IMPACT ASSESSMENT OF A HIGHWAY CONSTRUCTION ON RESIDENTIAL LAND PRICES: THE CASE OF THE SÃO PAULO'S BELTWAY

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ABSTRACT

This paper estimates the effect of new highway construction on land prices using the implementation of the west branch of a large beltway around Sao Paulo Metropolitan Area. This is a unique opportunity since the beltway is being implemented by branches. So, it is possible to use the zones surrounding the branches where construction has actually started as a treatment group to be compared with zones surrounding branches for which construction has not started yet. Since we have a proxy for land price data before and after construction, it is possible to estimate the impact by difference-in-difference. The evidence is that there are significant and asymmetrical effects caused by the highway construction. Parcels located close to ramps outbound of the track observed an increase in price faster than similar zones close to other (planned) branches. For parcels located inbound of the beltway, relatively far from the track (between 2.5 km and 5 km), the effects of construction and delivery/operation faced a (relative) decline in land prices. These results have consequences for transportation finance; betterment levies and value capture taxes; urban form and welfare.

Keywords: Highway Construction; Impact Assessment; Hedonic Prices; Land Outcomes; Difference-in-difference; Sao Paulo Beltway.

INTRODUCTION

The purpose of this paper is to evaluate the effects of the announcement and construction of a large beltway (Rodoanel) around São Paulo Metropolitan Area (SPMA) on land prices. According to Wheaton (1977), one must take into account benefits and costs of road investments, which include more than the direct effects. Thus, one should look for indirect effects on land use and location decisions. One way to do that is to evaluating the impacts on land prices.

This kind of study can shed light on several planning and urban policy questions, as pointed by Bouarnet & Charlermpong (2001). Urban economic theory states that, coeteris paribus, land value will be higher in locations that are more accessible to Central Business Districts (CBD) or other employment destinations. In order to test this hypothesis we choose Rodoanel which is the greatest road investment in the state of São Paulo. Rodoanel is a beltway around the city of São Paulo which surrounds its metropolitan area. The project of Rodoanel is divided into four branchs. Currently there are two branchs finished: the West and the South branch. In this paper we estimate the impact of Rodanel announcement and construction on residential land prices a posteriori.

Rodoanel is one of the biggest urban transport investments in Latin America and it has several interesting features. First the amount of the investment—US$ 1.6 billion just for the West Branch and total amount estimated in US$ 8.4 billion. Second the extension—approximately 170 km of two pairs of triple lanes for the entire beltway. Third, its role in public policy as an investment designed on the basis of robust studies and analyses that took into account environmental concerns and the results of public hearings.

A priori impact evaluation conducted by the state government shows that the West Branch of Rodoanel would have insignificant effects on residential land value and on commuting time to São Paulo downtown. This would happen because the purpose of Rodoanel is to re-direct cargo traffic passing-through the SPMA. So it would not produce accessibility gains for daily commuters from home to work. But considering the traffic problems of São Paulo and the peak-hour congestion, the West Branch of Rodoanel can be used as an alternative commuting route. In that case, its effects on accessibility will be higher than estimated in the government evaluation.

Thus, following urban economic theory, the accessibility improvement caused by Rodoanel will be reflected in higher land prices. One way to deal with higher land values is to increase the density for new residential developments.

The paper is divided into four sections. Following this introduction, the first section describes the main characteristics and the history of the Rodoanel beltway. The second section discusses the hedonic price approach to land use and housing analysis. The third section describes the empirical methodology. The fourth section evaluates the impacts of Rodoanel on land prices. The concluding remarks discuss the results and indicate some of the policy implications from the analysis.

1. THE HISTORY OF RODOANEL

The idea of a beltway around São Paulo is not a new one. Since the fifties there have been projects and initial developments which were partially executed. The marginal avenues along the Pinheiros and Tietê rivers were components of two previous beltway projects.

The first beltway was planned in the thirties and deployed in the sixties to surround the inner area between the rivers Pinheiros and Tietê which are the main water courses of São Paulo. That area consists of downtown and the principal neighborhoods where services and commerce are located. Nowadays that area corresponds to the "expanded center" and resembles the idea of a Central Business District.

The second beltway was planned in seventies as an extension of the first one. The edges of such area interfaced with industrial neighborhoods, but not completely. The idea of a third beltway with a far eastern new border called 'Jacu-Pêssego Avenue' has been attempted but was never completely built (it is still under construction – extensions, new ramps and new connections etc.).

Traffic jams in São Paulo continued to intensify over the years in spite of the road investments. Almost 40 percent of the total cargo transported by trucks in Brazil passes-through the SPMA. At the same time there are land use policies which affect mobility patterns. To address some of these issues a new beltway project has been developed in the late eighties and beginning of nineties and that is the origin of the 'Rodoanel Metropolitano'.

