Green Energy and Technology

Francesca Abastante · Marta Bottero ·
Chiara D'Alpaos · Luisa Ingaramo ·
Alessandra Oppio · Paolo Rosato ·
Francesca Salvo *Editors*

Urban Regeneration Through Valuation Systems for Innovation

Springer

Green Energy and Technology

Climate change, environmental impact and the limited natural resources urge scientific research and novel technical solutions. The monograph series Green Energy and Technology serves as a publishing platform for scientific and technological approaches to “green”—i.e. environmentally friendly and sustainable—technologies. While a focus lies on energy and power supply, it also covers “green” solutions in industrial engineering and engineering design. Green Energy and Technology addresses researchers, advanced students, technical consultants as well as decision makers in industries and politics. Hence, the level of presentation spans from instructional to highly technical.

Indexed in Scopus.

Indexed in Ei Compendex.

Francesca Abastante · Marta Bottero ·
Chiara D'Alpaos · Luisa Ingaramo ·
Alessandra Oppio · Paolo Rosato · Francesca Salvo
Editors

Urban Regeneration Through Valuation Systems for Innovation

Springer

Editors
Francesca Abastante
DIST
Politecnico di Torino
Turin, Italy

Marta Bottero
DIST
Politecnico di Torino
Turin, Italy

Chiara D'Alpaos
University of Padova
Padua, Italy

Luisa Ingaramo
PR.I.S.MA – Fondazione Compagnia di San Paolo
Turin, Italy

Alessandra Oppio
Chief Editor of the Springer SIEV Series
Politecnico di Milano
Milan, Italy

Paolo Rosato
DIA
University of Trieste
Trieste, Italy

Francesca Salvo
DIAM
University of Calabria
Arcavacata di Rende, Italy

ISSN 1865-3529 ISSN 1865-3537 (electronic)
Green Energy and Technology
ISBN 978-3-031-12813-4 ISBN 978-3-031-12814-1 (eBook)
https://doi.org/10.1007/978-3-031-12814-1

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface: At the Origin of Circularity

The planning of a "sustainable" development path for urban areas is a challenge both difficult and promising at the same time. In fact, heavily anthropized areas present the highest environmental and social criticalities and, nevertheless, are an ever-coveted source of opportunities and well-being.

Urban areas host most of the world's population, and United Nations predicts that in a few decades, 80% of the population will reside in urban areas both for incoming migratory flows and for the expansion of urban areas themselves.

This trend has been constant over time and has slowed down only during exceptional and contingent events, such as the Second World War.

More recently, the spread of telecommunication networks (ICT) and the COVID-19 pandemic seem to have slowed this trend, but it is not known whether it is a structural or contingent phenomenon.

Urban areas, strong generators of explicit and implicit knowledge, offer better job and income prospects, better social services, better schools, better health care, and much more; likewise, they are also the places of conflict and degradation where the expectations of immigrants, if disregarded, generate frustration and marginalization.

On the environmental level, cities are formidable sinks of raw materials and energy and, consequently, of pollution of all environmental matrices: soil, water, and atmosphere.

Cities are made up of fragile and obsolescent physical infrastructures which, if not properly maintained, easily degrade, triggering similar phenomena on a social level.

Urban systems are always in a dynamic equilibrium between development and degradation, according to the resources invested in them, both public and private, and even the objectives of the urban policies underlying these resources.

In this regard, the declared goal of the public decision-maker in recent decades is the design of a "circular city" capable of reabsorbing—in the broadest sense—the "toxins" produced by urban metabolism. This means not only ensuring correct management of material waste and technological externalities but also generating "value systems" capable of mobilizing the resources necessary for the regeneration of the most compromised areas.

But what are the basic principles of the circularity of economic systems in general and urban ones in particular?

Much has been written from many points of view, so much so that the concept risks are appearing elusive in its concrete application. To go back to the founding principles, it seems useful to recall scholars who at the end of the 1960s started a rethinking of the traditional economic approach based on the uncontrolled extraction of natural resources for production purposes: Kennet Boulding, John Krutilla, and Garret Hardin.

Boulding [1] theorizes the distinction between open (linear) and closed (circular) economic systems and distinguishes the systems (open or closed) according to the reference: matter, energy, and information. He advocates, with the need for the reuse of waste material, the construction of circular economic systems in a closed environment such as the earth ecosystem.

Krutilla [2] focuses his thought on the value of natural resources in a long-term perspective and points out that these resources have a "plus value" that transcends the mere use value and that is linked to the legacy for the future generations, the existence of all living beings, and to the future options of use (known and unknown) that may be exercised.

He highlights that the value of a resource (including cultural) changes according to the information acquired with its use (learning by doing).

Finally, he recognizes that technical progress can temper the effects of scarcity by improving resources use efficiency but points out that the effect of technical progress is asymmetrical with respect to the resources transformation function into public and private goods since it is the result of private investment. Technology tends to evolve towards forms that favour the production of private goods and services, often sacrificing public goods and services produced by environmental resources.

