An analysis of the noise pollution influence on the housing prices in the central area of the city of Bari

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Abstract. With reference to the European goals concerning the noise pollution control, the present research aims at verifying the existence and, eventually, determining the influence level of the acoustic component on the selling prices in the residential segment. The analysis has been contextualized to the city of Bari (Southern Italy) and the study sample concerns one-hundred residential units recently sold, for which the main influencing factors in the selling price formation processes have been identified. The implemented methodological tool is a data-driven technique, that employs a genetic algorithm to identify the functional relationships among the considered variables. The application to the case study has allowed the identification of a model characterized by good statistical accuracy and an algebraic form of simple interpretation, which denotes an appreciable contribution of the noise pollution factor on the housing prices.

1. Introduction

The noise pollution issue represents a global topic of pressing relevance, as it constitutes the second leading cause of diseases deriving from environmental factors after air pollution [1]. Noise levels are growing in the urban areas, mainly due to the increase in the traffic, industrial and recreational activities. It is estimated that almost 20% of the European Union population is exposed to noise pollution levels that can be considered unacceptable. The main strategic actions for the health and environment protection carried out by the European Union aim at avoiding or reducing the harmful effects of the noise exposure in the urban areas, by decreasing the number of individuals affected by too high sound levels and to encourage the development of more sustainable cities.

The European policies concerning the assessment and management of environmental noise are based on Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 [2]. The Directive aims at unifying the use of acoustic descriptors (L_{den}, L_{day}, $L_{evening}$, L_{night}) and the methods to evaluate the corresponding noise and disturbance, by identifying the different sources of noise pollution. In addition, the use of common determination methods allows the collection and classification of sound exposure data in the form of strategic noise maps for specific urban areas. These maps must be drawn up for all agglomerations with more than 250,000 inhabitants, for all the main road axes on which more than six million vehicles annually pass through, for the main railway axes on which more than 60,000

convoys annually pass through and for the main airports. For each strategic noise map, at least every five years starting from the first compilation an update must be provided.

On the basis of the noise mapping results, the European Directive requires the Member States committed to manage the respective noise pollution problems, and to define specific action plans coordinated for the environmental noise containment and for the protection of silent areas according to the common criteria of the different countries.

In Italy the main provisions on the acoustic issue have been introduced by the Law No. 447/1995 (as amended by the Legislative Decree No. 42/2017) [3, 4], which establishes the main principles for the protection of external and living environment from noise pollution, defines the specific competences of the regions and the criteria for identifying the temporal priorities of the territory acoustic remediation.

Among the influencing factors relating to the environmental quality of urban spaces, the level of noise pollution is one of the most relevant in the dynamics of the real estate market. With reference to different geographic contexts, in fact, there are numerous researches in the literature that aim at demonstrating the impact of the noise level on the selling prices or rental rates of residential, commercial and executive properties [5, 6, 7].

The increasing interest in the acoustics issue is linked to the awareness that the noise represents one of the main environmental problems of the urban areas and to the need of carrying out strategic initiatives able to satisfy the community's demand of a healthier living environment in the medium-long term.

2. Aim

The topic of the present research concerns the outlined framework. With reference to a study sample of one-hundred residential units collected in the central urban area of the city of Bari (Southern Italy), the paper aims at analyzing the contribution of the factor linked to noise pollution on the selling prices.

The research is part of a wider study aimed at assessing the effects generated by global exposure to noise deriving from sources such as road, rail and airport traffic, industrial activity sites including ports, on the real estate market of the entire municipal area.

The results obtained could constitute a useful reference for the Public Administrations in order to promote initiatives able to reduce the level of noise pollution (inclusion of limited traffic areas, introduction of ecological days, provision of public services for sustainable mobility - i.e. bike sharing) and to avoid a progressive decrease of the environmental quality in the urban areas.

The paper is structured as follows. In the third section, the sample collected and the variables considered have been illustrated. In the fourth section, the implemented methodology has been explained. In the fifth section, the method has been implemented to the study sample and the main functional relationships obtained have been interpreted. Finally, the results of the work have been discussed.

