A methodological proposal to estimate changes of residential property value: case study developed in Bogota

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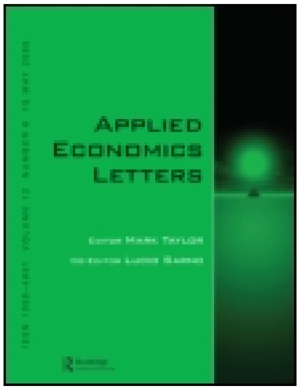

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A methodological proposal to estimate changes of residential property value: case study developed in Bogotá

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This article is an empirical study of residential land values in the vicinity of the TransMilenio system (Bus Rapid Transit, BRT) in Bogotá (Colombia). The results have been established through impact evaluation by means of nonparameteric approaches (Propensity Score Matching, PSM) and econometric approaches (Spatial Hedonic Price, SHP) indicating that access to the BRT system generates benefits on the change of property value.

Keywords: TransMilenio; Bogotá; impact evaluation; propensity score matching; spatial hedonic price; change of property value

JEL Classification: C14; C25; C52; L92; R11

I. Introduction

Transport progress opened in Bogotá in December 2000 with the Bus Rapid Transit (BRT) service (TransMilenio). The project system includes an infrastructure network for its operation (exclusive right-of-way with dedicated station, sidewalk, bridge, mixed traffic lane and so forth) supplied by the Colombian government because the total cost of the investment is significant (Mendieta and Perdomo, 2008). Nevertheless, some profits are perceived through positive externalities[1] (Rodríguez and Targa, 2004).

Therefore, the main objective of this article is to estimate the impact of the TransMilenio infrastructure on the price of residential properties in the vicinity, by means of impact evaluation through Propensity Score Matching (PSM) and Spatial Hedonic Price (SHP), using Geographical Information Systems (GIS) in Bogotá (Colombia). In this way value-capture mechanisms could be developed, which could be used to finance future phases of the BRT project.

Finally, the rest of the article is organized as follows: Section 2 contains empirical analysis on the topic. Section 3 describes analytical methods (SHP and PSM). Section 4 provides data description and presents the results on issues mentioned above. Section 5 concludes the article.

II. Related Literature

To my knowledge, there are only few studies on the topic, and in Colombia the study is in its initial stages of emergence. However, SHP technique has been implemented to estimate changes of property value in Bogotá by Rodríguez and Targa (2004) and Mendieta and Perdomo (2007); likewise, PSM method has been implemented by Perdomo *et al.* (2007) and mean comparison test by Rodríguez and Mojica (2008).

[1] Economic development, land-use strategy, improving accessibility, saving travel time, land-value increases, traffic accident decreases, reductions in crime rates and air pollution (Lleras, 2003; Sandoval and Hidalgo, 2003; Moreno, 2004; Mendieta and Perdomo, 2007; Perdomo *et al.*, 2007; Rodríguez and Mojica, 2008).

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Globally, the studies that are more closely related to the SHP and PSM methods indicate that the introduction of a new ordinance to Chicago in 1923 allowed determining the effects of zoning on relative land-value growth rates, once the authors controlled for initial land use and the endogeneity of zoning decisions with spatial econometrics and PSM (McMillen and McDonald, 2002).

Likewise, Vinha (2005) estimated the impact of the metro infrastructure on the development patterns in Washington, DC, by means of PSM. Empirical research about changes of residential property value with Hedonic Price (HP) and PSM are few (McDonald and Osuji, 1995; McMillen and McDonald, 2000, 2004; Batt, 2001). Besides, there are not many studies simultaneously conducted through both methods, so their results cannot be analysed and compared.

III. Analytical Methodology

To estimate the impact of the TransMilenio infrastructure on the values of residential properties in the vicinity, HP and PSM are used. Notwithstanding, before estimating HP and PSM it is important to have a spatial analysis using GIS to avoid any possible problem about spatial autocorrelation and endogeneity (Anselin, 1980), omitting a relevant variable or incorrect functional form (Rosales *et al.*, 2010).

In this sense, HP is an approach based on the market for heterogeneous goods developed by Rosen (1974). Therefore, residential price ($V(z)$) is a function (f) of property attributes (z) such as total bedrooms and baths, externalities (air pollution, noise, crime rates and so forth) and accessibility ($z_1, \ldots, z_k$). Hence, the equilibrium HP function is

$$V(z) = f(z_1, \ldots, z_k) \quad (1)$$

where the left-hand side of Equation 1 is the Willingness to Accept (WTA) a house price equal to the right-hand side or Willingness to Pay (WTP) for changes in property attributes. Thus, its empirical evidence is estimated by means of Box–Cox form (see Equation 2)[2] with maximum likelihood method.

