Incidence of Different Types of Urban Green Spaces on Property Prices. A Case Study in the Flaminio District of Rome (Italy)

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Abstract. Although the presence of an urban green areas seems to be an important factor in housing decisions, there are few empirical research on the incidence of different types of urban green spaces on housing prices. With reference to a study sample of apartments located in the Flaminio district of the city of Rome (Italy), an innovative data-driven technique has been implemented. In this way, it was possible to identify, among the main explanatory variables selected by the model as the most influential in real estate price formation phenomena, those relating to green areas and analyzing the marginal contribution of each of them on selling prices. The implemented methodology has allowed to obtain a model characterized by high statistical reliability, by a simplicity and high coherence in the empirical interpretation of the functional relationships between the influencing factors selected and the housing prices. The results clearly indicate that green space is not a homogeneous environmental amenity, rather it is a series of distinct elements that has a different impact on housing prices.

Keywords: Housing prices · Urban green spaces · Private green areas · Genetic algorithm

1 Introduction

In the last decades of the 21st century, urban growth has exceeded the capacity of cities to provide essential services and goods to the inhabitants. The unsustainability of this growth prompts the public administrations on the need for urban models able to deal with the growing demands for urban quality and basic ecosystem services [17, 24]. Public properties represent most of the ecosystem services but, as such, they require proper management skills by public administrations.

In the USA and China, national and local models have been implemented to promote urban forestry as a tool for sustainable urban development. In the Cape Verde city (Africa), green reserves have been increased in and around cities through new trees. Since 1990, the Food and Agriculture Organization of the United Nations

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(FAO) has been supporting the dissemination and development of strategic planning capable of supporting urban forestry policies. Recently, the Urban and Peri-urban Forestry Guidelines spreads by the FAO during the 3rd Habitat Conference in Quito (Ecuador) aimed at providing a global reference framework to integrate and connect urban green infrastructures in order to increase a sustainable urban development [25]. These experiences outline that the investments by communities and governments in the protection and restoration of urban forest and green spaces can provide a real contribution to a healthy and resilient urban environment [9, 11].

This situation requires efforts that aim at maintaining or restoring green areas for their importance in the cities' life quality [3, 30]. Urban green areas satisfy some functions and generate various benefits for dwellers [13]. Over the last few decades, numerous studies carried out corroborate the assumption that there is a significant impact of urban green areas on real estate prices [27, 31]. Crompton [5] provides a valuable overview of literature concerning this issue. Among 30 studies analyzed, he highlighted that there were only five that did not support the park proximity as a fundamental factor that raises property prices. Moreover, since 1964 Knetsch, in the USA, had studied this issue [32], finding that benefits of an attractive location may contribute to the growth in the property value. In the 1971 Hendon [14] did not find a uniform influence in the neighborhood of recreational areas on real estate prices. The discussion about green spaces often concerns their homogeneity with distinctions in some cases made with regard to the ownership [4] or the conservation status [16].

Most of the current state of the art on the subject deals with large-scale distinctions on green space such as nature reserves or agricultural fields [13, 20]. Others distinguish the green areas based on size and/or proximity [1]. Only in few cases, the effect that can vary depending on its type, accessibility, diversity, and extra recreation facilities [6, 7, 19, 22] has been studied. There is also some demonstration that scarcity of urban green in the city with high density of development can affect the urban green premium [15, 29]. Nonetheless, the proximity to a park causes negative externalities and decreases property values such as fire risk exposure or poor management, and vulnerability to crime [28].

The analysis of the existing literature allows to identify the following categories of general benefits of urban green areas [23]:

- *environmental*, such as ecological benefits, pollution reduction, cooling urban areas, ensuring biodiversity and wildlife safeguard;
- *economic*, including saving energy, influence on water balance, maximizing the tourist attractiveness of urban areas and increasing the value of properties;
- *social*, as a place of entertainment and recreation, improvement of health and physical and mental condition, strengthening social relationships, crime reduction.

