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SINFONIA Project Mass Appraisal: Beyond The Value Of Energy Performance In Buildings

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Abstract

Energy retrofit of existing buildings stock is today a major urban challenge and opportunity. Although a market appreciation of green buildings is generally recognized, specificities related to different countries, contexts and sectors still need further investigation. Moreover, the energy retrofit carries with it multiple elements, ranging from monetary savings to personal fulfillment of living greener. The ongoing European smart city project SINFONIA offers the chance to analyze a double international case study, and to estimate expected positive effects on dwellings' value, due to energy retrofit measures undertaken at the district level. This paper, starting from previous similar experiences, designs an operational approach based on spatial hedonic price method and analytic hierarchy process. Finally, it suggests how to develop a spatialized mass appraisal by linking results with a geographical information system. Such approach will contribute to assess the socio-economic impact of SINFONIA project and to evaluate the effectiveness of further smart city initiatives.

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Keywords: "spatial hedonic price; analytic hierarchy process; mass appraisal; energy retrofit; smart city"

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1. Introduction

Sustainable buildings are attracting the interest of academics from different fields, including engineers, architects, urban planners, sociologist, and economists. As a result, studies on this topic explores different directions, mainly related to the implementation of new materials and energy efficient technologies, innovative design approaches, understanding of users behaviors and health conditions, and implementation and maintenance costs and benefits (Acre & Wyckmans, 2015; Aelenei et al., 2013; Preval, Chapman, Pierse, & Howden-Chapman, 2010; Stuart, 2012; Thatcher & Milner, 2012). Moreover, real estate operators and specialized research departments are interested in deepening the knowledge about energy and overall sustainability performance of specific categories of buildings and their market value (Antoniucci, D'Alpaos, & Marella, 2015; Antoniucci, Marella, & D'Alpaos, 2015).

So far, this issue has been approached from the perspective of sales price premium for certified green or high efficient buildings, compared with the average value of existing building stock (Eichholtz, Kok, & Quigley, 2010; Stuart, 2012). However, the real estate value, according to Forte (1973) and Orefice (1984), is not only related to categories of factors concerning the building itself, its systems, and its attitude to generate an income. Also relevant are the context where the asset is located and the legal framework to which it is subjected.

The decision to energy retrofit a single-family house is usually undertaken by the owner, on the basis of individual needs and ambitions. On the contrary, refurbishing a large block of flats involves multiple owners or, at least, several tenants under a single ownership, having different expectations and priorities. Moreover, urban projects may jointly address not only the building level but also the district level, aiming at the overall improvement of the local conditions (European Commission, 2013). Consequently, the implementation of project measures will modify at least three out of four above-mentioned categories of factors (with the exception of the legal framework), thus raising specific questions. First: how the value of refurbished dwellings will change, qualitatively and quantitatively? Second: because the category "energy refurbishment" encompasses multiple interventions on hard (envelope, windows, systems) and soft elements (consumer awareness, acceptance), which are the most representative in the definition of the dwelling price, at a reference level of energy performance? Finally, how will the overall value of the urban residential building stock change if energy retrofit measures are extensively replicated?

One of the aims of the SINFONIA smart city project is to develop a spatialized model, based on quantitative and qualitative variables, to answer these questions. The proposed spatially-explicit appraisal model combines hedonic regressions with hierarchical processes, in order to understand the effects of the foreseen refurbishment on dwelling's prices. In this paper, a brief review of similar experiences in this field is presented, together with an operational approach, taking advantages both from hedonic price method and multi-criteria analysis propose to investigate two case studies. Insights gained from this mixed method are then linked to spatialized information of urban building stock, to perform a mass appraisal and to estimate the overall increase in retrofitted buildings value.

2. The toolbox: spatial hedonic price method, multi-criteria analysis and geographic information systems

The object of the investigation is to estimate the expected change in real estate value, generated by (i) the SINFONIA project intervention in selected buildings, (ii) the development of a massive refurbishment program at the urban scale. Finally, (iii) a deeper investigation of single elements contributing to the definition of the whole value is performed.