The announcement of Rodoanel was made in January 1995. Mario Covas was then state governor, elected in November 1994. As soon as Covas took office he decided to take up the new beltway project and start its construction. The necessary impact studies were carried out covering all technical, environmental and legal aspects, as well as financial arrangements. The timeline of Rodoanel West Branch and the project milestone events are shown in Figure 1.

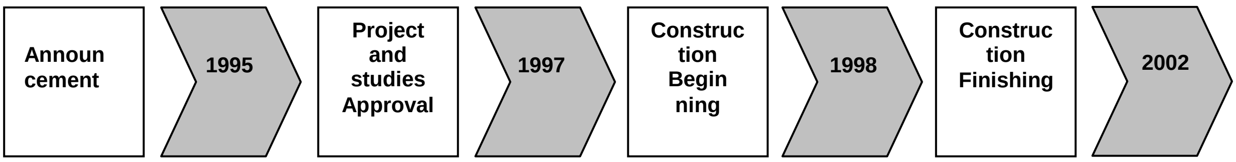

Figure 1 – Rodoanel West Section Timeline
Source: Secretaria de Estado dos Transportes de São Paulo

During project preparation, the main concern was the north branch. The original route planned would cross the Environmental Protection Area of Serra da Cantareira, which is one of the main water sources for the SPMA (see the green area at the north in Figure 2).
Finally approval was granted for a new planned route in the northern area that avoided any crossings through the Environmental Protection Area of Serra da Cantareira. The strategy to implement the Rodoanel consisted in dividing its construction into four phases—each of them a branch. The construction would begin by the western branch which was the cheapest and the easiest. The South branch started on 2008 and was recently delivered. The Sao Paulo State is starting the process to build the third branch on the east but it will not resume before the new governor is elected.

We test hypotheses related to two major events: the announcement and the construction of Rodoanel West Branch. According to Boarnet and Chalermpong (2001) whose study evaluates new toll roads in Orange County, California, it is important to consider some threshold years and evaluate them because the value of the roads would not be fully capitalized in the announcement or at the beginning of the construction. They note:

> "Even with some foresight on the part of home buyers, we expected that the market assessment of the likelihood that the roads would be built would rise over the early years of our data (…)." (Boarnet & Chalermpong 2001, pp.581)

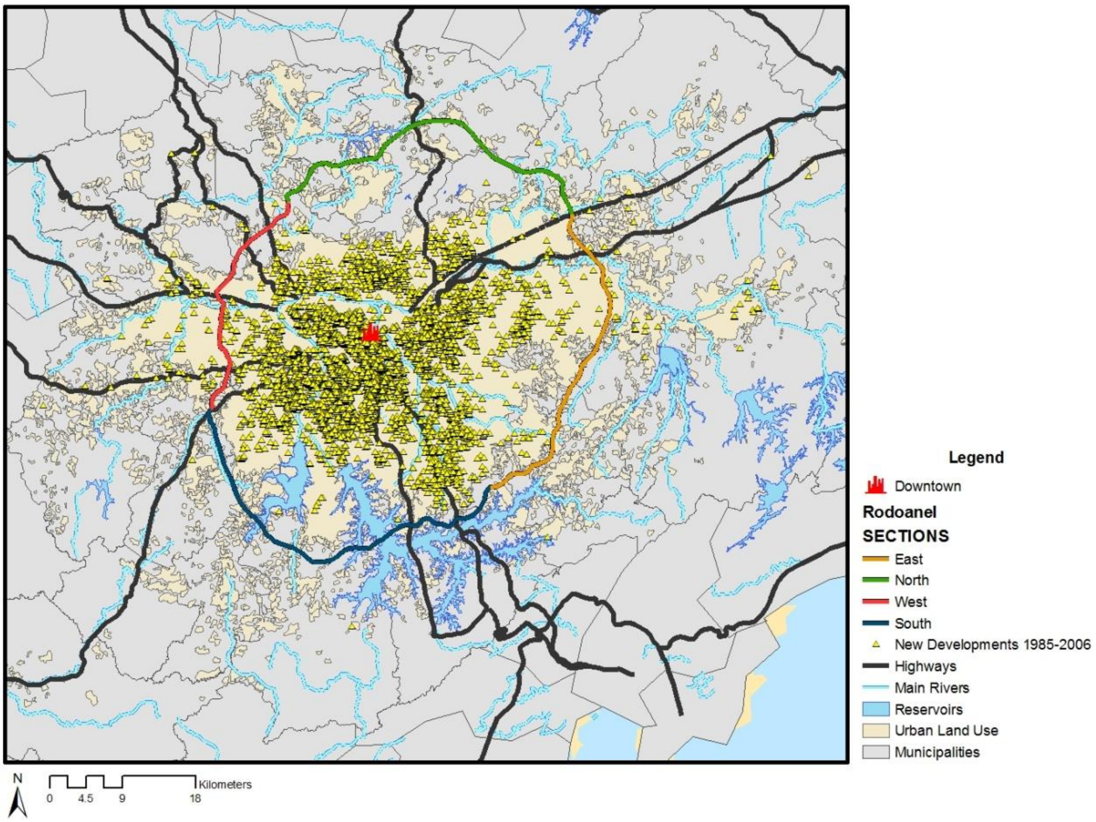

Figure 2 – Rodoanel Route (west branch detached in red color)
Source: Secretaria de Estado dos Transportes de São Paulo