Some of the benefits listed above can have market effects. Regarding a hedonic pricing framework, Sarkar et al. [26] identify five most important reasons that point out the ability of the proximity to urban green spaces to increase residential satisfaction, as well as to influence housing choices and housing prices: (*i*) generation of recreation possibilities, (*ii*) strengthening community relationships and increasing social capital; (*iii*) health and stress relief, (*iv*) natural filtration against pollution and (*v*) protection of urban heat islands.

2 Aim

Although the presence of an urban green space seems to be an important factor in housing decisions there are few empirical research on the incidence of different types of urban green spaces on the housing prices.

The aim of this research is to analyze and quantify in a systematic way the incidence of different types of urban green spaces on housing prices in a central district of Rome.

The functional relationships between property prices and the variables considered in this study have been defined through the implementation of a genetic algorithm called *Evolutionary Polynomial Regression* (EPR) in order to select functions that simultaneously maximize the accuracy of the data and the parsimony of the final mathematical relations.

The analysis is applied to the Flaminio district of the city of Rome (Italy). The study sample consists of 132 residential properties recently purchased, for which the selling prices and the main influencing factors have been detected.

The work is structured as follows. Section 3 describes the case study and specifies the (dependent and independent) variables considered in the model. Section 4 shows the methodology implemented (EPR), the main criteria used to assess the reliability of the returned models are explained and the methods of application are outlined. Section 5 describes the implementation of EPR to the case study and the results obtained in terms of specific statistic performances and empirical reliability of the functional relationships returned by the methodology. Finally, in Sect. 6 the conclusions of the work are discussed.

3 Case Study

The study sample consists of 132 residential properties sold in the last two months of 2018 in the Flaminio district of Rome. The choice of the study area is related to the presence of a wide variety of building tissues and, most of all, a close connection between some building typologies and types of green area. It is possible to identify the following five different building tissue:

- Low-density buildings of the Ex Olympic village built for the 1960 Olympics in Rome. The space in which they are located consists of large public green areas corresponding to the denomination of “Configured Gardens” according to the current urban planning regulations of the municipality of Rome. This configuration is defined by the variable *existence of public green areas* (Gp) among the indicators chosen for the classification of green typologies;
- Residential complexes such as “Villa Riccio”, built in 1919, consisting of several buildings in a private enclosed space. The ground between the buildings includes areas for garden represented by the variable called *existence of green areas accessible only to residents* (Gc);

- Social housing complexes ("ICP Flaminio I and II") respectively built in 1905 and in 1925. The first complex is located between Via Flamina and Viale Tiziano. The second complex, located between Lungotevere Flaminio and Viale del Vignola, presents large courtyards with a sequence of semi-public green spaces also included in the variable *existence of green areas accessible only to residents* (Gc) above mentioned;
- High-density buildings realized in 1940 between Via Guido Reni and Ponte Milvio with a few cases in which, inside the courtyard, there is a garden used by residents and taken over by the variable already mentioned as *existence of green areas accessible only to residents* (Gc);
- Historic building dating back to 1883. It consists of houses without green areas in the courtyards for which the variable *existence of green areas accessible only to residents* (Gc) takes zero value.

In Fig. 1 it is possible to notice the distribution of the study sample within the district. In particular, the two different skimmers underline the buildings for which the presence of green areas is related to the explanatory variables of the *existence of green areas accessible only to residents* (Gc) and of the *existence of public green areas* (Gp) above mentioned.

For each property of the study sample, the selling price (dependent variable) and the intrinsic and extrinsic factors (independent variables) most influential on the price have been recorded. As confirmed by the real estate agents operating in the district, the factors identified for this work represent the characteristics considered by buyers and sellers in the phases of negotiation of residential properties. The following three main categories describe the independent variables of the research.