$$V_i(z_{ki})^\theta = \beta_0 + \beta_1 z_{1i}^{(\lambda)} + \beta_2 z_{2i}^{(\lambda)} +, \ldots, + \beta_k z_{ki}^{(\lambda)} + e_i \quad (2)$$

where $V_i(z_{ki})^\theta = \frac{V_i(z_{ki})^\theta - 1}{\theta}$, $z_{ki}^{(\lambda)} = \frac{z_{ki}^{(\lambda)} - 1}{\lambda}$, $\beta_0, \beta_1, \beta_2, \ldots, \beta_k$ are the parameters; e_i represents the error term, identically and independently distributed (*iid*) with mean zero and unknown variance $[e_i \sim N(0, \sigma_e^2)]$; θ and λ are the transformation coefficients. Nevertheless, the spatial distribution of houses in an area and their distance attributes (to the city centre, train station, university, river or canal, near TransMileno, on major street and so forth) typically induce a spatial autocorrelation problem (Haab and McConnell, 2002, p. 267).

In this way, spatial econometrics methodology allowed problem solution by constructing a spatial weight matrix (**W**) that contains information on the neighbourhood structure for each location. Taking account of this adjustment and using Equation 2, the SHP model (Box–Cox form) is

$$V_i(z_{ki})^\theta = \beta_0 + \rho \mathbf{W} V_i(z_{ki})^\theta + \beta_1 z_{1i}^{(\lambda)} + \beta_2 z_{2i}^{(\lambda)} +, \ldots, + \beta_k z_{ki}^{(\lambda)} + \varepsilon_i \; \varepsilon_i = \gamma \mathbf{W} \varepsilon_i + e_i, \varepsilon_i \sim N(0, \Omega) \quad (3)$$

where ε_i represents error term (*iid*) with mean zero and unknown variance ($\varepsilon_i \sim N(0,\Omega)$), ρ and γ are parameters on the spatial lag. On the other hand, to estimate the impact of the TransMilenio infrastructure on the value of residential properties in the vicinity, PSM technique is used based on Heckman *et al.* (1997).

Therefore, houses in the vicinity of TransMilenio system accessibility are the treatment group (Y_1) whereas properties without this attribute determined the control group (Y_0), denoted in a binary response variable $D = 1$ and $D = 0$, respectively. The profit from the BRT infrastructure is $\Delta = Y_1 - Y_0$. However, spatial logit model must be used (see Equation 4) to estimate the conditional probability ($0 < \mathrm{P}_i (D = 1/\mathbf{X}) < 1$), because Δ is unobservable.

$$\mathrm{P}_i(D = 1) = \frac{1}{1 + e^{\rho \mathbf{W} D + \mathbf{X}\boldsymbol{\beta} + \varepsilon_i}} \quad (4)$$

where **X** is a matrix of explanatory variables such as distances (schools, universities, city centres, museums and so forth) and $\boldsymbol{\beta}$ is a vector of coefficients. Thus, the next step is to compare the price of residential properties, placing more weight on observations that have similar estimated probability ($\hat{\mathrm{P}}_i$) by means of nearest neighbour estimator (see details in Heckman *et al.*, 1997, p. 623). Finally, through Average Treatment on the

[2] The subscript i is to describe the cross-sectional observations, as property 1 up to 227 ($i = 1, 2, \ldots, 304$). Also, the subscript k is to describe total property attributes ($z_1, \ldots, z_k$) or explanatory variables.

Treated (ATT), the change of residential property value derived from the TransMilenio infrastructure is obtained.[3]

IV. Data and Empirical Results

The data used in the SHP and PSM methods reported in this research come from a sample of 304 residential properties in Bogotá (in the vicinity of the TransMilenio Portal in Suba and intersection of Boyacá Avenue and Primera de Mayo Avenue). The observations were extracted from a survey and GIS[4] in 2008.

Based on the SHP model by means of standard maximum likelihood method and spatial weight matrix (**W**), defined as the threshold distance between each property and other properties within 623 m (Euclidian distance), Table 1 presents the estimates[5] of the Box–Cox function. Specifically, the results of the explanatory variables that are most important (minimum distance between the observed property and the closest TransMilenio station or terminal, spatial lag price and error) are deterministic (significant at 1% and 10% levels, respectively).

The observations imply that if the minimum distance between the observed property and the closest TransMilenio station or terminal goes up by 1% (or 1 m), on average, its price (per square metre) goes down by about 0.05% (or US$0.02), once was controlled for the housing attributes (total number of bedrooms, bathrooms, garages, kitchens, age) and housing accessibility (distance to the bank, mall and park) and spatial autocorrelation.

On the other hand, logit model[6] is the first step in PSM; its results are provided in Table 2, where, binary response variable (D) takes on the value of 1 ($D = 1$) if the residential property is less than 500 m from a TransMilenio station or terminal, otherwise 0 ($D = 0$) if it is more than 500 m.

