors, there are other aspects that have enhanced the value of this type of housing:

- Firstly, it may be due to the effort made for many years by different public entities that have been able to promote the tourist value of cave houses through different projects and financing initiatives such as the Rural Development Leader programs I, II, and +, the Proder Operational Programs I and II for the Development and Economic Diversification of Rural Areas [99,100], and the Eurocuevas Project, launched by the provincial council of Granada, which has received financial aid from the European Union under the European Regional Development Fund—ERDF—and has had the following results: (a) the creation of an international association of caves [101]; (b) the creation of an interpretation center in the cave houses of Benamaurel [102]; (c) the start of the first phase of creating an inventory of cave houses in the province, which involves a series of provincial plans that improve the urban environment of cave houses [103–105]; and (d) the drafting of a manual for intervention in cave houses, with the aim of providing municipal technicians with tools to be able to carry out renovation work or new construction [106]. Moreover, Andalusia is one of the first autonomous communities to regulate the cave house typology through the Law for the Promotion of Territorial Sustainability in Andalusia [107].
- Secondly, there are construction technicians who are trying to promote the renovation of cave houses by producing documents that outline the necessary process to render them legal and the considerations that must be adopted in order to adapt this type of construction to the national regulations, that is, the Technical Building Code, which regulates the basic requirements [47,108].
- Thirdly, the promotion and distribution of this type of construction through the design of a cave house with the "ideas competition" promoted by the project "La Herradura" of Huéscar with the participation of the international research group "Aedificatio" from the University of Alicante, the City Council of Huéscar, and the Rural Development Group of the Altiplano de Granada, with the support of Forum UNESCO—University and Heritage [109].

Through the second objective, we propose to identify whether the energy rating is a relevant characteristic of cave houses, and, as such, the second hypothesis—H2—is proposed. Estimate 2 rejects this hypothesis. Regarding energy rating, a very small percentage of the sample provides information about the energy rating; around 8% of cave houses and 11% of single-family houses. The result about energy ratings for the cave house sample suggests that this characteristic is not relevant for the estimation of house prices. These results could be due to the fact that sellers and buyers know the thermal advantages of cave houses, which is why the letter of the energy rating is not taken into consideration in this typology. Therefore, it would be interesting to gather data in different sociocultural and economic contexts on the population of Granada to analyze the perception they have about the energy rating of cave houses and identify whether they are aware of the energy-saving potential of this typology against other houses. In contrast, in single-family houses, values in energy rating premiums are estimated in accordance with the literature, since houses with high—letters A and B—ratings obtain positive premiums of 8.6% and 14.2%, respectively. Houses with a low rating—letter G—receive a negative premium of 7.6%.

Regarding the HVAC systems, the third hypothesis—H3—is proposed. Estimates 2 and 3 (Table 3 and Figure 5) confirm that the availability of air-conditioning is not a determining characteristic at the time of buying a cave house. However, the availability of heating or a fireplace is a determining characteristic. The reason for these results may be because cave houses, as opposed to other typologies such as single-family houses, have a ground enclosure that has high thermal inertia and reduces heat gains in the summer, meaning it would not be necessary for these houses to have air-conditioning. However, the availability of air-conditioning is in fact a determining characteristic in terms of the price of single-family houses (with an economic premium of 5.4%). At the same time, cave houses reduce heat loss in winter due to the conduction of the enclosure (high density of the soil). This is in such a way that those cave houses that have heating have an economic premium that is four times that of single-family houses that are in similar condition (11.3% compared to 47.2%). Similarly, in cave houses, the availability of a chimney is positively valued (13.4%) since, as suggested by many authors [15,24,110], it is one of the characteristics of caves in Granada, while in single-family houses, this is not a determining characteristic.

With regard to neighborhood characteristics, cave houses increase in price three times more than single-family houses if they are located in areas with a higher percentage of foreigners. This price difference between typologies may be due, in the first place, to cave houses not being accepted by the local population for either socioeconomic or cultural reasons [45,110,111]. Secondly, as noted by Mejías del Río [48], at the end of 1990, an economic sector orientated toward foreigners was developed and was dedicated to the renovation and sale of cave houses.

In contrast, in areas where there is a high population of elderly people, the price premium of cave houses is four times lower than that of single-family houses. This difference in premiums may be due to these areas being depopulated, unequipped, and unattractive [112]. Lastly, the percentage of people with university studies has the same impact on cave houses as it does on single-family houses.

5. Conclusions

This study looks to study whether sustainable constructions, such as cave houses, have an economic impact with regard to other construction types in the real estate market in Granada. In addition, it is determined whether the energy rating and air conditioning systems are relevant characteristics in determining the price of cave houses. As far as the authors are aware, there have been no studies that analyze the prices of cave houses.

To carry out the research, a regression model estimated by ordinary least squares is used, using a sample of 61,573 properties offered for sale, both single-family houses and cave houses. Real estate prices have been collected in two time periods between 2017 and 2021 from two Spanish real estate portals.