The value of real estate proprieties, defined as the most probable selling price on the market, is estimable by applying different appraisal methods. A first distinction should be done between indirect (or analytic) and direct (or synthetic) methods. Indirect methods are adopted when the market for a certain typology of propriety is poor or even absent. They estimate the value as a function of expected actualised cash flow (rents), or as a function of production costs (unitary prices multiplied per quantities). Conversely, having an existing and active market, with real transactions, the analysis is usually done with a comparison between the object to be evaluated and the market prices of similar proprieties. Such direct appraisal methods are in turn classified as monoparametric or pluriparametric. The first are based on the comparison of a single paramount characteristic, mainly the dwelling's surface, and provide reliable results only if considered goods are enough homogeneous. The latter investigate multiple variables affecting the final real estate value and are useful in contexts where good's heterogeneity is predominant. One of the fundamental pluriparametric technique in the Italian real estate appraisal school is the so-called "*punti di merito*" approach, developed by Forte in the '70s (Forte & De Rossi, 1973). Forte's approach is founded on the assumption that if a certain propriety, similar to that we want to estimate, has the higher price on the market, it is, therefore, the one with the highest score (i.e. 100 points) based on four broad groups of characteristics (extrinsic location characteristics, intrinsic location ones, technological, and productive). The value of the object of estimation will be calculated as a weighted sum of its performances in the different four categories, and will be, obviously less than or equal to the reference case. The main critiques of this approach are the difficulty to find the higher transaction on the market and the weights definition. Additionally, some intrinsic or extrinsic characteristics may be affected by complementarity and reciprocity, because not practically distinguishable from the propriety as a whole.

To overcome these weaknesses, other methods, based on multiple regressions models, were developed with the aim of identifying the marginal contribution of a certain variable in the price function. Hedonic price (HP) is an econometric technique based on the rationale that the price of a certain good is a function, combining proper characteristics as well as external factors (Rosen, 1974). HP originated from Lancaster´s attribute theory, for which a value of a good is given by the sum of the values of its relevant attributes (Lancaster, 1966). By analysing a sample of the real transaction in the housing market, it is possible extrapolating the implicit price of a single characteristic and, consequently, understanding how the price is expected to change with respect to a reference case. The main arguments underpinning the reliability of the results are basically given by the quality of the sample, the right variables definitions, the appropriate algebraic function. In short, HP allows estimating how different attributes are capitalised in housing prices (Dastrup, Graff Zivin, Costa, & Kahn, 2012) or, in other words, the difference in the whole price determined by the variation of each single selected variable. Moreover, since the location is axiomatic in determining the real estate value (Krause & Bitter, 2012), several attempts have been done to incorporate this in house price modelling. As recalled by Won Kim, Phipps, & Anselin (2003), the first works in this field are those by Dabin and Can in the early 1990s. The spatial approach couples the information of the mere existence, or lack, of external factors with their proximity to the investigated object (Anselin, 1988), consequently it allows defining spatial relationships between external variables and price function. As a result, a spatial hedonic price (SHP) method may be implemented.

Among others, HP has been recently adopted to investigate how house prices may change due to better energy performance achievement, or by adopting renewable energy systems or even for air pollutant concentrations. Bonifaci & Copiello (2015) analysed the price premium of energy efficiency in the real estate market in a northern Italian city, Dastrup et al. (2012) the benefit of having solar panels on the roof in San Diego County, California (U.S.). Won Kim et al. (2003) offered an interesting application of an SHP approach, investigating the correlation between air quality and assets value in the Seoul metropolitan. They tested the spatial lag and spatial error models: two basic models adopted in spatial dependency investigation applied to real estate markets (Krause & Bitter, 2012). The first spatial dependency model, spatial-lag, assumes the presence of an indirect effect given by the prices of nearby houses on the price of each propriety (spillover). Conversely, the latter neglect such indirect effects, postulating the presence of one or more hidden and spatially related variables in the hedonic price equation.

Table 1 compares the main points of the abovementioned studies related to sustainable buildings and environmental features. These studies confirm how, in different magnitudes, green attributes of buildings and positive environmental conditions are appreciated by owners, and therefore translated into the real estate prices. However, the "energy refurbishment" is a so-called "macro" variable, which can be further decomposed into "micro" elements, representing the different values attributed by the market to detailed benefits strictly related to such interventions. Monetary savings, basically due to decrease in energy consumption (Krause & Bitter, 2012) and lower maintenance costs (Ürge-Vorsatz et al., 2010) are the most evident. Nevertheless, in a preliminary and not exhaustive list, other elements should also be mentioned, such as:

- the reduction of external noises, due to better acoustic insulation (D'Alpaos, Marella, Rosato, & Stellin, 2002; Jakob, 2006; Ürge-Vorsatz et al., 2010);
- a better thermal indoor comfort, due to thermal bridges reduction (Jakob, 2006);
- the decrease of air pollutant emission, especially Sox, due to a decrease in energy needs or improved efficiency in generators or fuel shifting (Won Kim et al., 2003);

- the lower risk of incurring in unforeseen additional costs, due to increas in energy prices or enactment of stringent energy regulations (Krause & Bitter, 2012);
- the expression of an individual green social status, due to the adoption of renewable sources (Dastrup et al., 2012), as well as an enhanced corporate image (Eichholtz et al., 2010; Krause & Bitter, 2012);
- the opportunity to reach one or more of the abovementioned co-benefits continuing to stay in a familiar place, saving the trouble of changing dwelling and neighborhood, and preserving the social capital (OECD, 2001).

