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An Empirical Measure of the Effect of Externalities on Location Choice

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Abstract The aim of this paper is to test if the urban structure of the Spanish city of Córdoba follows the standard neoclassical model. For this purpose, we explore the centripetal and centrifugal forces and the housing sizes. We also explore the shape of the spatial distribution of the variables involved. The main results are that, although the centripetal forces have more impact on the housing prices, there are also centrifugal forces –for example CBD congestion–, that in some cases have enough intensity to invert the distance–price gradient sign. The work shows very clearly the asymmetric distribution of the amenities.

J.E.L. Classification: R15, R21, D12

Key words Location Choice, Externalities, Housing Prices, Centrifugal and Centripetal Forces

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1 Introduction

Since the pioneering work of Alonso (1964), many papers have been devoted to explaining the causes of residential location choice. The monocentric model (Alonso, 1964; Mills, 1967; Muth, 1969; Solow, 1972; Fujita, 1989) introduces the commuting cost as the main variable to explain housing prices. The model supposes that all the working and commercial places are located at the CBD, so commuting costs are an increasing function of distance. The main features of this model are: 1) There exists one CBD the determines only one urban structure on a spatially symmetric. 2) Distance to the CBD is the explanatory variable of housing prices, with price decreasing with distance[1]. 3) The population density function has a exponential negative slope, known as the Muth-Mills gradient. Fujita proves that the localization equilibrium is optimal, satisfying the Paretian conditions in the absence of externalities.

Later papers address "depreciation and malleability of capital stock" (Anas, 1978 and Arnott, 1987), with special reference to the dynamic of the deterioration of the CBD. The deterioration process can be stop —breaking the negative agglomeration force— through urban renewal programs. "Filtering process" theories explain why individuals leave the CBD because of its agglomeration problems. The assumption of spatial symmetry determinate the circular growth of the city, with CBD as the central point of this process. The high income families leave the CBD to avoid congestion looking better environmental quality in the surrounding areas. In the same way, Ellis (1967), Yamada (1972) and Alperovich (1980) study the effect of environmental quality on location choice.

Other authors (Kain and Quigley, 1975; Papageorgiou, 1976; Freeman, 1979; Dubin and Hsing, 1990; Sivitanidou, 1996) have defended the importance of neighborhood quality (as average income, race, services, schools, park, and so on) in location choice, which is not considered in a simple monocentric model.

The literature of density gradients (α) is very extensive; Mills and Tang (1980) have obtained density gradients for a large number of cities of the world. McDonald (1989) has studied the problems to measure density gradients in cities where growth changes with time. Mieszkowski and Mills (1993) introduced real transport costs as measure of accessibility to the CBD. Clapp et al. (1997) and Anas et al. (1998) are examples of recent studies of density gradients in monocentric or weakly polycentric[2] urban structures; Chamorro and Martinez-Giralt (1997), Gaspar and Glaeser (1998) work on the influence of technology on urban agglomerations; finally, Fujita et al. (1999) concentrate in the study of city systems.

Fujita and Thisse (1996), Case and Mayer (1996) and Alonso-Villar (2001) introduce the "concepts of force" in dynamic models. They use centrifugal and

[1] $P_k = -1/q(T_k)$. See below equation (1).

[2] Weakly because there is not a common definition of secondary CBD. McMillen and McDonald (1998) find 15 subcenters in Chicago, Cervero and Wu (1997) 22 in San Francisco, a similar study is done by Giuliano and Small (1991) in Los Angeles metropolitan area. See Anas et al. (1998) for a survey and Turnbull (1990) or Yinger (1992) for a theoretical analysis.

centripetal forces to explain why agglomerations increase (or decrease) the population density in different parts of the city.

Our paper analyzes Córdoba (a southern Spanish city). The De Salvo (1977) theoretical framework is used in conjunction with Alperovich (1980) analysis of externalities. Córdoba is asymmetric for physical and historical reasons, and therefore the data is divided on a cardinal axes. The aim is to ascertain if the city has spatial asymmetry for population and price density. For this purpose the paper analyzes the distribution of the attributes (amenities); also, how these attributes affect the house prices (shadow prices); and, the equilibrium of agglomeration-dispersion forces (Fujita and Thisse, 1996) in each area of the city.

2 Theoretical framework

The framework has followed the theoretical approaches of De Salvo (1977) and Alperovich (1980), introduced by Kemper and Schmenner (1974). Alperovich (1980) builds a model with the objective of determining the role of neighborhood attributes on the population density, because the Muth-Mills model had a low significance level for explaining the population density function.