Hardin [3] addresses the problem of the long-term sustainability of population growth which can also be extended to the concentration of the urban population. He stresses that many properties of natural resources, such as the ability to assimilate waste and most of the "amenities", are "commons" for which the market is inefficient (unable) to achieve a socially optimal management. He also demonstrates that there is no optimal solution based on individual rationality but only a "moral" solution, anticipating Nobel Prize Elinor Ostrom's work [4] on the role of institutions in the management of common resources.

Finally, he poses the basic problem in the definition of the optimal social solution, of the "weighing" of private and public goods in the formation of well-being.

The basic principles theorized by these three authors have been extensively reworked and developed; however, they still remain an important theoretical and cultural reference for the generation of environmental economists of the last fifty years.

As mentioned earlier, the identification of concrete solutions for the construction of circular urban systems passes through the recognition of a coherent system of values and adequate evaluation tools.

This book collects contributions on evaluation models in decision-making processes for the construction of circular urban systems in the digital era, with particular attention to the improvement of social and individual well-being.

The book is organized into three sections, reflecting the main topics.

Part One, entitled “Models and Metrics for Social Impact Assessment”, presents some experiences in evaluating private and public assets in Italian cities, investigates the formation of value in urban regeneration projects, and tackles the problem of evaluating public and private advantages in urban planning choices.

Part Two includes eight contributions under the subtitle “Decision Making for Circular Cities” and addresses the problem of the transition between linear and circular systems in various fields: mining, social housing, and in the construction of architecture. It also presents some insights on the topic of sustainability with reference to the social, economic, and environmental dimensions.

Part Three faces the topic of “The Value of Spaces in the Digital Revolution” through five papers. The contributions focus, in particular, on the use of new technologies, such as webGIS and BIM, in economic and environmental assessment processes.

The book is addressed to experts and scholars working on urban regeneration and aims to encourage a multidisciplinary dialogue for shaping sustainable urban areas in the next future.

Turin, Italy — Francesca Abastante
Turin, Italy — Marta Bottero
Padua, Italy — Chiara D’Alpaos
Turin, Italy — Luisa Ingaramo
Milan, Italy — Alessandra Oppio (Chief Editor of the Springer SIEV Series)
Trieste, Italy — Paolo Rosato
Arcavacata, Italy — Francesca Salvo

References

1. Boulding K (1966) The economics of the coming spaceship earth. In: Jarrett EH (ed) Environmental quality in a growing economy. Resources for the future/Johns Hopkins University Press. Baltimore
2. Krutilla JV (1967) Conservation reconsidered. The American Economic Rev 57(4) (Sept 1967). The American Economic Association
3. Hardin G (1968) The tragedy of the commons, science, new series. 162(3859) (Dec 13, 1968)
4. Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge

Contents

Models and Metrics for Social Impact Assessment

An Analysis of the Housing Market Dynamics in the Italian Municipalities

Pierluigi Morano, Francesco Tajani, Marco Locurcio, Felicia Di Liddo, and Rossana Ranieri

Abstract The Covid-19 pandemic has caused numerous variations in the global economies with repercussions in all sectors. Once the emergency phase has finished, the entire worldwide population has changed its lifestyle and has had to adapt to live with the pandemic. In particular, the several modifications that have occurred in the job market and in schools and universities have determined a necessary reorganization of domestic spaces. The present study represents the first phase of a wider research aimed at verifying the transformation in the Italian residential market demand resulted by the Covid-19. The analysis carried out in this work has been performed at the municipal level, by considering the data published by the National Institute of Statistics collected for the 15th General Census of the population and housing in 2011. The dataset collected has been processed through an advanced econometric technique in order to identify the functional relationships between the residential average unit market value and the main architectural, socio-demographic and territorial factors. Further developments of this research will concern the application of the same methodological approach proposed to data detected by the National Institute of Statistics for the 16th Census scheduled for 2021.

P. Morano · M. Locurcio · F. Di Liddo (✉)
Department of Civil, Environmental, Land, Building Engineering and Chemistry (DICATECh), Polytechnic University of Bari, Via E. Orabona 4, 70126 Bari, Italy
e-mail: felicia.diliddo@poliba.it

P. Morano
e-mail: pierluigi.morano@poliba.it

M. Locurcio
e-mail: marco.locurcio@poliba.it

F. Tajani · R. Ranieri
Department of Architecture and Design, Sapienza University of Rome, Via Flaminia 359, 00196 Rome, Italy
e-mail: francesco.tajani@uniroma1.it

R. Ranieri
e-mail: rossana.ranieri@uniroma1.it

F. Abastante et al. (eds.), *Urban Regeneration Through Valuation Systems for Innovation*, Green Energy and Technology, https://doi.org/10.1007/978-3-031-12814-1_1

Keywords Covid-19 pandemic · Remote working · Housing market dynamics · Econometric models · Market value

1 Introduction

The Covid-19 pandemic, which started in early 2020, has led to relevant changes in both global economies and socio-economic dynamics of all countries [22]. In general terms, in the first months of 2020, the international economy, already characterized by a deceleration process from the previous year, has been strongly affected by the negative impacts of the sanitary emergency. The Covid-19 and the related containment strategies have led to a global recession that differs from other events mainly in two different aspects: (i) the epidemiological origin, external to the financial and economic unbalance usual causes, (ii) the transmission channels that have involved the market supply and the demand in a rapid and intense way. However, the International Monetary Fund—IMF—has observed a slight recovery in worldwide economies in 2021, despite the spread of the "*Delta variant*". This revival is heterogeneous, as it is associated to economic divergences in all over the world, mainly caused by large disparities in vaccine access and by different recovery and support policies [6].

