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This is a post print of the following article

*Original Citation:*

Modeling The Effects of Environmental Impacts and Accessibility on Real Estate Prices in Industrial Cities / Chiarazzo, V; Dell'Olio, L; Ibeas, A; Ottomanelli, Michele. - In: *PROCEDIA: SOCIAL & BEHAVIORAL SCIENCES*. - ISSN 1877-0428. - 111:(2014), pp. 460-469. [10.1016/j.sbspro.2014.01.079]

*Availability:*

This version is available at <http://hdl.handle.net/11589/4016> since:

*Published version*

DOI:10.1016/j.sbspro.2014.01.079

Publisher:

*Terms of use:*

(Article begins on next page)

EWGT2013 – 16<sup>th</sup> Meeting of the EURO Working Group on Transportation

## Modeling the effects of environmental impacts and accessibility on real estate prices in industrial cities

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### Abstract

This article presents hedonic Multiple Linear Regression models (MLR) to estimate real estate price variations in metropolitan areas as a result of changing environmental and accessibility conditions. The goodness of fit of the model has been compared along with a series of hypotheses about the performance of the specifications considering spatial relationships between observations. The case study for such analysis is the metropolitan area of Taranto (Southern Italy). The models which considered spatial dependence between observations offered a greater degree of fit in a scenario showing strong spatial correlation in MLR residuals.

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Selection and/or peer-review under responsibility of Scientific Committee

*Keywords:* Hedonic pricing models; Transport and land use interaction; accessibility.

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### 1. Introduction and objectives

Classic theories on urban economy are based on the trade-off between accessibility and space (Alonso, 1964). From this view, since certain decision makers are more willing to pay higher prices for them, then locations with better accessibility to the urban system services and activities usually have higher real estate values per unit area (Muth, 1969). These theories imply that investments in transport system can improve accessibility to certain locations and affect property values.

Actually, in addition to accessibility, and other relevant attributes, urban systems users have been addressing an increasing attention to the quality of the environment. Where pollution is relevant the quality of environment has become an important attribute that could affect the residential choice location behaviour and, consequently land-

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use, mobility and economy in the interested areas.

This issue is important in those cities where environmental problem are very relevant because of the location of big industrial plant and accessibility problem where people daily face the risk of diseases due to high pollution levels. This is the case of the city of Taranto (Southern Italy) where is located the biggest steel factory and the main industrial port in Europe as well as a big oil refinery. As consequence of these issues, the urban area is showing a residential migration flow towards zones far from the city centre that is closed to the industrial plants and to the port.

In addition, as it results from the Local Transport Master Plan, the chosen locations are affected by a lower accessibility and services without relevant potential benefit in term of real estate market prices.

Hedonic models can help in estimating the variation in real estate prices as function of environmental and other local attributes making them a potentially useful tool to support investment in transport projects through value capture policies. These studies was carried out by Court (1939), Lancaster (1966) and formalized by Rosen (1974) who finally showed how markets worked for heterogeneous goods. Furthermore, integrating hedonic models in Land Use/Transport Interaction models (LUTI models) it could also help the analyst to simulate the interactions generated in an urban system where location choices for housing or companies strongly depend on the real estate market (Löchl and Axhausen, 2010; Waddell et al., 2007).

The aim of this paper is to highlight the role of quality of environment on residential location choice considering the real estate price, accessibility and other local land-use attributes to assess how the risk of disease affects for example, the higher transportation cost.

This article presents hedonic regression estimators to verify, in accordance with the accepted economic theory, the hypothesis that the dwellings with better accessibility do capitalise, to a certain extent, these benefits; in other words, to verify to what extent a relationship between the accessibility conditions, environmental context and the dwelling market values does exist.

Throughout this paper, after the following section, presents the state of the art of the models developed to estimate the impacts on real estate, hedonic regression models will be estimated with and without considering the existence of spatial dependence between observations. Then, in Section 3 a Multiple Linear Regression (MLR) model is estimated using the traditional hedonic regression technique applied to a dataset from the urban area of Taranto (Southern Italy).

The specification of the proposed models is presented in Section 4 and the model calibrations are analysed and the results discussed. In the final section some conclusions are drawn on the opportunity to take into account the existence of spatial effects when modelling the real estate market as well as on the opportunity to use a given modelling specification to capitalize environmental issue onto the housing market prices.