In De Salvo (1977), consumer problem is expressed as:

$$\max_{N,q,k} U(N,q) \quad \text{s.t. } N + P(k) \cdot q + T(k) = Y,$$

being N the quantity of numeraire commodity; Y the income; k is the distance to the CBD; P_k the slope of the price function at distance k; q is the housing quantity[3]; and T_k is the commuting cost slope function at distance k.

So, individuals' location equilibrium is the point where households maximize their utility. This equilibrium can be described by:

$$P_k q + T_k = 0. \tag{1}$$

Alperovich (1980) introduces externalities that affect housing prices. If X is the exogenous attribute level (positive or negative), at distance k, then:

$$P_k q + T_k - X_k P^X = 0, \tag{2}$$

where X_k is the slope of the attribute function at k, and P^X is the shadow price of that externality, measured as the unitary marginal utility of this attribute for the consumer[4]. Equation (2) shows this new equilibrium situation. Consumer optimization implies:

$$\frac{U_q}{P_k} = \frac{U_X}{P^X}. \tag{3}$$

[3] In some models, housing size (lot) enlarges with the distance from the city center or CBD. If πr^2 is the surface of a circle, as the distance increases, the circumference length grows in a linear way, and also the surface of a ring of any given width.

[4] This price will be negative if the attribute does not mean an increase in the living standards of the individual, for example congestion, and positive in the other case.

So:

$$P^X = \frac{U_X P_k}{U_q}, \tag{4}$$

introducing (4) into (2), the equilibrium condition becomes:

$$P_k = \frac{1}{q}(-T_k + P_k \frac{U_X X_k}{U_q}), \tag{5}$$

where U_q and U_X are the marginal utility of houses and the externality respectively.

From this condition, we can summarize the following implications between externalities and location choice:

1) If $U_X > 0$ and $X_k > 0$, or $U_X < 0$ and $X_k < 0$, with $T_k < \frac{U_X X_k}{U_q}$ then $P_k > 0$.

When the attribute is positive (negative) and the quantity grows (falls) with the distance, individuals' location equilibrium is farther from the CBD. If the externality value is high enough to compensate for the commuting costs, then individuals will pay higher prices as they move away from the city center.

2) If $U_X > 0$ and $X_k > 0$, or $U_X < 0$ and $X_k < 0$, with $T_k > \frac{U_X X_k}{U_q}$ then $P_k < 0$.

If transportation costs are higher than the value of the externality, housing price decrease with the distance from the CBD.

Then, if some individuals give more value to environmental quality (more common in surrounding areas than in CBD.) than to the alternative use of the commuting cost expenses, they will pay a higher price at non-central locations.

Generalizing to n attributes, the population density function will be,

$$D(k) = D[k_0, X_1(k), X_2(k), ..., X_n(k)], \tag{6}$$

where D_k is the density at k; and X_i is the *i-th* attribute. Solving the model, we have:

$$D_{Xi} > 0 \Leftrightarrow (U_{Xi} X_{ik}) > 0$$
$$D_{Xi} = 0 \Leftrightarrow (U_{Xi} X_{ik}) = 0$$
$$D_{Xi} < 0 \Leftrightarrow (U_{Xi} X_{ik}) < 0.$$

Then, an increase (decrease) in externality level if it is desirable or a decrease (increase) in its level if it is undesirable will increase (decrease) population density at that point.

3 Hypothesis, Objectives and Methodology

3.1 Hypothesis and Objectives

Although this paper is based on the study of De Salvo (1977), it starts with somewhat different basic assumptions.

Hypothesis 1 The existence of desirable attributes (positive externalities) affect consumers demand, and their localization choice.

Some attributes (amenities) can change the shape of the urban structure, attracting people or repulsing them (Alonso-Villar, 1997). From (5) and (6) it can be concluded that the level of these externalities change population density.

Objective 1 Estimate the hedonic equation of house prices. We can then obtain the implicit price of each attribute and then the externalities shadow price (P^X). Three externalities of the neighborhood are analyzed: quality measured by household income; by building age; and by level of pollution. Housing attributes (size and other specific characteristics) are included.

Hypothesis 2 The attributes are not symmetrically distributed with respect to the city center.

For every attribute, z_i, generating externality (X_i) at distance k from the CBD in some direction (for example North); at distance k in the opposite direction the externality level will usually be different, that is $X_{i,N} \neq X_{i,S}$ for nearly every[5] k. For historical, political[6], and geographical reasons every city can have rigidities in the market, which break the symmetry of the utility level of the land.

Objective 2 Analyze the lot size in the four cardinal axes (sub-samples), testing if the lot size is an increasing function of the distance.