- *Intrinsic characteristics of the property*:
  - the total surface (S) of the property, expressed in square meters of gross floor area;
  - the floor of the property in the building (Lp);
  - the quality of the maintenance conditions of the property (St), taken as a qualitative variable and differentiated, through a synthetic evaluation, by the categories "to be restructured", "fit for habitation" and "restructured" which is assigned, respectively, value "1" for a property to be restructured, value "3" for habitable buildings and value "5" for restructured properties;
  - the existence of at least one view on a tree-lined avenue (Av) for the property, evaluated as a dummy variable, where the value "1" detects the respective presence and the value "0" the absence;
  - the existence of a view on the Lungotevere Flaminio (At) for the property, analyzed as a dummy variable, for which the value "1" defines the presence of this condition and the value "0" the absence.
    - *Technological characteristics of the building in which the property is located*:
      - the existence of the lift inside the building where the residential unit is located (A), considered as a dummy variable, where the value "1" shows the presence of this service and the value "0" detects the absence;

  - the existence of the covered or uncovered parking space (Pa) related to the property, assessed as a dummy variable with the value "1" that highlights its presence and the value "0" that detects the absence.

- *Extrinsic characteristics of the building in which the property is located*:
  - the distance from the nearest subway (Dm), expressed in kilometers it takes to walk to it;
  - the existence of green areas accessible only to residents (Gc). In the model this variable is detected as a dummy variable: the presence of this type of green area is indicated with the value "1", whereas the absence with the value "0";
  - the existence of public green areas (Gp), considered in the proposed model as a dummy variable: the value "1" denotes the presence of the above areas, whereas the value "0" detects the respective absence.

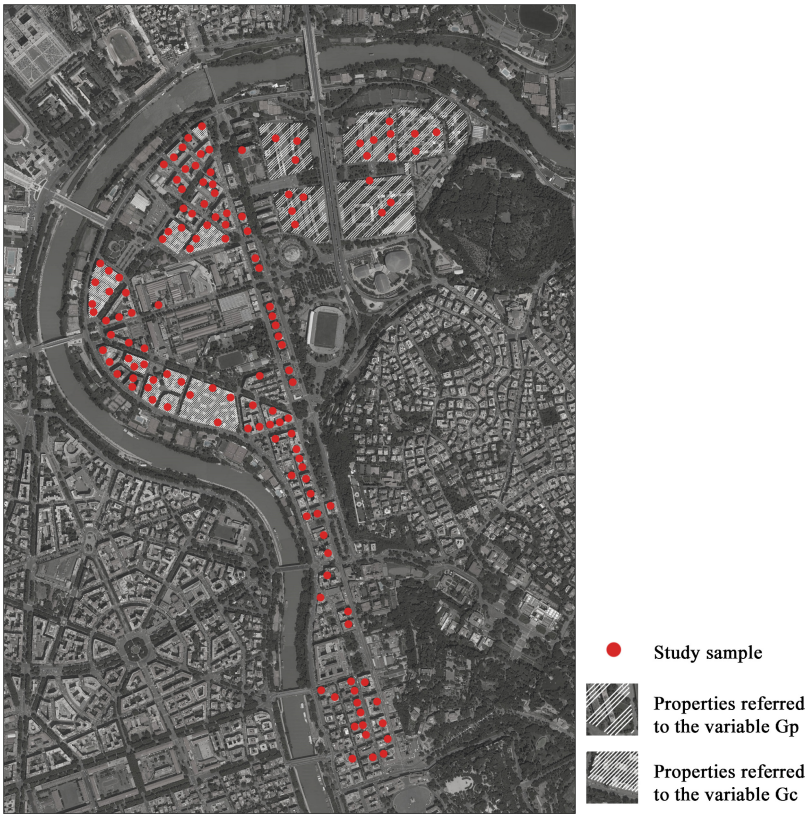


Fig. 1. Distribution of the study sample

4 Methodology

The econometric methodology applied in the present research is the *Evolutionary Polynomial Regression* which integrates the best features of numerical regression [10] with genetic programming [33]. The method proposed is based on a numerical and symbolic regression methods whit polynomial structures [12]. In particular, the technique, starting from experimental data, represents a versatile symbolic regression tool able to search for possible models in polynomial form. Each term that appears is composed of the combinations, with a different degree of complexity, of the input variables selected by the user. Equation (1) is a general non-linear functional structure of the methodology:

$$Y = a_0 + \sum_{i-l}^{n} \left[a_i \cdot (X_l)^{(i,l)} \cdot \ldots \cdot (X_j)^{(i,j)} \cdot f\left((X_l)^{(i,j+l)} \cdot \ldots \cdot (X_j)^{(i,2j)} \right) \right] \tag{1}$$

where n is the number of additive terms, a_i are numerical parameters to be valued, X_i are candidate explanatory variables, *(i, l)* - with *l = (1, ..., 2j)* - is the exponent of the *l*-th input within the *i*-th term in Eq. (1), f is a function selected by the user among a set of possible mathematical expressions. The exponents *(i, l)* are also selected by the user from a set of candidate values (real numbers).