In the Italian context, the health crisis impact on the national economy has been included in a near stagnation phase. In 2019, Gross Domestic Product—GDP—has grown by 0.3%, detecting a slowdown compared to 2018. Furthermore, in the 2020, the partial block of activities related to the health crisis has caused negative effects on the supply and demand, as in the main European countries, and the GDP has marked a contraction of − 7.8% in Italy.

In the Italian context, the Covid-19 pandemic has slowed down the residential property sales in 2020, whereas in the first quarter of 2021 an increase in the housing sales volume (+ 38.6%) has been detected, partly due to the comparison with the first three months of 2020 in which the sales have completely stopped. The increase has concerned all national geographic areas, with the highest growth for the city of Genoa (+ 36.7%), followed by the cities of Rome, Turin and Naples (+ 30%). In addition, in the first part of 2021, the greatest market appreciation has concerned the largest residential units, with indoor area between 115 and 145 m^2 (+ 41.2%) and over 145 m^2 (+ 48.5%) [8].

In the framework outlined, the Italian government has issued the so-called "Relaunch Decree" [9] which introduces the Superbonus, i.e. a tax benefit that provides for a 110% deduction rate for maintenance work on buildings involving: (i) expenses incurred for specific energy efficiency interventions, (ii) anti-seismic interventions, (iii) installation of photovoltaic systems; (iv) infrastructures for recharging electric vehicles.

The Covid-19 pandemic is having a relevant effect on different field of human activities, forcing to rethink current consolidated job models and lifestyle [17].

The lockdown period has determined a reorganization of the days' timeline and a redistribution of domestic spaces. The processes of reconfiguration of the activities and, consequently, of housing areas have been radically accelerated. The interpenetration of the private sphere, related to the usual actions to be carried out in home spaces (sleeping, having lunch, having dinner, having a shower, etc.) and of the public sphere (school space, workplace, sociality areas, etc.) represents a significant aspect resulting to forced period of "domestic isolation" [21].

The remote working and the distant learning have had consequences in many different aspects, such as the job markets, the real estate sectors, the transport systems, the personal wellbeing etc. Furthermore, the permanence of these conditions could also have repercussions on the office market sector (less office space may be required) and could drastically vary the domestic and the urban spaces (www.bloomberg.com) [1].

In this sense, the organization of domestic space is becoming increasingly relevant, after having lived it as hotel or, even, as dorm, because life was considered outside, in the city's streets and squares. Moreover, the digitalization of work has changed the perception and management of housing spaces. The Italian DPCM of 11 March 2020—art. 1, no. 7, lett. A), provides that, with reference to production and professional activities and in the lockdown period, "the maximum use by companies of agile working methods is implemented for activities that can be carried out at home or remotely" [2]. The remote working has been strongly influencing the relationship between user and home: new housing places have been created in order to integrate work and daily life models. These phenomena could contribute to change the "living space", by transforming the potential buyers' needs and, consequently, the residential market demand.

In this possible future scenario, every houses room and space will modify its uses in accordance with the new purposes: for example, the current open space living areas may be replaced by defined rooms suited to carry out the online teaching or the smart working activities. Furthermore, the new ways of working and living in houses could vary the users' perception of outdoor spaces, i.e. balconies, condominium gardens or courtyards, or, in the case of single villas, of private terraces and patios, as the pertinence external places having been highly regarded during the lockdown.

The different appreciation for specific housing elements, shown as a result of Covid-19 pandemic has been influencing the market demand and has had relevant impacts on residential selling prices in the near real estate future [11, 16].

2 Aim

With reference to the Italian context, the research aims to analyze the market behaviors, investigating the real estate dynamics that link the housing prices and the factors that have the highest impact on potential buyers' decisions. The analysis is carried out at the municipal level, considering the data published by the National Institute of Statistics—ISTAT—collected for the 15th general census of the population and housing in 2011 (www.istat.it) [14].

The research intends to examine the determinants of property average unit market values in 2011 in all Italian municipalities, i.e. the variables that have influenced the choices of each territorial context population in order to highlight the respective contribution to the selling prices formation processes. The function correlations between housing prices and the main variables considered have been explained through an econometric technique, which uses multi-objective genetic algorithms to search those model expressions that simultaneously maximize the accuracy of the data and the parsimony of the final mathematical functions. In particular, the implementation of an econometric technique has led to determine the functional relationships between the residential property values and the main architectural, socio-demographic and territorial factors.

It should be highlighted that the present work is part of a wider and relevant research line, currently in progress. The aim concerns the comparison of the results obtained in this analysis related to the 2011 with the outputs deriving from the elaborations on the 16th general census of the population and housing to be carried out in 2021. The research intends to underline the possible demand variation as results of economic and social events occurred in the recent years, i.e. related to the current global public health crisis. In this sense, the expected outputs concern the change in the market appreciation of the property influencing factors: the main reference is represented by the architectural variables, following the different domestic space use after the new need of remote worker, students and, in general, home users revealed after the Covid-19 pandemic lockdown period.