Objective 3 Undertake a spatial study of the attributes distribution (X_k) within the city (using the referred cardinal axes), testing their spatial distribution.

Objective 4 Using the attributes distribution (X_k) and its shadow price (P^X) find the direction of the force: agglomeration–dispersion effect.

Proposition 1 *In equilibrium, population density is not symmetrical, so* (6) *depends upon distance and orientation. This also means that $v(k_N) \neq v(k_S)$ for most values of k, being $v(k_N)$ (or $v(k_S)$) the population density at the point k in the North (South) direction.*

Is generally accepted that externalities affect the residential demand. However, when these are not distributed symmetrically and individuals do not value them in a linear way, then population does not distribute in a homogeneous manner.

Proposition 2 *When the population density is not symmetrical, housing price is also non symmetrical with respect to the CBD, so $\exists k_N, k_S$ so that $P(k_N) \neq P(k_S)$.*

The distance to the CBD and commuting costs are not the only variables explaining price. Some other attributes of urban geography also affect price.

Objective 5 Contrast the propositions.

[5] It is possible to find the same level in some sparse points, in a non-dense subset in $\mathbb{R}$.

[6] In many cities, Town Halls have not enough funds to develop urban renewal program along the whole city.

3.2 Methodology

Hedonic price methodology is used to estimate the attributes shadow price. Hedonic price models were introduced by Waugh (1928) and Court (1939) and later developed by Lancaster (1966), Chow (1967), Griliches (1971) and Rosen (1974)[7]. The essence of the hedonic method is the analysis of a good (for example, dwellings) as a bundle of characteristics.

For a good, Z, whose price depends on some characteristics or attributes z_i and other unknowns u:

$$P_z = \Omega(z_1, z_2, ..., z_n, u), \tag{7}$$

with the estimated model $\hat{P} = \hat{\alpha} + \sum \hat{\beta}_i z_i + e$ we can derive the marginal price of each attribute, $\partial\hat{\Omega}/\partial z_i$.

The implicit price equation is derived by using multivariate regression (in our case, Ordinary Least Squares). That is, the marginal price the individuals are willing to pay for each characteristic (Berndt, 1991). Consequently, the value of the externality shadow price (P^X) can be obtained.

A very simple methodology is employed for analyzing the spatial distribution of externalities or the intensity–distance gradient of an attribute. In order to arrive at its spatial distribution, i.e. X_k=$f(dCBD)$, OLS regressions of each one on the distance to the CBD were separately performed (see results section below).

Although is possible to found a certain degree of spatial autocorrelation and heterokedasticity in cross–section data, the introduction of distance variables in the model specification can minimize this problem[8].

4 Data and features of Córdoba

4.1 Data

The database used for the analysis is from the Statistics Department at the University of Córdoba. The database is built on surveys from real-estate agents in Córdoba and the opinions of municipal experts from the Town Hall, the Department of Urban Planning and the Traffic Department. Surveys were made at three real-estate agencies that are located in the CBD, the southwest, and the northeast. These were carried out from January to April of 1996. Each sample reflects the spatial position of the dwelling and its particular characteristics: surface, price, condition, orientation, etc.

The sample consists of 1,023 dwellings, about 20% of total sales for 1996. All of the dwellings under study are apartments, none of which are individual houses with garden. It must be emphasized that the survey reflects the spatial localization of housing for the entire city, its 26 neighborhoods.

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[7] See Berndt (1991) and Parker and Zilberman (1993) for a deeper and more detailed survey of this method.

[8] We wish to thank J. Suriñach, R. Moreno and E. Vayá at this point.

The total sample was divided into four groups to facilitate the analysis of the different sub-markets (see figure 1, page 8): Northwest (NW) 263 apartments, Northeast (NE) 155 apartments, Southwest (SW) 408 apartments, and Southeast (SE) 416 apartments. Each group includes all the CBD apartments (73). The variables used are the following:

Housing attributes: 1. Selling price of the dwelling in monetary units of 1996, (p); 2. Housing size in square meters ($size$); 3. Distance to the CBD, distance in meters from the neighborhood[9] to the city center ($dCBD$); 4. Specific distance from the apartment to the neighborhood center (sd).

Neighborhood attributes: Three externalities are analyzed: 1. Building age index (age). As an index for evaluating dwellings, this gives a higher value to the newest houses, and a lower value to the oldest apartments; 2. Average income index ($income$), this is determined by the Urban Department of the Town Council; 3. Congestion index ($congest$) . This includes congestion and pollution caused by traffic and is dependent on traffic level and infrastructure endowment. This index was created by the Traffic Department of Córdoba.