## 2. Literature review

The hedonic studies relating real estate prices with transport conditions have complemented the theories on urban economy and tested their hypotheses through multiple case studies (Ibeas and al., 2012).

Research about how transport conditions influence real estate prices was initiated by von Thünen (1826) and later served as a basis for creating a theory about the distribution of land use and rents in urban areas proposed by Alonso (1964), Muth (1969) and Mills (1972). The nucleus of the theory lies in the modelling of certain trade-offs in the choice of location, mainly between the transport costs of getting to the city centre and the cost of the space. This tradition has continued to grow through the use of ever more complex models. A systematic review of the various research work carried out can be found in Fujita (1989). Another kind of research, based around the relationship between transport and real estate values, is of a more empirical nature and has provided a growing number of case studies. These have been generally supported by the well-known hedonic regression technique formulised by Rosen (1974) to describe how markets function with heterogeneous goods.

Many hedonic studies have concentrated on the relationship between real estate prices and access to rail transport with heterogeneous results (Pagliara and Papa, 2011, Debrezion et al. 2007). The results highlight a significant influence of variables such as the type of property or station being studied on the variability of the

relationship between accessibility to railway stations and real estate prices. The properties located close to the rail stations also showed significant, but negative, changes in value. Martínez and Viegas (2009).

Another series of studies has concentrated on the impact caused by Bus Rapid Transit systems on real estate prices (Rodríguez and Mojica, 2009). These studies showed the impact on property values caused by introducing a Bus Rapid Transit (BRT) system in a city and found price increase. The influence of the same BRT system was again examined by Munoz-Raskin (2010) who found that the properties nearest the bus stops had a value 4.5% lower than the rest of the properties in Bogotá. However, they also found that properties located less than 5 min walk away from the stops were valued higher than those located between 5 and 10 min walk away concluding that households were prepared to pay more to be located close to the BRT system. Cervero and Kang (2011) used multilevel hedonic regression to estimate the capitalisation of introducing a new BRT system in Seoul, South Korea and found increases in property values for residents less than 300 m from a stop on the network.

The amenity value provided by urban green spaces, water bodies and good environmental quality is difficult to assess and incorporate into urban planning and development. View of green spaces and proximity to water bodies raised housing price, contributing notably at 7.1% and 13.2%, respectively (Jim, C.Y., Chen, Wendy Y., 2006).

This study explored the impacts of such key environmental elements including effect of big steel factory and the main industrial port that origin pollution and landscaping problems.

### 3. Multiple Linear Regression (MLR) models and the data set

The data set used to estimate the hedonic models is presented and described in this section. The models used in the present study will be estimated with data gathered from the metropolitan area of Taranto (see Fig.1).

Taranto is a coastal city in Apulia, Southern Italy. It is the capital of the Province of Taranto and is an important commercial port as well as the main Italian naval base. It is the third-largest continental city of Southern Italy: according to 2010 census data, it has a population of 195,800 but it was around 244,000 thirty years ago and 210,000 ten years ago. Taranto has well-developed steel and iron foundries, oil refineries, chemical works, some shipyards for building warships and food-processing factories. Its territory extends for 209,64 km<sup>2</sup> and in 1991 Taranto was declared a high environmental risk area by the Italian Ministry of Environment.

As a consequence of the pollutant discharged into the air by the factories in the area (most notably the ILVA steel plant, branch of Gruppo Riva), Taranto is the most polluted city in Italy and Western Europe. Only 7% of Taranto's pollution is inhabitants-related: 93% is factories-related. The European Pollutant Emission Register (EPER) showed that in 2004, estimated dioxin emissions from the ILVA plant were responsible for 83% of Italy's total reported emissions.

Apart from the capital, there are 28 urban centres around Taranto that forms the Province; the most important are Massafra, Palagiano, Mottola, Crispiano, Martina Franca, San Giorgio, Leporano and Pulsano.

The city of Taranto is located to the centre of the study area (see Fig. 1 and 2) and is connected to the other urban centres by road networks and transit services (both road and rail).

These networks are mainly made up of urban and interurban road systems, the urban and interurban public transport services. The interurban railway network does not connect the most important households in the study area. The household sample comes from a cross sectional data base obtained from various on-line real estate platforms. The data were collected by ad hoc surveys on October 2012 and contains information about asking prices and other structural characteristics for 512 properties located in the metropolitan area. The availability of the address of each of the sample observations meant that they could be coded with a geographical information system (GIS).