In conclusion, society is changing its perception of cave houses and is beginning to consider them to be a sustainable construction typology that allows for significant energy savings (between 23% and 35%) compared to other typologies, according to the results obtained by Kumar, et al. [113]. The consequence of this is that currently cave houses are being marketed at higher prices than single-family houses and the energy rating or the availability of air-conditioning are not determining characteristics of the price.

This study, as previously mentioned, has some limitations due to the lack of information from official resources regarding the transaction prices and the characteristics of the houses. The results are obtained from the people offering houses and refer to a specific place (province of Granada) and cannot be extrapolated to other places.

At the same time, the results are encouraging for the government as it can be considered that the economic aid and the projects carried out are having a significant impact on society, given that the energy crisis is having serious repercussions on energy costs.

This study presents many lines for future research. The first is the opportunity to analyze the perception of the population of Granada in terms of the economic and sustainable advantages of cave houses. The second is the opportunity to analyze the costs of renovating cave houses and complying with construction standards. The third is the opportunity to analyze the prices of cave houses within the tourist sector and the sharing economy.

Author Contributions: All authors contributed equally to this work. Conceptualization, M.-F.C.-L and R.-T.M.-G.; methodology, M.-F.C.-L and R.-T.M.-G.; software, M.-F.C.-L and R.-T.M.-G.; formal analysis, M.-F.C.-L and R.-T.M.-G.; investigation, M.-F.C.-L and R.-T.M.-G.; data curation, M.-F.C.-L and R.-T.M.-G.; writing—review and editing, M.-F.C.-L and R.-T.M.-G.; visualization, M.-F.C.-L and R.-T.M.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The authors do not have permission to share data.

Acknowledgments: Acknowledgement of the "Research project for innovation in earthen architecture, cave housing and urban development" (AYTOHUESCAR2-20T), financed by the Huescar City Council and its main researcher Antonio Jiménez Delgado.

Conflicts of Interest: The authors declare no conflicts of interest.

Note

[1] A *comarca* is a division of territory comprising several municipalities, forming an intermediate level of administrative subdivision between the municipalities and the provinces.

References

1. Ganem, C.; Esteves, A.; Coch-Roura, H. Traditional climate-adapted typologies as a base for a new contemporary architectural approach. In Proceedings of the 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland, 6–8 September 2006; p. 7.
2. IAE, International Energy Agency. *World Energy Outlook 2018*; International Energy Agency: Paris, France, 2018; p. 661. https://doi.org/10.1787/weo-2018-en.
3. Omer, A.M. Energy, environment and sustainable development. *Renew. Sustain. Energy Rev.* **2008**, *12*, 2265–2300. https://doi.org/10.1016/j.rser.2007.05.001.
4. The European Parliament and the Council of the European Union. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. *Off. J. Eur. Communities* **2003**, *1*, 65–71. Available online: http://data.europa.eu/eli/dir/2002/91/oj (accessed on 7 May 2022).
5. The European Parliament and the Council of the European Union. Directive 2010/31/EU of the European Parliament and of the council of 19 May 2010 on the energy performance of buildings. *Off. J. Eur. Union* **2010**, *153*, 124–146. Available online: http://data.europa.eu/eli/dir/2010/31/oj (accessed on 7 May 2022).
6. The European Parliament and the Council of the European Union. Directive 2012/27/eu of the European Parliament and of the council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. *Off. J. Eur. Communities* **2012**, *315*, 202–257. Available online: http://data.europa.eu/eli/dir/2012/27/oj (accessed on 7 May 2022).
7. The European Parliament and the Council of the European Union. Directive (EU) 2018/844 of the European Parliament and of the council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. *Off. J. Eur. Communities* **2018**, *156*, 75–91. Available online: http://data.europa.eu/eli/dir/2018/844/oj (accessed on 7 May 2022).
8. Ministerio de la Presidencia. *Real Decreto 47/2007, de 19 de enero, por el que se aprueba el Procedimiento básico para la certificación de eficiencia energética de edificios de nueva construcción*; Boletín Oficial del Estado: Madrid, España, 2007; pp. 4499–4507. Available online: https://www.boe.es/buscar/doc.php?id=BOE-A-2007-2007 (accessed on 23 July 2019).
9. Ministerio de la Presidencia. *Real Decreto 235/2013, de 5 de abril, por el que se aprueba el procedimiento básico para la certificación de la eficiencia energética de los edificios*; Boletín Oficial del Estado: Madrid, España, 2013; pp. 27548–27562. Available online: https://www.boe.es/buscar/doc.php?id=BOE-A-2013-3904 (accessed on 23 July 2019).
10. Anselm, A.J. Earth Shelters; A Review of Energy Conservation Properties in Earth Sheltered Housing. In *Energy Conservation*; Ahmed, A.Z., Ed.; IntechOpen: London, UK, 2012; pp. 125–148. https://doi.org/10.5772/51873.
11. Iannelli, L.; Fiora, J.; Gil, S. La tierra como acondicionador de aire. *Petrotecnia* **2013**, *13*, 34–41. Available online: https://www.petrotecnia.com.ar/junio13/Petro3-13.pdf (accessed on 28 July 2022).

