Dissertation

Master in Corporate Finance

The Housing Market in the District of Leiria:

A Hedonic Approach

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ABSTRACT

The real estate housing valuation is, even today, highly subjective. The sales comparison approach, which is based on the determination of housing value suported on sales price of similar housing in a particular market area, remains the most widely used method. Given this situation, the hedonic model should be seen as a solution to improve the quality of assessments, as it determines the price of housing according to the observable values of their different atributes.

This dissertation aims to develop a hedonic model for the housing market in the district of Leiria reported to 2010, in order to verify the characteristics of a house that most influence its price. It is proposed a hedonic model of house prices according to the characteristics of a housing listed by Angli and Gencay (1996), Goodman and Thibodaeu (1997), Maurer, Pitzer and Sebastian (2004), Morancho (2003), Ozzane and Malpezzi (1985), Pozo (2009), Rodrigues (2008), Selim (2008) and Wen, Jia and Guo (2005). The cubic functional form is used to proceed with the empirical study.

The results indicate that the price of a house is strongly influenced by some location variables, neighbourhood variables and structural variables. Some of these variables have a positive effect on the housing price, such as the location of housing in the county of Óbidos and the number of bedrooms of the housing, specifically housing with four or five bedrooms. Other variables have a negative effect on price, such as usage status of a house, namely used housing and the location of housing in the counties of Marinha Grande and Leiria.

Key words: hedonic model, housing market, real estate.

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1. INTRODUCTION

The housing market has a unique importance because the purchase of a home allows independence and privacy to a person so as to obtain a status in society. Moreover, this market is one of the great engines of a country's economy. In Portugal, most people have as a priority to buy a house. In fact, this is associated with a sign of "growth in life" and, thus, from the point of view of investment, housing is an asset to which most families channel their economies.

However, due to the crisis that has been experienced in recent times, an adequate estimate of the value of housing is crucial. This forecast will influence the allocation of housing credit which, in turn, will influence the purchase of housing. Moreover, housing has, as main characteristics, durability and spatial fixity, which means that, when a purchase takes effect, there ought to be some reflection.

Despite its importance, the real estate housing valuation is, even today, highly subjective. The most widely used criterion is the one of comparing sales prices in the market, ie, determining the value of housing based on sales' price of similar housing in a particular market area. Given this situation, the hedonic model should be seen as a solution to improve the quality of assessments, since it allows determining the price of goods according to their attributes. This model allows reducing the degree of subjectivity in the assessment of the value of houses, based on the size, age, architecture, number of the rooms and geographical location, among others.

Aware of the importance of this topic, we intended to develop the issue through an empirical research conducted for the housing market in the district of Leiria reported to 2010. The main objective is the specification of a hedonic model of housing prices. This study consists of four sections. The first section promotes a theoretical framework of the research problem. Specifically, it contains a brief characterization of the housing market, the review of various methods of housing valuation and a brief historical overview of the topic "hedonic price model." In the second section, we present the methodology and the data source. The third section describes and discusses the results. Finally, a fourth section describes the conclusions of the study and highlights also its limitations.

2. LITERATURE REVIEW

This section promotes a theoretical framework of the research problem. Specifically, it contains a brief characterization of the housing market, the review of various methods of housing valuation and a brief historical overview of the topic "hedonic price model".

2.1. Characterization of the housing market and its efficiency

Housing stands out from other goods because it has a set of characteristics that makes it unique.

Durability

One of the most relevant is the durability of housing. Its high duration is a general characteristic. As a result, there is a reduced rate of substitution of such goods.

Spatial fixity

Also important, is the spatial fixity, i.e., such type of good is fixed at a specific location. This is one of the characteristics that will greatly influence the value of the housing. So, there will be a set of exogenous factors to the good that will significantly influence its value. Examples of these factors are:

- access to infrastructure;
- access to shopping;
- transport routes;
- quality of neighbourhood;
- the jurisdiction of local government.

Heterogeneity

Real estate has, by nature, heterogeneous goods. There are not two equal housing, i.e., there is always some differentiating factor.

Other characteristics

Housing is also distinguished from other assets since the information and transaction costs are high, the liquidity is low, there is a high price for each item and this sector experiences big government intervention.

Fama (1970) identified three conditions that are sufficient to make an efficient market: absence of transaction costs, availability of information free of charge and existence of homogeneous expectations among consumers. Based on all the characteristics mentioned above, it may, then, be concluded that there is a low degree of efficiency in housing markets.

2.2. State of the art: review of various methods of real estate housing valuation

Pagourtzi, Assimakopoulos, Hatzichristos and French (2003) argue that each country has a different culture and experience that will influence and determine the methods adopted for any particular valuation. The authors divide the methods of housing valuation in two large groups. On the one hand, the traditional methods, which are based on direct observation.These methods are grounded on the direct comparison or may be related with the collection of informations that allows the establishment of a regression model to determine their market value. On the other hand, the advanced methods, which are more quantitative and try to, indirectly, simulate the behaviour of players, in order to estimate the transaction price.

2.2.1. Traditional valuation methods

Next, we present each of the traditional methods:

A) Comparable method

To Pagourtzi *et al*. (2003), the comparable method is the most widely used approach. The housing value is determined based on the sales price of similar housing in a given market area. To apply this method, there is a need to sometimes make adjustments in order to have comparable housing. If two housing are not identical, i.e., there are differences in size, age, construction quality, there must be an adjustment in the selling price to make them comparable. The authors speak of homogenization, i.e., set to be comparable. Thus, they advocate the need to perform the assessment in stages, when using the comparable method. Comparable sales analysis procedure may be viewed as a four-part process: (1) analysis of information on recent transactions of real estate, similar and comparable; (2) adjustment of the selling price, considering the different characteristics of each housing; (3) estimation of the market value and; (4) presentation of results in an accessible and visible set-up.

B) Income method

In the income method, the valuation of housing is identified with their ability to generate income. Pagourtzi *et al.* (2003) argue that income represents the return of money invested in the property by its owner.

C) Profits method

According Pagourtzi *et al.* (2003), the profits method is based on the analysis of potential income that the housing may generate, less the costs to be incurred to make the house operational to generate such income, here referred to as rent.

D) Residual method

The objective of residual method is to evaluate a vacant land or buildings that should be demolished. The evaluator will study its potential value, providing the revenue owners can get from the land for the development of a new venture. The residual value of land is calculated as the difference between the market value of the project ended and the alleged sum of all costs incurred during the development of the whole process. In short, the residual value of the land represents the maximum amount that an investor will be willing to give the land, so that, after all expenses incurred, he can still get the margin stipulated at the outset.

E) Cost method

The housing valuation by the cost method assumes the value of the reconstruction of a new building, with the same characteristics as the existing structure.

F) Multiple regression method

As its name implies, with the multiple regression method, the housing valuation is made by taking into account the analysis of a set of characteristics that influence the value of the housing. It means that the value of the housing is a variable that depends on a number of other explanatory variables, for example the characteristics of the housing.

G) Stepwise regression method

In the stepwise regression method, evaluation is performed also by a regression. It differs from the previous method since it interactively builds a sequence of regression models by adding or removing variables at each step.

2.2.2. Advanced valuation methods

2.2.2.1. Artificial neural network

According to Pagourtzi *et al.* (2003), an artificial neural network model must first be "trained" from a data set. Afterwards, the model is used to estimate the prices of new homes in the same market. Neural networks are artificial intelligence models originally designed to replicate the human brain's learning processes.

Limsombunchai, Gan and Lee (2004) argue that neural network consists of three main layers: input data layer (housing attributes), hidden layer(s) (commonly referred to as "black box"), and output layer (estimated house price). In the artificial neural network model, for a particular input, an output is produced. Subsequently, the model compares the output model (estimated house price) to the actual output (actual house price). The accuracy of this value is determined by the total mean square error and then black propagation is used in an attempt to reduce prediction errors, which is done through the adjusting of the connection weights.

Collins and Evans (1994), in their study of housing values with an artificial neural network model, argue that are two phases in the application of the model to a problem: training and interrogation. In the training phase, sets of data are put into the networks, and processed as they pass forward through the layers to the output neurons. For each data set presented to the network, the output neurons give a set of values which at first almost certainly differ greatly from the correct result. The training process is repeated many thousands of times on the same data sets until the network has learnt the underlying pattern in the data. Then, a train network may be interrogated by test data sets. Particularly, as a method of real estate housing valuation, the artificial neural network employs a number of inputs which are physical housing attributes variables, neighbourhood variables and has one output neuron, the value of housing. When learning has been achieved, the network is tested on data which had not been included in the training data set (the control sample). The test results provided by the network are compared with the true selling values of housing in the control sample.

For Nguyen and Cripps (2001), the use of a feed forward artificial neural network with propagation learning presents methodological problems, such as number of hidden layers, number of neurons in each hidden layer, selection and size of training set, selection and

size of validation set and overtraining must be addressed. The authors refer that the level of training and the number of hidden neurons affect the memorization and generalized predictability of the model. The model is able to produce the correct results for the training set when the more extensive training and the more hidden neurons are used.

2.2.2.2. Spatial analysis method

According to Pagourtzi *et al.* (2003), one of the characteristics of the spatial analysis method is that it is able to detect, for example, additional neighbourhood factors that should be considered in explaining variability in the market.

Anselim (1998) argues that the spatial econometrics and spatial statistics are very important for empirical analysis of housing markets. The importance of the spatial aspects of housing markets is unquestioned. For Anselim (1998), the spatial regression approach consists of four main phases: model specification, estimation, diagnosis and model prediction. Typically, a model is first estimated without incorporating spatial effects. The result is the starting point for the diagnosis for spatial effects. On the other hand, the results of spatial regression analysis may also be usefully applied to create "predicted" values at locations or for area units for which no observations are available.

Can and Megbolugbe (1997) also made his contribution for the spatial analysis method, providing a spatial analytical framework for the use of the Geographic Information Systems (GIS) technology in housing market research. It discusses the nature of neighbourhood effects and their influence in housing market. The authors conclude that GIS, coupled with spatial analytical tools, offers an ideal environment for modelling housing data sets.

2.2.2.3. Fuzzy logic

The main characteristic of the fuzzy logic model is to treat or handle the data or information, especially the ambiguous, dubious or even inaccurate one, in innovative ways. A major objective of this method is to translate verbal expressions, often very vague and with a qualitative connotation, into numeric values. The association is made between the verbal expressions with numerical values ranging from 0, when the association is absent, to 1, when the association is total. Another critical aspect of this

method is the definition of rules. These rules are based on logical expressions of a kind "if," "or" and "then" with implications of the types:

- If… <condition> then ... ... <result>.
- If ... <condition1> ... and ... <condition2> ... then ... <result>.
- If ... <condition1> ... or ... <condition2> ... then ... <result>.

Bagnoli and Smith (1998) demonstrated the application of fuzzy logic to housing market valuation. Fuzzy logic enables a rigorous processing of vague judgments and allows the formalization of the rules from which the judgments are derived. The method also allows their incorporation into formal investment and valuation methods. Bagnoli and Smith (1998), in order to demonstrate how fuzzy logic permits the formalization of the rules from which the judgments are derived, chose the attribute location and, for example, argued that we can interpret the fuzzy rating number as a result of fuzzy rules of the type: if distance is “Near” then the rating number is “Low”. Bagnoli and Smith (1998) believe that the estimated value of housing produced by a fuzzy system should be more realistic than the estimated value produced by a linear regression.

Perng, Hsueh and Yan (2005) analyzed a fuzzy logic decision system for sales-ratio evaluation. The authors argue that the fuzzy logic system consists of four components: fuzzifier, inference engine, rule base and defuzzifier. The process begins with the fuzzification of the key attributes, where the attributes are converted into fuzzy sets. Each fuzzy set consists of linguistic terms and associated memberships. Then the linguistic terms are matched with preconditions of fuzzy if-then rules. The last phase is the defuzzification of consequence terms.

