

# Does urban centrality influence residential prices? An analysis for the Barcelona Metropolitan Area

## ¿Incide la centralidad urbana en la formación de los precios residenciales? Un análisis para la Barcelona Metropolitana

Carlos Marmolejo-Duarte (Main and Correspondant Author)

Departamento de Tecnología en la Arquitectura, Centro de Política de Suelo, Escuela Técnica Superior de Arquitectura de Barcelona, Universidad Politécnica de Cataluña  
Diagonal, 649, 4a, Arq Legal, 08028, Barcelona, Spain  
carlos.marmolejo@upc.edu

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### Abstract

The bid rent theory (BRT), originally conceived for a monocentric city suggests a trade-off between land value and transport costs. Thus, in most of the practical applications, the simply distance/time/cost to the CBD is used as a proxy of accessibility. Nonetheless, in contemporary metropolises, employment and services do not cluster in one CBD but in many centers, furthermore the centrality quality does not follow a smooth gradient as distance to centers increases. Consequently, taking the distance/time/cost to centers in the context or hedonic models is problematic for collinearity issues and too simplistic since it directly assumes a smoothed gradient function. In this paper we test in Barcelona Metropolitan Area, a very well recognized polycentric city, whether some *continuous* indicators of centrality are key determinants of housing prices. Using listing prices, a hedonic model is built, and the asking price is regressed over two continuous indicators of centrality, one of them calculated departing of the spatial-temporal behavior of people, which itself is a novelty in this kind of studies. The results suggest that continuous centrality indicators do exert a moderate influence on housing prices after controlling for other structural and locative attributes. Nevertheless, the main determinants of prices are related to the socioeconomic stratification not accessibility as suggested by BRT. Energy class appears also as a factor influencing dwellings' price.

**Key words:** Hedonic price models, real estate valuation, polycentrism, time-geography, Barcelona.

### Resumen

La teoría de la renta ofertada (TRO) originalmente concebida en un contexto monocéntrico sugiere la existencia de un efecto compensatorio entre el valor del suelo y los costes de transporte. Por ende, en la mayor parte de las aplicaciones empíricas, la simple distancia/tiempo/coste al centro es usada como un indicador de la accesibilidad. Sin embargo, en la mayor parte de las metrópolis contemporáneas tanto el empleo como los servicios se localizan en varios centros, mientras que la cualidad de centralidad no se desvanece de forma uniforme a medida que la distancia a los centros incrementa. Por tanto, utilizar la distancia/tiempo/coste a los centros en el contexto de los modelos hedónicos es problemático debido a la multicolinealidad y demasiado simple, puesto que se asume una función de un gradiente suavizado. En este artículo probamos hasta qué punto dos indicadores continuos de centralidad son elementos clave en la formación de precios residenciales en la policéntrica área metropolitana de Barcelona. A partir de precios de oferta se construye un modelo hedónico en el cual los precios son regresados sobre dos indicadores de centralidad, uno de ellos construido a partir del análisis del comportamiento espacio-temporal de la población, lo cual en sí mismo es una novedad en este tipo de estudios. Los resultados sugieren que los indicadores de centralidad continuos ejercen una influencia moderada sobre los precios una vez que se controlan los atributos arquitectónicos y locativos de la vivienda. Sin embargo, los principales determinantes de los precios están relacionados con la estratificación socioeconómica y no con la accesibilidad como sugiere la TRO. La clase energética aparece también como un factor con influencia en el precio de la vivienda.

**Palabras clave:** Modelos de precios hedónicos, valoración inmobiliaria, policentrismo, geografía del tiempo, Barcelona.