12. Cárdenas y Chávarri, J.D.; Maldonado Ramos, L.; Barbero Barrera, M.d.M.; Gil Crespo, I.J. Sostenibilidad y mecanismos bioclimáticos de la arquitectura vernácula española: El caso de las construcciones subterráneas. In Proceedings of the 14 Convención Científica de Ingeniería y Arquitectura. Primer Congreso Medio Ambiente Construido y Desarrollo Sustentable MACDES, Havana, Cuba, 2-5 December 2008; p. 10. Available online: http://oa.upm.es/5649/ (accessed on 21 April 2021).
13. Jiménez-Delgado, A.; Manfredi, C.; Travaglio, P.; Vengoechea, P. The town of Huéscar conservation of cave-houses as a tool of urban development. In Proceedings of the III Congreso Internacional sobre Documentación, Conservación, y Reutilización del Patrimonio Arquitectónico, Valencia, Spain, 22-24 October 2015; pp. 1924–1930. Available online: https://riunet.upv.es/handle/10251/56060 (accessed on 16 April 2021).
14. ICOMOS, International Committee of Vernacular Architecture. Charter on the Built Vernacular Heritage (1999). In Proceedings of the 12th General Assembly, Mexico City, Mexico, 17-23 October 1999. Available online: https://ciav.icomos.org/category/charters/ (accessed on 30 April 2022).
15. Barbero-Barrera, M.M.; Gil-Crespo, I.J.; Maldonado-Ramos, L. Historical development and environment adaptation of the traditional cave-dwellings in Tajuña's valley, Madrid, Spain. *Build. Environ.* **2014**, *82*, 536–545. https://doi.org/10.1016/j.buildenv.2014.09.023.
16. Bouillot, J.; Huang, L. Cave dwelling in China climatic conditions & microclimatic effects. In Proceedings of the 25th Conference on Passive and Low Energy Architecture (PLEA 2008), Dublin, 22–24 October 2008; pp. 1–7. Available online: http://web5.arch.cuhk.edu.hk/server1/staff1/edward/www/plea2018/plea/2008/content/papers/poster/PLEA_FinalPaper_ref_434.pdf (accessed on 4 May 2022).
17. Cañas, I.; Martín, S. Recovery of Spanish vernacular construction as a model of bioclimatic architecture. *Build. Environ.* **2004**, *39*, 1477–1495. https://doi.org/10.1016/j.buildenv.2004.04.007.
18. Widera, B. Comparative analysis of user comfort and thermal performance of six types of vernacular dwellings as the first step towards climate resilient, sustainable and bioclimatic architecture in western sub-Saharan Africa. *Renew. Sustain. Energy Rev.* **2021**, *140*, 110736. https://doi.org/10.1016/j.rser.2021.110736.
19. Granell Berbel, R. Casa Cueva 2.0: Análisis de la Eficiencia Energética de una Casa Cueva en el Siglo XXI. Master's Thesis, Universidad Jaume I, Castelló de la Plana, Spain, 2013. Available online: http://hdl.handle.net/10234/77986 (accessed on 21 April 2021).
20. Torralba Izuel, C. Estudio y Análisis de Parámetros Bioclimáticos. Condiciones de Ventilación Adaptado a los Sassi de Matera, Italia y a las Casas Cueva de Paterna, Valencia. Degree Thesis, Universidad Politécnica de Valencia, Valencia, Spain, 2014. Available online: https://riunet.upv.es/handle/10251/45308 (accessed on 7 November 2021).
21. Montalbán Pozas, B.; Neila González, F.J. Hygrothermal behaviour and thermal comfort of the vernacular housings in the Jerte Valley (Central System, Spain). *Energy Build.* **2016**, *130*, 219–227. https://doi.org/10.1016/j.enbuild.2016.08.045.
22. Anselm, A.J. Passive annual heat storage principles in earth sheltered housing, a supplementary energy saving system in residential housing. *Energy Build.* **2008**, *40*, 1214–1219. https://doi.org/10.1016/j.enbuild.2007.11.002.
23. Li, Y.; Geng, S.; Yuan, Y.; Wang, J.; Zhang, X. Evaluation of climatic zones and field study on thermal comfort for underground engineering in China during summer. *Sustain. Cities Soc.* **2018**, *43*, 421–431. https://doi.org/10.1016/j.scs.2018.08.002.
24. Piedecausa-García, B. La Vivienda Tradicional Excavada: Las Casas-Cueva de Crevillente. Análisis Tipológico y Medidas de Calidad del Aire. Ph.D. Thesis, Universidad de Alicante, San Vicente del Raspeig, Spain, 2012. Available online: http://hdl.handle.net/10045/24997 (accessed on 3 August 2022).
25. Piedecausa-García, B.; Frutos-Vázquez, B. Radon concentrations in cave houses of Crevillente: A study about typological factors and proposals for remedial actions based on ventilation techniques. *Rev. De La Construcción. J. Constr.***2018**, *17*, 60–71. https://doi.org/10.7764/RDLC.17.1.60.
26. Goel, R.K.; Singh, B.; Zhao, J. *Underground Infrastructures: Planning, Design, and Construction*; Butterworth-Heinemann: Oxford, UK, 2012. https://doi.org/10.1016/C2010-0-67210-5.
27. Carmody, J.; Sterling, R. Design Considerations for Underground Buildings. *Undergr. Space* **1984**, *8*, 352–362. Available online: https://media.journals.elsevier.com/content/files/design-considerations-for-underground-11101240.pdf (accessed on 5 May 2022).
28. Amado, A.R. Capitalization of Energy Efficient Features into Home Values in the Austin. Texas Real Estate Market. Master's Thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2007. Available online: http://hdl.handle.net/1721.1/39848 (accessed on 4 March 2019).
29. Salvi, M.; Horehájová, A.; Müri, R. *Minergie Macht sich Bezahlt*; Universität Zürich: Zürich, Switzerland, 2008; p. 11. Available online: https://www.minergie.ch/media/zkb_minergie_studie_2008.pdf (accessed on 15 November 2018).
30. Soriano, F. *Energy Efficiency Rating and House Price in the ACT*; Department of the Environment, Water, Heritage and the Arts: Parkes, NSW, Australia, 2008; p. 56. Available online: https://webarchive.nla.gov.au/awa/20130418173214/http://nathers.gov.au/about/publications/pubs/eer-house-price-act.pdf (accessed on 7 January 2018).
31. Bloom, B.; Nobe, M.C.; Nobe, M.D. Valuing Green Home Designs: A Study of ENERGY STAR® Homes. *J. Sustain. Real Estate* **2011**, *3*, 109–126. https://doi.org/10.1080/10835547.2011.12091818.