Guan, Zurada and Levitan (2008) argue that, more recently, fuzzy logic has been proposed as non-conventional approach to house price valuation. The authors stated that, in simple cases, one can build membership functions and fuzzy rules using common sense. In the more complex cases, choosing the parameters for a membership is a trial and error process at best. A solution to this problem is to combine the advantages of a fuzzy system with the learning capability of artificial neural networks. The result is an adaptive neuro-fuzzy inference system that allows creation and refinement of fuzzy rules through neural networks.

2.2.2.4. Autoregressive integrated moving average (ARIMA)

Pagourtzi *et al.* (2003), note that ARIMA is the only assessment method that relies on time variables. The ARIMA model is essentially an approach to economic forecasting, based on data time series.

Tse (1997) argues that ARIMA produces forecasts that are likely to be more accurate than the forecasts produced by other approaches. Because short-term factors are expected to change slowly, ARIMA proved to be an excellent short-term model for a wide variety of times series. Tse (1997) asserted that, when a price series crosses its correct moving average, the price series will continue in the direction of the crossing. Briefly, for Tse (1997), the core of the ARIMA model is premised on the fact that the market price is revealed by the pattern of prior price movements.

Chen, Kawaguchi and Patel (2004) argue that ARIMA models suggest many cycles' in house prices series for many years and these cycles may all be affected by a general business cycle. The authors also argue that a short one-year cycle is also found in all these series and all these cycles have a stochastic nature, suggesting the markets are not steady and are still changing.

2.2.2.5. Hedonic pricing model

Pagourtzi *et al.* (2003) describe the hedonic pricing model as an advanced method. It will be developed in later sections.

2.3. Brief historical review of hedonic price model

In 1939, Court, an experienced analyst in the American automobile industry, has established the first hedonic price model (Goodman, 1978). The analyst retained the term "hedonic" establishing the price of the car as a function of its different characteristics, which are by nature very heterogeneous.

Later, Lancaster (1966) addressed what was called the "new consumer theory". This one is distinguished from previous approaches because the goods are not the direct subject of utility, but the utility is derived from their properties or characteristics. The author argues that consumption is an activity in which the goods, either individually or combined, are the inputs and in which the outputs are a collection of their characteristics. The new

theory represents a break with the traditional theory since: (1) the good itself does not supply utility or benefit to the consumer; in fact, what provides usefulness are its characteristics; (2) a good has more than one characteristic and some of these characteristics can be shared by more than one good; and (3) a good, when combined with another, has characteristics that are different from the ones it would have if it were considered separately.

To formalize his assumptions, Lancaster (1966) considered the following ones: (1) an individual good or a set of goods is seen as a consumer activity associated with a scale that is not more than the level of activity; (2) each consumption activity produces a vector of fixed characteristics, being its relationship linear; and, (3) one seeks to maximize the utility function of the characteristics of the good.

The model could be analyzed according to the model of Samuelson and Nordhaus (1993), in which the situation of consumption that maximizes its utility is considered taking into account specific budget constraints. In traditional theory, the budget constraint and utility function are related even in the graph of indifference curves. As Lancaster (1966) claims, the utility function can be related with the budget constraint only if they are defined after the same space. There are, then, two choices: to transform the utility function in "goods-space" and relate them directly to the budget constraint, or to change the budget constraint on "characteristics-space" and relate them to the utility function.

Another major driving force advancing towards the consolidation of the hedonic price theory was the work of Rosen (1974). To this researcher, the set called hedonic or implicit prices takes form with the observation of prices of goods and analysis of the characteristics associated with each good. For Rosen (1974), hedonic prices can be defined as the implicit prices of the attributes of different goods and the specific characteristics of each of these goods. The study by Rosen (1974) differs from the one from Lancaster (1966), since it examines not only consumer behaviour but also the market equilibrium. The producers and retailers tend to meet consumer demand at least cost, and buyers (consumers) value the utility of goods.

King (1977) stated that individuals do not buy a good as a good, but as a package of characteristics. It is the characteristics that are valued and the purchase decision depends

on the efficiency of each one of them. King (1977), using the hedonic price, estimated the price of a housing based on four characteristics. These are the so-called structural characteristics (Struck); quality interior and exterior (IS); interior space (SPACE); and the land, public services and quality of neighbourhood (SITE). Each characteristic has an associated set of components and each component is part of one and only one characteristic. The value of each characteristic is the sum of the hedonic prices of each of its components. Specifically, the researcher estimated the hedonic price equation based on 683 properties sold in New Haven, in the metropolitan area, between 1967 and 1970. The results were consistent with the "new consumer theory of Lancaster."

Goodman (1978) also made his contribution to the development of hedonic models in the real estate appraisal, specifically by the sub-division of the market into submarkets. For each submarket, the researcher determined the changes in housing values through a set of components, which are ranked as the structural and neighbourhood. The author applied a hedonic model in his study on properties sold in New Haven between 1967 and 1969. Thus, he divided the market into submarkets, from the centre of New Haven to its suburbs. For each sub-area, he estimated a linear regression based on hedonic prices, and then analysed the differences between the submarkets. In each regression, the value of the housing could be measured based on two types of components: structural and neighbourhood.

Malpezzi (2002), in a selective review of hedonic pricing models, argues that the method of hedonic equations is the decomposition of housing value in measurable quantities and prices. The value of identical or different properties in different places can be predicted and compared. Simply put, a hedonic equation is a regression of the value of housing based on its characteristics. As Malpezzi (2002) discusses, the hedonic model arises because of heterogeneous housing stock and heterogeneous consumers. Not only does each house contain different characteristics, but those characteristics may be valued differently by different consumers.

The author broke down the hedonic equation in the following way:

$$R = f(S, N, L, C, T) \tag{2.1}$$

Where:

R = value of housing

S = structural characteristics

N = neighbourhood characteristics

L = location in the market

C = contract conditions

T = time that is given to sale or rent

The author also asserts that the hedonic price model arises due to the heterogeneity of the housing market. He also refers to the hedonic models as two phases models. In the first phase, we have a simple equation which estimates the hedonic price in a superficial way; it simply estimates the effect of characteristics on the value, and only in the second phase we take into account the structural parameters of each individual characteristic.

Malpezzi (2002), in his literature review, argues that:

✓ The distinction between demand and supply, as well as their interaction, has been a "torment" for econometrics.

✓ With the hedonic nonlinear models (logarithmic or other), prices and quantities are correlated. Thus, when consumers choose a quantity of some characteristics, they are implicitly choosing its price.

Another point made by the author is that the costs in the housing market are vast and that adjustments have to be made, assuming that the market is in equilibrium, which, in fact, is not the case. One possible approach to the problem of the imbalance is to estimate hedonic price functions using observations at, or near, equilibrium. We must, then, specify the nature of the process that distinguishes equilibrium from disequilibrium observations, which is not always obvious.

Ottensmann, Payton and Man (2005) also give their contribution to improving the theory of hedonic model of prices in the housing market. The hedonic model used by the authors includes structural characteristics, such as the number of bedrooms, area and the presence of other amenities and it also includes neighbourhood characteristics, such as the quality of schools, the percentage of population of a certain race, the distance to the city centre, among others. The main objective of the authors' work is to test the performance of

alternative measures of location. To test this performance, they retain distance and time to the urban centre, the various centres of employment and measures of accessibility to employment. The authors conclude that the location with respect to employment should be included for the proper specification of hedonic housing price models. The combination of accessibility to employment and change in accessibility to employment provides the best specification of location.

In recent decades, based on housing as a bundle of characteristics, many authors have addressed this issue by giving their contribution to the implementation of the hedonic model in the housing market.

Table 1:

Summary of empirical evidence of studies employing the hedonic model

The table lists the theoretical predictions of influence of the house characteristics on the house price and corresponding empirical evidence. Those studies which provide significant evidence of the theoretical prediction appear after the word "Yes". Those which findings provide significant evidence but are contrary to the theoretical prediction appear after the word "No". Those studies that do not support the theoretical prediction appear after the word "No evidence".

Theorical prediction	Empirical Evidence
HOUSE PRICE:	
Structural Characteristics	
House size	
Increases when house size increases	**Yes:** Angli and Gencay (1996), Bartik (1987), Bourassa and Peng (1999), Can and Megbolugbe (1997), Canavarro, Caridad and Ceular (2010), Furtado (2007), Goodman and Thibodeau (1995), Goodman and Thibodeau (1997), Morancho (2003), Palmiquist (1984), Pasha and Butt (1996), Parsons (1986), Pozo (2009), Rasmussen and Zuehlke (1990), Rodrigues (2008), Selim (2008), Tse (2002), Wen *et al.* (2005) **No evidence:** Limsombunchai *et al.* (2004), Neto (2008)
Number of bathrooms	
Increases when the number of bathrooms increases	**No:** Angli and Gencay (1996) **Yes:** Canavarro *et al.* (2010), Dubin (1998), Goodman and Thibodeau (1997), King (1977), Limsombunchai *et al.* (2004), Maurer *et al.* (2004), Morancho (2003), Ottensmann *et al.* (2008), Ozanne and Malpezzi (1985), Palmiquist (1984), Pasha and Butt (1996), Pozo (2009), Rodrigues (2008) **No evidence:** Kain and Quigley (1970), Tarré (2009), Tse (2002), Vieira (2005)

(continued)

Table 1 (*continued*):

Summary of empirical evidence of studies employing the hedonic model

Theorical prediction	Empirical Evidence
HOUSE PRICE:	
Structural Characteristics	
Type of House	
Increases with a given type of house	***Housing:*** **No**: Morancho (2003), Rodrigues (2008), Selim (2008) **Yes**: Pozo (2009) ***Story Home:*** **Yes:** Morancho (2003) ***Flat:*** **No**: Selim (2008) **Yes**: Kain and Quigley (1970), Pozo (2009), Rodrigues (2008)
Number of bedrooms	
Increases when the number of bedrooms increases	**Yes**: Awan, Odling-Smee and Whitehead (1982), Angli and Gencay (1996), Canavarro *et al.* (2010), Kain and Quigley (1970), Morancho (2003), Ottensmann *et al.* (2008), Pozo (2009), Rasmussen and Zuehlke (1990), Selim (2008), Vieira (2005) **No evidence**: Limsombunchai *et al*. (2004)
House age	
Increases when the house age increases	**No**: Bourassa and Peng (1999), Can and Megbolugbe (1997), Dubin (1998), Furtado (2007), Goodman and Thibodeau (1995), Goodman and Thibodeau (1997), Kain and Quigley (1970), Limsombunchai *et al.*(2004), Morancho (2003), Ottensmann *et al.* (2008), Pozo (2009), Rasmussen and Zuehlke (1990), Selim (2008), Tse (2002) Vieira(2005) **Yes:** Bartik (1987) **No evidence:** Awan *et al. (*1982), Wen *et al.* (2005)
Garage/private parking	
Increases when the house has garage or parking	**Yes:** Angli and Gencay (1996), Canavarro *et al.* (2010), Dubin (1998), Goodman and Thibodeau (1997), King (1977), Limsombunchai *et al.* (2004), Maurer *et al.* (2004), Morancho (2003), Ottensmann *et al.* (2008), Palmquist (1984), Pozo (2009), Rodrigues (2008), Tarré (2009),Wen *et al*. (2005)

(continued)

Table 1 (*continued*):