The “standard urban model” based in the bid rent theory, with roots in the von Thünen’s (1826) and Hurd’s (1924) works, as it was depicted by Alonso (1965), explains that both land rent and urban density declines as the distance to center increases. In such model, it is assumed that most of the employment is concentrated in the center, which foster a daily commuting between peripheral residential zones and it. By having the employment clustered in the center it also is assumed that services follow such spatial trend. All in all, result in increasing transport cost and time (Haig, 1926) as distance to center increases, and consequently a trade off with rent allocated to residential land. It is the existence of the land rent gradient that underlies the formation of density in a competitive market scenario. If it is considered that developers invest capital in land and building when developing a site, and constant returns per unit of land are relaxed (i.e. once substitution between land and building costs is allowed), real estate developers economize on the use of expensive land in more central locations where prices peak. In optimizing developments, they add more building capital per unit of capital invested on land (i.e. they build multi-story structures instead of low rise ones), despite the fact that

high rise building is costlier per sq. meter than low rise ones. Nonetheless, the capital saved in land outbids the over cost invested in the construction. Consequently, it emerges a density gradient following that of land prices. The parallelism between rent and density gradients depends upon the elasticity of substitution between land and capital (Kau & Lee, 1976). Mills and Hamilton (1984) demonstrated, starting from the monocentric city model, that under certain constraints, such as Cobb-Douglas's production function for housing, users with identical tastes and income and unit price elasticity of demand for housing, density gradients adopt a negative exponential function. According to the above state theory, built densities are proxies for centrality, and theoretically, if land rent does not only reflect accessibility but all the remaining local amenities, built densities also proxy for them and not only for centrality.

### Description of the problem

Nonetheless, monocentric metropolises do not more exist and probably have never existed as they were stylized in theoretical models (Anas et al., 1998; Batty, 2001). Furthermore, employment is not the only driver of urban mobility and recent studies have reported a decrease of its relative importance in relation to non-obligated mobility (Cerdeira & Marmolejo, 2010). On the other hand, taking the distance to subcenters and/or CBD is problematic itself for a number of reasons:

- 1) Firstly, it is necessary to previously identify subcenters and validate them which is itself problematic (McDonald, 1987)
- 2) Secondly, it is not possible to identify clear limits of centralities, since centrality quality is an attribute that has a spatial fading (centrality gradient) departing from centers, even in very well planned cities where exclusive zoning is implemented
- 3) Thirdly, the centrality gradient is not regular enough to be substituted by the simple distance to centers; though it is always possible to use more sophisticated locally adjusted regression models, like those used by Marmolejo & González (2009)
- 4) Fourthly, in polycentric metropolitan areas, where multiple centers give structure to quotidian flows, taking as many distances as subcenters there are results into multicollinearity when hedonic prices are calibrated (Aguirre & Marmolejo, 2010). Conversely, taking only the distance to the nearest center neglects the fact that sites may receive the multiple influence of neighboring subcenters not only the nearest (García-López & Muñiz, 2010).

For the above stated issues, in this paper we test whether 2 continuous indicators of centrality, one based on built density and other on the spatial-temporal behavior of population (depicting all urban activities not only labor ones), are able to explain the spatial trends of housing prices. In doing so, a hedonic price model (Rosen, 1974) is built departing from listing prices for multifamily dwellings in Metropolitan Barcelona, taking as explanatory variables both structural attributes and locative ones. In this latter continuous indicators of centrality are included, of them that departing from spatial-temporal population trends is a novelty by itself in this kind of studies.

The remaining of the paper is organized as follows. First, a brief literature review is offered; followed by the presentation of data, case study and methodology used; the results and discussion is presented next; in the concluding epigraph, the main findings are highlighted.

### Brief literature review

For analytical purposes real estate values, can be easily split in land rent and the value related to the building (quality, area, design, facilities, etc.). In urban economics land rent is basically associated to accessibility to centers where services and employment is supposed to be concentrated (O'Sullivan, 2007).

In Barcelona, the pioneering work of Josep Roca (1988) uses many proxies for accessibility:

- 1) The *average accessibility index*, that measures the average distance/time both in public and private transport to access from a given zone to all the others
- 2) The *average weighted accessibility index*, is the same as the previous one but weighted by the actual commuting flows between zones. This index accounts for the actual location of employment, and is plenty coherent with the bid rent theory, since it allows for account the residential/job location functional tensions
- 3) Finally, the author tests the distance to some "qualitative" hypothesis of centers such as the Plaça Catalunya, the Cinc d'Ors and the emblematic Plaça Francesc Macià.