2. HEDONIC PRICES AND IMPACT ASSESSMENT

Hedonic price models have been regularly used in applied studies since the fifties, although they were formally developed in forties (Bartik, 1987). A hedonic price model refers to the demand for a good which encompasses several attributes. Therefore according to Lancaster (1966) the consumer does not buy a single good, but a bundle of different characteristics. Durable goods such as cars or appliances are typical examples. Houses also can be seen as a hedonic good because consumers buy simultaneously location, dimension, and quantity of bedrooms, bathrooms and other characteristics.

One of the attributes of houses is distance from the CBD. This characteristic refers to land use and consequently to land price. Alonso (1964) shows the trade-off between land price and distance from CBD. This trade-off is due to transport costs, which are increasing to distance as represented in Figure 3 for a linear city model

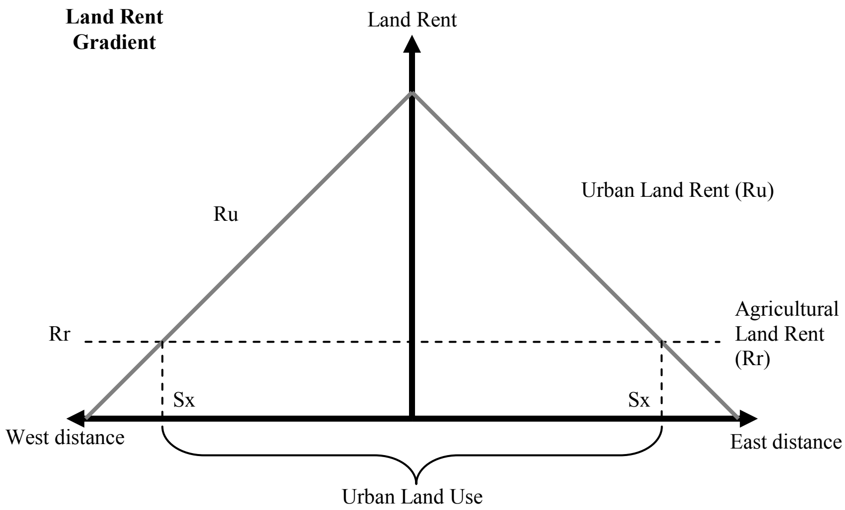

Figure 3 – Land Rent Gradient in a Linear City

On the other hand there are negative externalities associated to the new infrastructure. As pointed out by Bouarnet and Chalermpong (2001), the proximity to the lanes (around 500 meters) can bring down house prices. The cause is the noise and air pollution due to the traffic.

So there are two driving forces interacting: accessibility and negative externality. The first helps to increase land prices and the second helps to decrease them. A priori we do not know which one is greater and where each predominates (around the beltway). Thus, following the methodology of Boarnet and Chalermpong (2001), Wilson and Frey (2007) and Gatzlaf and Smith (1993) we develop hedonic price regressions.

3. RESEARCH STRATEGY: HOW TO TEST OUR HYPOTHESIS

We do not want to explore specific situations of Rodoanel West Branch such as informal settlements accessibilities or conflicts. We would like to find the <u>average effects of the new highway on land prices</u> related to its construction. So we adopt the traditional econometric methodology for hedonic price estimation.

3.1. Hypothesis

Assuming the monocentric shaped city and the gradient land price according to Alonso (1960), the main hypothesis we test is that Rodoanel West caused increases in land price on the west side of its ramps. In spite of Rodoanel adoption is focused only on cargo transportation, <u>we suspect that its lanes can be adopted for commuting purpose</u> as the traffic jams in SPMA have been increasing and new routes are always looked for.

Conversely, proximity to the lanes may result in negative effects such as noise and air pollution due to traffic. These impacts tend to decrease the land price

In summary, there are two types of effects that are not necessary exclusive: accessibility and negative externalities. We can state the hypothesis in three parts:

1. Increasing land prices on the 'outside' of the beltway (e.g. accessibility effect predominates)

$$H_0 : \Delta p_{ij} > 0$$
$$H_1 : \Delta p_{ij} \leq 0$$

2. Decreasing land prices on the vicinity of the beltway's lanes (e.g. negative externalities predominate)

$$H_0 : \Delta p_{ij} < 0$$
$$H_1 : \Delta p_{ij} \geq 0$$

3. No changes on land prices on the 'inside' of the beltway (e.g. none of the effects predominate)

$$H_0 : \Delta p_{ij} = 0$$
$$H_1 : \Delta p_{ij} \neq 0$$

(Where $p_{i,j}$ is the residential land price for a dwelling unit *i* located in zone *j*)

If our hypothesis is confirmed it will allow us to conclude that those who live outbound of the beltway have an improvement in accessibility, while those who live near the lanes suffer negative effects from traffic, and those who live inbound experience no effect. The consequences for public policy will be several as we discuss further.