Summary of empirical evidence of studies employing the hedonic model

Theorical prediction	Empirical Evidence
HOUSE PRICE:	
Structural Characteristics	
Garage/private parking	
Increases when the house has a garage or parking	**No Evidence:** Selim (2008), Vieira (2005)
Pool	
Increases when the house has a pool	**Yes**: Goodman and Thibodeau (1997), Palmiquist (1984), Selim (2008)
Monthly condominium	
Increases when the monthly condominium increases	**Yes**: Furtado (2007)
Terrace	
Increases when the house has a terrace	**Yes**: Maurer *et al.*(2004)
Garden	
Increases when the house has a garden	**Yes**: Limsombunchai *et al.* (2004), Maurer *et al.* (2004) **No evidence**: Morancho (2003)
Air conditioning	
Increases when the house has an air conditioning	**Yes**: Angli and Gencay (1996), Dubin (1998), Canavarro *et al.* (2010), Goodman and Thibodeau (1997), Ottensmann *et al.* (2008), Palmquist (1984),
Elevator	
Increases when the house has an elevator	**Yes**: Maurer *et al.* (2004), Morancho (2003), Pozo (2009), Selim (2008) **No evidence:** Tarré (2009)
Sauna – Jacuzzi	
Increases when the house has a sauna or jacuzzi	**Yes**: Selim(2008)
Cable television	
Increases when the house has cable television	**Yes**: Selim(2008)
Equipped kitchen	
Increases when the house has an equipped kitchen	**Yes**: Rodrigues (2008)
Usage status	
Increases with a given housing usage status	***New:*** **Yes:** Maurer *et al.* (2004), Pozo (2009), Rodrigues (2008) ***Used:*** **Yes:** Rodrigues (2008)

(continued)

Table 1 (*continued*):

Summary of empirical evidence of studies employing the hedonic model

Theorical prediction	Empirical Evidence
HOUSE PRICE:	
Location Characteristics	
Near a lake / river / sea	
Increases when the the house is near a lake, a river or sea	**No**: Wen *et al.* (2005)
Near urban green spaces	
Increases when the house is near urban green spaces	**Yes:** Kong, Yin and Nakagoshi (2007), Morancho (2003)
Centre of township	
Increases when the house is located on the centre of township	**No**: Ottensmann *et al.* (2008), Ozanne and Malpezzi (1985) **Yes:** Pozo (2009)
Housing in a particular zone/district/county	
Varys when the House is located in a particular zone / district / county	**Yes**: Goodman (1978), Goodman and Thibodeau (1997), Limsombunchai *et al.* (2004), Neto (2008), Pasha and Butt (1996), Pozo (2009), Rodrigues (2008) **No evidence**: Kain and Quigley (1970)
Neighbourhood Characteristics	
Environmental quality	
Increases when the environmental quality increases	**Yes**: Wen *et al.* (2005)
Sea View	
Increases when the house has a sea view	**Yes**: Pozo (2009), Tse (2002)
Neighborhood quality	
Increases when the neighborhood quality increases	**Yes**: King (1977), Parsons (1986)
Near entertainment facility (tennis court, healthy club,etc)	
Increases when the house is located near an entertainment facility	**Yes**: Wen *et al.* (2005), Tse (2002)
Near public services (bank, supermarket, hospital, post office, School, university etc)	
Increases when the house is located near public services	**Yes**: Kong *et al.* (2007), Tse (2002) **No evidence:** Limsombunchai *et al.* (2004), Wen *et al.* (2005)

Internationally, the hedonic models have integrated the framework of several studies. Pasha and Butt (1996) applied a conventional framework of analysis of implicit markets to determine the characteristics of demand of housing attributes of quantity and quality in the urban area of a large, low-income developing country like Pakistan. The data set consists of 650 urban owner-occupier households located in the 11 major cities of

Pakistan. This study is innovative because it includes a weighted factor score for measurement of housing quality and the incorporation of the effect of changes in housing prices on demand for housing attributes. The authors concluded that, due the slow growth in the real incomes and the double-digit inflation in Pakistan residential overcrowding, conditions tend to get worse and worse.

Bourassa and Peng (1999), focusing their study on an area with a relatively high percentage of Chinese households in New Zealand, used the hedonic price model to investigate whether house values are affected by lucky and unlucky house numbers. The results demonstrate that lucky house numbers are capitalized into house values.

Morancho (2003) analysed the link between housing prices and urban green areas endowments using the hedonic prices. To explain housing prices, three environmental variables are included in the model: the existence of views of a park or a public garden, the distance from housing to its nearest green area and the size of that open space. The sample is composed of 810 housing from the city of Castellón (Spain). The study shows that the living area of the housing is the most relevant variable on the price. Regarding the environmental variables, only the distance from a green area is significant and, there is an inverse relationship between the selling price of the housing as expected and its distance from a green urban area.

Wen *et al.* (2005) analyzed a hedonic price model for Hangzhou City, in China. The study uses the characteristic analysis frame of structure-neighbourhood-location, chooses 18 housing characteristics as the independent variables of the model. This research found that 14 out of 18 characteristics had significant influence on housing price, such as floor area, garage, distance to city centre, traffic condition, entertainment facilities, etc.

Kong *et al.* (2007) applied a hedonic price model to valuate the urban green space amenities. The study was conducted in Jinan City, the capital of Shandong Province in China. The sample was composed of 124 housing clusters. The housing clusters are located within the urban area and compared by roads. Results confirmed the positive amenity impact of proximity to urban green area spaces on house prices. The results should also provide insights to policy-makers involved in urban planning.

Selim (2008) analyzed the determinants of house prices in Turkey. The sample is composed of 2004 housing. The results showed that the most important variables that affect house rents are the type of house, type of building, number of rooms, size, and other structural characteristics such as water system, pool and natural gas.

Pozo (2009) analyzed the factors shaping the price of private housing in Spain, specifically in Malaga. The results obtained enable us to both identify the housing attributes that most influence price and quantify their impact in monetary terms. The study concluded that some structural attributes, such as surface area, number of bathrooms, private parking or poor natural light, and certain location attributes, such as proximity to the seaside or city centre and location within a given district, have a determinant effect on the price of housing.

In Portugal, hedonic pricing models have been a subject of some research.Vieira (2005), based on the island of São Miguel in Azores, developed his study analyzing the price that individuals are willing to pay for a house in view of its characteristics. The results showed that the most important variable that affect housing prices is the number of rooms. Overall, her results also demonstrated that the price of housing decreases with the increase of its age. However, there are housing with high age that, given their value and heritage, do not confirme the inverse relation between age and price. Finally, the study also noted that the fact that a person is unmarried and has a higher yield increases his/her predisposition to buy a more expensive housing.

Rodrigues (2008) developed his research with the aim of specifying a hedonic model of housing prices to Portugal. The study concludes that the housing price is positively affected if the housing is located in Coimbra, Lisboa, Porto and Setúbal. The inverse relation takes place when the housing is located in Leiria or Braga. The housing price is also positively influenced, although in different proportions, by the existence of garage, equipped kitchen, full bathroom and size. Finally, the typology of housing and the usage status also influence housing price.

Later that year, Neto (2008) restricted the application of a hedonic model for evaluation of housing in Gaia. The author divides the market into three zones of study and concludes

that, for each zone, the housing price is influenced by quality of construction, project quality and the housing location.

Tarré (2009) also made her contribution by implementing the hedonic model, at two distinct zones of Lisbon (parish of Benfica and São Domingos Benfica and parish of Lapa, Santo Condestável and Santa Isabel). The results show that the value of the evaluation per square meter of a housing situated in the parish of Benfica and São Domingos Benfica is strongly influenced by the usage status of housing, number of parkings and by the specificity of the property. In the parish of Lapa, Santo Condestável and Santa Isabel, the value is strongly influenced by the number of parkings, the specificity of the property and the existence of storage room.

In all these works, several different variables have been used. The authors resorted to a variety of sources of information from credit bureaus, rating agencies, real estate and real estate portals accessible on the Internet, where, instead of selling prices, there are bid values. A limitation pointed by most authors in this area, is the difficulty in obtaining data for the application of hedonic models.

3. METHODOLOGY

In this section, we present the problems associated with the hedonic price model and a brief review of possible functional forms. We also present, the methodology and the data source.

3.1. Problems associated with the hedonic price model

The housing market has, in itself, a behaviour that makes it distinct from other markets. The characteristics of the buildings are sometimes unique and an analysis of their value is at times not an easy task. On the one hand, there is no information from agents; on the other hand, there is some difficulty in understanding the mechanism of these markets.

Usually, the price analysis is done with the multiple regression analysis. However, the use of multiple regression analysis poses several problems affecting the statistical validity of the model.

According Gageiro and Pestana (2005), in order for the analysis of multiple regression analysis to be valid, it is necessary to check the following assumptions: (1) homoscedasticity of residues (the variance is constant); (2) the residues must follow a normal distribution; (3) absence of autocorrelation (independence between the residuals); and, (4) multicollinearity among independent variables (there is independence between the independent or explanatory variables).

On what concerns the housing market, which presents unique characteristics, there is always the risk of failing to observe any of these assumptions.

González and Formoso (2000) refer essentially two limitations of using multiple regression analysis: spatial correlation and the determination of functional form. When there is spatial autocorrelation, the estimators obtained by ordinary least squares are ineffective, thus causing restrictions on the models' validity. Moreover, another problem is the determination of the appropriate functional form, that is, which variables to include and in what format. The authors also describe other problems associated with hedonic models, such as multicollinearity, caused by strong inter-relationships between the

independent variables, and heteroscedasticity caused by not proper account for spatial variations in the model.

Sheppard (1997) also points out two problems intrinsic to the econometric estimation of hedonic prices: collinearity and the lack of stochastic independence between observations. With respect to collinearity, the author argues that it is natural to expect collinearity associated with the estimation of hedonic prices, given the similarity in the preferences of housing and limits on the technology of constructing the building. The author argues that a solution to solve the problem of collinearity is to obtain more information. Regarding the problem of lack of stochastic independence between observations, the author argues that an error in an observation correlates with observations automatically located nearby.

Goodman and Thibodeau (1995) also refer to the problem of variance of residuals. The authors concluded that the variance of the residues in the hedonic equation increases with the age of housing. This conclusion has been challenged, particularly critics substantiate that the expression used by the authors was not appropriate because there are important structural characteristics omitted. On the other hand, it was argued that the heterogeneity observed could be attributed to the influences of neighbourhood, which occurred because the empirical analysis had not sufficient spatial detail. Two years later, Goodman and Thibodeau (1997) found that, the addition of a wider set of structural characteristics to the hedonic expression, as well as the subdivision of the market study, contributes to the segmentation control and by consequence seeks to control for heteroscedasticity.

3.2. Functional form

There is no theoretical basis for choosing the correct functional form for a hedonic regression. Several authors have tested different functional forms, such as linear, logarithmic, quadratic and cubic.

Follain and Malpezzi (1980 as cited in Malpezzi, 2002, pp. 20-21) tested the linear and logarithmic form and found that the logarithmic form has some advantages over the linear form. Five of these advantages are: (1) enhancement of the variation of each characteristic; (2) making easy the interpretation of coefficients, since a coefficient can be interpreted as the change in value given a change in an independent variable; (3) helping

to combat the statistical problem known as heteroscedasticity; (4) turn to be computationally simple and very adaptable to examples; and (5) has more flexible specification, since it allows the use of dummy variables in the estimation.

Cropper, Deck and McConnell (1988) examined how errors in measuring marginal attribute prices vary with the form of the hedonic price function. The authors conclude that when all attributes are observed, linear and quadratic Box-Cox forms produce lower mean percentage errors. In these cases, linear and quadratic functions of Box-Cox transformed variables provide the most accurate estimates of marginal prices. But when some attributes are unobserved or replaced by proxies, linear and linear Box-Cox functions perform better. In these cases, a simple linear hedonic price consistently outperforms the quadratic Box-Cox function, which provides badly biased estimates of "hard to measure" attributes.