3. Case study

The case study concerns a sample of one-hundred residential properties located in the center of the city of Bari (Southern Italy) and recently sold. For each apartment, the main factors that contribute to the formation of the selling prices have been collected, taking into account the indications of the real estate agents on the ordinary appreciations in the residential market segment of the central area of the city of Bari. In particular, the variables considered are the following:

- the unit selling price (Y), expressed in €/m^2, that represents the dependent variable of the model;
- the total surface of the property (S), expressed in square meters of gross floor area of the apartment;
- the floor on which the property is located (Lp);
- the quality of the maintenance condition of the property (Sc), assessed through a scoring scale: the score "1" indicates properties characterized by a poor maintenance conditions, the score "3" refers to properties in acceptable conditions, the score "5" is assigned to the properties recently renovated or built, whose conservation state is excellent;
- the distance from the nearest green space (Dv), expressed in kilometers it takes to walk to it;
- the distance from the nearest railway station (Ds), expressed in kilometers it takes to walk to it;

• the sound level (L_{den}), expressed in decibels dB(A), calculated on day, evening and night intervals, planned in the street where the property is located, according to the Strategic Noise Map [2]. This information is taken from the Strategic Noise Map of the Bari agglomeration, developed by the Scientific Directorate of the Regional Agency for Environmental Prevention and Protection of the Puglia Region (ARPA Puglia) in June 2017 [8]. The map for each road axis of the city shows the sound power level expressed in decibels and divided into the following seven classes of rating: *i)* Rating 1: ≤40 dB(A); *ii)* Rating 2: >40 dB(A) and ≤50 dB(A); *iii)* Rating 3: >50 dB(A) and ≤55 dB(A); *iv)* Rating 4: >55 dB(A) and ≤60 dB(A); *v)* Rating 5: >60 dB(A) and ≤65 dB(A); *vi)* Rating 6: >65dB(A) and ≤70 dB(A); *vii)* Rating 7: >70 dB(A) and ≤75 dB(A).

Figure 1 shows the excerpt of the Strategic Noise Map of the city of Bari with the location of the study sample properties. It should be noted that the decibel considered in the map (dB(A)) represents the variation in the level of sound intensity that takes into account the minor sensitivity of the human ear at low frequencies.

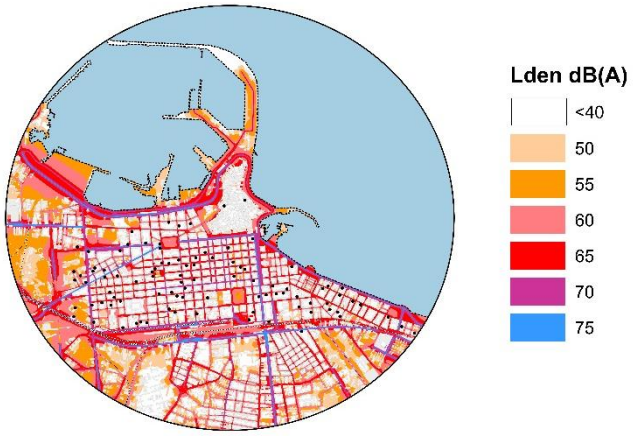

Figure 1. Excerpt of the Strategic Noise Map of the city of Bari with the location of the study sample properties.

4. Method

The method implemented in the present research, named Evolutionary Polynomial Regression (EPR), is a data-driven technique that uses a simple genetic algorithm engine, in order to combine symbolic and numerical regression methods by means polynomial structures [9, 10].

EPR represents a versatile symbolic regression tool on the base of experimental data. The generic expression of the models generated from the technique is given by Eq. (1):

$$Y = a_0 + \sum_{i=1}^{n} [\, a_i \cdot (X_1)^{(i,1)} \cdot \ldots \cdot (X_j)^{(i,j)} \cdot f((X_1)^{(i,j+1)} \cdot \ldots \cdot (X_j)^{(i,2j)})] \qquad (1)$$

where n is the number of additive terms, i.e. the length of the polynomial expression (bias excluded), a_i are the numerical parameters to be valued, X_i are candidate explanatory variables selected by the algorithm during the elaboration, *(i, l)* - with $l = (1, \ldots, 2j)$ - is the exponent of the l-th input within the i-th term in Eq. (1), f is a function selected in the preliminary phase.