3.2. Data

Land prices are not systematic available in datasets, especially in Brazil. One must look primary for information from field work. One way to deal with this problem is estimate land prices indirectly from house prices. In order to do that we follow Biderman (2001) whose study was the pioneer in using Embraesp (Empresa Brasileira de Estudos Patrimoniais) residential sales database for academic purposes.

Embraesp data cover the SPMA since 1985 and register the asking price only of new residential developments. So these data are not appropriate to evaluate repeated sales as is the usual practice in empirical housing market studies in the US. From 1985 to 2006 there are 10,367 observations in the Embraesp database. 9,460 of them could be geocoded, of which 9,093 have information about the area of the land parcel. It is not a statistical sample stricto sensu but contains all formal publicly-announced new developments. Thus it can be representative for some inferences about population. As a consequence our analysis of Rodoanel impacts does not take into account informal markets or commercial developments or re-sales. The Embraesp database contains dwelling-specific information (useful area, quantity of bedrooms and bathrooms etc.).

We incorporate the information on location-specific aspects using block data from the 2000 Census made available by CEM (Centro de Estudos da Metrópole) from CEBRAP (Centro Brasileiro de Análise e Planejamento). Cheshire and Sheppard (1995, pp. 248) suggest that 'if location-specific characteristics of housing are appropriately measured monocentric models can perform well.' So each new residential sale was spatially joined to its

2000 Census block attributes. The SPMA has more than 17,000 census blocks, each of them with about 400 dwellings units.

We also associated each residential unit with its Census 1991 sector. The purpose of doing so is to get the average income information from the heads of households in the sector. Further we explain the need for this information.

3.3. Theoretical model and empirical methodology

The first step is to get information about new residential development prices, which is the dependent variable here. Embraesp dataset covers the asking prices of new residential properties, i.e. combines the value of the land and the building in the property asking price. A possible way to obtain a proxy for land prices is by dividing the asking price of the dwelling unit by the area of the land parcel area of the parcel where the dwelling unit is build.

$$\frac{\text{Proxy for Land Price}}{\text{square meters}} = \frac{\text{value of the new development}}{\text{parcel area in square meters}}$$

In doing so we need to control for all other variables that drive prices up and down (this is the reason we adopted the hedonic price model). It is important to mention that these values are in reais (R$) deflated to the year of 2000. We take into account Cheshire and Sheppard (1995) suggestion that linear forms of the hedonic land price model may have non-normal errors. Therefore we adopt the log-form specification. In addition to support this choice, Figure 4 shows the histogram of the natural logarithm of land prices. The distribution of the logarithm of the prices seems to be closer to the log-normal distribution.

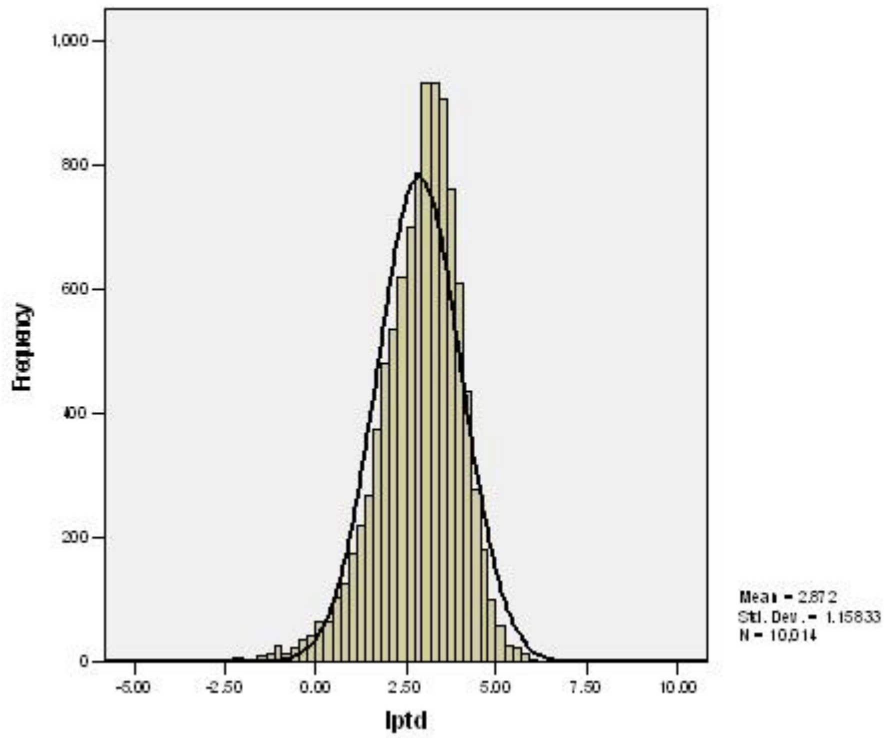

Figure 4 – Histogram of the Natural Log of Square Meter Price of Land – deflated values (1985-2006)