32. Aroul, R.R.; Hansz, J.A. The Value of "Green": Evidence from the First Mandatory Residential Green Building Program. *J. Real Estate Res.* **2012**, *34*, 27–50. https://doi.org/10.1080/10835547.2012.12091327.
33. Stephenson, R.M. Quantifying the Effect of Green Building Certification on Housing Prices in Metropolitan Atlanta. Master's Thesis, Georgia Institute of Technology, Atlanta, GA, USA, 2012. Available online: http://hdl.handle.net/1853/50137 (accessed on 4 March 2019).
34. Fuerst, F.; McAllister, P.; Nanda, A.; Wyatt, P. *An Investigation of the Effect of EPC Ratings on House Prices*; 13D/148; Department of Energy & Climate Change: London, UK, 2013; p. 41. Available online: https://www.gov.uk/government/publications/an-investigation-of-the-effect-of-epc-ratings-on-house-prices (accessed on 30 November 2018).
35. Cajias, M.; Fuerst, F.; Bienert, S. Tearing down the information barrier: The price impacts of energy efficiency ratings for buildings in the German rental market. *Energy Res. Soc. Sci.* **2019**, *47*, 177–191. https://doi.org/10.1016/j.erss.2018.08.014.
36. Zhang, L.; Li, Y.; Stephenson, R.; Ashuri, B. Valuation of energy efficient certificates in buildings. *Energy Build.* **2018**, *158*, 1226–1240. https://doi.org/10.1016/j.enbuild.2017.11.014.
37. Aydin, E.; Brounen, D.; Kok, N. The capitalization of energy efficiency: Evidence from the housing market. *J. Urban Econ.* **2020**, *117*, 103243. https://doi.org/10.1016/j.jue.2020.103243.
38. Evangelista, R.; Ramalho, E.A.; Andrade e Silva, J. On the use of hedonic regression models to measure the effect of energy efficiency on residential property transaction prices: Evidence for Portugal and selected data issues. *Energy Econ.* **2020**, *86*, 104699. https://doi.org/10.1016/j.eneco.2020.104699.
39. Taruttis, L.; Weber, C. Estimating the impact of energy efficiency on housing prices in Germany: Does regional disparity matter? *Energy Econ.* **2022**, *105*, 105750. https://doi.org/10.1016/j.eneco.2021.105750.
40. Yang, X. Measuring the Effects of Environmental Certification on Residential Property Values-Evidence from Green Condominiums in Portland, U.S. Master's Thesis, Portland State University, Portland, OR, USA, 2013. https://www.doi.org/10.15760/etd.1113.
41. Jensen, O.M.; Hansen, A.R.; Kragh, J. Market response to the public display of energy performance rating at property sales. *Energy Policy* **2016**, *93*, 229–235. https://doi.org/10.1016/j.enpol.2016.02.029.
42. Cornago, E.; Dressler, L. *Incentives to (Not) Disclose Energy Performance Information in the Housing Market*; ECARES Working Paper; Université Libre de Bruxelles: Bruxelles, Belgium, 2018; p. 50. Available online: https://ideas.repec.org/p/eca/wpaper/2013-249921.html (accessed on 13 March 2019).
43. Cespedes Lopez, M.-F.; Mora Garcia, R.-T.; Perez Sanchez, V.R.; Perez Sanchez, J.-C. Meta-Analysis of Price Premiums in Housing with Energy Performance Certificates (EPC). *Sustainability* **2019**, *11*, 6303. https://doi.org/10.3390/su11226303.
44. Fizaine, F.; Voye, P.; Baumont, C. Does the Literature Support a High Willingness to Pay for Green Label Buildings? An Answer with Treatment of Publication Bias. *Rev. D'économie Polit.* **2018**, *128*, 1013–1046. https://doi.org/10.3917/redp.285.1013.
45. Urdiales Viedma, M.E. Las cuevas-vivienda en Andalucía: De infravivienda a vivienda de futuro. *Scripta Nova: revista electrónica de geografía y ciencias sociales* **2003**, *7*. Available online: https://revistes.ub.edu/index.php/ScriptaNova/article/view/690 (accessed on 4 August 2022).
46. Villar Navascués, R.A. Las viviendas subterráneas y el riesgo sísmico. *GeoGraphos* **2016**, *7*, 147–170. https://doi.org/10.14198/GEOGRA2016.7.88.
47. Jiménez López, L. Process of the legalization of cave-house as house. *Build. Manag.* **2018**, *2*, 33–43. https://doi.org/10.20868/bma.2018.3.3840.
48. Mejías del Río, J.M. Casas-cueva en Galera (Granada): Una nueva vida para una vivienda tradicional. *Estudo Prévio* **2015**, 8, 1–23. Available online: http://hdl.handle.net/11144/2447 (accessed on 3 August 2022).
49. Lancaster, K.J. A new approach to consumer theory. *J. Political Econ.* **1966**, *74*, 132–157. https://doi.org/10.1086/259131.
50. Ridker, R.G.; Henning, J.A. The determinants of residential property values with special reference to air pollution. *Rev. Econ. Stat.* **1967**, *49*, 246–257. https://doi.org/10.2307/1928231.
51. Zietz, J.; Zietz, E.N.; Sirmans, G.S. Determinants of house prices: A quantile regression approach. *J. Real Estate Financ. Econ.* **2008**, *37*, 317–333. https://doi.org/10.1007/s11146-007-9053-7.
52. Sirmans, G.S.; Macpherson, D.A.; Zietz, E.N. The composition of hedonic pricing models. *J. Real Estate Lit.* **2005**, *13*, 3–43. https://doi.org/10.1080/10835547.2005.12090154.
53. Martínez Díaz, L.; Algarín Comino, M.; Santana Rodríguez, R.J. El arte de habitar el paisaje. Arquitectura troglodita en Canarias, un análisis tipológico y constructivo en su evolución. In *Arquitectura en Tierra, Patrimonio Cultural, Proceedings of the XII CIATTI 2015, Congreso Internacional de Arquitectura de Tierra, Tradición e Innovación,* Cuenca de Campos, Spain, 25–27 September 2015; Universidad de Valladolid: Valladolid, Spain, 2016; pp. 25–34. Available online: http://www5.uva.es/grupotierra/publicaciones/digital/libro2016/02xiiciatti2015_martinez.pdf (accessed on 3 August 2022).
54. Johnson, R.R.; Kuby, P.J. *Elementary Statistics*, 11th ed.; Richard Stratton: Boston, MA, USA, 2011.
55. INE, Instituto Nacional de Estadística. Censo de Población y Viviendas de 2011. Available online: https://www.ine.es/censos2011_datos/cen11_datos_resultados.htm (accessed on 10 October 2019).
56. Horowitz, J.L. The role of the list price in housing markets: Theory and an econometric model. *J. Appl. Econom.* **1992**, *7*, 115–129. https://doi.org/10.1002/jae.3950070202.