Rasmussen and Zuehlke (1990) argue about the usefulness of quadratic models in the estimation of hedonic price functions. The authors conclude that a quadratic semi-log model outperforms the linear Box-Cox specification in terms of explanatory power without the corresponding loss in the ability to interpret the coefficient estimates.

More recently, Bello and Moruf (2010) advocate that different types of functional forms, such as linear form, semi-log form and log form have been applied in empirical studies. The authors used hedonic price models to study the house prices in Lagos, Nigeria. Three functional forms were used in the models: linear form, semi-log form and double-log form. From the whole three, semi-log functional form gives the best fit, especially with respect to the coefficient of determination, i.e., the results show the superiority of semi-log specification over other functional forms.

In our work, the linear, logarithmic, squared and cubic forms will be tested to choose the best functional form.

3.3. Empirical model specification

After having carried out a literature review, it appears that there are characteristics associated with housing that are common to various authors. The empirical study will use the independent variables listed by Angli and Gencay (1996), Goodman and Thibodeau

(1997), Maurer *et al.* (2004), Morancho (2003), Ozzane and Malpezzi (1985), Pozo (2009), Rodrigues (2008), Selim (2008) and Wen *et al.* (2005). According to what has been previously stated, many functional forms, such as linear, logarithmic, squared and cubic will be tested and only the best form is used to proceed with the empirical study. The general formula considered of the hedonic function is as follows:

$$P(X) = f(L, S, N) \quad (3.1)$$

Where:

P(X) - Housing price

L - Location characteristics

S - Structural characteristics

N - Neighbourhood characteristics

3.4. Source of sample collection

The collection of data necessary to proceed with the empirical research was carried out solely from information available on the Internet. For the compilation of the sample, *Portal Casa Sapo* was selected. The website chosen has a great coverage nationwide, so that will be used exclusively. Moreover, the use of multiple portals could bias the study, since there might be a risk of repeated observations. The period of data collection took place between the months of October 2010 and December 2010. We proceeded to market segmentation into submarkets, that is, the division was made from observations in 16 submarkets (counties belonging to the district of Leiria). The final sample is composed of 4022 housing, offered for sale, in *Portal Casa Sapo* , in the district of Leiria. Figure 1 shows the distribution of observations by the analyzed counties.

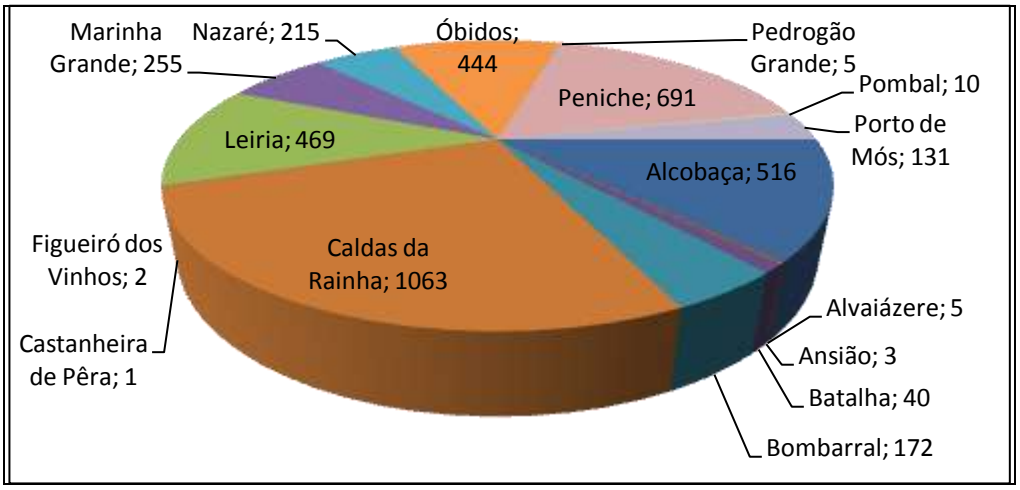

Figure 1: **Distribution of observations by counties**

The most represented county in the sample is Caldas da Rainha, followed by Peniche, Alcobaça and Leiria. Counties of Ansião, Castanheira de Pêra, Figueiró dos Vinhos and Pedrógão Grande are sparsely represented in the sample, so there will be difficulties on the convergence for these counties in the regression models.

3.5. Variables definition

3.5.1 Dependent variable

According, Canavarro *et al.* (2010), Kong *et al.* (2007) and Morancho (2003), as dependent variable, the offer price by housing available for sale, rather than sale value, was considered.

3.5.2. Independent variables

Independent variables were selected according to the characteristics set of housing, available on the *portal Casa Sapo*. For inclusion in the model, the transformation of qualitative variables in dummy variables was made.

Table 2:

Definitions and sources of independent variables

Variable	Variable name	Definition	Source	Expected sign on price
Structural characteristics				
Age	Age of housing	The difference between the current year, i.e., 2011, and the year when housing began to be built or restored	Goodman and Thibodeau (1997)	Negative (-)
Hs	House Size	Total floor area of one housing in square meters. For estimation of the model we use the useful area	Goodman and Thibodeau (1997)	Positive (+)
CTV	Cable TV	Dummy=1 if the housing has cable TV; 0 otherwise	Selim (2008)	Positive (+)
PL	Pool	Dummy=1 if the housing has pool; 0 otherwise	Goodman and Thibodeau (1997)	Positive (+)
JZZ	Jacuzzi	Dummy=1 if the housing has jacuzzi; 0 otherwise	Selim (2008)	Positive (+)
SN	Sauna	Dummy=1 if the housing has sauna; 0 otherwise	Selim (2008)	Positive (+)
GRPK	Garage or parking	Dummy=1 if the housing has garage or parking; 0 otherwise	Pozo (2009)	Positive (+)

(*continued*)

Table 2 (*continued*):

Definitions and sources of independent variables

Variable	Variable name	Definition	Source	Expected sign on price
		Structural characteristics		
EQK	Equipped kitchen	Dummy=1 if housing has equipped kitchen; 0 otherwise	Rodrigues (2008)	Positive (+)
TYP	Type of house	We include 6 dummy variables identifying the type of housing [a)]	Pozo (2009), Morancho (2003) Selim (2008)	Positive (+)/ Negative (-)
BED	Number of bedrooms	We include 9 dummy variables identifying the number of bedrooms (1 to 9 bedrooms)	Angli and Gencay (1996)	Positive (+)/ Negative (-)
TRR	Terrace	Dummy=1 if housing has terrace; 0 otherwise	Maurer *et al.* (2004)	Positive (+)
US	Usage status	We include 5 dummy variables identifying the usage status of housing [b)]	Rodrigues (2008)	Positive (+)
		Location characteristics		
NRSL	Near a river, sea, lake	Dummy=1 if housing is located near a river, sea or lake; 0 otherwise	Wen *et al.* (2005)	Positive (+)
NFGMP	Near green spaces (field, gardens, mountains, pine forest)	Dummy=1 if housing is located near green spaces; 0 otherwise	Morancho (2003)	Positive (+)
CT	Housing is located in a particular county	To control for differences in housing prices between counties, we include 15 counties dummy variables [c)]	Pozo (2009)	Positive (+)/ Negative (-)
DWT	Downtown or in the city	Dummy=1 if housing has good access to the downtown; 0 otherwise	Ozzane and Malpezzi (1985)	Negative (-)
		Neighbourhood characteristics		
NEF	Near entertainment facility (playground, shopping centre, tennis court, gym)	Dummy=1 if housing is located near entertainment facility; 0 otherwise	Wen *et al.* (2005)	Positive (+)
NPS	Near public services (schools, police station, pharmacy, supermarket, public transportations, health centre, hospital, banks, train, fire-brigade, church)	Dummy=1 if housing is located near public services; 0 otherwise	Wen *et al.* (2005)	Positive (+)

(continued)

Table 2 (*continued*):

Definitions and sources of independent variables

Note. [a)] To represent the type of house variable we use 6 dummy variables TYP_1 (flat); TYP_2 (old house); TYP_3 (cottage); TYP_4 (story home); TYP_5 (housing) and TYP_6 (germinated housing). [b)] To Usage status Variable we use the following dummy variables: US_un (under construction); US_nw (new); US_tc (to recover), US_rc (recovered) and US_us (used). [c)] To represent the location of a housing in one of the existent counties (16 counties) at the Leiria district we creat 15 dummy variables: CT_al (Alcobaça); CT_av (Alvaiázere); CT_an (Ansião); CT_bt (Batalha); CT_bo (Bombarral); CT_cr (Caldas da Rainha); CT_fv (Figueiró dos Vinhos); CT_l (Leiria); CT_mg (Marinha Grande); CT_nz (Nazaré); CT_ob (Óbidos); CT_pg (Pedrogão Grande); CT_pe (Peniche); CT_pb (Pombal) and CT_pm (Porto de Mós).

4. PRESENTATION AND DISCUSSION OF RESULTS

This section describes and discusses the results. We present the descriptive statistics, and the multiple linear regression model.

4.1. Descriptive statistics

The sample integrates 4022 observations. Tables 3 and 4 provide summary statistics of the dependent variable and independent variables. In the sample, the price has a mean value of € 168 918.00, with a dispersion value of 108 028. The minimum and maximum values are, respectively, € 17 500.00 and € 1 500 000.00. The age has a mean value of 7.55 years, with a dispersion value of 11.65. The minimum and maximum values are, respectively, 0 and 111 years. The house size has a mean value of 183.38 m^2, with a dispersion value of 161.82. The minimum and maximum values are, respectively, 20m^2 and 2980 m^2. In table 4, we present the percentage of each characteristic in the sample.

Table 3:

Summary statistics of dependent variable and continuous independent variables

	N	Mean	Std. Deviation	Minimum	Maximum
Dependent Variable:					
OFFER PRICE	4022	168 918	108 028	17 500	1 500 000
Independent Variables:					
Structural characteristics:					
Age of housing	4022	7.55	11.65	0	111
House size: Floor area (m2)	4022	183.38	161.82	20	2980

Table 4:

Summary statistics of dummy independent variables

	N	%
Structural Characteristics		
Cable TV	266	6.6%
Pool	253	6.3%
Jacuzzi	6	0.1%
Sauna	10	0.2%
Garage or parking	1389	34.5%
Equipped kitchen	380	9.4%
Terrace	310	7.7%
Type of house:		
Flat	650	16.2%
Old house	81	2.0%
Cottage	88	2.2%
Story home	3	0.1%
Housing	2209	54.9%

(continued)

Table 4 *(continued)*:

Summary statistics of dummy independent variables

	N	%
Structural Characteristics		
Type of house:		
Housing geminated	989	24.6%
Number of bedrooms:		
Bed 1	327	8.1%
Bed 2	973	24.2%
Bed 3	1880	46.7%
Bed 4	669	16.6%
Bed 5	114	2.8%
Bed 6	29	0.7%
Bed 7	14	0.3%
Bed 8	5	0.1%
Bed 9	7	0.17%
Usage status:		
Under construction	547	13.6%
New	1725	42.9%
To recover	61	1.5%
Recovered	72	1.8%
Used	1557	38.7%
Location Characteristics		
County:		
Alcobaça	516	12.8%
Alvaiázere	5	0.1%
Ansião	3	0.1%
Batalha	40	1.0%
Bombarral	172	4.3%
Caldas da Rainha	1063	26.4%
Figueiró dos Vinhos	2	0.1%
Leiria	469	11.7%
Marinha Grande	255	6.3%
Nazaré	215	5.3%
Óbidos	444	11.0%
Pedrogão Grande	5	0.1%
Peniche	691	17.2%
Pombal	10	0.2%
Porto de Mós	131	3.3%
Downtown or in the city	560	13.9%
Near Green Spaces	616	15.3%
Near a River, Sea, Lake	208	5.2%
Neighbourhood Characteristics		
Near entertainment facility	772	19.2%
Near public services	1097	27.3%

4.2. Multiple linear regression model

Analytically, our hedonic equation is defined as follows:

$$\begin{aligned} Y_i = {} & \beta_0 + \beta_1 \cdot Age_i + \beta_2 \cdot Hs_i + \beta_3 \cdot CTV_i + \beta_4 \cdot PL_i + \beta_5 \cdot JZZ_i + \beta_6 \cdot SN_i \\ & + \beta_7 \cdot GRPK_i + \beta_8 \cdot EQK_i + \sum_{j=1}^{6} \beta_{8+j} \cdot TYP_{j,i} + \sum_{j=1}^{9} \beta_{14+j} \cdot BED_{j,i} + \beta_{24} \cdot TRR_i \\ & + \sum_{j=1}^{5} \beta_{24+j} \cdot US_{j,i} + \beta_{30} \cdot NRSL_i + \beta_{31} \cdot NFGMP_i + \sum_{j=1}^{15} \beta_{31+j} \cdot CT_{j,i} + \beta_{47} \cdot DWT_i \\ & + \beta_{48} \cdot NEF_i + \beta_{49} \cdot NPS_i + \varepsilon_i \end{aligned} \tag{4.1}$$

Y_i is the dependent variable, in this case, the offer price. i represents the i^{th} sample observation in n observations. β_k are the model parameters that indicate the variation on the expected value of Y, due to the variation of one unit in independent variables, when all the other independent variables in the model remain constant. ε_i is the random term (or perturbation term), which represents all the variables with explainable power over the dependent variable not included in the model. To find "good" estimators of regression parameters, we use the least squares method.