Therefore, even if the results do not reflect the current residential market phenomena, the aim of the present research is a first fundamental step for the definition of a methodological approach able to assess the variation in the functional correlations between housing prices and different influencing factors. The methodological approach developed could be useful for the Public Administration (i) to monitor the market dynamics that influence the purchase choices of potential buyers, (ii) to address the future planning decisions according to the needs detected in each territorial context and (iii) to identify the most convenient areas for the investment, also in view of the current fiscal incentives aimed at promoting building works for the energy efficiency improvement. Furthermore, the proposed method could be a valid reference for the private investors (i) to provide a framework for addressing the design phases of single residential unit and (ii) to support the investment decision processes aimed at planning effective and profitable initiatives.

3 Case Study

The population of the three study samples concerns a total of 8,064 Italian municipalities located in the three macro-areas in which the national territory is ordinarily divided (Northern Italy, Central Italy and Southern Italy and the Islands).

Compared to the total number of Italian municipalities in 2011—8092 municipalities, it should be noted that in the analysis 28 municipalities have been excluded for data unavailability. In particular, in the Northern cluster the Valle d'Aosta, Piedmont, Lombardy, Trentino-Alto Adige, Veneto, Liguria, Emilia-Romagna and Friuli Venice Julia regions are included with 4534 municipalities; in the Central macro-area Tuscany, Lazio, Umbria and Marche regions are included with 993 municipalities; in the Southern and the islands macro-area the territory of Apulia, Molise, Basilicata, Calabria, Abruzzo, Campania, Sicilia and Sardinia regions are covered with a total of 2537 municipalities.

3.1 Variables

Within each macro-area, the property average unit market values (P), expressed in €/m^2 represents the dependent variable of the model. The data related to this variable have been collected through the analysis of the elaborations on the market transactions published by the Observatory of the Real Estate Market and Estimative Services of the Italian Revenue Agency—OMI—(www.agenziaentrate.gov.it) [7]. In particular, the information considered in the analysis is the average value between the minimum value and the maximum one of the "civilian housing" and "economic housing" categories.

With reference to the data published by ISTAT for the 15th general census of population and housing in 2011, the variables considered in the model for each municipality of the three samples are classified as follows:

Architectural variables

- the number of residential load-bearing masonry buildings [M];
- the number of residential buildings in reinforced concrete [C];
- the number of residential buildings in other materials (steel, wood, etc.) [O];
- the number of residential buildings built before 1919 [Ba];
- the number of residential buildings built from 1919 to 1980 [Bb];
- the number of residential buildings built after 1980 [Bc];
- the number of residential buildings with a maximum of eight residential units or flats [Fa];
- the number of residential buildings with more than eight residential units or flats [Fb];
- the number of residential buildings characterized by excellent maintenance condition [Me];
- the number of residential buildings characterized by good maintenance condition [Mg];
- the number of residential buildings characterized by mediocre/inadequate maintenance condition [Mm];
- the number of residential buildings characterized by very poor maintenance condition [Md];

- the surface of the residential unit per occupant/inhabitant in the occupied flats, expressed as the number of inhabitants in square meters of gross floor area [S].

Socio-demographic variables

- the resident population under the age of 30, expressed as the number of inhabitants [Pa];
- the resident population between ages of 30 and 45, expressed as the number of inhabitants [Pb];
- the resident population over the age of 45, expressed as the number of inhabitants [Pc].
- the resident population with old and the new order university degree or non-university tertiary diplomas, expressed as the number of inhabitants [Ps];
- the total resident population of 15 years and more producer of job income, expressed as the number of inhabitants [Pj].

Territorial variables

- the value of degree day recorded for each municipality [Sc][1];
- the seismic zone in which the municipality is located [Sc][2].

[1] Degree days are defined by Presidential Decree n. 412/93 as the sum, extended to all days of a conventional annual heating period, of the only daily positive differences between the ambient/room temperature, conventionally set at 20 degrees Celsius, and the average daily external temperature. The unit of measurement used is the degree-day (DD). In brief, a low value of DD indicates the hottest areas where the external temperatures are closer to 20 °C and, therefore, there is less need for heating. On the other hand, a high DD value shows the areas in which the daily temperatures are very different from 20 °C and a more rigid climate with higher need for heating is found. On the basis of degree days values, the Italian territory has been divided into six climatic zones, for which the same or very similar climatic conditions are detected. In particular, the zone A indicates the warmest municipalities, whereas the F one refers to the coldest ones. The Presidential Decree n. 412/93 updated to 31 October 2009—Table A reports the climatic zones classified according to the list of Italian municipalities divided by regions and provinces [3].