These micro variables cannot be measured and estimated with the HP method, thus, a more specific investigation is needed to understand consumers' and owners' priorities and values. For examples multiple aspects may result from generating own green electricity: the "value" of avoided purchase, the quantitative contribution of avoided emissions and also an ''existence value'' for "*households who derive pleasure from knowing that they are generating their own* [green] *electricity"* (Dastrup et al., 2012, pg. 962).

Table 1. Hedonic price models comparison.

Reference Study	Model	Object of investigation	Function	Categories of characteristics	N of characteristics	Sample size (thousands of records)	City dimension (thousands of inh.)	Sample/inhabitants (%)	Characteristic/samples
(Bonifaci & Copiello, 2015)	HP	Energy Label	Log-linear	Location (L) Property (P) Technological (T)	L=1 (ZONES OMI) P=5 (SING, GAR-PARK, BATH, AME, SUR) T= 2 (CONDITIONS, E-LABEL) Total=8	1	200	0.5	1/ 118
(Won Kim et al., 2003)	SHP (Spatial-lag and spatial error)	Local Air Quality	Semi log	Neighborhood (N) Structural (S) Environmental (E)	N= 4 (DINCOM ,ACSHPT, ACSSCH, ACSPRK) S= 6 (DHOUS, TFLSP, NMRMS, NMBATH, HSAGE, DFUEL) E= 2 (NOx, SO2) Total= 12	0.6	10.000	0.006	1/ 50
(Dastrup et al., 2012)	HP + time series	Solar panels	Log	Solar (S) Others (X) Technical (N)	S= 1 (Solar) X= 8 (Square feet, Bedrooms, Baths, View, Pool, Acres, Owner occupied, Building year) N=3 (System cost, System size , Incentive amount) Total= 12	365	3.000	12	1/ 30416

To tackle similar issues, that are very case specific, because related to local habits and social behaviors, several multi-criteria techniques, dealing with both quantitative and qualitative indicators, have been developed in the last decades. These techniques may help in providing a solution to multiple objectives problems, and are based on various weighting methods, comparisons of choices, priorities definitions and outranking. Among others, the analytic hierarchy process (AHP) is a popular tool adopted in many different fields, ranging from energy planning (Pohekar & Ramachandran, 2004) to lead market drivers assessment (Zubaryeva, Thiel, Barbone, & Mercier, 2012), and also for indoor internal conform indicator definition (Chiang & Lai, 2002). Originally developed by Saaty (1980), it allows the evaluator to define the so-called decision tree underlining the choice of an object or the definition of a project's goal as the output of a coherent and objective decision process. Through pairwise comparison, a pool of experts is asked to define some key criteria, built upon more specific attributes, and to weight the relative importance (percentage) of each attribute within the unitary value of the output (expressed as 100%). An AHP has been also adopted by D'Alpaos et al. (2002) to predict how public works, dealing with environmental conditions improvement, should result in the overall building stock price change. The authors performed a so-called "mass appraisal" on a small community having around two thousand buildings. First, they set up a database with basic information on assets (age, typology, dimensions and location). Then, they defined and classified the characteristic determining the price, as usually done in an HP model. Finally, supported by a panel of local experts they weighted each characteristic. By defining the value function, and having few prices of existing transactions on the market, authors were able to assess the expected positive impact given by the improvement of extrinsic location characteristics. As a final result, they estimate a 32% increase of the overall building stock value, although no direct intervention on buildings was done. Similarly, experts opinion elicitation has also been used by Zubaryeva, Thiel, Barbone, & Mercier (2012) to identify key criteria and to weight their relevance in electric vehicles market development.

3. A double international case study

Moving from above reported experiences and considering the need to frame first the macro dimension and then the micro criteria, we suggest investigating the expected impact of energy refurbishment on housing prices and the weight of different elements in determining that, by adopting an innovative method, mixing the SHP and the AHP. To test it, a double case study is identified, represented by two similar European cities: Bolzano and Innsbruck.