The EPR execution involves the selection and generation of a series of models whose functional form is the best combination of the input variables *Xi*, identifying for each one the exponents *(i, l)* and the numerical coefficients a_i, evaluated by a Least Squares method. The complexity and the number of models that the methodology can return depends on the maximum number of terms that the mathematical expression can contain and on the possible exponents through which the variables are elevated. The user will perform these choices during the preliminary phase of the implementation of the data-driven technique.

The Coefficient of Determination (COD) is indicative of the accuracy of each model returned, defined in Eq. (2):

$$COD = 1 - \frac{N-1}{N} \cdot \frac{\sum_{N} \left(y_{estimated} - y_{\det ected} \right)^2}{\sum_{N} \left(y_{\det ected} - mean(y_{\det ected}) \right)^2} \tag{2}$$

where $y_{estimated}$ are the values of the dependent variable estimated by the methodology, $y_{detected}$ are the collected values of the dependent variable, N is the sample size in analysis. The statistic reliability of each model is greater when the COD is close to the unit value.

Therefore, the methodology leads to a range of solutions for the user, each one characterized by a more or less complex algebraic form and by a different level of statistical accuracy in terms of COD. The user selects and chooses the most appropriate solution according to the specific needs linked to the purpose of the analysis, the knowledge of the phenomenon and the type and quantity of experimental data used.

5 Application of the Method

The EPR methodology is implemented considering the structure of the generic model identified in Eq. (1) without function f selected and with the dependent variable P (selling price) as the natural logarithm of it ($Y = ln\ (P)$) [18]. Each additive monomial term of the mathematical expression is assumed as a combination of the inputs - the explanatory variables Xi - raised to the proper numerical exponents. In particular, in order to have a wide range of models, the candidate exponents belong to the set (0; 0.5; 1; 2) and the maximum number n of additive terms in final expressions is assumed to be seven.

The implementation of the econometric method has generated several solutions, each one characterized by a different number of additive terms, combination of the variables and a different level of COD. Table 1 shows the main models provided by the EPR technique and, then, chosen by the user.

Table 1. Equations obtained by the implementation of EPR

Eq. (n)	Model	COD [%]
(3)	$Y = -0.032455 \cdot Dm^2 + 0.18437 \cdot S^{0.5} + 0.16134 \cdot Lp^{0.5} + 10.9939$	85.52
(4)	$Y = -0.11758 \cdot Dm + 0.17635 \cdot S^{0.5} + 0.30376 \cdot At^{0.5} \cdot Av^{0.5} + 0.16911 \cdot Lp^{0.5} + 11.1426$	86.94
(5)	$Y = -0.034534 \cdot Dm^2 + 0.18224 \cdot S^{0.5} + 0.14626 \cdot St \cdot Pa^{0.5} \cdot Gc^{0.5} + 0.07516 \cdot Lp^{0.5} \cdot St^{0.5} + 11.0644$	88.34
(6)	$Y = -0.033504 \cdot Dm^2 + 0.1761 \cdot S^{0.5} + 0.30689 \cdot At^{0.5} \cdot Av^{0.5} - + 0.1792 \cdot A^{0.5} \cdot Gp^{0.5} + 0.85067 \cdot Lp^{0.5} - 0.19259 \cdot Lp + 10.5385$	89.48
(7)	$Y = -0.035082 \cdot Dm^2 + 0.17403 \cdot S^{0.5} + 0.059122 \cdot At^{0.5} \cdot Av^{0.5} \cdot Dm^2 + 0 \cdot St + - 0.18802 \cdot A^{0.5} \cdot Gp^{0.5} + 0.8494 \cdot Lp^{0.5} - 0.1928 \cdot Lp + 10.5706$	89.62
(8)	$Y = -0.035281 \cdot Dm^2 + 0.17336 \cdot S^{0.5} + 0.004466 \cdot At^{0.5} \cdot Av^{0.5} \cdot S^{0.5} \cdot Dm^2 + - 0.19455 \cdot A^{0.5} \cdot Gp^{0.5} + 0.8526 \cdot Lp^{0.5} - 0.1938 \cdot Lp + 0 \cdot Lp^2 \cdot St^2 \cdot Pa^2 \cdot Gc^{0.5} + 10.5777$	89.76
(9)	$Y = -0.39624 \cdot Dm + 0.13269 \cdot S^{0.5} + 0.023317 \cdot S^{0.5} \cdot Dm + 0.21289 \cdot St^{0.5} \cdot Pa^{0.5} \cdot Gc^2 \cdot Av^{0.5} + 0 \cdot A^{0.5} \cdot Gp^2 \cdot S + 0.033674 \cdot A^2 \cdot At^{0.5} \cdot Av \cdot Dm^2 + 0.078459 \cdot Lp^{0.5} \cdot St^{0.5} + 11.7277$	89.83