4.2 The city of Córdoba

Córdoba is a medium–size city located in Southern Spain. It has a privileged geographical position, because is located at the center of Andalucía, 140 km. from Sevilla, 170 from Málaga and 160 from Granada. Its communications with the rest of Spain are excellent. It is connected to Madrid (400 km.) by high velocity train and by highway.

Regarding the city itself, we need to point out several important factors that influence spatial distribution of housing price.

(1) The city of Córdoba is located in a valley. To the northwest are mountains, to the southeast is the Guadalquivir River, and to both the northeast and the southwest are plains. Given its extreme climate, especially the heat, the northwest is the most desirable place to live.

(2) Until 1992 the city was divided on an east–west axis by the railway, and connecting routes between the sides were minimal. The railway complex was completely reformed and buried by 1992, unifying the city. The covered areas have been converted into new neighborhoods with modern infrastructures (gardens, parks, etc.) and high prices, 130-150 thousand pesetas per square meter (see figure 2, lines areas).

(3) With regard to the general maintenance of the city, there are two zones that have traditionally been underprivileged. The area on both banks of the river has not been maintained, relegating it to a marginal position. One could say that the city has turned its back to the river. The other zone of evident neglect up to 1992 borders the train tracks. This explains why prices were very low here, in spite of its proximity to the center. It is interesting to note that prices remain low here[10].

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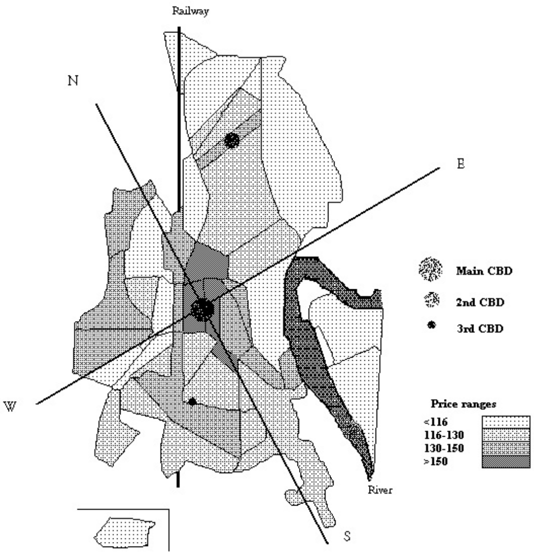
[9] The main office of Cajasur (the local financial institution) is used to define the central point of each neighborhood.

[10] See fig. 1, prices less than 116,000 pesetas per square meter for river and rail areas.



Where light shade means low prices ($< 116,000$ ptas) and dark ones high prices ($> 150,000$ ptas). The three black points are the main, second and third CBD.

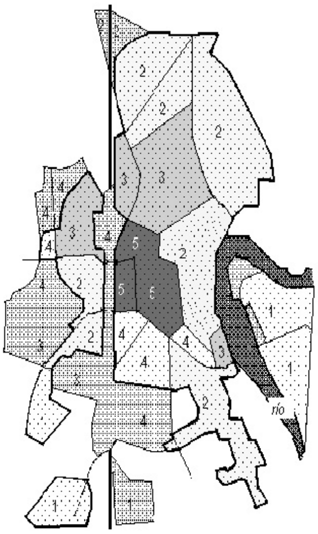
Fig. 1 Average Housing Prices and CBDs.

(4) Córdoba has three CBD (See fig. 1). The largest is located in the center of the city, generating most of the commercial activity and employment. The second, situated to the northeast, is characterized by high-end commercial activity and generates substantial employment. Housing prices are understandably high here. The third, much less important, is to the southwest of the city. It has some commercial activity but generates little employment. In particular, it tends to be shifting even more towards the southwest, an area of new development.

The second map (fig.2) shows income per capita levels for each zone and zones of new development. It also allows us to analyze population density.

(1) The CBD and the adjoining neighborhoods are high-income areas (rank 5). This is due not only to its location but also to its general appearance, the municipal government having promoted public works and the restoration of older buildings here.

(2) However, a clear east–west asymmetry can be observed. Given a similar distance from the center, in general the neighborhoods situated to the west have higher income than those to the east, and almost all the new neighborhoods are located in the west. It can also be observed that people with high rent (rank 4) occupy the new neighborhoods, due to high prices. An exception to this tendency is the area immediately to the west of the railway, which continues to be somewhat marginal.



Where lined areas are new neighborhood, and the pointed areas old ones. Numbers 1–5 means increasing levels of relative per capita income (1 means very low and 5 very high).