His findings point an exiguous relationship between land value and accessibility indexes. On the contrary, the distance to "historic" landmark centralities are highly correlated to land prices. These results suggest that the trade-off mechanism behind transport costs between the site of residence and the site of employment exerts a weak influence

on residential prices. Conversely, social hierarchy imbedded in qualitative centralities is more correlated with real estate prices. In Roca (1986) the author studies price formation in the context of the 26 municipalities of the Metropolitan Corporation of Barcelona. Again, the results of this latter study, suggest that employment accessibility has a small role in explaining prices, that in some case become null or even erratic (i.e. prices increases as distance to employment centers increases). Such findings are compatible with the influence on prices that is exerted by other locative factors, such as the environment quality and the social segmentation produced by residential segregation that may imply both market premiums for prestigious locations and market discounts for stigmatized neighborhoods (Roca, 1988).

In the international scene, McMillen (1996) analyses the relationship between housing prices and the urban structure (proximity to CBD and subcenters) using historical data from Chicago finding an ambiguous relationship. Using a locally weighted regression the author estimates regression surfaces for the period 1936-1928 founding that the monocentric model correctly represents the spatial distribution of land values during the 19th century in such city. Nonetheless, in the post-war period, 1960-1990, especially after the suburbanization boom in the US the models suggest that Chicago is no longer a monocentric city, since subcenters, such as that located near the O'Hare Airport, are important employment clusters and as consequence also influence land prices. Such a finding was consistent with previously published evidence for the same city, as matter of fact McDonald and McMillen (1990) reported that, as early as 1928, that specific aeronautic subcenter was already significant in the distribution of land values. The same authors (McMillen & McDonald, 2002) also have studied whether land values were affected by the introduction of exclusive zoning for residential blocks in 1923 in Chicago. Their results indicate that exclusive zoning did not produce any modification of spatial trends in land values, except for that non-residential blocks where, departing up to zoning ordinance, were allowed to have also residence.

The problem with those studies is that most of them does not suffices in including all control variables that influence land values, such as amenities, externalities and social status, obscuring, in this way the role of centrality on real estate values. Aguirre and Marmolejo (2010) try to cope with these issues in their study for Metropolitan Barcelona, nevertheless they find multicollinearity problems since the distance to the nearest subcenter results pretty well correlated with the proximity to other subcenters and CBD. This study is different since it controls both the structural and location variables that may influence values, and non-distance to subcenter is used, but instead continuous indicators of centrality, as it is explained in the following section.

## Case study, data and methodology

The study area is the Metropolitan Region of Barcelona comprised by 164 municipalities, nonetheless after discarding those municipalities without information or erratic outlier values only 137 municipalities containing 3,479 dwellings' price offers are analyzed here.

Listing data was acquired from Habitaclia.com, as for November 2014, this website is one of the most important real estate listings specialized in sale and lease transactions in the residential market at Catalonia. The original data set retrieved comprises 35,116 selling cases for flats (multifamily dwellings), however, due the very recent obligation to obtain the energy certification in Spain (1st June 2013), a vast majority of cases did not report the energetic qualification claiming it was on pending of issue. Since this research was also concerned with the inclusion of such an environmental performance variable it was decide to exclude from the analysis all the cases where such information was not available.

Beyond asking prices, listing information includes variables regarding both the structural features of flats, and condominium services. Structural features include: area, number of rooms, number of baths, living room area, terrace/balcony area, story where the flat is placed, heat/air conditioning systems, information regarding renewal, energetic EPC class, penthouse position, number of levels (in the case of duplex/triplex dwellings), etc. Condominium services/features include: lift, swimming pool, private greenery, age, etc. Besides listing information, the following data and sources are used to control the effect of location on asking prices:

### **From the 2001 National Census, at census track level:**

(Unfortunately, it was not possible to use 2011 data census since, due the crisis in Spain, such a census is based on a restricted sample survey, which is not reliable at census track level).