[2] The seismic zone in which the municipality is located is defined by considering the Ordinance of President of the Council of Ministers n. 3274 of 20 March 2003. The Italian territory has been divided into 4 main categories that indicate each municipality seismic risk, calculated according to the Peak Ground Acceleration—PGA, i.e. the peak acceleration to the ground, and to the frequency and intensity of events: seismic zone 1 (high seismicity—PGA over 0.25 g), seismic zone 2 (medium–high seismicity—PGA between 0.15 and 0.25 g), seismic zone 3 (medium–low seismicity—PGA between 0.05 and 0.15 g), seismic zone 4 (low seismicity—PGA between less 0.05 g). Zone 1 is the most dangerous, as catastrophic events are frequent; in zone 2 strong earthquakes, although of lesser intensity, can occur and create significant damage. Zone 3 is characterized by a low seismicity, which however in particular geological contexts increase. Finally, Zone 4 is the lowest seismic risk area in the national territory, as slight and sporadic tremors are possible, with a low possibility of causing damage [15].

4 Method

The method implemented in the present research is a data-driven technique, called Evolutionary Polynomial Regression EPR [5], that is a versatile symbolic regression tool. The technique has been already explained in several researches, as it has been implemented in the real estate appraisal field in [13, 18–20].

In the present research an evolution of EPR has been proposed and tested. This technique, called Multi-Case Strategy for EPR (MCS-EPR), allows to obtain generalized prediction models able to identify the functional relationships that simultaneously describe the selling prices mechanism in different study samples, i.e. in different territorial contexts or for different situations. In this sense, in order to study a phenomenon in different cases/contexts, the MCS-EPR defines a "generalized" equation for determining the price, in which the influential factors between those initially considered and the related functional correlations with market values are identified. The several models obtained from the implementation of the technique are valid for all the samples analyzed.

In the present study only the main characteristics able to clarify the MCS-EPR use are illustrated. In brief, the MCS-EPR strategy searches for the model unique expression, in which the explanatory variables are combined. Furthermore, the different polynomial coefficient parameters for all considered data samples are identified. Thus, although the functional relationships between influencing factors and property prices are the same in absolute terms for all study samples, the numerical multiplicative parameters are different for each case analyzed. In the real estate sector the MCS-EPR has been implemented in order to study the influence of influencing factors on selling prices in three Italian study samples [12] and in the different urban areas of the city of Bari [4].

In particular, the generic polynomial expression is reported in Eq. (1):

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

where n is the number of additive terms of the polynomial expression (bias excluded), 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 variable input within the i-th term in Eq. (1), f is a function constructed by the process during the implementation of the methodology. The exponents (i, l) are also selected by the user in the preliminary phase from a range of real numbers. The parameters a_j are evaluated by a Least Squares method. The quantity and the mathematical complexity of the models generated by the technique depend on the maximum number of terms and of exponents that the user set in the preliminary phase of the implementation.

Therefore, the technique generates a wide range of solutions, each one characterized by a more or less complex algebraic structure and by a different level of statistical accuracy. With reference to the statistical performance of each model, a generalized Coefficient of Determination (COD_{MCS}) defined in Eq. (2), is calculated. The closer to the unit value the COD_{MCS} is, the more suitable the model structure is in representing the overall observed dataset.

$$COD_{MCS} = 1 - \frac{\sum_{k=1}^{m} \sum_{N_k} (y_k - y_{rilevato})^2}{\sum_{N} (y_{rilevato} - media(y_{rilevato}))^2} \quad (2)$$

The final choice of the best solution is made by the user, taking into account the knowledge of the study phenomenon and the purpose of the analysis carried out.

5 Application of the MCS-EPR Technique to the Three Study Samples

Before explaining the application of the MCS-EPR technique to the three study samples, it is necessary to specify that the first test carried out to analyze the functional correlation between the explanatory variables and selling prices with reference to 2011, has been concerned the implementation of the EPR technique to a unique database of 8064 Italian municipalities. In this sense, the division of the three study samples (Northern Italy macro-area, Central Italy macro-area, Southern Italy and Islands) has not been considered in this first step of the analysis. The results obtained have not been good in statistical terms and the functional relationships have not been confirmed the empirical phenomena expected. This situation could be explained either by the dataset detected in the original step of the analysis, i.e. the factors selected, or by the presence of anomalous data.

Thus, the detected data analysis has led to verify the existence of three different clusters in which the property prices formation processes could be unique. With reference to the three Italian geographical macro-areas ordinarily considered, the MCS-EPR technique has been implemented in order to investigate the housing market phenomenon related to the formation of prices.

Therefore, in the present research, the MCS-EPR technique has been implemented considering the base model structure reported in Eq. (1) with no function f selected. In the model the dependent variable is represented by the natural logarithm of the property average unit market values (Y = ln(P)), in line with the reference literature relating the property market [10].