Fig. 2 Income per capita of Neighborhoods and New Zones

(3) The neighborhoods east of the river like those of the peripheral southwest show a very low income per capita (rank 1). This can be explained in large measure by delinquency and official abandonment.

(4) As regards population density[11], the division by the railway and the historical characteristics of the city have been determinant factors: a) The areas to the right of the tracks and the northwest zones of new construction have a low–density (L). Population diminishes as distance from the CBD increases in the direction of the mountains. b) The historic zone[12] of the city has a medium–density (M), which diminishes in relation to its proximity to the river (L). On the far side of the river the density is medium (M). c) On the left side of the tracks, the area between the second CBD and the third CBD (which includes the main CBD) has a high-density (H). To the northeast of this zone the density is medium (M), while there is low-density (L) in the newly constructed neighborhoods to the southwest.

[11] We are grateful to the City Hall of Córdoba for their help on this point. H: high, M: medium, L: low and VL: very low.

[12] The historic area, known as the Jewish quarter, is located in the southeast quadrant of the city. See figure 1. It extends from the main CBD to the river.

5 Results

The empirical study is divided into four parts. First, an hedonic equation of implicit prices is estimated, in which the shadow price of each externality is evaluated. Second, the spatial distribution of each neighborhood attribute is analyzed, to determine if the distribution is symmetric. Third, on the basis of these results, we analyze the centrifugal or centripetal forces that are caused by externalities. Finally, the propositions listed in the previous section are examined.

5.1 Hedonic Equations and Shadow Prices

Standard hedonic price function (Berndt, 1991) is used in each sub-sample to evaluate the shadow price (P^X), given the intensity-distance gradient (X_k) of an attribute. The utility level based on the implicit price is obtained with this estimation. For obtaining the equation of implicit prices, multivariate regressions are estimated, where the dependent variable is the housing price and the z_i explanatory are housing attributes ($size$, $dCBD$, and sd) and neighborhood characteristics ($congest$, age and $income$).

Although housing attributes are not used in this study, they were introduced in order to establish the best specification. With these variables accuracy can be improved, also mis–specification problems can be avoided. Following Box–Cox optimum values of λ[13], we use logarithmic specifications, in each case:

$$\hat{P} = e^{\hat{\alpha}} z_1^{\hat{\beta}_1} z_2^{\hat{\beta}_2} z_3^{\hat{\beta}_3} ... z_n^{\hat{\beta}_n} e, \quad i = 1, ..., 6. \tag{8}$$

Where $\hat{\beta}_i$ show the elasticity of housing prices with respect to the i-attribute. We estimate (8) in each zone, as well as in the whole sample, using OLS. Table 1 summarises the results.

Table 1 Estimation of shadow prices

	Total Sample	Northeast	Northwest	Southeast	Southwest
intercept	5.30 (51.3)	5.21 (23.2)	5.42 (30.4)	5.55 (37.2)	5.75 (34.5)
size	0.93 (41.8)	0.92 (19.0)	0.88 (23.5)	0.87 (26.8)	0.86 (24.9)
dCBD	-0.06 (-11.7)	-0.05 (-3.2)	-0.06 (-5.4)	-0.07 (-11.9)	-0.06 (-9.8)
sd	-0.03 (-9.4)	-0.02 (-2.6)	-0.03 (-4.9)	-0.03 (-6.5)	-0.03 (-4.7)
congest	—	—	-0.03 (-2.5)	0.02 (4.3)	-0.08 (-2.5)
age	—	—	—	—	-0.01 (-2.2)
income	0.04 (8.4)	0.18 (2.9)	0.17 (3.7)	0.03 (5.5)	0.05 (5.5)
R^2	0.81	0.87	0.88	0.86	0.80

* between bracket we show the t-student test value.

[13] Being the Box–Cox optimum value of λ for the variable "housing price" or *price*: λ_{SE}=0,1; λ_{NE}=-0,6; λ_{SO}=-0,3; λ_{NO}=–0,5. See Freeman (1979) for a discussion.

As expected, lot surface ($size$) is a determinant variable in house price (positive for all cases). Distance to the city core ($dCBD$) has the negative expected sign, its explanatory capability is very low (in all cases $\hat{\beta}_i$ is close to -0.05). The specific distance, (sd), is also negative and shows a low elasticity, that is, its influence on housing price is relatively limited.

However, the externality shadow price estimation results are more interesting because they point to more variability between axes.

Congestion level. The elasticity is not significant for the NE. The other three cases are very different; in the NW and SW, valuation is negative ($\hat{P}^X < 0$), while in the SE the congestion seems to be a desirable attribute. The last case can only be explained if the inhabitants of this zone perceive congestion as a result of commercial activity. Commercial activity normally goes parallel to congestion.