This measure is imperfect because we do not have the actual cost of production. The implication is the underline assumption of a constant capital-land relation which is a very strong assumption. As we know, the relation capital-land is increasing as we approach the CBD due to higher land prices. If we had the construction costs information the adequate land price could be computed as:

$$\frac{\text{Land Price}}{\text{square meters}} = \left(\frac{\text{value of the new development - construction costs}}{\text{built area in square meters}}\right) \cdot \frac{\text{built area in square meters}}{\text{parcel area in square meters}}$$

By using appropriate GIS software we calculate the minimum straight-line distance from each new residential unit offered for sale to the downtown center. Such measure is very important, as pointed out by Cheshire and Sheppard (1995), because it brings the urban rent theory approach to the analysis. The theory suggests a trade-off between land price and distance from CBD (e.g. a trade-off between accessibility and transport costs).

We also calculate the minimum straight-line distance from each new residential unit offered for sale to the Rodoanel West Branch's lanes and ramps. This allows us to define buffers for the area of influence of the road and thus the treatment group (see Figure 5).

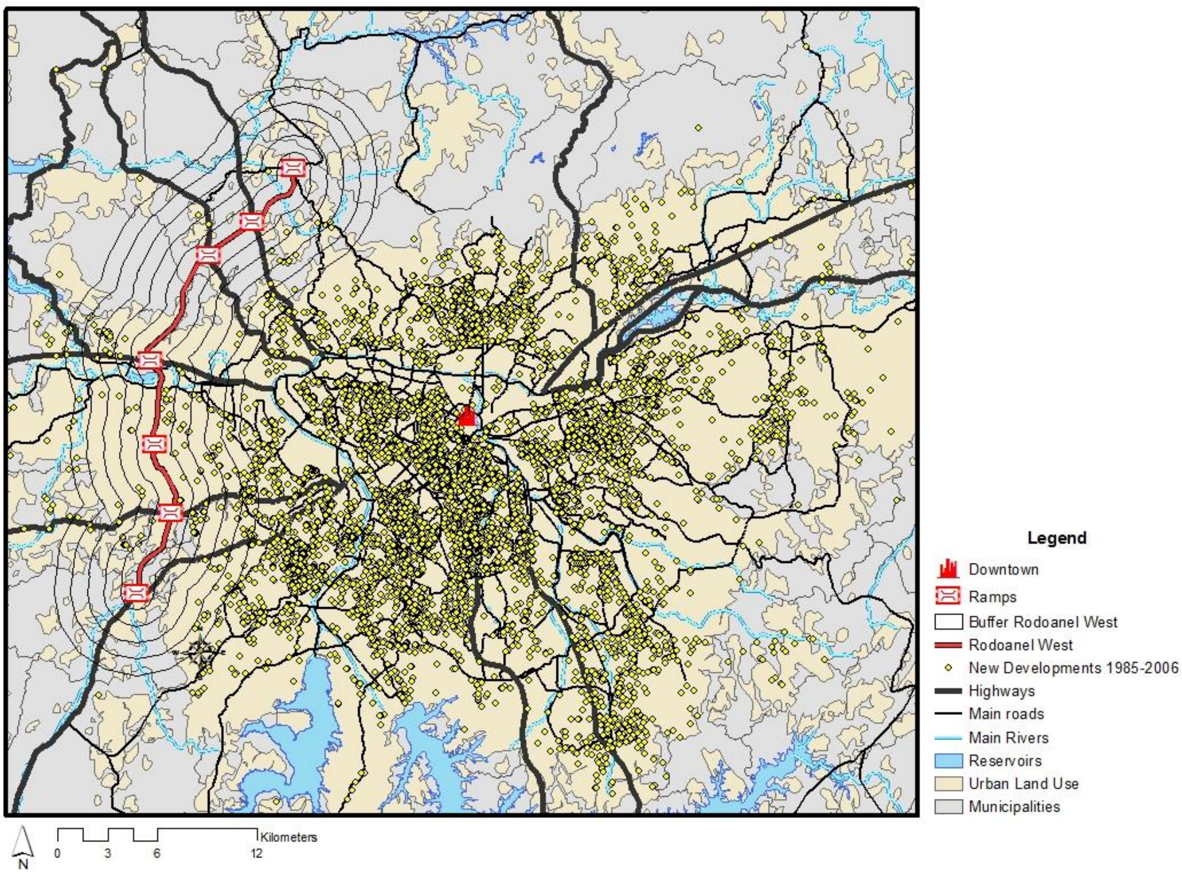

Figure 5 – New residential Developments (1985-2006) and Rodoanel West Branch (track, ramps and buffers)
Source: Embraesp and Centre of Studies of Public Sector Politics and Economics at Getulio Vargas Foundation (CEPESP/FGV)

So we can apply difference-in-differences ('dif-in-dif') technique in order to estimate the impacts caused by Rodoanel West Branch. According to Stock and Watson (2003), the basic dif-in-dif specification is:

$$\Delta Y_i = \beta_0 + \beta_1 X_i + \mu_i$$

Where ΔY_i can be considered as the variation on prices for the land parcel i, X_i is the binary variable that informs if the land parcel is surrounding Rodoanel´s ramps and β_1 is the causal effect from the deployment of Rodoanel.