The implementation of the technique to the three study samples has generated several models. The mathematical form of each equation consists of an algebraic sum of monomial terms, and each one is a combination of the input variables (i.e.

the explanatory variables) raised to appropriate numerical exponents. In the present research, the possible candidate exponents are equal to (0; 0.5; 1; 2), whereas the maximum number of terms of each returned equation is equal to eight. Among the model generated by MCS-EPR, the generalized model selected is reported in Eq. (3). In particular, it is characterized by a good level of statistical reliability, confirmed the COD_{MSC} value equal to 66.03%.

$$\begin{aligned} Y = {} & a_1 \cdot Sc^{0.5} + a_2 \cdot Ps^{0.5} + a_3 \cdot Ps^{0.5} \cdot S^{0.5} \\ & + a_4 \cdot Ps \cdot Md + a_5 \cdot Pb \cdot Ps^{0.5} \cdot Sa^2 \\ & + a_6 \cdot Pa^{0.5} \cdot Fa^{0.5} \cdot Sa^{0.5} \cdot Sc^2 \\ & + a_7 \cdot Pa^{0.5} \cdot Ps^{0.5} \cdot Pj^{0.5} \cdot Fa^2 \\ & + a_8 \cdot Pa^2 \cdot Pj^{0.5} + a_0 \end{aligned} \tag{3}$$

The analysis of the model of Eq. (3) gives rise to interesting considerations. First of all, the variables selected in the generalized model as the most influential in the explanation of the property average unit market values processes in all the three macro-areas of the Italian territory are the following:

- for the architectural variables: the surface of the residential unit per inhabitant in the occupied flats [S], the number of residential buildings characterized by inadequate maintenance condition [Md], the number of residential buildings with a maximum of eight residential units or flats [Fa];
- for the socio-demographic variables: the resident population under the age of 30 [Pa]; the resident population between ages of 30 and 45 [Pb]; the resident population with old and the new order university degree or non-university tertiary diplomas [Ps]; the total resident population of 15 years and more producer of job income [Pj];
- for the territorial variables: the value of degree day recorded for each municipality [Sc] and the seismic zone in which the municipality is located [Sa].

The other variables, initially considered in the analysis, are not included in the generalized model. This attests that in 2011—reference year of the collected data—some typological and architectural residential buildings characteristics were not taken into consideration by the ordinarily buyers in all Italian municipalities. In other words, in 2011 a scarce attention of the market operators has been highlighted with reference to the structure typology—load-bearing masonry, reinforced concrete or other materials, as steel, wood, etc., or the building age or the excellent maintenance conditions, that might indicate the presence of innovative technological systems. The scarce market appreciation to these aspects attests a perception lack of the added value that could result from one architectural factor rather than another.

Moreover, from the analysis of model of Eq. (3), it should be observed that all variables are combined within the same additive terms and, in some cases, also appear several times within the expression.

In order to identify the specific model of each study sample, the numerical multiplicative parameters a_i have been replaced in the model. In Table 1 the coefficients of the generalized model selected for each of the three study samples are reported.

Given the specific parameters for each study sample, the three models for the three Italian macro-areas considered are illustrated in Eqs. (4), (5) and (6) (Table 2).

The models obtained are characterized by COD values respectively equal to 70.78% for the Northern Italy macro-area, to 66.55% for the Central Italy macro-area and to 67.46% for the Southern Italy and Islands macro-area.

All coefficients are different from the zero value, except for the a_8 parameter for the Southern Italy and Islands study sample: anyway, this multiplicative coefficient does not nullify the influence of the variables Pa and Pj—that are in the same term with $a8$—as the same factors are in other terms of the mathematic expression.

Table 1 Numerical coefficients a_j of the generalized model

	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8
Northern Italy	8.85	− 4.31	14.89	− 11.3	− 3.30	− 6.58	5.90	− 12.9	− 5.60
Central Italy	7.98	− 1.99	12.70	− 8.35	− 7.10	3.36	3.44	− 17.6	− 17.11
Southern Italy and Islands	6.13	− 0.55	12.21	− 7.84	− 6.04	2.53	1.61	− 17.0	0

Table 2 Models obtained for each Italian macro-area analyzed

Northern Italy	$Y = -4.31 \cdot Sc^{0.5} + 14.89 \cdot Ps^{0.5} - 11.28 \cdot Ps^{0.5} \cdot S^{0.5} - 3.30 \cdot Ps \cdot Md - 6.58 \cdot Pb \cdot Ps^{0.5} \cdot Sa^2 + 5.90 \cdot Pa^{0.5} \cdot Fa^{0.5} \cdot Sa^{0.5} \cdot Sc^2 - 12.91 \cdot Pa^{0.5} \cdot Ps^{0.5} \cdot Pj^{0.5} \cdot Fa^2 + 5.60 \cdot Pa^2 \cdot Pj^{0.5} + 8.85$	(4)
Central Italy	$Y = -1.99 \cdot Sc^{0.5} + 12.71 \cdot Ps^{0.5} - 8.35 \cdot Ps^{0.5} \cdot S^{0.5} -7.10 \cdot Ps \cdot Md + 3.37 \cdot Pb \cdot Ps^{0.5} \cdot Sa^2 + 3.44 \cdot Pa^{0.5} \cdot Fa^{0.5} \cdot Sa^{0.5} \cdot Sc^2 - 17.62 \cdot Pa^{0.5} \cdot Ps^{0.5} \cdot Pj^{0.5} \cdot Fa^2 + 17.11 \cdot Pa^2 \cdot Pj^{0.5} + 7.98$	(5)
Southern Italy and Islands	$Y = -0.55 \cdot Sc^{0.5} + 12.21 \cdot Ps^{0.5} -7.85 \cdot Ps^{0.5} \cdot S^{0.5} -6.04 \cdot Ps \cdot Md + 2.54 \cdot Pb \cdot Ps^{0.5} \cdot Sa^2 + 1.61 \cdot Pa^{0.5} \cdot Fa^{0.5} \cdot Sa^{0.5} \cdot Sc^2 - 17.00 \cdot Pa^{0.5} \cdot Ps^{0.5} \cdot Pj^{0.5} \cdot Fa^2 + 6.13$	(6)

In this regard, it should be pointed out that for each variable selected by the technique and shown in the Eqs. (4), (5) and (6) does not allow to immediately check the empirical consistency of the signs of the independent variables with the real phenomena, due to the presence of several variables in the same additive terms and/or the repetition of the same variables in more expression terms, also with opposed functional correlation.