As this is a multiple linear regression model, beyond the inference for each parameter, we must determine if the model is globally significant, through a test of significance of the coefficient of determination (F test), which allows checking if the multiple linear regression model is globally significant. This test, however, does not indicate if all the variables are significant, or which ones are most important; it is, therefore, necessary to apply the t test to determine the significance of each variable in particular.

The coefficient of determination (R^2) appears as a measure of the effect of the explanatory variables in reducing the variation of Y_i, i.e., in reducing the uncertainty associated with the prediction of Y_i. Otherwise, the R^2 measures the percentage or proportion of total variation of Y_i explained by the model.

Adding more variables to the regression model can only increase the R^2. To address this, it is usually suggested a measure that adjusts for the number of independent variables in the model – determination coefficient. The adjustment is simply to divide the two sums of squares by their degrees of freedom. This coefficient can assume a lower value, when introducing an additional explanatory variable, because a reduction in the sum of squared errors can be compensated for the loss of one more degree of freedom in the denominator.

4.2.1. Selection of the best functional form for the regression model

The linear, logarithmic, squared and cubic functional forms were tested, and the quality of the linear fit obtained, with the coefficient of determination (R^2) and the adjusted coefficient of determination (Ra^2) being used as a criterion to select the best functional form. In these linear regression models, all the independent variables are used.

Table 5:

Determination coefficients and functional forms

Model	R Square	Adjusted R Square
Linear	0.510	0.504
Logarithmic	0.494	0.488
Squared	0.546	0.540
Cubic	0.553	0.547

The quality of the obtained fit is better for the cubic functional form, with R^2 = 55.3%, followed by the squared functional form, with R^2 = 54.6%, being the quality of the adjustment lower for the linear (R^2 = 51.0%) and logarithmic (R^2 = 49.4%) functional forms. Among others, see Anglin and Gengay (1996) with R^2 = 68.7%, Ozanne and Malpezzi (1985) with R^2 = 56% and Pasha and Butt (1996) with R^2 = 54.1%. The same remarks can be made upon the comparison of the adjusted coefficient of determination. Thus, we can easily conclude that the cubic functional form should be used. In the cubic functional form, we will use the dependent variable *price* and our hedonic equation is now defined as follows:

$$\begin{aligned} Y_i = {} & \beta_0 + \beta_1 \cdot Age_i + \beta_2 \cdot Age_i^2 + \beta_3 \cdot Age_i^3 + \beta_4 \cdot Hs_i + \beta_5 \cdot Hs_i^2 + \beta_6 \cdot Hs_i^3 + \beta_7 \cdot CTV_i \\ & + \beta_8 \cdot PL_i + \beta_9 \cdot JZZ_i + \beta_{10} \cdot SN_i + \beta_{11} \cdot GRPK_i + \beta_{12} \cdot EQK_i + \sum_{j=1}^{6} \beta_{12+j} \cdot TYP_{j,i} \\ & + \sum_{j=1}^{9} \beta_{18+j} \cdot BED_{j,i} + \beta_{28} \cdot TRR_i + \sum_{j=1}^{5} \beta_{28+j} \cdot US_{j,i} + \beta_{34} \cdot NRSL_i + \beta_{35} \cdot NFGMP_i \\ & + \sum_{j=1}^{15} \beta_{35+j} \cdot CT_{j,i} + \beta_{51} \cdot DWT_i + \beta_{52} \cdot NEF_i + \beta_{53} \cdot NPS_i + \varepsilon_i \end{aligned} \tag{4.2}$$

The cubic functional form has been used, for example, by Goodman and Thibodeau (1995) for capturing the effects age. We will have two types of reading in the cubic functional form:

- For continuous independent variables, the rate at which an amenity adds to the price of a house does not stay constant, and can change at a rate that, it self, varies. For example, a case of decreasing additional returns followed by increasing additional returns. This would visually represented by an approximate S-shaped curve;

- For dummy variables, the presence of the characteristic causes an average change of the dependent variable *OFFER PRICE* equal to the value of the coefficient.

4.2.2. Construction of the regression model

The baseline regression model integrates all the independent variables. In table 6, we present the most relevant results for the regression model originally built, as well as the independent variables selected in this model, and levels of significance or probative value.

The determination coefficient indicates that 55.3% of the variation that occurs in the dependent variable *OFFER PRICE* is explained by the variables included in the model. The adjusted coefficient of determination is 54.7%.

The *F* test, for overall significance of the model, is validated by having zero significance, less than 5%, which allows rejecting the hypothesis that there are no significant independent variables for the model.

Table 6:

Coefficients for the variables in the baseline model and significance level

	Predicted influence	β_i	*t*
(Constant)		41.087	(0.672)
Age	-	0.043	(0.888)
Age^2	-	-0.231**	(-2.084)
Age^3	-	0.173**	(2.338)
House size	+	1.030***	(20.207)
House $size^2$	+	-1.266***	(-11.487)
House $size^3$	+	0.575***	(7.523)
Cable TV	+	0.015	(1.229)
Pool	+	0.095***	(7.827)
Jacuzzi	+	0.035***	(3.268)
Sauna	+	0.031**	(2.849)
Garage or parking	+	-0.020	(-1.494)
Equipped kitchen	+	0.031***	(2.620)
Flat	+ / -	0.035	(0.200)
Old house	+ / -	0.016	(0.230)
Cottage	+ / -	-0.007	(-0.101)
Story home	+ / -	0.003	(0.150)
Housing	+/-	-0.004	(-0.015)

(continued)

Table 6 *(continued)*:

Coefficients for the variables in the baseline model and significance level

	Predicted influence	β_i	*t*
Geminated housing	+ / -	-0.047	(-0.226)
Bed_1	-	-0.069	(-0.714)
Bed_2	-	-0.085	(-0.569)
Bed_3	+	-0.051	(-0.293)
Bed_4	+	0.098	(0.758)
Bed_5	+	0.124**	(2.111)
Bed_6	+	0.108***	(3.468)
Bed_7	+	0.050**	(2.184)
Bed_8	+	0.038**	(2.330)
Bed_9	+	0.161***	(8.983)
Terrace	+	0.036***	(3.137)
Under construction	+	-0.043**	(-1.350)
New	+	-0.104*	(-2.354)
To recover	+	-0.106***	(-6.597)
Recovered	+	-0.043***	(-2.689)
Used	+	-0.153***	(-3.475)
Near a river, sea, lake	+	0.063***	(5.339)
Near green spaces	+	-0.023*	(-1.805)
Alcobaça	+ / -	0.221	(0.329)
Alvaiázere	+ / -	0.001	0.053)
Ansião	+ / -	0.026	(1.205)
Batalha	+ / -	0.010	(0.149)
Bombarral	+ / -	0.050	(0.363)
Caldas da Rainha	+/-	0.226	(0.757)
Figueiró dos Vinhos	+/-	-0.002	(-0.081)
Leiria	+ / -	0.075	(0.346)
Marinha Grande	+ / -	0.023	(0.137)
Nazaré	+ / -	0.163	(1.068)
Óbidos	+ / -	0.333	(1.574)
Pedrogão Grande	+ / -	0.010	(0.386)
Peniche	+ / -	0.180	(0.705)
Pombal	+ / -	0.015	(0.413)
Porto de Mós	+ / -	0.023	(0.189)
Downtown or in the city	-	-0.012	(-0.789)
Near entertainment facility	+	0.011	(0.645)
Near public services	+	-0.032*	(-1.855)
R Square	0.553		
Adjusted R Square	0.547		
F test	92.757 ***		
Durbin-Watson	1830		
Observations	4022		

(continued)

Table 6 *(continued)*:

Coefficients for the variables in the baseline model and significance level

Note. β_i is the coefficient estimation for variable i. The significance levels are indicated by *, ** and *** that represent 10%, 5% and 1% level, respectively. The predicted influence column indicates that the corresponding variable is predicted to have + (positive), - (negative) or + /- (variable from case to case) influence on the Offer Price.

The variable which estimated coefficient has positive value contributes positively to the increase in the dependent variable *OFFER PRICE* and the ones having negative estimates produced the opposite effect. For dummy variables, the presence of the characteristic causes an average change in price equal to the value of coefficient, keeping other variables constant. For example, the presence of *pool* causes an average change positively in price of 0.095 units. For continuous variables, with the cubic functional form, the rate at which a characteristic adds to the price does not stay constant. For example, the *house size*, it is a case of decreasing additional returns followed by increasing additional returns.

The next step is a crucial moment in the study of the relationship between the variables. The regression model, initially, can integrate all the independent variables. Through a process of systematic analysis of the importance of each variable in the model developed, not relevant variables will be eliminated step by step, according to the criteria for analysis of the significance of independent variables - the maximum adjusted coefficient of determination. Using the *stepwise*, *backward* or *forward* procedures, which primarily develop a sequence of regression models, adding or removing (as appropriate) at each step an independent variable, exactly the same results are produced, in terms of R^2. The procedure *stepwise* was used, since it produces more significant variables. In table 7, the results are presented.