- Information regarding the social status of the neighborhood (e.g. education level, hierarchic position of resident employed population in the context or their productive organizations, percentage of residential buildings with doorkeeper service, etc.)
- Information regarding the accessibility level (e.g. declared time to get the workplace)
- Information regarding the environmental quality of the neighborhood (e.g. greenery perception)

- Information regarding the available services (health, education, sociocultural, retail, office based services, etc.)

**From the Cadastral database, at census track level:**

- Built up surface, net built area, floor area allocated for different land uses

**From the 2001 Metropolitan Mobility Survey, at transport zone level:**

- Information regarding the chain-trip or chain of daily activities
- Information regarding the length and duration of travels

**Table 1.** Descriptive statistics of selected variables. Source: Own elaboration.

	Variable	N	Min	Max	Mean	Std. Deviation	
Structural features of Dwellings	Price (Euros)	3479	34.000	715.000	159.707	88.018	
	Unitary price (Euros/sqm)	3479	845	3.542	1.885	662	
	Area (sqm)	3479	25	234	84	28	
	Number of baths	3479	-	4	1,29	0,51	
	Number of rooms	3479	-	15	2,91	0,90	
	Baths/room	3459	-	2	0,48	0,23	
	Energy qualification (ordinal)	3479	1	7	5,29	1,25	
	Story	3479	-	13	2,14	1,63	
	Terrace/balcony area (sqm)	3479	-	256	9,73	14,53	
	Livingroom area (sqm)	3479	-	90	12,04	9,83	
	AC (dummy)	3479	-	1	0,29	0,46	
	Heating (dummy)	3479	-	1	0,42	0,49	
	Renewal (dummy)	3479	-	1	0,10	0,30	
	Penthouse (dummy)	3479	-	1	0,04	0,18	
Duplex/triplex (dummy)	3479	-	1	0,06	0,23		
Structural features of Building	Swimmingpool (dummy)	3479	-	1	-	0,05	
	Private greenery (dummy)	3479	-	1	0,09	0,28	
	Building year	3479	-	2.014	737,87	957,61	
	Lift (dummy)	3479	-	1	0,45	0,50	
Centrality	Built density (zone)	3479	0,19	5,90	1,93	1,24	
	Time-density	3479	324	1.134.098	118.964	146.950	
	Centrality index	3479	2,52	20,41	11,29	2,29	
	Diversity of land uses (zone)	3479	0,35	1,64	1,02	0,21	
	Diversity of activities (zone)	3479	-	2,92	2,03	0,38	
	Average time-to-work (zone)	3479	8,94	37,01	23,47	4,59	
	Diversity of land uses at basement (zone)	3479	-	1,77	1,11	0,23	
Environmental quality	Average age of buildings (zone)	3479	21	124	53,99	14,33	
	Perception greenery presence (zone)	3479	12,45	97,89	64,37	13,58	
	% premises devoted to health services (zone)	3479	-	42	2,01	2,89	
	% premises devoted to educative services (zone)	3479	-	93,00	2,13	2,97	
	% premises devoted to social services (zone)	3479	-	66,66	1,85	4,32	
	% premises devoted to cultural services (zone)	3479	-	95	1,52	3,35	
	% premises devoted to retail services (zone)	3479	-	89,93	41,45	13,47	
	% premises devoted to office services (zone)	3479	-	100,00	14,09	11,11	
Neighborhood	% premises devoted to manufacturig (zone)	3479	-	97	9,51	11,57	
	Residents with university grade (zone)	3479	2,34	66,10	19,07	11,25	
	Residential buildings with doorkeeper	3479	-	52,55	6,37	6,77	
	PCA factor for low professional profile	3479	-	1,70	7,42	0,13	0,93
PCA factor for high professional profile	3479	-	3,26	3,24	-	0,32	0,77