57. Knight, J.; Sirmans, C.; Turnbull, G. List Price Information in Residential Appraisal and Underwriting. *J. Real Estate Res.* **1998**, *15*, 59–76. https://doi.org/10.1080/10835547.1998.12090913.
58. Malpezzi, S. Hedonic Pricing Models: A Selective and Applied Review. In *Housing Economics and Public Policy*; O'Sullivan, T., Gibb, K., Eds.; Blackwell Science: Oxford, UK, 2003. https://doi.org/doi:10.1002/9780470690680.ch5.
59. Lyons, R.C. Can list prices accurately capture housing price trends? Insights from extreme markets conditions. *Financ. Res. Lett.* **2019**, *30*, 228–232. https://doi.org/10.1016/j.frl.2018.10.004.
60. Agnew, K.; Lyons, R.C. The impact of employment on housing prices: Detailed evidence from FDI in Ireland. *Reg. Sci. Urban Econ.* **2018**, *70*, 174–189. https://doi.org/10.1016/j.regsciurbeco.2018.01.011.
61. Bian, X.; Fabra, N. Incentives for information provision: Energy efficiency in the Spanish rental market. *Energy Econ.* **2020**, *90*, 104813. https://doi.org/10.1016/j.eneco.2020.104813.
62. Bisello, A.; Antoniucci, V.; Marella, G. Measuring the price premium of energy efficiency: A two-step analysis in the Italian housing market. *Energy Build.* **2020**, *208*, 109670. https://doi.org/10.1016/j.enbuild.2019.109670.
63. Cornago, E.; Dressler, L. Incentives to (not) disclose energy performance information in the housing market. *Resour. Energy Econ.* **2020**, *61*, 101162. https://doi.org/10.1016/j.reseneeco.2020.101162.
64. Khazal, A.; Sønstebø, O.J. Valuation of energy performance certificates in the rental market—Professionals vs. nonprofessionals. *Energy Policy* **2020**, *147*, 111830. https://doi.org/10.1016/j.enpol.2020.111830.
65. Aggarwal, C.C. *Outlier Analysis*, 1st ed.; Springer: New York, NY, USA, 2013; p. 446. https://doi.org/10.1007/978-1-4614-6396-2.
66. Mariani, M.C.; Tweneboah, O.K.; Pia Beccar-Varela, M. Data Preprocessing and Data Validations. In *Data Science in Theory and Practice*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2021; pp. 109–120. https://doi.org/10.1002/9781119674757.ch8.
67. van Dijk, D.; Siber, R.; Brouwer, R.; Logar, I.; Sanadgol, D. Valuing water resources in Switzerland using a hedonic price model. *Water Resour. Res.* **2016**, *52*, 3510–3526. https://doi.org/10.1002/2015WR017534.
68. Stetler, K.M.; Venn, T.J.; Calkin, D.E. The effects of wildfire and environmental amenities on property values in northwest Montana, USA. *Ecol. Econ.* **2010**, *69*, 2233–2243. https://doi.org/10.1016/j.ecolecon.2010.06.009.
69. Simmons, K.M.; Kruse, J.B.; Smith, D.A. Valuing mitigation: Real estate market response to hurricane loss reduction measures. *South. Econ. J.* **2002**, *68*, 660–671. https://doi.org/10.2307/1061724.
70. Hite, D.; Chern, W.; Hitzhusen, F.; Randall, A. Property-Value Impacts of an Environmental Disamenity: The Case of Landfills. *J. Real Estate Financ. Econ.* **2001**, *22*, 185–202. https://doi.org/10.1023/a:1007839413324.
71. Zahirovich-Herbert, V.; Gibler, K.M. The effect of new residential construction on housing prices. *J. Hous. Econ.* **2014**, *26*, 1–18. https://doi.org/10.1016/j.jhe.2014.06.003.
72. Bin, O. A prediction comparison of housing sales prices by parametric versus semi-parametric regressions. *J. Hous. Econ.* **2004**, *13*, 68–84. https://doi.org/10.1016/j.jhe.2004.01.001.
73. Nicodemo, C.; Raya, J.M. Change in the distribution of house prices across Spanish cities. *Reg. Sci. Urban Econ.* **2012**, *42*, 739–748. https://doi.org/10.1016/j.regsciurbeco.2012.05.003.
74. Schulz, R.; Werwatz, A. A State Space Model for Berlin House Prices: Estimation and Economic Interpretation. *J. Real Estate Financ. Econ.* **2004**, *28*, 37–57. https://doi.org/10.1023/A:1026373523075.
75. Fuerst, F.; McAllister, P.; Nanda, A.; Wyatt, P. Energy performance ratings and house prices in Wales: An empirical study. *Energy Policy* **2016**, *92*, 20–33. https://doi.org/10.1016/j.enpol.2016.01.024.
76. Ogwang, T.; Wang, B. A Hedonic Price Function for a Northern BC Community. *Soc. Indic. Res.* **2003**, *61*, 285–296. https://doi.org/10.1023/a:1021905518866.
77. Nicholls, S.; Crompton, J.L. The Impact of Greenways on Property Values: Evidence from Austin, Texas. *J. Leis. Res.* **2005**, *37*, 321–341. https://doi.org/10.1080/00222216.2005.11950056.
78. Hwang, J.W. Reflections of School Quality on the Housing Market: Extending the Definition of Better Schools. Graduate Research Paper. 2005. p. 18. Available online: https://economics.ecu.edu/wp-content/pv-uploads/sites/165/2019/04/JeeHwang.pdf (accessed on 2 August 2018).
79. Kohlhase, J.E. The impact of toxic waste sites on housing values. *J. Urban Econ.* **1991**, *30*, 1–26. https://doi.org/10.1016/0094-1190(91)90042-6.
80. Kestens, Y.; Thériault, M.; Des Rosiers, F. Heterogeneity in hedonic modelling of house prices: Looking at buyers' household profiles. *J. Geogr. Syst.* **2006**, *8*, 61–96. https://doi.org/10.1007/s10109-005-0011-8.
81. Casas del Rosal, J.C. Urban Valuation Methods. Ph.D. Thesis, Universidad de Córdoba, Córdoba, Spain, 2017. Available online: http://hdl.handle.net/10396/15417 (accessed on 11 April 2018).
82. Lama Santos, F.A.d. Determination of Qualities of Value in Real Estate Valuation. The Influence of Socio-Economic Status on the Valuation of Housing. Ph.D. Thesis, Universidad Politécnica de Valencia, Valencia, Spain, 2017. https://doi.org/10.4995/Thesis/10251/90526.
83. Bauer, T.K.; Feuerschütte, S.; Kiefer, M.; an de Meulen, P.; Micheli, M.; Schmidt, T.; Wilke, L.-H. Ein hedonischer Immobilienpreisindex auf Basis von Internetdaten: 2007–2011. *AStA Wirtsch.-Und Soz. Arch.* **2013**, *7*, 5–30. https://doi.org/10.1007/s11943-012-0125-7.