Therefore, more accurate analyzes are necessary for the empirical interpretation of the model of Eqs. (4), (5) and (6).

In order to (i) verify the trend of each factor selected by the generalized model and (ii) quantitatively specify the contribution of each independent variable in the formation of the housing prices, an exogenous mathematical approach has been implemented. In particular, by varying the *i-th* influencing factor in the eligible range for the three study samples, and by keeping constant the values of the other factors, for each variable the analysis of the functional correlation between the specific variable and the property average market values has been carried out.

For all explanatory factors selected as influencing in the property market value formation, the trends detected have been found consistent with the expected outputs. In Fig. 1 the main functional links related to the architectural variables are reported.

With reference to the aim of the present research, the choice to investigate in detail the factors connected to the architectural aspects is reasonably justified. In fact, it is recalled that the present analysis represents a first step of a research work in progress that will be implemented with the outputs deriving from the elaborations on the 16th general census of the population and housing to be carried out in 2021. In general terms, in fact, the research intends to underline the possible demand variation as

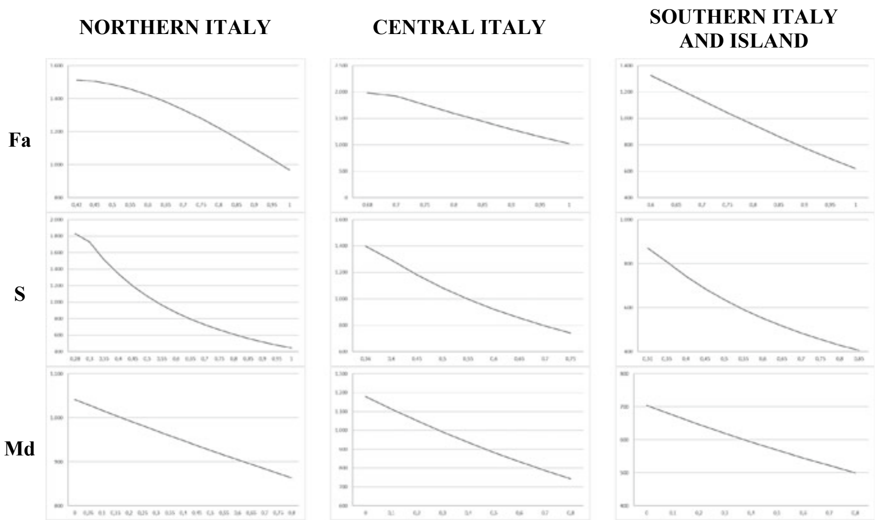

Fig. 1 Functional correlations between the main influencing architectural factors ([Fa]; [S]; [Md]) and the property average unit market values

results of relevant economic and social events occurred in the recent years, e.g. the Covid-19 pandemic.

6 Conclusions

The present study constitutes the first phase of a wider research aimed at analysing and monitoring the housing market dynamics that influence the purchase choices of potential buyers. In particular, the main goal of this research concerns the definition a methodological approach capable of: (i) providing a framework for addressing the design of individual housing units due to possible changes in market demand and/or the definition of new home spaces; (ii) guiding the future investment choices of public operators for the drafting of planning strategies in the residential segment; (iii) defining a valid reference for private operators for the definition of effective and profitable investments.

Recent developments regarding the global health crisis have highlighted that "the pandemic is not over anywhere until it is over everywhere". If Covid-19 pandemic were to have a prolonged impacts into the medium and long term, it could reduce GDP by a cumulative $5.3 trillion over the next five years (www.imf.com), and permanently vary the community requirements of domestic spaces.

This study has developed a methodological approach able to analyse the correlation between the main influencing factors in the housing prices formation mechanisms and to monitor the dynamics modifications by taking into account different market phases. Future developments of the research will concern the verification of the existence and extension of significant changes that could occur in the housing market appreciation of architectural, socio-demographic and territorial factors by the potential buyers.

As regards the future implications on real estate markets, the outputs obtained in the present research provide a reference framework able to appropriately describe the price formation mechanisms in Italy. The application of the same methodology in the post Covid-19 pandemic situation will allow to verify the effects of this event on real estate market and to monitor the functional correlations typologies, in order to attest the permanence or the resilience of the dynamics observed. These analyses represent a fundamental tool to be implemented to orient the investment choices processes consistently with the currents needs and the most relevant influencing factors considered by the potential buyers and sellers in the bargaining phases, towards effective and profitable decisions. The trend of real estate market should be examined both in terms of variations of selling prices and of different intrinsic developments, for the purpose to investigate its evolution over time and the permanent and/or temporary impacts caused by exogenous events.