More specifically we are looking land parcels in the site A affected by Rodoanel. If there is a site B that has not been crossed by Rodoanel, we can use it as a control group to compare the changes between A and B between the two periods (before and after its deployment). So we run the regression:

$$\Delta Y_i = \beta_0 + \beta_1 T_i + \beta_2 SA_i + \beta_3 (T * SA_i) + \mu_i$$

Where Y is the price of land parcels for each site per period of time, T is the time (period) dummy, SA is the state dummy for site A, and $T*SA$ is the interaction of the period dummy and the site A dummy. Table 1 displays the hypothetical percentage variation on prices of land parcels in each state and time period and Table 2 explains what each coefficient in the regression represents.

Table 1 – Hypothetical percentage variation on the prices of land parcels

Time Period	**Site A (surrounding Rodoanel´s ramps)**	**Site B (not surrounding Rodoanel´s ramps)**
Period 1 (before the deployment of Rodoanel)	b	a
Period 2 (after the deployment of Rodoanel)	d	c

Table 2 – Calculation and interpretation of regression coefficients

Coefficient	**Calculation**	**Interpretation**
β_0	a	Baseline average
β_1	c − a	Time trend in the control group
β_2	b − a	Differences between the two sites in period 1 (before the deployment of Rodoanel)
β_3	(d − b) − (c − a)	Difference in the changes over time, e.g. the 'true' impact of Rodoanel.

We defined several treatment groups according to the interaction of site specific and period specific variables. Following Figure 1, the time specific variables marks the three general stages for the deployment of a transport infrastructure: planning, construction and operation. Each period comprehends a dummy variable which assumes '1' during the respective stage and '0' otherwise.

The site specific variables are divided into four groups of dummies. The first group is formed by residential units offered for sale located up to 2,500 meters from Rodoanel's ramps outbound. The second group is obtained in the same fashion but inbound. The third group captures the residential units offered for sale located beyond 2,500 meters from Rodoanel's ramps outbound. The fourth site specific group stands for the same range of distance from Rodoanel's ramps as the previous but inbound till 5,000 meters.

After matching addresses by condominiums and filtering out inappropriate data (as 'missing values') we are left with 7,392 new dwelling units from 1985 to 2006 with complete range of information. Table 3 summarizes the distribution of observations by interacting site specific and location specific variables. They are the treatment groups and their coefficients represent the net effect of Rodoanel West Branch.

Table 3 – Treatment Groups (number of observations)

Interactive Dummies (site*period)	**Announcement and Planning**	**Construction**	**Delivery and Operation**
Group 1 (outbound till 2500m)	0	2	8
Group 2 (inbound 2500m)	8	5	14
Group 3 (outbound 2500m)	0	4	42
Group 4 (2500m<inbound<5000m)	12	7	32

But we know there are others factors driving the prices that we must take them into account. Thus our estimator is a kind of dif-in-dif with additional regressors (hedonic price regression).

$$\Delta Y_i = \beta_0 + \beta_1 T_i + \beta_2 SA_i + \beta_3 (T * SA_i) + \beta_j \sum_{j=4}^{k} W_{ji} + \mu_i$$

The model should consider the two groups of factors that drive the land prices as we calculated: dwelling-specific and location-specific factors. Thus the model general specification[1] is:

$$\begin{aligned}
\ln(p) = {} & \beta_0 + \text{Dwelling_Unit}'\beta + \text{Site}'\gamma + \partial_1 \text{Announcement} + \partial_2 \text{Construction} + \partial_3 \text{Delivery} + \\
& + \partial_4 \text{Group1} + \partial_5 \text{Group2} + \partial_6 \text{Group3} + \partial_7 \text{Group4} + \\
& + \partial_8 \text{Announcement.Group1} + \partial_9 \text{Announcement.Group2} + \\
& + \partial_{10} \text{Announcement.Group3} + \partial_{11} \text{Announcement.Group4} + \partial_{12} \text{Construction.Group1} + \\
& + \partial_{13} \text{Construction.Group2} + \partial_{14} \text{Construction.Group3} + \partial_{15} \text{Construction.Group4} + \\
& + \partial_{16} \text{Delivery.Group1} + \partial_{17} \text{Delivery.Group2} + \partial_{18} \text{Delivery.Group3} + \\
& + \partial_{19} \text{Delivery.Group4} + \varepsilon
\end{aligned}$$

Where p = new home sales asking price deflated to 2000 Reais, using the General Price Index (IGP-DI) for Brazil provided by the Getulio Vargas Foundation and *Dwelling_Unit* = vector of dwelling unit characteristics such as size (useful area), number of bedrooms, number of bathrooms, number of parking spaces etc.; and *Site* = vector of site attributes such as water

[1] Following Bartik (1987) and Cheshire and Sheppard (1995).

system and sewage coverage, head of household average monthly income, dummy for home located in the municipality of São Paulo, straight-line distance from São Paulo downtown.