84. Cebula, R.J. The hedonic pricing model applied to the housing market of the city of Savannah and its Savannah historic Landmark district. *Rev. Reg. Stud.* **2009**, *39*, 9–22. https://doi.org/10.52324/001c.8197.
85. Collazos Reyes, E.; Gamboa Pérez, W.; Prado Velasco, P.; Verardi, V. Análisis espacial del precio de oferta de la vivienda en el área metropolitana de Cochabamba. *Revista Latinoamericana de Desarrollo Económico* 2006; pp. 33–62. Available online: http://www.scielo.org.bo/scielo.php?script=sci_arttext&pid=S2074-47062006000100003&nrm=iso (accessed on 23 March 2018).
86. Cerin, P.; Hassel, L.G.; Semenova, N. Energy Performance and Housing Prices. *Sustain. Dev.* **2014**, *22*, 404–419. https://doi.org/10.1002/sd.1566.
87. Kauko, T.; Hooimeijer, P.; Hakfoort, J. Capturing Housing Market Segmentation: An Alternative Approach based on Neural Network Modelling. *Hous. Stud.* **2002**, *17*, 875–894. https://doi.org/10.1080/02673030215999.
88. Davis, P.T.; McCord, J.; McCord, M.J.; Haran, M. Modelling the effect of energy performance certificate rating on property value in the Belfast housing market. *Int. J. Hous. Mark. Anal.* **2015**, *8*, 292–317. https://doi.org/10.1108/IJHMA-09-2014-0035.
89. Rephann, T.J. Explaining property values: Quantitative evidence from Sweden. In Proceedings of the 36th Annual Meeting of the North American Regional Science Association International, Santa Fe, NM, USA, 13–16 November 1998; pp. 1–23. Available online: https://www.researchgate.net/publication/2612749 (accessed on 2 August 2018).
90. Murdoch, J.C.; Singh, H.; Thayer, M. The Impact of Natural Hazards on Housing Values: The Loma Prieta Earthquake. *Real Estate Econ.* **1993**, *21*, 167–184. https://doi.org/10.1111/1540-6229.00606.
91. Keskin, B. Hedonic analysis of price in the istanbul housing market. *Int. J. Strateg. Prop. Manag.* **2008**, *12*, 125–138. https://doi.org/10.3846/1648-715X.2008.12.125-138.
92. Fitch Osuna, J.M.; Soto Canales, K.; Garza Mendiola, R. Assessment of Urban-Environmental Quality. A Hedonic Modeling: San Nicolás de los Garza, Mexico. *Estud. Demográficos Y Urbanos* **2013**, *28*, 383–428. Available online: http://www.redalyc.org/articulo.oa?id=31230010004.
93. Kain, J.F.; Quigley, J.M. *Housing Markets and Racial Discrimination: A Microeconomic Analysis*; National Bureau of Economic Research: New York, NY, USA, 1975; p. 393.
94. *IBM SPSS Statistics for Windows*, version 26; IBM Corp.: Armonk, NY, USA, 2019.
95. Kleinbaum, D.; Kupper, L.; Nizam, A.; Rosenberg, E. *Applied Regression Analysis and other Multivariable Methods*, 5th ed.; Cengage Learning: Boston, MA, USA, 2013; p. 1072.
96. Chatterjee, S.; Simonoff, J.S. *Handbook of Regression Analysis*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2013; p. 240.
97. Montgomery, D.C.; Peck, E.A.; Geoffrey Vining, G. *Introduction to Linear Regression Analysis*, 5th ed.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2012.