The structure of the function f is selected by the user among a set of possible alternatives, including no function selection

The exponents *(i, l)* are also chosen by the user in the first phase of the implementation from a set of candidate values (real numbers) which should include the value "0". The parameters of the function are evaluated through a Least Squares method. The quantity and the complexity of the models that EPR generates during the elaboration phase depend on the possible exponents and the maximum number of

terms, that represents two choices of the user in the preliminary phase. The statistical accuracy of each equation returned is assessed through the respective Coefficient of Determination [11]. The model statistical performance is higher when the Coefficient of Determination (COD) is close to the unit value.

The genetic algorithm underlying EPR is able to simultaneously pursue different objective functions. In particular, EPR carries out a multi-objective optimization strategy based on the Pareto dominance criterion. The three objectives are usually conflicting and aim at: *i)* the maximization of the model accuracy, through the satisfaction of appropriate statistical criteria of verification of the equation; *ii)* the maximization of the model's parsimony, through the minimization of the number of terms (a_i) of the equation; *iii)* the reduction of the complexity of the model, through the minimization of the number of the explanatory variables (X_i) of the final equation.

In this way, the technique generates a range of models. Among these, the user could select the most appropriate solution according to the specific needs, the knowledge of the phenomenon in analysis and the type of experimental data used.

5. Application of the Method

In the present research, EPR has been applied to the case study considering the structure of the generic model identified in Eq. (1) without the function *f* selected and with Y (unit selling price) as the dependent variable. Each model generated following the algorithm implementation, consists of a polynomial expression of several terms, in which each one is a combination of the inputs considered in the analysis (explanatory variables raised to the proper numerical exponents). In particular, the maximum number of terms of each expression and the possible positive exponents, selected in the preliminary phase, are equal to ten terms and four exponents (0, 0.5, 1, 2).

The models generated by EPR are characterized by an increasing level of statistical accuracy in terms of COD and by a progressively more complex algebraic form connected to the number of terms present and the combinations of explanatory variables in each monomial term.

The model of Eq. (2), selected as the best among those generated, is characterized by *i)* an appreciable level of statistical accuracy (COD = 69.48%), *ii)* a quite simple functional form. Furthermore, the model of Eq. (2) includes all the factors considered in the analysis, i.e. the total surface of the property (S), the floor on which the property is located (Lp), the quality of the maintenance condition of the property (Sc), the distance from the nearest green space (Dv), the distance from the nearest railway station (Ds), the sound level (L_{den}) in the street where the property is located.

$$\begin{aligned} Y = & -5{,}976 \cdot Ds + 3{,}309 \cdot Ds^2 + 13{,}493 \cdot Lp^2 - 14{,}788 \cdot Lp^2 \cdot Dv + \\ & + 1{,}623 \cdot S + 1{,}743 \cdot Lden^{0.5} \cdot Sc^2 \cdot Ds - 14{,}817 \cdot Lden \cdot S^{0.5} \cdot Lp \cdot Dv^{0.5} + \\ & + 16{,}667 \cdot Lden^2 \cdot Lp \cdot Dv^2 \cdot Ds^{0.5} + 3{,}387 \end{aligned} \tag{2}$$

It should be noted that for none of the variables in Eq. (2) it is possible to immediately verify the empirical consistency of the explanatory variable coefficients signs and to determine its percentage incidence on the unit selling price. Each variable, in fact, is combined with the other characteristics in the different terms of the equation and appears also several times in the polynomial expression. The use of an exogenous approach that considers the values of the other independent variables constant and equal to their average value, allows to determine the percentage increase (or decrease) in the value of the dependent variable (unit selling price) deriving from the change in the value of each variable analyzed in the range admissible by the study sample.