The models are characterized by a progressively complex algebraic form and a higher statistical accuracy (COD). Each solution has direct and indirect functional links between the dependent variable of the model (selling price) and the independent variables chosen for the analysis. In particular, the model of Eq. (9) has been identified as the best because (*i*) it is defined by a mathematical expression of simple interpretation, not much more complicated than the previous models, (*ii*) it is characterized by a COD equal to 89.83% attesting an excellent statistical reliability of the model, (*iii*) its polynomial form includes most of the explanatory variables chosen, allowing to analyze the contribution of each one in the phenomena of selling price formation.

The variables selected by the methodology as the most influential on property prices in the market in question are: the distance from the nearest metro station (Dm), the total surface of the property (S), the conservative state of the building (St), the presence of the parking space (Pa), the presence within the residential complex of which the property is part of a garden (Gc), the view of the property on a tree-lined

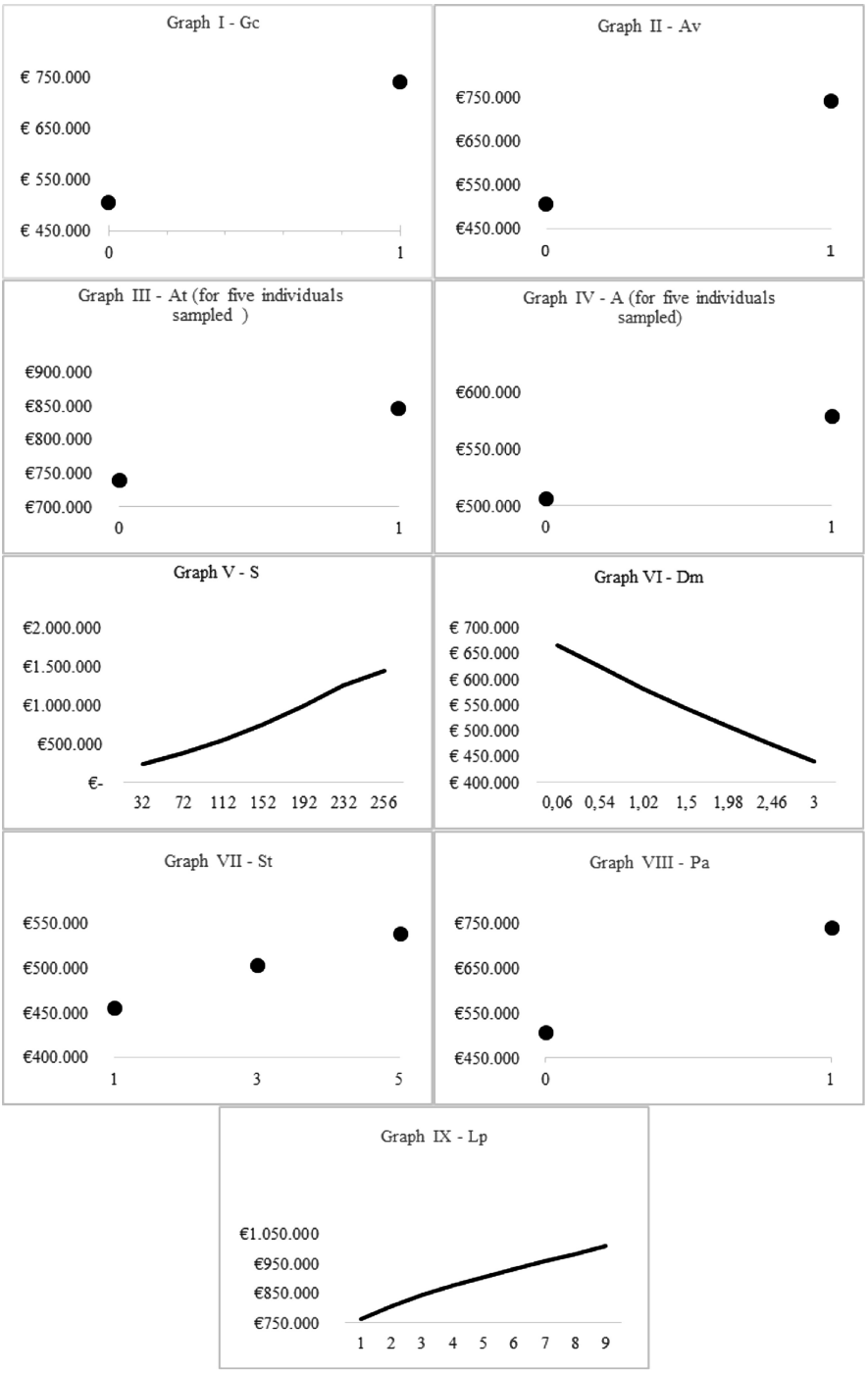


Fig. 2. Functional relationships between the influencing factors selected by the model and the housing prices

avenue (Av), the presence of the elevator (A), the presence of the public garden (Gp), the view of the property on the Lungotevere (At) and the level of the floor (Lp). With regard to the aim of the research related to analyze and to quantify in a systematic way the incidence of different types of urban green spaces on housing prices in a central district of Rome, it should be noted that the model chosen includes all four variables selected for this analysis concerning green spaces.