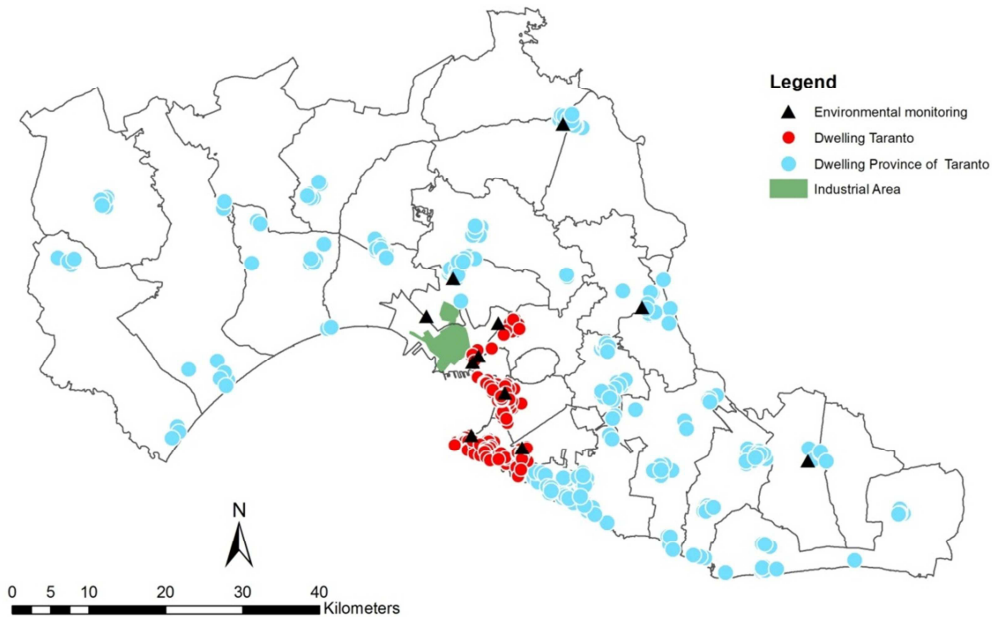


Fig. 1. Location of sampled dwellings, industrial area and environmental monitoring in the study area.

The spatial distribution of the aggregated asking prices over large administrative areas shows how the highest average prices (around 950,000 Euros) are concentrated in the city of Taranto and more specifically in the residential area San Vito-Lama, located to the South of the city, to the opposite area of the industrial zone. This neighbourhood is characterized by a large area with beaches and parks and the traffic is not congested as well.

Other areas with high average prices are located along the oriental coast (Leporano and Pulsano). In this places there are individual family houses and also close to the coast and beach areas (Gandoli, Saturo, Fatamorgana and Onda Blu). This area is found to the east of Taranto where several coastal settlements are made up mainly of homes that in the past were used just for holiday. Recently many families sold their houses in the city centre and choice to live on the coast in these houses.

The price of real estate in central zone of Taranto is not so high for a capital. The areas with the lowest average prices are located in Tamburi, the nearest neighbourhood to the steel industry ILVA, where the population try to sell their house without succeed. This area has been strongly affected by negative environmental spillovers from industrial development and port activity.

The data on environmental pollution levels have been measured and provided by Regional Agency for the Prevention and Protection of the Environment of Apulia Region (ARPA - Agenzia Regionale per La Prevenzione e la Protezione dell'Ambiente della Regione Puglia). The pollutants are measured by eleven fixed air quality stations located in the study area as depicted in Fig. 1.

All the data were input into the GIS and a various range of variables relating to the environment and the location of the properties could be obtained when the data was crossed with the exact location of each household

with various other socio-demographic characteristics present in the population and household census zoning data. The following variables are contained in the data base (see Table 1):

- LN(P) is the natural logarithm of the property asking price.
- ROOMS is the number of bedrooms at the property.
- BATH is the number of bathrooms at the property.
- TE is a dummy variable taking a value of 1 if the property has a terrace.
- GA is a dummy variable taking a value of 1 if the property has a garden.
- LIFT is a dummy variable taking a value of 1 if the building where the property is located has a lift (elevator).
- BCH is a dummy variable taking a value of 1 if the property is located at a beach at less than 800 m from a beach
- GAR is a dummy variable taking a value of 1 if the property has a garage.
- LTI is the number of internal lines bus serving the zone.
- TRAIN is a dummy variable taking a value of 1 if the property is less than 500 m from a suburban train station.
- ILVA is the distance in kilometres to reach the industrial centre from the property using the road network.
- TACC is the time in minutes which it takes at morning rush hour to reach the city's CBD from the property using the road network, considering congestion.
- ACC<sub>active</sub> is a Hansen type measure (gravitational) of employment active accessibility.
- CO is value of measured environmental pollutants ( $\mu\text{g}/\text{m}^3$  293K).