98. Yan, X.; Gang Su, X. *Linear Regression Analysis. Theory and Computing*; World Scientific Publishing Co. Pte. Ltd.: Singapore, 2009; p. 328.
99. Caro de la Barrera, E. El programa LEADER y su aplicación en Andalucía. In *Hacia un Nuevo Sistema Rural*; Cruz Villalón, J., Ramos Real, E., Eds.; Ministerio de Agricultura, Alimentación y Medio Ambiente, Centro de Publicaciones Agrarias, Pesqueras y Alimentarias: Madrid, Spain, 1995; pp. 709–740. Available online: https://www.miteco.gob.es/ministerio/pags/biblioteca/fondo/9772.htm (accessed on 4 August 2022).
100. Junta de Andalucía. *LEADER I, Relaciones entre Actividades de Desarrollo de la Economía Rural*; Consejería de Agricultura, Pesca, Agua y Desarrollo Rural: Sevilla, Spain, 1991–1993. Available online: https://www.juntadeandalucia.es/organismos/agriculturaganaderiapescaydesarrollosostenible/servicios/estudios-informes/detalle/71273.html (accessed on 4 August 2022).
101. Diputación de Granada. Asociación Europea de Zonas de Cuevas. European Regional Development Fund (ERDF): 13,263.60€, 2007–2013. Available online: https://dipgra-feder.org/proyectos/tema-ecemed/indice-ecemed/actuaciones-ecemed/22-ecemed/87-asociacion-europea-de-zonas-de-cuevas.html (accessed on 4 August 2022).
102. Diputación de Granada. Centro de interpretación de cuevas en Benamaurel. Dipgra Feder: 147,470.57€, 2007–2013. Available online: https://dipgra-feder.org/proyectos/tema-ecemed/indice-ecemed/actuaciones-ecemed/22-ecemed/101-centro-de-interpretacion-de-cuevas-en-benamaurel.html (accessed on 4 August 2022).
103. Diputación de Granada. Intervenciones urbanísticas de entornos de viviendas-cueva de municipios del noreste de Granada. Creación de una ruta de cuevas. Dipgra Feder: 2,288,043.38€, 2007–2013. Available online: https://dipgra-feder.org/proyectos/tema-ecemed/indice-ecemed/actuaciones-ecemed/22-ecemed/100-intervenciones-urbanisticas-de-entornos-de-viviendas-cueva-de-municipios-del-noreste-de-granada-creacion-de-una-ruta-de-cuevas.html (accessed on 4 August 2022).
104. Diputación de Granada. *Plan Provincial Intervenciones Urbanísticas VIVIENDAS-CUEVA Granada 2018*; Boletín Oficial de la Provincia de Granada: Granada, Spain, 2019; pp. 14–16. Available online: https://bop2.dipgra.es/opencms/opencms/portal/DescargaPDFBoletin?fecha=11/04/2019 (accessed on 4 August 2022).
105. Diputación de Granada. *Plan Provincial Intervenciones Urbanísticas VIVIENDAS-CUEVA Granada 2020*, Boletín Oficial de la Provincia de Granada: Granada, Spain, 2020; pp. 3-–5. Available online: https://bop2.dipgra.es/opencms/opencms/portal/DescargaPDFBoletin?fecha=08/10/2020 (accessed on 4 August 2022).
106. Marín Segura, B.; Jiménez Torrecillas, A.; Panella, M.; Ramos Puertollano, M.Á.; Fuentes-Guerra, R.; Fischer, J.; Aranda Delgado, M.; Santiago Pérez, I. *Cuevas en la Provincia de Granada. Aspectos Técnicos, Urbanísticos, Legales, Patrimoniales y Perspectivas para el*