Bolzano is located in northern Italy; capital city of South Tyrol, having close to 106,000 inhabitants, on a surface of 53 sqkm (2,033 Inh/sqkm). It is the economic, demographic and administrative core of a sound mountain province. South Tyrol has committed themselves to achieve relevant climate-energy targets by 2050, claiming as a "KlimaLand" (i.e. climate friendly territory) and moving toward a low-carbon development. Sustainability issues, rooted in the farmer mountain society, are since decades emerging in local development policies and plans. In particular, the local interest towards clean energy issues led to the creation of the CasaClima agency, responsible the for the certification of building energy performance, and to the establishment of the "Institute for Renewable Energy" within the already existing research center EURAC (EURopean ACademy).The city itself has recently joined the Covenant of Major and is involved in the implementation of the Sustainable Energy Action Plan, contributed by EURAC.

Innsbruck, in the Austrian province of Tyrol, has 126,000 inhabitants on 105 sqkm (1,209 Inh/sqkm). Despite different population densities, both cities are comparable with regards to the urban structures and offered services (university, research centers, an extended cycling path network, energy efficiency advice services, etc.). Similarly, both Provinces are involved in the implementation of a multiyear climate-energy plan. The Tyrolean Energy Strategy 2020 is mainly based on measures dealing with energy efficiency improvement in buildings' space heating and cooling, promotion of clean energy production from renewable sources and electricity consumption growth stopping. Innsbruck is also implementing the "Energy Masterplan" developed by alpS, a local research and consulting agency operating in the fields of climate change and sustainable development.

These two cities share a history of lasting economic, institutional and educational relationships. One of the latest, and most relevant, cooperation project between above-mentioned municipalities started in mid-2014, when they jointly launched a five years smart cities and communities project, funded under the European Union's Seventh Programme for research (FP7).

The FP7 SINFONIA project, whose acronym stands for "Smart INitiative of cities Fully cOmmitted to iNvest In Advanced large-scaled energy solutions", will mainly develop an innovative district approach for the energy refurbishment of buildings and networks at neighborhood level. The main aim of the project is to contribute to the development of smart energy cities (Mosannenzadeh et al., 2015). In a first stage, the project will act on select public owned residential buildings, although the general aim is to develop a scalable and replicable procedure, to be easily extended to a wider urban district as well as to be exported toward other cities (named "early adopters"). Although primary focuses on CO_2 emissions reduction, the SINFONIA project is expected to deliver a wide range of co-benefits at the urban level, and one of the highlighted co-benefits, probably incorporating some others, is thus the increase in refurbished dwellings value (Bisello, Grilli, Balest, Stellin, & Ciolli, 2015).

Within this project, energy refurbishment activities on social house buildings are foreseen in both cities. The project also concerns an improvement on the local District Heating and Cooling networks (DHC), integration of photovoltaic (PV) panels and solar thermal (ST) panels in buildings façades, the introduction of innovative and efficient Heating, Ventilation and Air Conditioning (HVAC) systems. As a project activity, also, a Geographic Information System (GIS) has been set up, where buildings are spatially georeferenced and related with a database having relevant information such as age, dimensions and volume, intended use, and estimated energy performance.

4. The mixed investigation model

On the basis of the above-mentioned methods, the two case studies of Bolzano and Innsbruck are investigated and value changes, related to SINFONIA project activities (i.e. energy refurbishment of existing social house dwellings), estimated by mixing the SHP and the AHP.

Thus, the operational research steps are defined as follows: (i) definition of categories and characteristics, (ii) data collection and the creation of a housing advertisements database, (iii) setting up of the SHP model and estimation of the marginal implicit price of the energy retrofit, as a “macro variable”. Then the (iv) definition of the “micro variables” contributing to the “macro variable”, (v) setting up of the AHP model, (vi) data collection through direct surveys, (vii) “micro variables” weighting and breaking down of the marginal implicit price of energy retrofit. Finally, by linking these results with the GIS a mass appraisal at urban scale is performed (viii).

In step (i) four categories are assumed: Location characteristics (L), Environmental characteristics (E), Propriety characteristics (P), and Technological characteristic (T). According to previously described experiences, the overall number of characteristics should range between 8 and 12, while specificities between Innsbruck and Bolzano may emerge. Variables may be categorical or continuous. Within (T) the energy performance is listed as a proxy of energy refurbishment.