One option would be to adopt a panel data regression (as 'fixed effects' methodology). Unfortunately the micro level data are not a true panel. Each new development appears once in the sample (as noted earlier, it is not a repeated-sale database). Even if we aggregate the units for a local average it will be an unbalanced panel, with less degree of freedom. For this reason the use of pooled data and dummies seem to be more appropriate.

Take into account that we want to evaluate the effects of the Rodoanel on surrounding parcels, we have a quasi-experiment. The model that we adopt to estimate the impact of the Rodoanel on the variation of prices from surrounding parcels is a type of dif-in-dif regression. Note that the dependent variable $ln(p_i)$ is equivalent to $\Delta p_i / p_i$.

It is important to mention how the average monthly income of the head of household is computed. For all residential development launched before the announcement of Rodoanel we adopt the values from the 1991 Census. Otherwise we adopt the values from the 2000 Census. Therefore we take into account changes in income that could drive the demand for dwelling units which may affect their prices.

4. FINDINGS: ASSESSING THE IMPACTS

We run six regressions by changing the treatment and the control group (see Appendix). In the first regression we considered the full sample and decomposed each time-period described on Figure 1 and each group described on Table 3. The second and the third regressions collapsed the time and site specific dummies in order to look for more general effects. Regressions 4 to 6 constrain the sample to housing located at the same distance from the CBD as the treatment groups.

Almost all control variables are significant at 1 percent and in general have the expected sign. The variables of interest are the interaction between site location (the groups) and the timing. For instance, the interaction between the construction period dummy and group 1 dummy would give us the (counter-factual) impact of the beltway construction on land prices within 2.5 km outbound of the beltway.

The most important result came from Regression 6. In that regression we then restrict the sample of new developments for which distance from CDB is at least 15.5 km (see Figure 6). This threshold is the closest distance to the CBD from any development in the treatment group. If the rent gradient is changing over time, using the entire sample could imply that we are confounding the impact on the (whole) gradient with the impact of the road. Concentrating on the same distance from the CBD would allow us to control for such possible pattern.

Also we drop from the analysis the new residential developments located up to 1km from the lanes. This follows a similar procedure used by Boarnet and Chalermpong (2001) in order to deal with noise and air pollution externalities from the traffic. With this new restriction we end up with 493 observations.