The expression of the model does not allow to immediately verify the empirical consistency of the signs of the coefficients of the independent variables for none of the selected characteristics, since there are no variables that individually appear in the additive terms. In order to interpret the functional relationships between the dependent variable Y and the independent variables, it is necessary to use a mathematical exogenous approach that allows to quantitatively express the influence of each factor selected by the model of Eq. (9) on the housing prices. In particular, the variation of the *i-th* variable in the range of admissible values in the sample taken is analyzed by assuming the mean values for the quantitative variables (Dm, S, Lp) or measured by a scale of scores (St) and the value 1 for the dummy variables (Pa, Gc, Av, A, Gp, At).

In this respect, it is important to pay attention to any alternative situations for the variables belonging to the same category that cannot simultaneously be equal to 1. Figure 2 shows the functional relationships obtained.

The functional relationships obtained confirm the expected empirical phenomena. Firstly, regarding the variables chosen for the green areas, there is a direct functional relationship between the variable *existence of green areas accessible only to residents* (Gc) and the housing prices. This contingence is verified in the only situation in which the property is equipped of parking space and a view on a tree-lined avenue (Pa = 1 and Av = 1), being the Gc variable combined within the same term with Pa and Av. In the condition in which the green space in the courtyard (Gc), the parking space (Pa) and the view on a tree-lined avenue (Av) are simultaneously factors of the property, the increase in prices is equal to +46.19%.

The same percentage (+46.19%) of increase in selling prices is shown for the properties with a *view on the tree-lined avenue* (Av = 1) when, also in this case – as they appear in the same term of the model - the simultaneous presence of the parking space (Pa = 1) and the garden in the courtyard (Gc = 1) is attested.