Notes:

Energy qualification 1=A=more efficient, 7=G=less efficient

Using this latter information regarding the spatial-temporal behavior of people a synthetic indicator of centrality is built as follows:

- 1) Firstly, some intermediate-variables were computed. Some of such intermediate-variables are: time-density (Marmolejo & Cerda, 2012); diversity of activities; socioeconomic diversity of people that make activities in a given

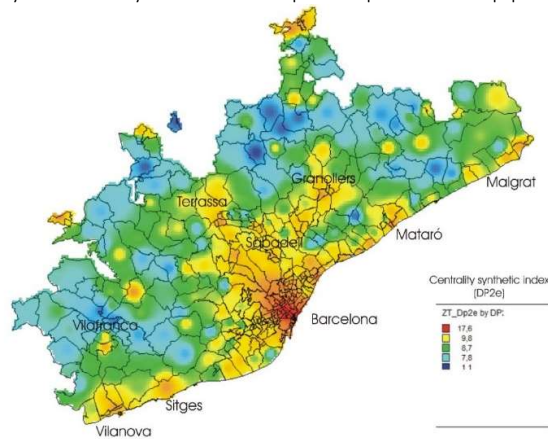
zone; distance travelled by people making activities in a given zone, etc. All the variables were computed for different days in the week and 5 time-strips.

2) Secondly, intermediate-variables were encapsulated in a synthetic indicator of centrality using DP2 methodology (Pena, 1977, Zarzosa, 2009).

In Marmolejo & Cerda (2014) all the details concerning the construction of the synthetic indicator of centrality are provided and theorized in the more general framework of time-geography, see in Figure 1 below the spatial distribution of such a variable.

Since the geographical entities of data used are divergent: points for studied dwellings, census track for census and cadastral data and transport zones for mobility information, it was used a geographic information system. Using a buffer of 300 m (In addition, it was used a buffer of 600 m radius; nevertheless, the model built with such data was less able to explain prices in comparison to that presented in this paper) radius around each flat and geospatial queries all the information was transferred to the 35,116 selling cases contained in the original database. Table 1 summarizes basic statistics for selected variables.

Figure 1. Spatial distribution of synthetic centrality index based on the spatial-temporal behavior of population. Source: Own elaboration



In Table 1 diversity indexes were computed using the entropy index proposed by Shannon:

$$H_i = -1 * \sum_i^n P_{x_i} \cdot \ln(P_{x_i}) \tag{1}$$

In (1)  $H$  is the diversity index for an  $i$  zone,  $P$  is the probability to find the  $x$  category from  $n$  possible of a given phenomenon in the  $i$  zone. (for example to find an office oriented premise among all the premises in zone  $i$ ).

On the other hand, PCA factors refers to a principal component analysis carried out departing from the socioprofessional classification of residents (managerial, professional, clerical, manufacturing, non-qualified, etc.). High values for PCA factor for high professional profiles are associated to zones where live the working population occupying the most-remunerated job positions. High values for PCA for low professional profile are associated with traditional zones of residence of working-class population.

The final selection of the cases introduced in the model was the result of an elimination process as follows:

- Firstly, all those flats with unitary prices beyond +/-1 standard deviation from the average unitary price were discarded.
- Next, a family of regression models was calculated, using the model with the best fit the Mahalanobis Distance was computed. According to Marmolejo & González (2009) this procedure allows for the elimination of outliers in the  $n$ -variables used in the regression analysis.
- Finally, using a sedimentation analysis it was detected the Mahalanobis Distance breaking point (i.e. the value where the slope increases abruptly).

After applying the above stated process there were identified 3,479 valid cases.

The functional model used is log-linear since it accomplishes with the basic statistics premises for OLS calibrating process: normality of residuals, homoscedasticity, and multicollinearity absence.

## Results and discussion

The best of the models was able to explain 65.2% of the variance of asking prices of multifamily dwellings at the Metropolitan Region of Barcelona (see table 2).