Table 1. Descriptive statistics of the variables contained in the residential property data base, N = 512 ( Data Istat Census 2001).

Variable	Minimum	Maximum	Mean	Std. Deviation	Measurement unit
LN(P)	10,0432	13,7642	11,8154	0,6402	Ln (price )
ROOMS	1	10	4,0508	1,8748	No. of rooms
BATH	0	6	1,5851	0,7797	No. of bathrooms
LIFT	0	1	0,1781	0,3829	Elevator
TE	0	1	0,1898	0,3925	-
GA	0	1	0,3796	0,4858	-
BCH	0	1	0,1859	0,3894	-
GAR	0	3	0,4637	0,5443	-
LTI	0	5	1,7279	1,8959	No. of internal lines
TRAIN	0	1	0,3757	0,4848	-
ILVA	1	55	20,6065	13,4082	Km
TAC	1	28	7,4598	6,3848	Minutes
ACC <sub>active</sub>	45565,5156	70499,2876	52547,0586	5485,0861	-
CO	0,2772	0,7001	0,3831	0,1542	$\mu\text{g}/\text{m}^3$ 293K°

The property prices are not market values; they are asking prices by online platform. This is not a problem because previous research has shown that asking prices have a high correlation to selling prices and generally represent 90% of the equilibrium price (Hometrack, 2005). The dependent variable, the property asking price, has been specified in logarithmic form, so the estimated parameters can be interpreted as semi-elasticity (Malpezzi, 2008).



Fig. 2. Spatial distribution of average asking prices aggregated by zoning in the study area.

The most relevant variables, according to the aim of this study, are ROOMS, BATH, GAR.GA, BCH,TE and those which refer to transport conditions: LTI, TRAIN and ACC\_ACTIVE.

LTI, as described earlier, represents the interaction between the presence of a bus stop at least 500 m away and the number which service that bus stop. This variable represents an indicator of bus services supply availability to each of the properties. The TRAIN variable represents an accumulated opportunities measure of accessibility to railway services (Handy and Niemeir, 1997). It has been assumed that all the properties located at less than 500 m from the railway station in the study area have access to the train mode.

The TAC variable represents access time in minutes which it takes at morning rush hour to reach the city's CBD from the property using the road network, considering congestion.

ACC\_active is a Hansen (1959) type indicator of gravitational accessibility to employment which therefore, considers the possible multi-centric nature of the urban area. This indicator has been calculated from the employment tables available from the National census data. The active accessibility used is as follows (Coppola and Nuzzolo, 2011):

$$ACC\_active(o) = \sum_d W(d)^{\alpha_1} \cdot \exp(\alpha_2 \cdot C(o, d)) \quad (1)$$

Where:

- $W(d)$  is the number of services (expressed in thousands) in the zone "d";
- $C(o, d)$  is the generalized travel cost between zones "o" and "d";
- $\alpha_1$  and  $\alpha_2$  are estimated parameters respectively equal to 0.85 and 1.25 (Nuzzolo and Coppola, 2007).

Differently and in addition to traditional studies, we focused our attention on environmental related variables too. From this view we consider among the others, the environmental variable "ILVA", that represents the distance between the steel industrial plant ILVA from the property. The distance is measured in kilometres considering the route length from the property using the road network.

In the study seven different pollutants were also considered: SO<sub>2</sub>, NO<sub>x</sub>, NO, NO<sub>2</sub>, CO, O<sub>3</sub>, PM<sub>10</sub>. The models described in the paper are those with the most statistically significant pollutants (MLR2).

### 3.1 MLR estimates

From the spatial point of view, at the early stage, the research was focused on all cities of the Province of Taranto, but the results showed high level of dispersion.

Then, in the second stage we specified two specific models: the first model considers the study area but the city of Taranto, the second one considers the city of Taranto only.