Desarrollo Local en la Provincia; Diputación Provincial de Granada: Granda, Spain, 2007. Available online: https://www.geoparquedegranada.com/wp-content/uploads/2020/02/CUEVAS-EN-LA-PROVINCIA-DE-GRANADA.pdf (accessed on 21 April 2021).

107. Comunidad Autónoma de Andalucía. *Ley 7/2021, de 1 de Diciembre, de Impulso para la Sostenibilidad del Territorio de Andalucía*; Boletín Oficial del Estado: Madrid, España, 2021. Available online: https://www.boe.es/eli/es-an/l/2021/12/01/7/con (accessed on 4 August 2022).
108. Jiménez López, L. The collection of environmental data in the analysis of the hygrothermal and air quality behavior of a cave house in Almería. *Build. Manag.* **2021**, *5*, 9–21. http://doi.org/10.20868/bma.2021.3.4710.
109. Jiménez-Delgado, A.; Travaglio, P.; Manfredi, C.; Vengoechea, P.; Lawlor, M.; McClure, J.; Puente Burgos, C.; Líndez Vílchez, B.; López Serrano, C.V.; Quiroz Pico, C.A.; et al. *La Vivienda Cueva en el Altiplano de Granada. Proyecto "La Herradura", Huéscar. Universidad y Patrimonio*; Alarifes Asociación Cultural, Ed.; Alarifes Asociación Cultural: Toledo, Spain, 2017. Available online: http://hdl.handle.net/10045/72615 (accessed on 10 April 2022).
110. Pérez Casas, Á. The gypsies and their caves in Granada. *Gaz. De Antropol.* **1982**, *1*, 1–23. https://doi.org/10.30827/Digibug.6718.
111. Algarín Comino, M.J. Context and landscape in low density territories: The rehabilitation of the Troglodyte House sets. *A Obra Nasce* **2018**, *13*, 25–38. Available online: https://hdl.handle.net/11441/99786 (accessed on 3 August 2022).
112. Rodríguez García, N. Recuperación del Conjunto de Viviendas Cuevas del Barrio "La Herradura", Municipio de Huéscar, Granada. Degree Thesis, Universidad Politécnica de Cataluña, Barcelona, Spain, 2016. Available online: http://hdl.handle.net/2117/87907 (accessed on 3 August 2022).
113. Kumar, R.; Sachdeva, S.; Kaushik, S.C. Dynamic earth-contact building: A sustainable low-energy technology. *Build. Environ.* **2007**, *42*, 2450–2460. https://doi.org/10.1016/j.buildenv.2006.05.002.