The remaining variables related to the green space typology, *existence of public green areas* (Gp) and *existence of a view on the Lungotevere Flaminio* (At), require considerations that are more detailed. The first variable (Gp) appears in a single term of the model, whose numerical coefficient is equal to zero and, therefore, this extrinsic factor is not influential in the phenomena of housing price formation in the market and for the reference sample.

The characteristic *existence of a view on the Lungotevere Flaminio* (At), instead, compares in the model of Eq. (9), in the same additive term with the variables *existence of the lift inside the building* (A), *distance from the nearest subway* (Dm) and *existence of at least one view on a tree-lined avenue* (Av). This feature is appreciated by the market analyzed exclusively for a limited number of properties in the sample (equal to 5 properties) for which, due to the angular position taken, there is the presence of the two features At and Av. Therefore, although for the total study sample, excluding the five properties mentioned, there is the incompatibility of the characteristic Av with the

characteristic At, as the impossibility of the contextual presence of the two views in the same property is evident, the incidence of the variable *existence of a view on the Lungotevere Flaminio* on the housing prices is only analyzed with reference to the five properties mentioned above (graph III).

For the variable *existence of the lift inside the building* (A) a similar situation occurs. In fact, although the model of Eq. (9) returns a functional relationship that provides for the significance of the contribution of variable A on property prices, the presence in the algebraic expression of the variable A is verified, in the term with numerical coefficient 0 and characterized by the presence of the variables At and Av that, as shown above, simultaneously occur only for five properties of the sample.

In Fig. 2 the graph V shows a direct relationship between the *total surface* (S) variable and the housing prices and, specifically, there is a percentage of increase in housing prices equal to an average of +7%.

The inverse relationship between the variable *distance from the nearest subway* (Dm) and the housing prices highlights the empirical evidence of a negative influence on the selling prices of the buildings placed at a greater distance from the nearest metro stop, equal to −0.85%.

For the variable *quality of the maintenance conditions of the property* (St), the direct relationship with the housing prices shows a greater appreciation of the market for properties in excellent condition compared to those in good conditions (+29.23%) and, in the same way, for apartments that have a good state of preservation compared to those in poor state of repair (+19.31%). Furthermore, the analysis reflects a direct relationship between the housing prices and the variable *existence of the covered or uncovered parking space* (Pa) in the only situation in which the property has a *garden in the courtyard* (Gc = 1) and a *view on a tree-lined avenue* (Av = 1). In this condition, the increase in prices recorded following the presence of the parking space is equal to +46.19%.

Finally, for the variable *floor of the property in the building* (Lp), the model of Eq. (9) shows an average variation in the selling prices of +3.60% for each increase in the floor.

6 Conclusions

The growing importance attributed to the natural open spaces within the consolidated contexts of the cities has led to the start of works of environmental recovery in degraded areas [8, 21] and to the reconversion of "urban voids" in areas intended for public and/or private green areas. Along these lines, there is a need for public administrations and public authorities to prepare and adopt policy tools for the correct planning, regulation and programming of urban green space management interventions, in order to guarantee a synchronous growth of the city and its green heritage [2].

This research is linked to the issue outlined. In particular, in the work the aim has been to analyze and quantify in a systematic way the incidence of different types of urban green spaces on the housing prices. With reference to a study sample of apartments located in the Flaminio district of the city of Rome (Italy), an innovative data-driven technique has been implemented. In this way, it has been possible to identify, among the explanatory variables selected by the model as the most influential in the

property price formation phenomena, the factors relating to green areas and to analyze the marginal contribution of each of them on the selling prices.

The implemented methodology has allowed to obtain a model characterized by high statistical reliability, by a simplicity and high coherence in the empirical interpretation of the functional relationships between the influencing factors selected and the housing prices.

Further insights may address the application of the methodology used in this work in other Italian and international contexts. It could also be interesting to propose the same analysis for another district of the city of Rome, characterized by urban green space typologies similar to those analyzed in this research. Subsequently, the comparison of the results could give rise to inspiring considerations. Another development could concern the extension of the categories of urban green spaces considered, including, for example, among the independent explanatory variables, urban parks or equipped green areas, in order to analyze the contribution of these types of green spaces in the processes of property price formation.

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