For all the factors considered in the research, the functional relationships between these variables and the dependent variable of the unit selling price are empirically verified, as they are consistent with the expected phenomena related to the mechanisms for the formation of housing prices in the central area of the city of Bari.

With reference to the sound level in the street where the property is located (L_{den}), the graph in Figure 2 shows the inverse correlation between the unit selling prices and the L_{den} label. It is interesting to note that the average percentage decrease in the selling price due to an increasing change in the class rating

of the noise pollution level, is equal to -2%. It should also be observed that the percentage variation in the unit selling residential prices in the central area of the city of Bari, passing from the best situation characterized by rating 1 (<40 dB(A)) to the worst situation defined by rating 7 (>70 and ≤75 dB(A)), is equal to about -11%. The observed phenomenon confirms the empirically expected results. The analysis of the unitary contribution of the explanatory variable L_{den} on the housing prices has revealed an average decrease in the unit selling prices equal to -0.34%. Furthermore, it should be outlined that there is a progressive attenuation of the weight of the noise pollution on the unit selling prices for increasing values of the considered independent variable.

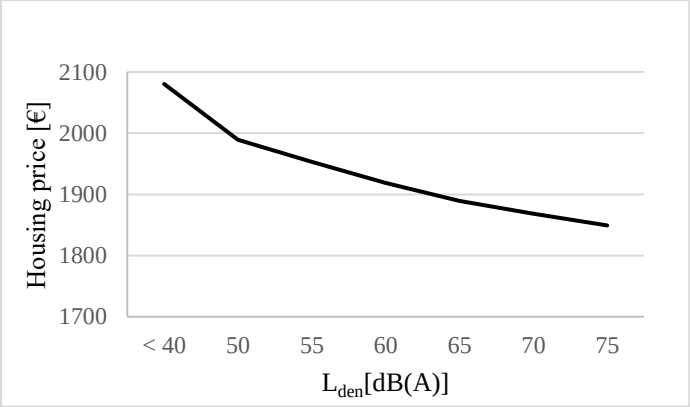

Figure 2. Functional relationship between the L_{den} label and the housing prices

Table 1 shows the percentage variations of the unit selling prices obtained in correspondence with the passage from a noise pollution class rating to the next one.

Table 1. Unit selling prices percentage variations for the noise pollution classes rating

Rating	Percentage variations of the unit selling prices
1	
2	-4,37%
3	-1,81%
4	-1,79%
5	-1,53%
6	-1,10%
7	-1,02%

6. Conclusions

With reference to the context of the city of Bari (Southern Italy), in this research the influence of the noise pollution level on the residential property selling prices formation has been analyzed.

The econometric analysis implemented on the sample of one-hundred residential units located in the central area of the city, has allowed to verify the existence of an inverse functional correlation between the acoustic variable and the unit selling prices and to determine the relating contribution in terms of percentage decrease of the market values. The results obtained confirm the empirical expected phenomena relating to the incidence of the noise factor on the unit selling housing prices also on the

basis of the detections carried out by the operators of the real estate market in the city of Bari, who attest to the significance of this factor in the selling phases between buyers and sellers.

The work is part of a wide and highly topical research line, consistently with the main national and European objectives of reducing noise pollution with a view to an increasingly sustainable urban development.

Future research insights may concern the implementation of Conjoint analysis (e.g. contingent valuation) during the phase for the data collection relating to the noise level, in order to evaluate the subjective perception declared by individuals of the sample identified for the examination and to integrate it with the objective data detected by the strategic noise maps. The outputs obtained could be also compared with those achieved through the application of the EPR technique to other Italian urban contexts for *i)* assessing the noise pollution level on the selling prices in the different urban areas and *ii)* orienting the choices of Public Administrations towards strategic actions to limit the noise effects on the living quality of the local communities. Moreover, further studies will concern the analysis on more widespread data samples, in order to obtain outputs characterized by a higher statistical performance, as well as the analysis of the effect on the unit selling price determined by the joint action of the floor level at which the property is located, and the noise level to which the property is exposed on the basis of the informations on the Strategic Noise Map for the city of Bari.

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