**Table 2.** Model performance. Source: Own elaboration.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
14	0.808 <sup>n</sup>	0.653	0.652	0.28556

Table 3 reports the result of coefficients that have resulted significant at 95% of confidence; such coefficients are reported both in their original scale and in terms of z-values (Beta coefficients), this latter allows for comparison among independent variables. According to Beta coefficients the listing price is obviously influenced first by the floor area of the analyzed flats, nonetheless such a relation is not linear since the square of such area has a negative influence on prices. Such a finding suggests the existence of diminishing returns in the formation of prices, so the marginal addition of extra square meters produce a reduction in the willingness to pay in comparison to the previous incorporated area.

According to the beta coefficients, the next predicting variables are those related to the socioeconomic aspects of the neighborhood. In this dimension, the presence of resident population (PCA factor for high profile professions) employed in managerial and professional positions do have an important positive impact on real estate selling prices, as well as the presence of very well educated population in the surrounding of the dwelling (percentage of residents with university education). Also in this field it is worth to note the positive impact of the existence of buildings with high standing services such as doorkeeper. Whether those results evidence that such population has a higher purchase power or there is a market premium coming from the existence of a segregation process remains on the analysis.

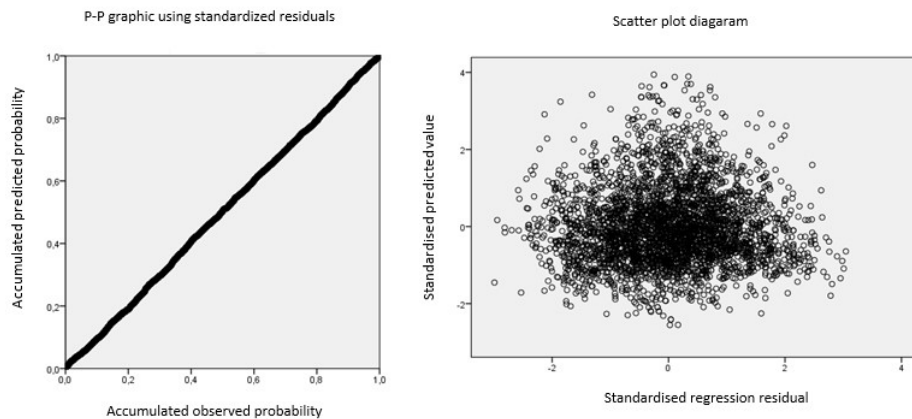
Next, it appears an indicator of centrality (built density), which is associated to dense and central zones and proxies for the existence of local based services and land rent gradient explained both by accessibility and other amenities. It is worth to point that the synthetic centrality index, built on the spatial temporal behavior of population, also appears producing a complementary positive impact on residential asking prices. The inclusion of both of the continuous indicators of centrality in the model, having non-serious multicollinearity problems, means that they are measuring different aspects of centrality. Therefore, the built density (sq. meters of floor space/sq. meter of land) proxies for the historic fixed capital accumulated over the years; meanwhile the synthetic centrality index accounts for the actual use of the city by residents whose give contents and make differentiation between centers and non-centers.

Some structural variables associated to the quality of flats and buildings are in the next position with a positive impact such as the heat ventilation air conditioning, the interaction variable (Such interaction variable is constructed multiplying the level of the flat by a dummy variable, such a latter variable adopts the unitary value when the lift is present; and a negative unitary value otherwise) lift presence\*story level where the flat is located, the existence of condominium services like swimming pool, the number of bathrooms. The energy qualification has a positive impact on prices, for each step that it increases, in the "ladder of environmental efficiency", the listing prices increment 0.9%. That means that the difference on selling prices between the worst qualification (G) and the most efficient flats in terms of energy efficiency (A) is 5.11%, that implies that taking as a reference the mean value in the sample the difference is *ceteris paribus* 8.167 Euro.