Filtering processes. age was only significant in the SW case; consequently we can assume that people does not value this attribute very high, this does not allow us to measure the importance of the forces related to this attribute. In particular, we cannot analyze the effect of filtering processes on housing price. The case of SW inhabitants has a simple explanation. A high percentage of the city's new flats are located in this area, so there is a notable contrast between very old apartments and new ones (see figure 2, page 9).

Average income. We find some differences in the estimated parameters. In both North zones the value is much higher than in the South and in the total sample. As expected, people in every zone value neighborhood quality positively, but the North residents give it a higher value.

5.2 Asymmetrical Distribution of Attributes

In this part is analized the spatial distribution of each attribute in the distance (from the CBD to the end of each axes). Lot size is also analyzed to contrast the second objective. Regressions were calculated, where the dependent variable is the attribute and the explicative is the distance to the CBD ($dCBD$). The same analysis is repeated for each attribute and in each group, using the following functional form[14]:

$$y = e^{\alpha} x^{\beta}, \tag{9}$$

y being the attribute (X) and x the distance (k). The results are summarized in the following table:

Dwelling size. The monocentric model supposes –see footnote 1– that lot size q is a linear increasing function of distance k. The first row of table 2 shows the distribution of lot size in relation to distance. In all cases R^2 is really low, so we can assume that there is no relation between size and distance to the center. No significant differences in the constant are found; but there are some

[14] We use this non-linear specification because of its better adjustment (Suriñach and Martori, 1997).

Table 2 Spatial distribution of attributes

	Northwest		Northeast		Southwest		Southeast	
	δ	$\hat{\beta}$	δ	$\hat{\beta}$	δ	$\hat{\beta}$	δ	$\hat{\beta}$
size	103.54 (131.7)	−0.00 (−0.05)	99.48 (115.7)	−0.03 (−2.4)	102.61 (178.8)	−0.03 (−3.2)	91.83 (182.1)	−0.06 (−7.1)
	R^2=0.00		R^2=0.05		R^2=0.03		R^2=0.13	
congest	2.48 (8.3)	−0.30 (−6.5)	3.28 (59.7)	−0.22 (−110.5)	3.7 (41.7)	−0.13 (−11.8)	2.77 (12.5)	−0.19 (−6.5)
	R^2=0.13		R^2=0.46		R^2=0.25		R^2=0.09	
age	0.23 (−8.9)	−0.01 (−0.2)	0.24 (−7.2)	−0.02 (−0.3)	0.19 (−10.1)	−0.07 (−1.2)	0.21 (−9.2)	−0.01 (−0.3)
	R^2=0.0002		R^2=0.0008		R^2=0.003		R^2=0.0001	
income	2.77 (39.3)	−0.15 (−13.7)	2.58 (40.3)	−0.22 (−24.8)	3.38 (17.1)	−0.32 (−12.4)	2.18 (12.3)	−0.33 (−14.3)
	R^2=0.41		R^2=0.80		R^2=0.27		R^2=0.33	

* between bracket we show the t-student test value.

** note that δ=$e^{\hat{\alpha}}$. The t values are obtained for $\hat{\alpha}$.

differences in the elasticity level. However these are always negative. In the SE case the value is double that of the SW and NE, which are quite similar. The NW value is not significant. This means that housing size does not increase as we move out of the CBD. If there is any relation at all it is inverse. That is, the larger apartments are located in the city center, and this relationship is not symmetric.

Congestion level. This type of amenity is usually not desirable; if the externality source is the CBD, this will act like it a centrifugal force. If the cause is a factory at the city edge, the force will be centripetal. Due to data limitations, this externality distribution is evaluated with the variable $congest$ (row 2, table 2). In the constant ($\delta = e^{\hat{\alpha}}$) there is a variability of nearly 50 percent. The elasticity of congestion also has large variations. The explanation is that there are significant differences in how the congestion gradient interact with the different axes of the city, and these results have a direct relation to population density. Both δ and $\hat{\beta}$ have significantly different value in the NW axes than in other areas: the congestion level is low and declines rapidly here (keeping in mind that the NW is close to the mountains). SW and NE are the opposite cases: they are characterized by very high level of congestion and a slow decline. In every case the congestion level falls with an increase in the distance from the center, so a negative externality is clearly located in the city center. However the gradient of this externality is not symmetric, and the NW case is especially relevant.