Hence, the probability that a house might have at TransMilenio system accessibility is 0.01% once controlled for the deterministic explanatory variables (significant at the 1% level) or housing accessibility. Based on the probabilities produced by the logit

Table 1. Spatial hedonic price model

Dependent variable (price per square metre)			
Explanatory variables	Coefficient	Marginal effect	Elasticity
Constant	101 460***	–	–
W* (price per square metre)	(–0.0422243)*	–	–
W* error term	0.0022905***	–	–
Minimum distance between the observed property and the closest TransMilenio station or terminal	(–0.0082713)***	–0.02	–0.05
Minimum distance between the observed property and the closest bank	(–0.0219449)	–0.03	–0.03
Minimum distance between the observed property and the closest mall	(–0.002186)***	–0.01	–0.06
Minimum distance between the observed property and the closest park	(–0.0405559)**	–0.02	–0.01
Total number of bedrooms	895.2617**	13.79	0.09
Total number of bathrooms	304.0087	2.99	0.01
Ubication level (floor)	364.2438	4.90	0.03
Total number of garages	8868.799***	39.56	0.06
Total number of kitchens	13 801.82***	70.59	0.13
Age (constructed years)	(–189.8815)	–7.50	–0.14
Lambda (λ)	(–1.901517)***		
Theta (Θ)	0.8262217***		
Loglikelihood	(–4133.2238)		
Number of observations (n)	304		

Note: *, ** and ***Significant at 0.10, 0.05 and 0.01 levels, respectively.

[3] To ensure the existence of a common support for the group of properties compared, the sample contains properties that would have the same probability of having access to TransMilenio system but not account with it. Thus, their spatial distribution is near to major avenue where is possible construct the BRT project and because socio-economic aspects are similar in both zones of the study.

[4] XY-coordinates of the residential properties.

[5] In Geoda (spatial econometrics) and Stata 9 (Box–Cox form and PSM), through robust SEs and generalized least square methods to remove heteroscedasticity.

[6] Omitted spatial lags, because they were insignificant at the 10% level.

Table 2. Logit model

Binary response variable ($D = 1$ and $D = 0$)		
Explanatory variables	Coefficient	Elasticity
Constant	(−43.02498)***	–
Minimum distance between the observed property and the closest bank	(−0.0089769)***	−4.22
Minimum distance between the observed property and the closest fire station	(−0.0296427)***	−66.09
Minimum distance between the observed property and the closest police station	0.0188992***	32.87
Minimum distance between the observed property and the closest museum	0.009136***	50.97
Minimum distance between the observed property and the closest parking lot	(−0.024989)***	−110.87
Minimum distance between the observed property and the closest hotel	0.0089844***	45.74
Minimum distance between the observed property and the closest inter-urban transport terminal	0.0094514***	73.86
Minimum distance between the observed property and the closest church	0.0118758***	11.24
Probability	0.00007428	
Loglikelihood	(−28.271899)	
Pseudo R^2	0.7947	
LR χ^2	218.90***	
Number of observations (n)	227	

Note: ***Significant at 0.01 level.

Table 3. Propensity score matching results

Method	Sample	Treated	Controls	Difference in price
Nearest neighbour (5)	Unmatched	US$510	US$462	US$48***
	ATT	US$510	US$451	US$59***

Note: ***Significant at 0.01 level.

model, these results were matched through nearest neighbour (5) (see Table 3).

Table 3 indicates that the difference in price is US$59 (per square metre), on average, between residential property with and without TransMilenio system accessibility. In other words, this shows that the development of the TransMilenio infrastructure has an important impact on the price of residential properties in the vicinity[7] (significant at 1% level).

V. Conclusion

This article utilized recent advances in HP approach, impact evaluation technique and a set of 304 housing in Bogotá (in the vicinity of the TransMilenio Portal in Suba and intersection of Boyacá Avenue and Primera de Mayo Avenue) to examine the impact of the TransMilenio infrastructure on the price of residential properties in the vicinity, using GIS and spatial econometrics.

The analysis of SHP reveals that if the minimum distance between the observed property and the closest TransMilenio station or terminal goes up by 1% (or 1 m), on average, its price (per square metre) goes down by about 0.05% (or US$0.02). The results of the estimation can be used to value changes such as follows.

Consider the location of a residence to 2500 m from TransMilenio station. The Box–Cox form predicts to willing to pay or marginal effect is US$50 (2500 × 0.02). In other words, US$50 is average received profit (per square metre) by the residential property owner to less than 1 m from TransMilenio station. Likewise, the PSM technique, through nearest neighbour (5), shows that the development of the TransMilenio infrastructure has an important impact on the price of residential properties in the vicinity.

Besides, the changes of residential property value, which is US$59 (per square metre), on average, are similar to that obtained (US$50) in SHP. In this way, both methodologies might be developed by the Colombian government as value-capture mechanisms that could be used to finance future phases of the BRT project.

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[7] Less than 500 m.

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