Table 7:

Coefficients for the variables in the model and significance level

	Predicted influence	β_i	*t*
(Constant)		58 809	(12.090)
Age	-	-0.035***	(-2.784)
Age^2	-	na	
Age^3	-	na	
House size	+	1.036***	(20.803)
House $size^2$	+	-1.282***	(-11.814)
House $size^3$	+	0.586***	(7.755)
Cable TV	+	na	
Pool	+	0.095***	(7.936)

(continued)

Table 7 *(continued)*:

Coefficients for the variables in the model and significance level

	Predicted influence	β_i	*t*
Jacuzzi	+	0.035***	(3.258)
Sauna	+	0.032***	(2.906)
Garage or parking	+	na	
Equipped kitchen	+	0.028***	(2.450)
Flat	+/-	0.041***	(3.455)
Old house	+/-	na	
Cottage	+/-	na	
Story home	+/-	na	
Housing	+/-	na	
Geminated housing	+/-	-0.041***	(-2.721)
Bed_1	-	na	
Bed_2	-	na	
Bed_3	+	0.055***	(3.956)
Bed_4	+	0.178***	(12.221)
Bed_5	+	0.158***	(13.296)
Bed_6	+	0.126***	(11.324)
Bed_7	+	0.062***	(5.736)
Bed_8	+	0.045***	(4.149)
Bed_9	+	0.171***	(15.804)
Terrace	+	0.032***	(2.849)
Under construction	+	na	
New	+	-0.044***	(-2.790)
To recover	+	-0.094**	(-7.740)
Recovered	+	-0.026**	(-2.998)
Used	+	-0.092***	(-5.566)
Near a river, sea, lake	+	0.063***	(5.412)
Near green spaces	+	-0.027**	(-2.157)
Alcobaça	+/-	0.056***	(4.835)
Alvaiázere	+/-	na	
Ansião	+/-	na	
Batalha	+/-	-0.039***	(-3.597)
Bombarral	+/-	-0.052***	(-4.650)
Caldas da Rainha	+/-	na	
Figueiró dos Vinhos	+/-	na	
Leiria	+/-	-0.083***	(-7.282)
Marinha Grande	+/-	-0.099***	(-8.820)
Nazaré	+/-	0.052***	(4.675)
Óbidos	+/-	0.179***	(15.524)
Pedrogão Grande	+/-	na	
Peniche	+/-	na	
Pombal	+/-	na	
Porto de Mós	+/-	-0.063***	(-5.698)

(continued)

Table 7 *(continued)*:

Coefficients for the variables in the model and significance level

	Predicted influence	β_i	*t*
Downtown or in the city	-	na	
Near entertainment facility	+	na	
Near public services	+	-0.035***	(-2.949)
R Square	0.551		
Adjusted R Square	0.547		
F test	148.032***		
Durbin-Watson	1830		
Observations	4022		

Note. β_i is the coefficient estimation for variable i. The significance levels are indicated by *, ** and *** that represent 10%, 5% and 1% level, respectively, *na* indicates that the variable are not significant in explaining the dependent variable and is therefore, excluded form model. The predicted influence column indicates that the corresponding variable is predicted to have + (positive), - (negative) or + /- (variable from case to case) influence on the Offer Price.

With *stepwise* process, only variables with less than 10% *p-value* are included in the model. The variables that have *p-value* exceeding 10% are excluded from the model and, so, are not significant in explaining the dependent variable. The adjusted coefficient of determination is 55.1%. The coefficients are adjusted. Now, in what respects continuous independent variables, the variables Age^2 and Age^3 become not significants and the variable *Age* becomes significant, but with negative influence on *OFFER PRICE*. Some of the variables dummies have also some changes in their behavior. The variable *Under construction* becomes not significant and the variables *germinated housing*, *Batalha*, *Bombarral*, *Leiria*, *Marinha Grande* and *Porto de Mós* become significants, with negative influence on *OFFER PRICE*. The variables *Bed_3*, *Bed_4*, *Nazaré* and *Óbidos* become significants with positively influence on *OFFER PRICE*.

The significance of the *t* test for each variable tells us the probability that this variable takes a null value in the model.

The next step is the outliers' analysis. The outliers are extreme cases influential in the statistical analysis. In the development of models, it is important to determine the set of observations that can be considered as outliers in order to equate their disposal in the construction of subsequent models so as to obtain refinements. The analysis of outliers, with the aim of identifying observations with such characteristics, will be made with the help of the following statistics: standardized residuals, studentized delete residuals, leverage, Cook's distance, standardized DfFit and standardized DfBeta (see appendix A).

4.2.3. Construction of the regression model without outliers

A new model was developed, excluding the outliers previously detected to explain the statistical relationships between variables in the analysis. After the removal of outliers, the sample actually studied consists of 3161 observations. The significant results for the final regression model are presented in table 8. It is worth noting that the variables *Jacuzzi, Sauna, Bed_6, Bed_7, Bed_8, Bed_9, To recover and Batalha* are not integrated in the model, at the outset, because they are constants or have missing correlations.

Table 8:

Coefficients for the variables in the final model and significance level

	Predicted influence	β_i	*t*
(Constant)		74 387	(19.141)
Age	-	-0.040***	(-3.843)
Age^2	-	0.019	(0.689)
Age^3	-	0.023	(1.294)
House size	+	0.772***	(10.708)
House $size^2$	+	-0.145	(-1.177)
House $size^3$	+	-0.045	(-0.686)
Cable TV	+	0.012	(1.077)
Pool	+	0.092***	(9.259)
Garage or parking	+	0.017	(1.565)
Equipped kitchen	+	0.031***	(3.104)
Flat	+/-	0.021**	(2.017)
Old house	+/-	0.017	(1.565)
Cottage	+/-	-0.006	(-0.572)
Story home	+/-	0.017	(1.565)
Housing	+/-	0.001	(0.110)
Geminated housing	+/-	-0.044***	(-3.043)
Bed_1	-	-0.012	(-0.974)
Bed_2	-	0.015	(0.817)
Bed_3	+	0.086***	(6.366)
Bed_4	+	0.194***	(14.188)
Bed_5	+	0.159***	(15.680)
Terrace	+	0.023**	(2.379)
Under construction	+	-0.044	(-1.400)
New	+	-0.122***	(-8.704)
Recovered	+	-0.052***	(-5.437)
Used	+	-0.212***	(-14.482)
Near a river, sea, lake	+	0.090***	(8.914)
Near green spaces	+	-0.017	(-1.584)
Alcobaça	+/-	0.056***	(5.617)
Alvaiázere	+/-	-0.017	(-1.603)

(continued)

Table 8 *(continued)*:

Coefficients for the variables in the final model and significance level

	Predicted influence	β_i	*t*
Ansião	+/-	0.013	(1.203)
Bombarral	+/-	-0.077***	(-8.035)
Caldas da Rainha	+/-	0.020	(1.365)
Figueiró dos Vinhos	+/-	-0.008	(-0.752)
Leiria	+/-	-0.126***	(-12.657)
Marinha Grande	+/-	-0.151***	(-15.496)
Nazaré	+/-	0.054***	(5.650)
Óbidos	+/-	0.184***	(18.630)
Pedrogão Grande	+/-	-0.007	(-0.613)
Peniche	+/-	-0.013	(-0.990)
Pombal	+/-	-0.010	(-0.927)
Porto de Mós	+/-	-1.07***	(-11.035)
Downtown or in the city	-	-0.001	(-0.097)
Near entertainment facility	+	0.011	(0.726)
Near public services	+	-0.026***	(-2.523)
R Square	0.730		
Adjusted R Square	0.728		
F test	338.465***		
Durbin-Watson	1701		
Observations	3161		

Note: The significance levels are indicated by *, ** and *** that represent 10%, 5% and 1% level, respectively. The predicted influence column indicates that the corresponding variable is predicted to have + (positive), - (negative) or +/- (variable from case to case) influence the Offer Price. . In β_i column *na* indicates that the variable are not significant in explaining the dependent variable and is therefore, excluded form model. Other variables presented in the table are significant for the model, because their p-value is less than 5% or at least 10%, being significant in explaining the dependent variable.

There is exclusion from the model of the variables that have p-value exceeding 10% and so are not significant in explaining the dependent variable.The determination coefficient indicates that 73% of the variation that occurs in the dependent variable *OFFER PRICE* is explained by the variables included in the model. The adjusted coefficient of determination is 72.8%, having increased when compared to the model with outliers.

The *F* test, for overall significance of the model, is validated by having zero significance, less than 5%, which allows rejecting the hypothesis that there are no significant independent variables for the model. The significance of the *t* test for each variable tells us the probability that this variable takes a null value in the model, being not significant, presenting all variables p-values of 5% or a minimum of 10% set as desirable.

The most important changes for the final model without the outliers, from the first built, reside in: (a) the increase of the coefficient of determination (the variation that occurs in the dependent variable, explained by the variables of the model); (b) the decrease in the standard deviation and (c) the reduction of variation associated to the coefficients of the significant independent variables. In Table 9 we present the summary of the empirical study.

Table 9:

Summary of empirical results

Variable	Variable name	Expect sign on price	Empirical result (sign on price)
Structural characteristics			
Age	Age of housing	Negative (-)	Negative (-)
Hs	House size	Positive (+)	Positive (+)
CTV	Cable TV	Positive (+)	No evidence
PL	Pool	Positive (+)	Positive (+)
JZZ	Jacuzzi	Positive (+)	Not integrated in the model
SN	Sauna	Positive (+)	Not integrated in the model
GRPK	Garage or parking	Positive (+)	No evidence
EQK	Equipped kitchen	Positive (+)	Positive (+)
TYP	Type of house	Positive (+) / Negative (-)	Positive (+): *flat* Negative (-):*geminated house* No evidence: *old house , cottage, story home, housing*
BED	Number of bedrooms	Positive (+) / Negative (-)	Positive *(+): 3 bedrooms, 4 bedrooms, 5 bedroom,* No evidence: *1 bedroom, 2 bedrooms* Not integrated in the model: *6 bedrooms, 7 bedrooms, 8 bedrooms, 9 bedrooms*
TRR	Terrace	Positive (+)	Positive (+)
US	Usage status	Positive (+)	Negative (-): *new, recovered, used* No evidence*: under construction* Not integrated in the model: *to recover*
Location characteristics			
NRSL	Near a river, sea, lake	Positive (+)	Positive (+)

(continued)

Table 9 *(continued)*:

Summary of empirical results

Variable	Variable name	Expect sign on price	Empirical result (sign on price)
Location characteristics			
NFGMP	Near green spaces (field, gardens, mountains, pine forest)	Positive (+)	No evidence
CT	Housing is located in a particular county	Positive (+) / Negative (-)	Positive (+): *Alcobaça, Nazaré, Óbidos* Negative (-): *Bombarral, Leiria, Marinha Grande, Porto de Mós* No evidence: *Alvaiázere, Ansião, Caldas da Rainha, Figueiró dos Vinhos, Pedrogão Grande, Peniche, Pombal* Not integrated in the model: *Batalha*
DWT	Downtown or in the city	Negative (-)	No evidence
Neighbourhood characteristics			
NEF	Near entertainment facility (playground, shopping centre, tennis court, gym)	Positive (+)	No evidence
NPS	Near public services (schools, police station, pharmacy, supermarket, public transportations, health centre, hospital, banks, train, fire-brigade, church)	Positive (+)	Negative (-)

To summarize, we find results largely consistent with expections. We found signs contrary to those expected in the variables *New, Recovered, Used* and *Near public services*. With regard to *Usage status* variables, the results are due to the fact that the crisis has negatively influenced the sales of housing which led to its devaluation even in the case of new housing. Regarding the variable *Near public services*, we concluded that people, due to the stress of day to day, prefer houses in quiet places, away from public services, where the movement of people is greater.

4.2.4. Final regression model validation, without the outliers

Regression models must meet certain conditions, the verification of which validates the developed models. Thus, it is necessary to perform statistical tests, including residual graphic analysis, study of multicollinearity, analysis of homoscedasticity and measurement of auto-correlation, with the purpose of validating the models. First, they

will be checked for homoscedasticity that, etymologically, means constant variance. One of the alternative procedures for analyzing the homoscedasticity is to observe the relationship between standardized residuals and standardized estimated values of the dependent variable and between studantized residuals and standardized estimated values of the dependent variable. In Figures 2 and 3, these relationships are illustrated.