Filtering processes. When an area is old and the housing stock has deteriorated there are clear incentives for people to move out. Significant spatial differences in the age of the houses (row 3, table 3) are tested to define these incentives. In all cases R^2 is very low and the value of δ is similar, and close to 0.20. None of $\hat{\beta}$ are significant. There is no significant variability along the axes regarding the age of the houses, and therefore a city growth model based on circles is not acceptable. Although many new houses have recently been built in the West (see figure 2), there are also many new ones in the East. In addition, many of the "new neighbourhoods" are located relatively near the CBD. Once again we see that the division of the city by the railway has been determinant in its pattern of growth.

Income. The CBD in historic cities, has high–income inhabitants, acting like a centripetal force; however, centrifugal forces can appear caused by other high–income areas outside the center. Our estimations (row 4, table 2) show that different orientations have different constant, been higher in the SW, but lower in the SE direction. The exponent of the distance (always negative, that means that there is a clear centripetal externality) is also different. The elasticity in SW and SE cases is the double that NW and NE ones. This attribute declines faster in the South than the North. A possible explanation can be found through the commercial activity: the main and second CBDs are located in both North areas. In the South we only find the 3rd CBD but this is still not well–established; even south areas has problems caused by deterioration and official abandonment.

5.3 The Effect of Centrifugal and Centripetal Forces on Housing Price

In this third section we define the forces that shape each part of the city. This involves an analysis of the attributes distribution (X_k) and their shadow price (P^X[15]). Using a simple Muth-Mills price/distance analysis the balance between forces can be discerned, supposing commuting costs increase with the distance to the CBD (but equal in every point i at the same $dCBD$); that is,

$$T_k^{i)}(dCBD) = T_k(dCBD), \quad \forall i. \tag{10}$$

The price based on the distance ($P(k) = f(dCBD)$) is estimated in each sample. The result will indicate the direction (centripetal of centrifugal) of the total force. So, the estimated distance–price gradient ($\hat{\beta}$, i.e. P_k) is the result of the balance between forces. Also, it must be considered that commute is always centripetal. Table 3 illustrates this analysis.

Using the results shown in table 1, 2 and 3, the effect of centrifugal and centripetal forces can be observed.

Northeast: One significant attribute, income, is found with a positive shadow price ($U_{income} > 0$) which decreases with the distance ($income_k < 0$), so it is a centripetal force. Obviously, with this result price is a decreasing function of the distance ($P(k) = f(dCBD), \quad P_k = \hat{\beta} = -0.11$).

Northwest: Here there are two attributes, income ($U_{income} > 0$ and $income_k < 0$) and congestion ($U_{congest} < 0$ and $congest_k < 0$); with one centripetal and one centrifugal force. As there are two opposite forces, the resulting force is centripetal ($\hat{\beta} = -0.08$), but with a very flat slope.

[15] Although, we have estimated the shadow prices not U_X, is evident than a positive shadow price is the consequence of positive utility.

Table 3 Estimation of Distance-Price Slope

$y = e^{\hat{\alpha}} k^{\hat{\beta}}$	(being y the housing price and k the distance)				
Southwest		coeff.	st. error	t-stat.	prob.
	intercept	9.61	0.02	366.5	0.00
R^2=0.23	*logDCBD*	-0.1	0.009	-11.7	0.00
Northwest		coeff.	st. error	t-stat.	prob.
	intercept	9.58	0.03	271.7	0.00
R^2=0.11	*logDCBD*	-0.08	0.014	-5.8	0.00
Northeast		coeff.	st. error	t-stat.	prob.
	intercept	9.57	0.03	289.5	0.00
R^2=0.36	*logDCBD*	-0.11	0.01	-9.3	0.00
Southeast		coeff.	st. error	t-stat.	prob.
	intercept	9.47	0.02	384.9	0.00
R^2=0.39	*logDCBD*	-0.15	0.009	-16.5	0.00

Southwest: Again there are two attributes: income ($U_{income} > 0$ and $income_k < 0$) and congestion ($U_{congest} < 0$ and $congest_k < 0$), one centripetal and one centrifugal; centripetal forces are more intense, so the resulting total force is centripetal with a slope $\hat{\beta} = -0.10$, some way between the NE and NW cases.

Southeast: Again, as in the SW and NW, we found two attributes: income ($U_{income} > 0$ and $income_k < 0$) but congestion ($U_{congest} > 0$ and $congest_k < 0$) is also centripetal. As all the forces are centripetal, the gradient ($\hat{\beta} = -0.15$) is higher (in absolute value) than in the other zones. In this area the price falls more rapidly than in the rest of the city.

5.4 Interpretation of the results in terms of the actual city

Most of the results have a reasonable explanation if the characteristics of the actual city are taken into account.