The best first hedonic model (MLR1) was estimated with the 10 independent variables of data base and considering the towns of the first ring around Taranto (i.e. Leporano, Statte, San Giorgio, Crispiano, Mottola etc.). All the parameters had theoretically correct signs, but not all were significant according to the t-test at a 95% confidence level (see Table 2). Among the variables related to the property's structural conditions, which had a positive effect on property values, the presence of an additional bathroom, the presence of a garage, a garden, a terrace and finally the presence of a lift implied an increase in the value.

The important parameter related to this last variable may not only be due to the availability of a lift but also the age of the building because more recent and better quality buildings normally include a lift.

The parameters related to the transport conditions LTI showed positive signs if the buildings were located at least 500 meters away from a bus stop and train station, showing a higher real estate values.

The TRAIN variable, which had a positive sign, implying that people who live near a train station perceive it as a possibility to reach the Taranto's CBD.

Finally, the MLR1 includes also the mentioned ILVA variable. This variable was not significant but had a negative correct sign if the buildings were located farther the industrial area showing a low decrease in real estate values. This is valid for the other cities of the Province of Taranto, where environmental polluters is nor a big problem.

MLR2 and MLR3 are alternative models containing different variables that give optimal results in both of two cases for the only city of Taranto (second specific model). These two models (MLR2 and MLR3) were specified and calibrated considering 7 and 6 independent variables respectively contained in the data base (see Table 2).

Table 2 Estimated parameters of the MLR models: Study Area without Taranto (MLR1) and City of Taranto (MLR2 and ML3)

Variables	MLR1		MLR2		MLR3	
	Parameter	t-ratio	Parameter	t-ratio	Parameter	t-ratio
Constant	10,9301	111,2389	6,5988	7,484	10,5249	134,1612
ROOM	0,0969	5,9176	0,2056	8,7084	0,205	8,1321
BATH	0,1913	5,2623	0,1306	2,2841	0,1985	3,329
LIFT	0,1752	2,4132				
TE	0,1293	2,1503				
GA	0,2289	3,7904			0,2424	3,4511
GAR	0,1286	2,5798	0,1637	2,4559		
BCH	0,1175	1,8806			0,2183	2,5962
LTI	0,0499	2,2431	0,1788	3,4968		
TRAIN	0,2805	4,6702	-0,3245	-3,0292		
ILVA	-0,0039	-1,293			0,0208	2,8112
ACC_active			0,0001	4,5502		
TAC					-0,0138	-2,4828
CO			-0,5629	-2,467		
R <sup>2</sup>	0,5232		0,7374		0,6975	
R <sup>2</sup> <sub>adj</sub>	0,5086		0,7276		0,688	
N	337		197		197	

In MLR2 the parameter LTI related to the transport conditions showed positive signs. The exception was the TRAIN variable which had a negative sign implying that properties nearest to the train station had a lower value in the city of Taranto. This issue can be explained assuming that railway infrastructures usually imply a series of negative impacts such as noise, lower landscaping and environmental quality (Armstrong and Rodríguez, 2006). In MLR3 are significant the parameters related to the house features and facilities (i.e. garden and beach) show an increased real estate values.

In MLR2, the parameter of the environmental pollution variables CO has negative signs, indicating that an increase of pollutant quantity implies a decrease in real estate values.

Both MLR2 and MLR3 include an accessibility measure which is calculated differently: in MLR2 there is ACC\_active, an indicator of gravitational accessibility to employment, while in MLR3 there is the TAC variable that represents the access time (in minutes) to reach the Taranto's CBD on the morning rush hour moving from the property.

In MLR2 the parameter related to the accessibility (ACC\_active) showed sign positive, indicating that an increase of accessibility index implies an increase in real estate values.

The MLR3 includes the ILVA variable, that was significant when together with TAC, that takes negative sign.

Therefore in MLR1 the ILVA variable showed a decrease in real estate values, indicating an accessibility value to the industrial area (and then to the Taranto CBD): people of the other cities of the Province prefer live "nearer" to the ILVA district.

On the opposite side, in MLR3 people do not prefer living near to the industrial area, since they constantly suffer the environmental polluters generate in the city of Taranto.

MLR2 returns more significant results than MLR3. In fact, MLR2 shows a higher value of both  $R^2$  and  $R^2_{adj}$  and it better explains the influence of environmental polluters, while MLR3 presents the ILVA parameter alone.