References

1. Bloomberg news. Available online https://www.bloomberg.com/news/storythreads/2021-04-28/what-will-the-world-of-work-look-like-after-covid-19. Accessed on 18 Oct 2021
2. Decree of the President of the Council of Ministers (March 11, 2020) Further provisions implementing decree-law no. 6 of February 23, 2020, on urgent measures for the containment and management of the epidemiological emergency from COVID-19, applicable throughout the country
3. Decree of the President of the Republic No. 412 (August 26, 1993) Regulation laying down rules for the design, installation, operation and maintenance of heating systems of buildings for the containment of energy consumption, in implementation of article 4, paragraph 4, of law January 9, 1991, no 10
4. Di Liddo F, Morano P, Tajani F, Torre CM (2020) An innovative methodological approach for the analysis of the effects of urban interventions on property prices. Valori E Valutazioni 26
5. Giustolisi O, Savic DA (2006) A symbolic data-driven technique based on evolutionary polynomial regression. J Hydr 8(3):207–222
6. International Monetary Fund (IMF) (2021) Outlook October 2021. Available online https://www.imf.org/en/Publications/WEO/Issues/2021/10/12/world-economic-outlook-october-2021. Accessed on 18 Oct 2021
7. Italian Revenue Agency (2021) Observatory of the real estate market (OMI). Available online https://www.agenziaentrate.gov.it. Accessed on 10 Feb 2021
8. Italian Revenue Agency (2021) Trading volumes. Available online https://www.agenziaentrate.gov.it/portale/web/guest/schede/fabbricatiterreni/omi/banche-dati/volumi-di-compravendita/archivio-volumi-di-compravendita. Accessed on 18 Oct 2021
9. Law decree n. 34/2020 converted into law, by law n. 77, 17 July 2020, urgent measures on health, support for work and the economy, and social policies related to the epidemiological emergency from COVID-19
10. Lynch AK, Rasmussen DW (2004) Proximity, neighbourhood and the efficacy of exclusion. Urb Stud 41:285–298
11. Mattiacci A, Nocenzi M, Sfodera F, Sofia C (2020) Le conseguenze sull'attività professionale: tra incertezze e opportunità. In: Lombardo C, Mauceri S (eds) La Società catastrofica, vita e relazioni sociali ai tempi dell'emergenza Covid-19. FrancoAngeli, Milan, Italy, pp 100–130
12. Morano P, Rosato P, Tajani F, Manganelli B, Di Liddo F (2019) Contextualized property market models vs. generalized mass appraisals: an innovative approach. Sustainability 11(18):4896
13. Morano P, Tajani F, Locurcio M (2018) Multicriteria analysis and genetic algorithms for mass appraisals in the Italian property market. Int J Housing Mark Anal 11(2):229–262
14. National Institute of Statistics (ISTAT) (2021) General census 2011. Available online https://www.istat.it/it/censimenti-permanenti/censimenti-precedenti/popolazione-e-abitazioni/popolazione-2011. Accessed on 10 Mar 2021
15. Ordinance of president of the council of ministers n. 3274 of 20 March 2003, first elements on general criteria for the seismic classification of the national territory and technical regulations for buildings in seismic areas
16. Signorelli C, Capolongo S, D'alessandro D, Fara GM (2020) The homes in the COVID-19 era. How their use and values are changing. Acta Biomed 91(9):92–94
17. Stanghellini S, Breglia M (2020) Valutare nell'incertezza, un modello previsivo 2020–2025. Available online https://www.scenari-immobiliari.it/2020/04/30/valutare-nellincertezza-un-modello-previsivo-2020-2025/. Accessed on 25 July 2021
18. Tajani F, Morano P, Locurcio M, D'Addabbo N (2015) Property valuations in times of crisis: artificial neural networks and evolutionary algorithms in comparison. In: Gervasi O et al (eds) Computational science and its applications—ICCSA 2015. Lecture notes in computer science. Springer, Cham, pp 194–209

19. Tajani F, Morano P, Saez-Perez MP, Di Liddo F, Locurcio M (2019) Multivariate dynamic analysis and forecasting models of future property bubbles: empirical applications to the housing markets of Spanish metropolitan cities. Sustainability 11(13):3575
20. Tajani F, Ntalianis K, Di Liddo F (2017) An assessment model for the periodic reviews of the market values of property assets. In: Gervasi O et al (eds) Computational science and its applications—ICCSA 2017. Lecture notes in computer science, vol 10406. Springer, Cham, pp 490–500
21. Tajani F, Morano P, Di Liddo F, Guarini MR, Ranieri R (2021) The effects of covid-19 pandemic on the housing market: a case study in Rome (Italy). In: Gervasi O et al (eds) Computational science and its applications—ICCSA 2021, Lecture notes in computer science, vol 12954. Springer, Cham, pp 50–62
22. World Health Organization (WHO) (2021) Corona virus (COVID 19) dashboard. Available online https://covid19.who.int/. Accessed on 25 May 2021