The database creation, step (ii), requires on the field as well as on-line data collection. Housing advertisements are available through local real estate agencies and specialized websites. Advertisements must provide all the data defined in (i), needed to fill the database. Concerning the sample size, this should be related to the dimension of the city (inhabitants or number of dwellings). Previous similar studies adopted various coverages, ranging by 0.5% to 12% of inhabitants. Advertisements should cover energy-refurbished dwellings, low-performance dwellings and new high-performance ones

Step (iii) deals with the definition of the most appropriate function describing the dependencies. In the HP literature, there is not a pre-defined econometric model for the estimation, although linear and semi-logarithmic models are the most common choices. Usually, the functional form is determined by the box-cox transformation. Then a default parameter should be associated with each variable (best, worst or mean), acting as a threshold. Consequently, the qualitative hypothesis should be formulated on the expected algebraic sign (positive or negative) associated with all other possible differing values. The spatial component is added to the classic HP model by investigating spatial dependency among selected variables (by using spatial lag and spatial error models), obtaining the SHP model. Statistical analysis and sensitivity tests contribute to determining the appropriateness and robustness of the model in estimating the marginal implicit price of energy retrofit. Given the high number of factors affecting house prices, several variables are going to be analysed and tested. The number of variables to be included in the model may be reduced through statistical techniques, such as principal component analysis.

In step (iv) the “micro variables” embedded in the energy refurbishment of dwellings are listed and defined, thus becoming the specific attributes of key criteria. According to general rules of AHP, the number of elements in the matrix for pairwise comparison should not exceed seven (Saaty, 1980).

In setting up the AHP model (v), the most relevant criteria to be included in the definition of the AHP decision tree will be defined starting from result provided by the SHP in (iv). Moreover, results gained by stakeholders’ focus groups organized within the project, assessing the local knowledge and perception about co-benefits, can be considered.

The model is then calibrated in cooperation with a panel of local experts (vi). Real estate agents, social housing managers and professionals employed in agencies for energy performance certification are asked to validate model assumptions and to attribute weights to the different "micro variables". According to other experiences, the experts number should range between 17 and 20 and a semi-structured survey is needed.

By integrating findings from specialized literature and experts' opinion into the AHP model, the "micro variables" are weighted (vii). Indeed, the marginal implicit price of energy refurbishment of old and low performance dwellings is decomposed in a pool of multiple benefits belonging to different aspects of health, environment, well-being, and economy.

The last step (viii) links the results of SHP and AHP with information available through the GIS already developed by the project and thus leads to a mass appraisal. By isolating houses and dwelling from the whole existing building stock, and knowing the reference energy needs, is possible to estimate the expected positive impact on their value (price) given by the improvement of technological characteristics and the increase of the energy performance (by one or more classes).

5. Discussion and conclusions

This study has defined an appraisal model to estimate the relevance and value at the urban scale of energy retrofit measures on existing dwellings. First a spatial hedonic price method and an analytic hierarchy process are linked together, then results are applied to a geographical information system, to spatialize information and to hypnotize effects, on the whole, residential building stock. This lead to a mass appraisal on two real case studies.

Accuracy in advertisement database filling and reliability in weights attribution are the most critical operational steps, therefore, an adequate tradeoff between time and resource constraints, and the number of samples as well as of expert involved a should be carefully considered. According to Bisello, Grilli, Balest, Stellin, & Ciolli (2015) findings, the HP is a recurrent technique for assign multiple co-benefits delivered by urban energy retrofitting projects. Therefore, estimates provided by this study are suitable to partially assess the socioeconomic impact of the European smart city project SINFONIA itself. Moreover, they can sustain the formulation of further sustainable energy projects, policies for a sound improvement of urban competitiveness, innovative tools for effective actions at metropolitan scale (Calabrò & Della Spina, 2014). In particular, the decision to promote a large-scale energy retrofit campaign should result in "*good performance of a whole city, in terms of both buildings energy efficiency as well as real estate market efficiency*" (Bonifaci & Copiello, 2015, pg. 15). Asset managers of commercial buildings also consider that "*if tenants would prefer sustainable buildings, then sustainable buildings could have longer economic lives than conventional buildings*" (Eichholtz et al., 2010, pg. 2494).

Moreover, façades of a completely refurbished block of flats may play an exemplary role. As solar panels on the roofs of detached houses, they are readily apparent, and in a local context sensible to environmental issues may re-enforce the commitment, increasing the demand for similar interventions (Dastrup et al., 2012). In this way, by measuring the real estate value positive change, and including further investigation on employment benefits due to construction works, it is possible to demonstrate how such projects can become a catalyst for a green local economic development and social enhancement. Finally, by adding in the model also variables and criteria dealing with project activities improving the location characteristics (extrinsic variables), it will be possible to assess public works (D'Alpaos et al., 2002) and policies (Won Kim et al., 2003) cost effectiveness.

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