The MLR1, MLR2 and MLR3 were therefore specified as in eqs. (2), (3) and (4) respectively:

$$\begin{aligned} \ln(\hat{P}_i) = & \beta_0 + \beta_1 \text{ROOMS} + \beta_2 \text{BATH} + \beta_3 \text{GA} + \beta_4 \text{TE} + \beta_5 \text{LIFT} + \beta_6 \text{GAR} + \beta_7 \text{LTI} + \\ & + \beta_8 \text{TRAIN} + \beta_9 \text{BCH} + \beta_{10} \text{ILVA} + \varepsilon_i \end{aligned} \quad (2)$$

$$\begin{aligned} \ln(\hat{P}_i) = & \beta_0 + \beta_1 \text{ROOMS} + \beta_2 \text{BATH} + \beta_3 \text{GA} + \beta_4 \text{LTI} + \\ & + \beta_5 \text{TRAIN} + \beta_6 \text{ACC}_{\text{ACTIVE}} + \beta_7 \text{CO} + \varepsilon_i \end{aligned} \quad (3)$$

$$\ln(\hat{P}_i) = \beta_0 + \beta_1 \text{ROOMS} + \beta_2 \text{BATH} + \beta_3 \text{GA} + \beta_4 \text{BCH} + \beta_5 \text{ILVA} + \beta_6 \text{TAC} + \varepsilon_i \quad (4)$$

#### 4. Conclusions

The work described in this article specifies the role of quality of environment considering the real estate price, accessibility and other local land-use attributes. The proposed models were estimated using data collected in the metropolitan area of the city of Taranto and were compared to determine which of them presented the best fit and the explicative variables.

The estimated models were useful in highlighting how different transport characteristics as well the environmental quality affect the prices of real estate properties. In these models all the considered variables had

theoretically correct signs, but not all were significant according to the t-test at a 95% confidence level. The models had a good fit in both the value of  $R^2$  and  $R^2_{adj}$ .

Among the variables related to the property's structural conditions, which had a positive effect on property values, the presence of an additional bathroom, the presence of a garage, a garden, a terrace and finally the presence of a lift it implied an increase in value.

The parameters related to the environmental conditions of the properties showed positive signs if the buildings were located near beach areas, a variable which could also include the effects of better landscaping.

Most of the parameters related to the transport conditions had signs which agreed with the hypothesis that improved transport conditions resulted in increased real estate values. The parameters of the bus accessibility indicators LTI indicate that each additional nearby public transport line can imply an additional increase in property values. However, this result should be interpreted with care because the city of Taranto is the one served by the best public transport.

In this sense, the hypothesis that a better supply of public transport services implies increased property values could be reversed and due simply to the fact that the more central areas have more public transport services due to the travel demand to that area from all the other zones of the city (Felsenstein et al., 2010).

Thus in the case study of Taranto, the LTI variable, as a measure of accessibility to bus transport, is three times larger than the Province of Taranto.

The TRAIN variable indicating accessibility using suburban railway transport, presented a different sign parameter in agreement with previous research (Ibeas *at al.*, 2012). The reason may be because railway infrastructures imply diseconomies related to noise and a lower landscaping and environmental quality in the city of Taranto, in this case had negative sign. On the opposite, where the TRAIN variable had a positive sign imply that people who live near a train station perceive it as a possibility to reach the Taranto's CBD or use railways to go to job in the case of other cities (MLR1).

The ILVA parameter has different signs: in MLR1 ILVA had negative sign showing a little decrease in real estate values for the cities of the Province; conversely in MLR3, ILVA parameter has positive sign because people suffer worst environmental conditions.

The parameter of the accessibility variable indicates that an increase in the employment accessibility index implies an increasing in real estate values.

Finally, the parameters related to the environmental conditions of the properties showed a negative signs if the buildings had a high level of CO value connected with air pollution, indicating that an increase of values corresponding to a decrease in real estate values.

The last result is very important and allows the evaluation of environmental context for real estate values assuming that users are available to have higher transport cost to achieve better environmental condition and quality of life.

## Acknowledgements

Authors wish to thank the Regional Agency for the Prevention and Protection of the Environment of Apulia Region (ARPA - Agenzia Regionale per la Prevenzione e la Protezione dell'Ambiente) for providing the data on environmental pollution in the study area.

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