Northeast: There is a high degree of economic activity in this area of Córdoba, and the second CBD located there is increasingly important. However, it also has a congestion problem because there are very few parks or other open areas. This problem cannot be easily solved, and this negative externality will probably increase. In contrast to other areas, its possibilities for expansion are very limited (is close to the highway).

Northwest: It clearly has the best environment and the highest level of income of all the areas studied. The results of the data analyzed lead us to believe that the northwest will have prices as high as those of the CBD in the future. In this case, prices will not fall with distance.

Southwest: It should be recalled that many new neighborhoods are being located in this area. Although these neighborhoods are not completely developed at this time, it is reasonable to believe that they will eventually be very desirable because of environmental conditions like parks and open areas.

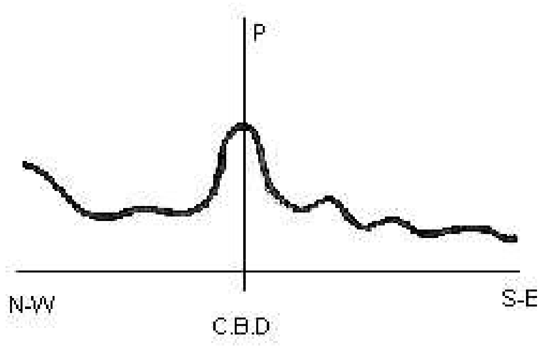


Fig. 3 Housing prices (NW;SE)

Southeast: This is the most deprived zone of the city, where government intervention has been very limited. The degradation of the river area could be a major influence on the zone. However, the government is now improving and remodeling the river and its banks, which possibly could have a positive affect on the zone in general.

5.5 Proposition Verification

Claim (For proposition 1)

The heterogeneous values of externalities, like congestion and neighborhood quality, lead to the conclusion that the population density is asymmetric. Equation (6) postulates that the population density depends on externalities. The neighborhood quality asymmetry is explained because people want to live near a particular externality. Also, in most European cities the North has a higher value for that externality, as is the case here.

Claim (For proposition 2)

Figure 3 and 4 are used to validate this proposition, in which housing price is plot[16] on the distance (k) to CBD. The first reflects the spatial evolution of the price along the NW-SE axes, the second along the SW-NE axes.

The *NW* is a very attractive zone with a high income level and low congestion, so in this case the inverse of the Muth-Mill model was found. Price increases with the distance to the city center because are located in this area ample and expensive houses. The rapid decline of price on *SE* is caused by the degradation of the area, very limited commercial activity and environmental problems.

The *NE* axes is completely different than that of the NW, the fall in price is very similar to the expected values of the Muth-Mills model. Although the 2nd CBD is

[16] For figures 3 and 4, we have used price per square meter not only for flats but also for houses, which includes the luxury houses in the NW mountains.

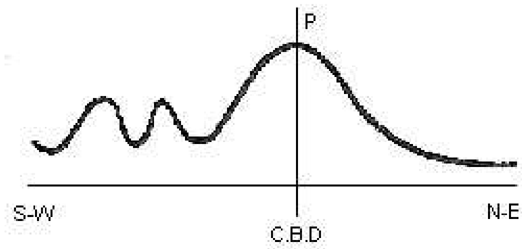


Fig. 4 Housing prices (SW;NE)

located in this area, the problems of congestion affect housing prices negatively. The *SW* has two important "island" prices (Brañas-Garza et al., 1999), both caused by commercial activity (the extended 3rd CBD) around the residential zones; at the edge the historical slumps are reflected.

The conclusion therefore, is that housing prices in the city are not symmetrical around the CBD axes.

6 Conclusions

The aim of this paper is to contrast the effect of externalities on location choice with its consequences on housing prices. To this end, the De Salvo (1977) and Alperovich (1980) analysis is used in a concrete urban nucleus, Córdoba. The results seem to confirm that there is a relation between amenities, valuation and housing prices. These results can be summarised as follows.

First, the externality shadow price depends on the particular features of the area chosen, so there are also asymmetries in the attribute valuation. Also, the best results are obtained from non linear models.

Second, some of the externalities that affect the localization choice, specially congestion and neighborhood quality, show clear spatial asymmetries.

Third, with respect to centrifugal/centripetal forces we have shown that: CBD congestion always acts like a centrifugal force, but its intensity depends upon the particular case. However, neighborhood quality may be centrifugal or centripetal, depending on the source location.

Fourth, filtering processes do not appear significant in this case. So we have not analyzed it.

Fifth, population density and housing prices are asymmetric variables along the axes considered; but figure 1 and 2 show that there is not a clear relation between them.

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