**Table 3.** Model coefficients. Source: Own elaboration.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
14 (Constant)	10.297	0.055		186.731	0.000
Area (Sq. M.)	0.018	0.001	1.023	23.435	0.000
Residents with university degree (%)	0.005	0.001	0.112	4.452	0.000
AC	0.101	0.013	0.095	7.503	0.000
Area (Sq. M.)^2	-4.104E-05	0.000	-0.505	-11.880	0.000
Built density	0.038	0.006	0.097	6.264	0.000
Interaction lift*story level	0.013	0.002	0.070	5.846	0.000
Swimming pool	0.136	0.026	0.055	5.204	0.000
Number of baths	0.062	0.012	0.065	5.189	0.000
Heating	0.046	0.013	0.046	3.453	0.001
PCA factor for high professional profile	0.061	0.014	0.096	4.466	0.000
Residential buildings with doorkeeper (%)	0.005	0.001	0.063	4.128	0.000
Centrality synthetic index	0.010	0.003	0.049	3.481	0.001
Renewal	0.043	0.017	0.027	2.512	0.012
Energy qualification	0.009	0.004	0.022	2.076	0.038

**Figure 2** Analysis of residues. Source: Own elaboration.



## Conclusions

Our findings suggest that, apart from structural variables concerning the quality and fittings of studied flats, centrality does exert an intermediate impact on real estate values. By using continuous centrality indexes such as that related to built density or the actual use of the city (synthetizing the spatial-temporal behavior of population) some of the habitual problems in multicentric hedonic price models have been solved with basic econometric approaches.

As it has been found previously in Barcelona (Roca, 1986, 1988, Roca et al., 2003, Marmolejo, 2008), most of the locative variables with the highest incidence on residential values are associate to the spatial segregation of population. So, locations characterized by very well educated population employed in managerial and professional positions do imply a significant and important positive impact on asking prices in our model. According to the b coefficient, which measures semi-elasticity in our log-lin model, by increasing 1% the neighbors with university studies, asking prices rise 0.5%, that



implies that the value gap between the zone with the lowest presence of high educated residents and the zone with the highest level of such population foster residential values 3.2 times (320%), by solely modifying this factor. Whether such finding is masking a higher acquisitive power and not or not only the existence of a market premium linked to the social perception (prestige/prejudice) remains in the impossibility to isolate the income effect since in Spain such data is not asked in the Census. It is necessary, thus, to review the enthroned importance of trade-off theory by relativizing it with other important factors such as socioresidential segregation. Especially in cities where real estate markets arbitrate both the formation of land values and land use allocation.