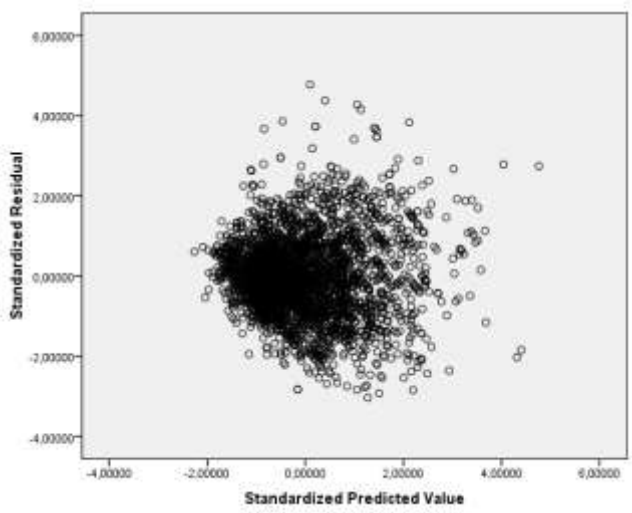

Figure 2: **Relationship between standardized residuals and standardized estimated values of the dependent variable**

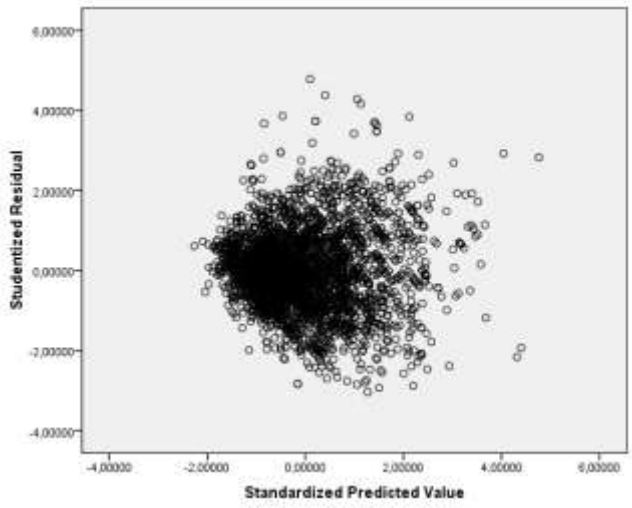

Figure 3: **Relationship between studentized residuals and standardized estimated values of the dependent variable**

There is an identical dispersion of residues to the entire range of standardized estimated values, which does not suggest a significantly different dispersion values over the values of the dependent variable.

A second assumption is to examine the lack of auto-correlation (independence) between the independent variables, using the Durbin-Watson test, which allows verifying if the error terms are independent, i.e., if the parameter of self-correlation is null. To test the null hypothesis of autocorrelation to be zero, for a significance level of 5%, we use the tables of Savin and White, that for more than 20 independent variables and sample size greater than 200 produce *dL* = 1.554 and *dU* = 1.991. The Durbin-Watson test has the following assumptions: (a) if the observed value of the test statistic is less than *dL*, the hypothesis of autocorrelation to be zero is rejected and we accept the assumption of positive autocorrelation; (b) if the test statistic is higher than *dU*, we do not reject the null hypothesis, there is no autocorrelation, and (c) if the value of the test statistic is between *dL* and *dU*, the test is inconclusive. In this context, we might err on the side of conservatism and not reject the null hypothesis.The test statistic has a value of 1.701. For a significance level of 5%, it is between the limits of *dL*=1.554 and *dU*=1.991, thus the test is inconclusive and the hypothesis that the autocorrelation is zero is not rejected. Thereby, there is no autocorrelation.

A third assumption states that the residuals must follow a normal distribution which can be verified with the Kolmogorov-Smirnov (KS) test, with the correction of Lilliefors, shown below in table 10.

Table 10:

Kolmogorov-Smirnov test

Statistics K-S (Lilliefors)	Degrees of freedom	Value of proof
0.034	3161	**0.000**

In Kolmogorov-Smirnov test the null hypothesis (H_0) is: the residuals follow a normal distribution. Usually, a significance level of 5% is required to not reject the hypothesis that residuals follow a normal distribution, which does not happen in this model, because the probative value is lower than 5%, thus, the hypothesis that residues follow a normal distribution is rejected. This may be due to the large sample size. In order to complement the study of normality of residuals, the graph that records the difference between the histogram of the distribution of residual random variables and normal distribution is presented, denoting the correspondence between the distribution of relative frequencies of residuals and the normal distribution curve.

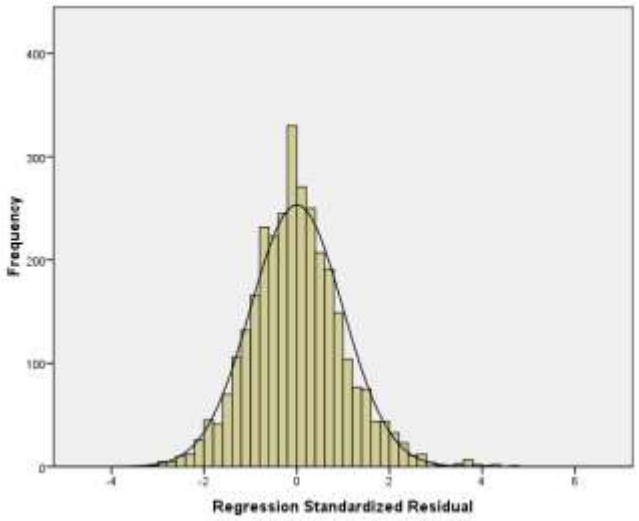

Figure 4: **Distribution of relative frequencies of residuals and the normal distribution curve**

Deviations from normality can also be observed in the graph, which presents the QQ graphs. This graph illustrates, by deviations from the oblique line, the differences from the normal distribution. Despite the results of Kolmogorov-Smirnov test, it appears that these deviations have hardly any relevance.

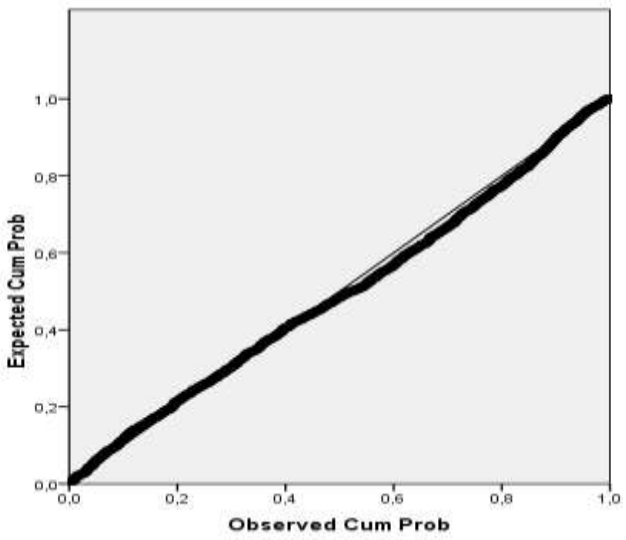

Figure 5: **QQ graphs**

Thus, we can conclude that the deviations from the normal distribution are not a big issue.

Finally, the assumption of the absence of multicollinearity should be checked. We use the variance inflation factor (VIF) as a measure of multicollinearity, which accounts for the inflation experienced by the variance of estimated regression coefficients caused by the correlation between variables. It can be shown that this factor, for a variable *k*, is:

$$(VIF)_k = \left(1 - R_k^{\,2}\right)^{-1} \qquad \text{k = 1, 2, …, p-1} \tag{4.3}$$

Where $R_k^{\,2}$ corresponds to the determination coefficient, when the independent variable *k* is related through a linear regression model, with the remaining *(p-2)* independent variables. High values of *VIF* are indicators of multicollinearity, the values above 10 are considered to influence the estimated regression coefficients. The *VIF* are presented for the variables used in the model, which high values indicate the existence of multicollinearity, and the *tolerances* (inverse of *VIF*) are also presented, which lower values below 0.1 also indicate the existence of multicollinearity. The multicollinearity means that there are independent variables strongly correlated between them, which causes that small changes in data values may lead to large changes in estimates of the coefficients of independent variables.

Table 11:

Tolerance and VIF test

	Tolerance	VIF
Age	0.805	1.242
House size	0.017	60.248
Pool	0.881	1.135
Equipped kitchen	0.655	1.158
Flat	0.770	1.299
Geminated housing	0.417	2.399
Bed_3	0.473	2.113
Bed_4	0.462	2.167
Bed_5	0.844	1.185
Terrace	0.923	1.084
New	0.440	2.274
Recovered	0.956	1.046
Used	0.403	2.481
Near a river, sea, lake	0.842	1.187
Alcobaça	0.869	1.151
Bombarral	0.951	1.051
Leiria	0.871	1.148

(Continued)

Table 11 *(continued)*:

Tolerance and VIF test

	Tolerance	VIF
Marinha Grande	0.907	1.102
Nazaré	0.935	1.069
Óbidos	0.881	1.135
Porto de Mós	0.918	1.090
Near public services	0.782	1.279

The *VIF* values are lower than the reference value of 10 for most variables, so there is no multicollinearity for these variables. However, the *VIF* values are more than 10 for the variable *House size*, responsible for the existence of multicollinearity. This situation has been referred by González and Formoso (2000), among others.

The analysis of the constructed model shows that it can be applied to the data studied, since it meets, in general, the assumptions tested.

5. CONCLUSION

The study developed in the previous sections aimed at the specification of a hedonic price model for the housing market in the district of Leiria.

It began with a brief characterization of the real estate, as well as possible methods for their evaluation. It was followed by an approach to the work previously carried out by several authors, both internationally and nationally. Afterwards, the necessary framework for the development of the study was built. The collection of data in order to proceed with the empirical research was conducted solely from information available on the Internet. This collection had its source in the *portal Casa Sapo* reported to 2010. It is worth noting that a single source of collection was adopted, in order to avoid repetition of observations and because it took into consideration that this portal has a wide national coverage.

The methodology proved to be effective in order to decompose the market price for the housing market in the district of Leiria.

According to the estimated results, it is expected that housing located in the counties of Alcobaça, Nazaré and Óbidos have a higher price. Thus, the location of the house in such counties influences its price positively. Conversely, it is also expected the fact that the price of a house located in the counties of Bombarral, Leiria, Marinha Grande and Porto de Mós tends to be lower. With respect to the variables of location and neighbourhood, the study concludes that a house located near a river, sea or a lake tends to be more expensive. The same is not true for houses located near public services, such as banks, schools, supermarkets, hospitals, where the price tends to be lower. With regard to structural characteristics, it was found that the fact that the house is a flat, also positively influences its price. Otherwise, germinated housing are cheaper. How is expected, housing with more bedrooms tend to be more expensive and, regarding usage status, recovered housing, new housing and used housing are cheaper. The study also shows that a house with pool, equipped kitchen and terrace tends to have a higher value. The area also positively influences the housing price. Contrarily, the age of house influences its price negatively. Summing up, the results support in a large scale those identified in the review of the literature by several authors for other geographical areas.

To conclude this dissertation, it is important to note some limitations that will be the challenge for future work. The main limitation to highlight relates to the fact that the sample does not mirror the housing market throughout the district of Leiria in sticking only to housing in which the information is complete with respect to the independent variables discussed. On the other hand, it was only possible to obtain information from 7 of the 16 counties of the district on grounds of loss of significance of its coefficient.

Another no less important limitation is that the price supplied by the portal is a figure quoted by the owner, and this tends to over-evaluate the housing, meeting his satisfaction rather than the market reality.

In short, although the model can be applied to the data studied, it is crucial to develop further studies to try to overcome the limitations stated.

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Appendix A: Outliers' analysis

In order to carry out outliers' analysis, it is important to introduce the H matrix, which understanding is facilitated by the matrix formulation of the model.