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## References

- Aguirre, C., & Marmolejo, C. (2011). El impacto del policentrismo sobre la distribución espacial de los valores inmobiliarios: un análisis para la Región Metropolitana de Barcelona. *Revista de la construcción*, 10(1), 78-90. <https://dx.doi.org/10.4067/S0718-915X2011000100008>
- Anas, A., Arnott, R. & Small, K. (1998). Urban Spatial Structure. *Journal of Economic Literature*, 36(3), 1426-1464.
- Alonso, W. (1965). *Location and Land Use: toward a general theory of land rent*. Cambridge: Harvard University Press.
- Batty, M. (2001). Polynucleated Urban Landscapes. *Urban Studies*, 38(4), 635-655. <https://doi.org/10.1080/00420980120035268>
- Cerda Troncoso, Jorge, & Marmolejo Duarte, Carlos. (2010). De la accesibilidad a la funcionalidad del territorio: una nueva dimensión para entender la estructura urbano-residencial de las áreas metropolitanas de Santiago (Chile) y Barcelona (España). *Revista de geografía Norte Grande*, (46), 5-27. <https://dx.doi.org/10.4067/S0718-34022010000200001>
- García-López, M.A. & Muñiz, I. (2010). The Polycentric Knowledge Economy in Barcelona. *Urban Geography*, 31(6), 774-799. <http://dx.doi.org/10.2747/0272-3638.31.6.774>
- Secchi, B. (1968). *Hacia la Comprensión de la Metropoli*. In *Análisis de las Estructuras Territoriales* (First Edition). Barcelona: Gustavo Gili.
- Hurd, R. (1924). *Principles of City Land Values*. (First Edition). New York, USA: Arno Press.
- Kau, J. B. & Lee, C. F. (1976). Capital-Land Substitution and Urban Land Use. *Journal of Regional Science*, 16(1), 83-92. <http://dx.doi.org/10.1111/j.1467-9787.1976.tb00950.x>
- McMillen, D.P. (1996). One Hundred Fifty Years of Land Values in Chicago: A Nonparametric Approach. *Journal of Urban Economics*, 40, 100-124. <https://dx.doi.org/10.1006/juec.1996.0025>
- McMillen, D.P. & McDonald, J.F. (2002). Land Values in a Newly Zoned City. *The Review of Economics and Statistics*, 84(1), 62-72. <https://dx.doi.org/10.1162/003465302317331928>
- Marmolejo, C. (2008). La incidencia de la percepción del ruido ambiental sobre la formación de los valores residenciales: un análisis para Barcelona. *Revista de la Construcción*, 7(1), 4-19.
- Marmolejo, C. & González, C. (2009). Does noise have a stationary impact on residential values? *Journal of European Real Estate Research*, 2(3), 259-279. <http://dx.doi.org/10.1108/17539260910999992>
- Marmolejo, C. & Cerda, J. (2012). La densidad-tiempo, otra perspectiva de análisis de la estructura metropolitana. *Scripta Nova*, 16, 15.
- Marmolejo, C. & Cerda, J. (2014). En búsqueda de los lugares estructurales: un análisis de comportamiento espacio temporal de la población para la identificación de centralidades urbanas. In *10º Congreso Ciudad y Territorio Virtual*. Monterrey, México.
- McDonald, J. F. (1987). The Identification of Urban Employment Subcenters. *Journal of Urban Economics*, 21, 242-258. [https://dx.doi.org/10.1016/0094-1190\(87\)90017-9](https://dx.doi.org/10.1016/0094-1190(87)90017-9)
- McDonald, J. F. & McMillen, D.P. (1990). Employment Subcenters and Land Values in a Polycentric Urban Area: the Case of Chicago. *Environment and Planning A*, 22(12), 1561-1574. <https://dx.doi.org/10.1068/a221561>
- Mills E.S. & Hamilton B.W. (1984). *Urban Economics*. Glenview, IL., USA: Scott Foresman.
- O'Sullivan, A. (2007). *Urban Economics* (Sixth Edition). McGrawHill.
- Pena Trapero, J. B. & Pena Trapero, X. (1977). *Problemas de la medición del bienestar y conceptos afines. Una aplicación al caso español*. Madrid, España: Instituto Nacional de Estadística.
- Roca, Josep (1986). *Los precios del suelo en el ámbito metropolitano*. Barcelona, España: Corporación Metropolitana de Barcelona.
- Roca, Josep (1988). *La estructura de los valores urbanos: un análisis teórico-empírico*. Madrid, España: Instituto de Estudios de Administración Local.



Roca, J., Clusa, J. & Mur, S. (2003). El mercat immobiliari de la Regió Metropolitana de Barcelona i comarques centrals de Catalunya, Barcelona, España: CPSV.

Rosen, S. (1974). Hedonic prices and implicit markets: production differentiation in pure competition. *Journal of Political Economy*, 82(1), 34-55.

Thünen, J. H. (1966). Von Thunen's isolated state: an English edition of *Der isolierte Staat* / by Johann Heinrich Von Thunen; translated [from the German] by Carla M. Watenberg; edited with an introduction by Peter Hall. Oxford, UK: Pergamon Press.

Zarzosa, P. (2009). Estimación de la pobreza en las comunidades autónomas españolas, mediante la distancia DP2 de Pena. *Estudios de Economía Aplicada*, 27(2), 397-416.