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \dots \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & \dots & X_{1,p-1} \\ 1 & X_{21} & \dots & X_{2,p-1} \\ \dots & \dots & \dots & \dots \\ 1 & X_{n1} & \dots & X_{n,p-1} \end{bmatrix} \cdot \begin{bmatrix} \beta_0 \\ \beta_1 \\ \dots \\ \beta_{p-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \dots \\ \varepsilon_n \end{bmatrix} \text{ or } \underset{(n\times 1)}{Y} = \underset{(n\times p)}{X} \cdot \underset{(p\times 1)}{\beta} + \underset{(n\times 1)}{\varepsilon} \tag{4.4}$$

The H matrix results from:

$$\underset{(n\times n)}{H} = X \cdot \left(X'X\right)^{-1} \cdot X' \text{, being X´ the transposed matrix of X.} \tag{4.5}$$

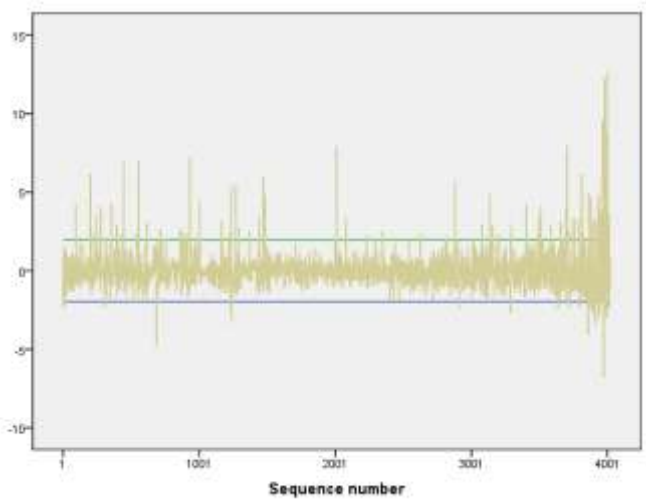
The residuals, for each observation, are calculated as the difference between the observed and the estimated values from the model for the dependent variable:

$$e_i = Y_i - \hat{Y}_i \tag{4.6}$$

From this values the standardized residuals can be determined:

$$e_i^{\,*} = \frac{e_i}{\sqrt{MSE}} \tag{4.7}$$

It is considered as an outlier any observation that the standardized residual has an absolute value above 1.96, for a significance level of 5%. In the model, some observations are identified as outliers, represented by the lines that exceed the limits in appendix A.1.



Appendix A.1: **Standardized residuals**

From the analysis of the standardized residuals, illustrated by appendix A.1, the detection of outliers identifies 156 cases. A first refinement, which makes the residuals more effective in the recognition of outliers, is the recognition of the fact that the observations may have different standard deviations between them. The standard deviation of an observation is estimated using the expression, where h_{ii} is the main diagonal element of matrix H for observation *i*.

$$s(e_i) = \sqrt{MSE(1 - h_{ii})} \tag{4.8}$$

The quocient between each residual and the estimated standard deviation is the studentized residual (4.9):

$$r_i = \frac{e_i}{s(e_i)} \tag{4.9}$$

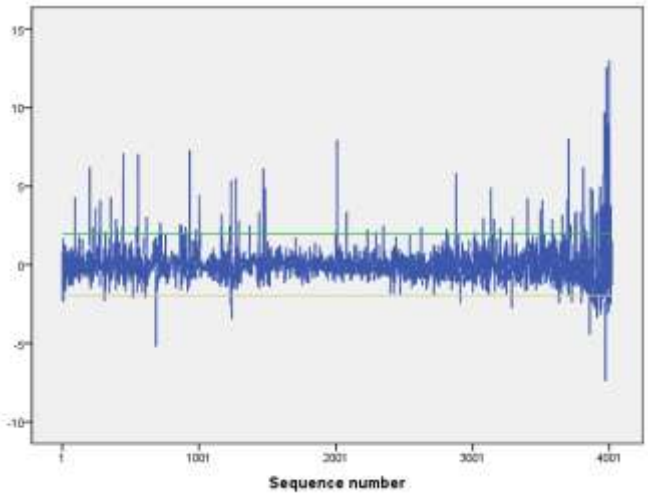
A second improvement results from the calculation of the residuals for observation i, when the regression model is based on all data, with the exception of observation i, obtaining the deleted residuals (4.10):

$$d_i = Y_i - \hat{Y}_{i(i)} \tag{4.10}$$

Combining both introduced forms, the studentized deleted residuals can be calculated:

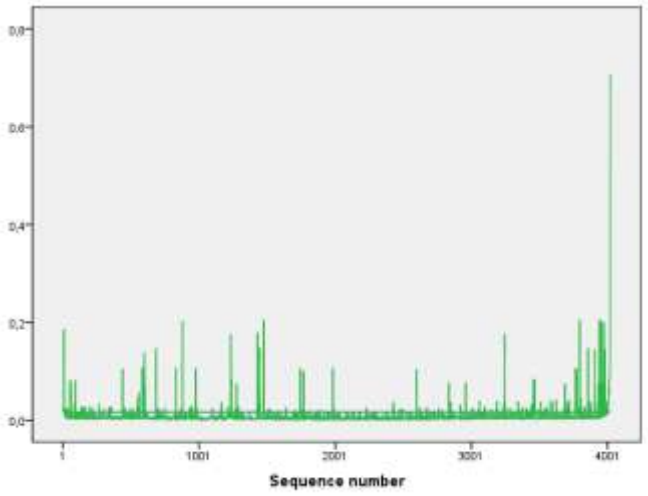
$$t_i = \frac{d_i}{s(d_i)} \tag{4.11}$$

These enable a better diagnosis of outliers that result from the observations, which studentized deleted residuals are high in absolute value. It can be shown that this type of residuals follow a t Student distribution, so it is possible to define a critical value, from which an observation is considered as an outlier. For a significance level of 5%, the critical value is also 1.96. Thus, in appendix A.2 the outliers obtained are shown. From the analysis of the studentized deleted residuals, illustrated by appendix A.2, the detection of outliers identifies 159 cases.



Appendix A.2: **Studentized deleted residuals**

The leverage test, given by the main diagonal element (h_{ii}) of matrix H, defined previously, represents the influence of observation *i* in the quality of the adjustment made. An observation is considered influential if leverage test is greater than *2(p+1)/n*. In this case, with *p*(independent variables)= *33* and *n*(observations) *=4022*, the reference value is 0,01691, above which the observation is considered influential. Appendix A.3 illustrates the outliers identified by this rule.



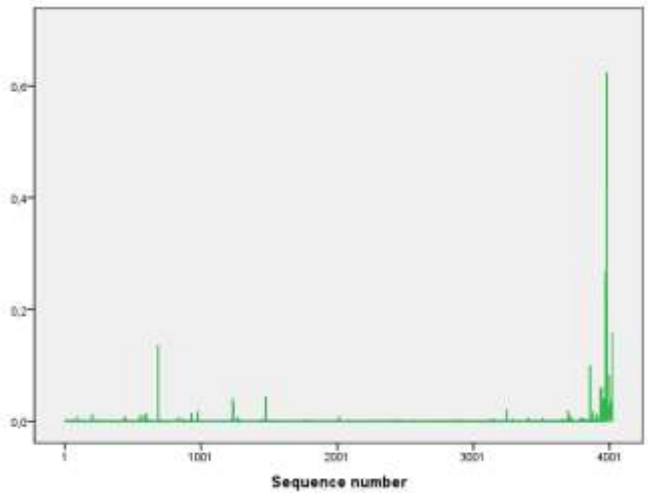
Appendix A.3: **Leverage test**

With Leverage test, 273 cases are identified as outliers. After identification, as outliers, with respect to the values of dependent and independent variables, their influence ought to be checked on the model behaviour. This influence can be quantified by the Cook

distance, standardized dfBetas and standardized dfFit. An observation is considered to be influential if its exclusion causes substantial changes in the estimated regression function. The Cook's distance considers the variation caused in the residuals of all observations, when observation *i* is excluded from the calculation of the regression coefficients. It can be calculated without resorting to a new estimation of regression function, each time an observation observation is deleted, by an equivalent expression (4.12):

$$D_i = \frac{\sum_{j=1}^{n}\left(\hat{Y}_j - \hat{Y}_{j(i)}\right)^2}{(p+1)\cdot MSE} \Leftrightarrow D_i = \frac{{e_i}^2}{(p+1)\cdot MSE}\left[\frac{h_{ii}}{(1-h_{ii})^2}\right] \quad (4.12)$$

An observation is considered influential if Cook's distance is greater than *4/(n-p-1)*. In this case, with *p*(independent variables)= *33* and *n*(observations) *=4022*, the reference value is 0.00100, for the observation to be considered influential. The corresponding outliers are illustrated in appendix A.4.



Appendix A.4: **Cook's distance**

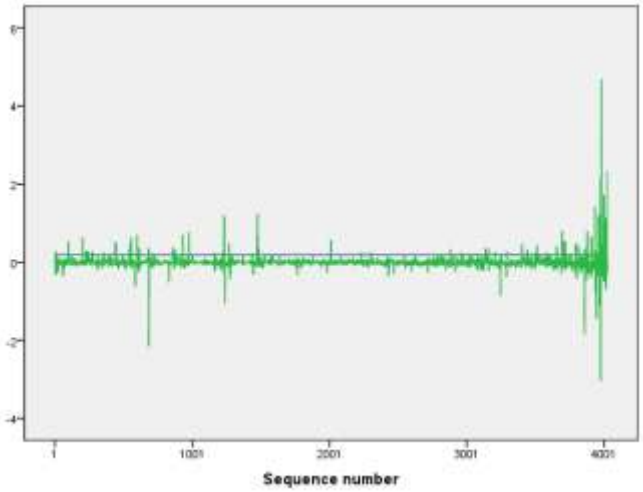
With this rule 199 cases are identified as outliers.

The standardized dfFit (4.13) represents the difference between the value estimated by the model for observation *i*, when all observations are used and the estimated value for the same observation, when case *i* is excluded from the calculation of the regression function. As in the previous equation, it can be calculated through an equivalent

expression, which does not require the calculation of the regression function, each time an observation is excluded from the model.

$$dfFits_i = \frac{\hat{Y}_i - \hat{Y}_{i(i)}}{\sqrt{MSE_{(i)} h_{ii}}} \Leftrightarrow dfFits_i = t_i \sqrt{\frac{h_{ii}}{1 - h_{ii}}} \tag{4.13}$$

An observation is considered influential if standardized dfFit absolute value is greater than $2.\sqrt{(p+1)/(n-p-1)}$. In this case, with *p*(independent variables)= *33* and *n*(observations) =*4022*, the reference value is 0,1847, for the observation to be considered influential. The corresponding outliers are illustrated in appendix A.5.



Appendix A.5: **Standardized dfFit**

With this rule 114 cases are identified as outliers. The measure of the influence of an observation *i* in each regression coefficient β_k, results from the difference between the estimated value for the regression coefficient based on all observations and the same value if omitting case *i*. The standardized DfBeta (4.14) is obtained by the ratio between this difference and the estimated standard deviation of regression coefficient in the analysis:

$$dfBeta_i = \frac{b_k - b_{k(i)}}{\sqrt{MSE_{(i)} c_{kk}}} \qquad k = 0, 1, \ldots, p\text{-}1 \tag{4.14}$$

In which c_{kk} is the *k* element f the main diagonal of matrix $(X'X)^{-1}$. The value of DfBeta is calculated for all observations for all parameters and the model constant. The observations are considered outliers when the absolute value of DfBeta is more than $2/\sqrt{n}$

In this case, with *p*(independent variables)= *33* and *n*(observations) *=4022*, the reference value is 0,0315. Associated graphics are not presented, as this would require a chart for each independent variable. The analysis identifies outliers those cases that are not within the limits imposed by DfBeta, being identified 744 cases as outliers. The outliers' analysis presented identifies the extreme cases considered influential for the models, which are excluded in the construction of new regression functions. Extreme cases were considered influential observations that violate the conditions imposed to the residuals, leverage, Cook's distance and DfFit, or that are not within the limits imposed for the DfBeta. The criteria allow the detection of 861 outliers in the model, which will be removed from the analysis models, hence, the total number of cases decreased from 4022 to 3161. It is worth noting that the vast majority are being identified as an outlier for more than one criteria.