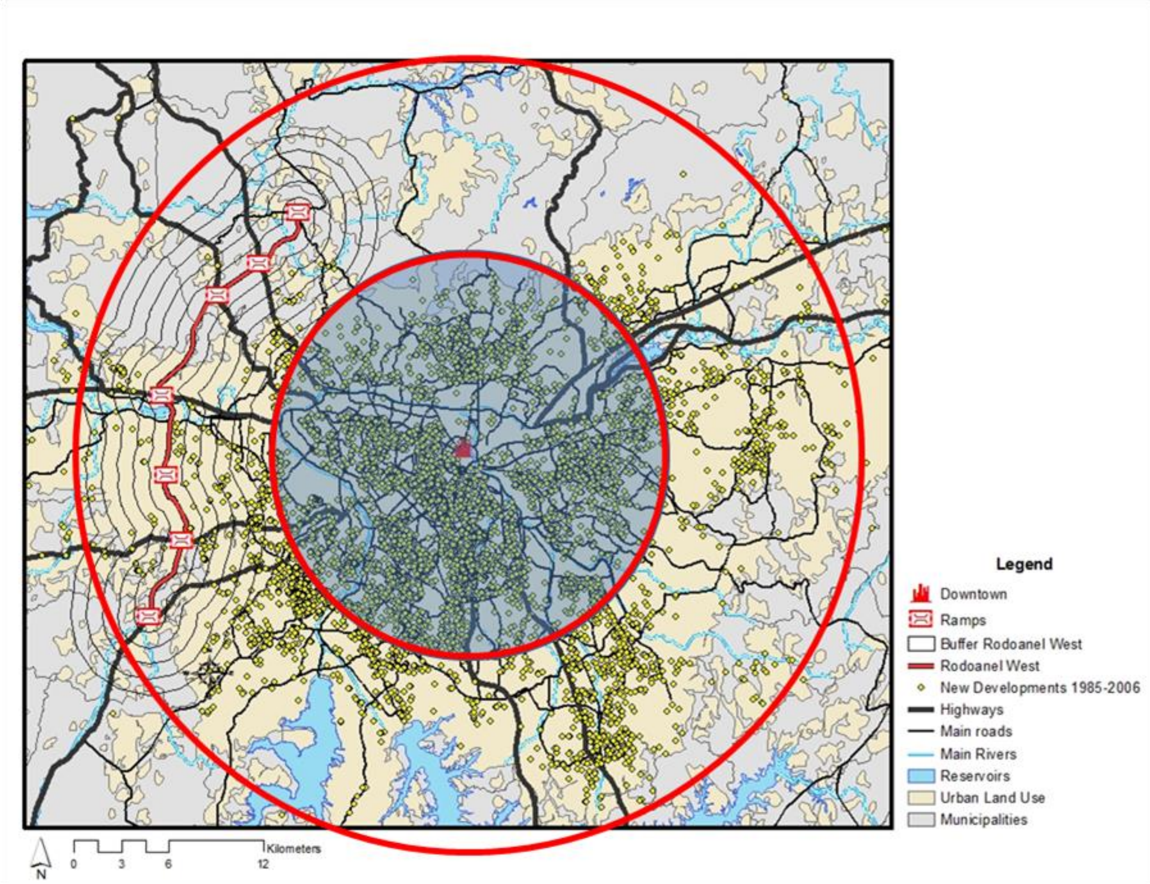

Figure 6 – Relevant Transport Investments (buffers), New residential Developments which distance from CDB is at least 15.5 km (1985-2006) and Rodoanel West Branch (track, ramps and buffers)
Source: Embraesp and Centre of Studies of Public Sector Politics and Economics at Getulio Vargas Foundation (CEPESP/FGV)

As we can see the in Table 4, the impact of Rodoanel's operation is again positive on the prices of treatment groups 1 and 2, but it is significant just for the first one. The sign and significance are exactly the same found in the other regressions and the magnitude of the coefficients is very similar to the Regression 5 (see Appendix). Thus it seems that the eventual negative effects of being near the lanes are not stronger enough to overcome the benefits of accessibility.

Table 4 – Impact of the Rodoanel Construction on Land Price in its Inbound and Outbound Surrounding Areas – Sites with no Relevant Investment in Transport, more than 15.5km far from the CBD and more than 1km far from the Rodoanel.

'Causal' Effects	Construction and Operation
Group 1 (outbound till 2500 m)	0.9084* (0.4701)
Group 2 (inbound till 2500 m)	0.3177 (0.3578)

*Robust standard errors below coefficients. * p<0.10, ** p<0.05, *** p<0.01*

CONCLUSIONS AND FINAL REMARKS

This paper shows the findings from a research about the impact of the West Branch of the Rodoanel beltway on land prices. We evaluate road announcement, construction and delivery/operation events. The results of the econometric methods used show that there are significant and asymmetrical effects attributed to Rodoanel:

1. Residential land parcels around the track of Rodoanel have negative or null price changes depending on the different sides from its lanes and the different distances from its ramps (when compared to more restricted comparison groups – e.g. similar characteristics but distant from any relevant transport intervention and/or equally distant from CBD).
2. The different periods of deployment have different effects on land prices. Rodoanel is a huge infrastructure project that took seven years from the announcement to the beginning of operations for its first branch. If we do not take this into account we will misunderstand how Rodoanel has affected land prices.
3. Residential land parcels around the track of Rodoanel have negative or null or positive price changes depending on the different sides from its lanes and the different distances from its ramps (when compared to less restricted comparison groups).

Let us take the information in Table 4 in order to discuss these results. Although the results corroborate the general hypothesis of asymmetry, there are some specific differences highlighted in Box 1.

Box 1 – Expected versus Estimated Effects: conclusions

Original Hypothesis	Conclusion
Increasing land prices on the 'outside' of the beltway (e.g. accessibility effect predominates)	The effects are significant and positive for residential land parcels closer to the Rodoanel's ramps*.
Decreasing land prices on the vicinity of the beltway's lanes (e.g. negative externalities predominate)	The negative externality from closer proximity seems to be not significant (at least for the new residential developments).
No changes on land prices inbound the beltway (e.g. none of the effects predominate)	The effects are not significant (statistically null) for residential land parcels closer to Rodoanel's ramps**.

* For parcels which are located farther (beyond 2.5 km) the effects are not significant (statistically null).
** For parcels which are located farther (between 2.5 km and 5 km) the effects are negative and significant.

Figure 7 shows a schematic representation of the result found: a kinked land rent gradient which is below the former land rent gradient for residential land parcels located on the right side of the ramps to the lanes and it is above the former land rent gradient for residential land parcels located up to 2.5 km on the left from the ramps to the lanes. The latter are those who really seem to obtain commuting benefits from the beltway. It should be noticed that there were no significant improvement in commuting alternatives (such as bus and commuter rail) along the west side of SPMA during the period evaluated. What seems to be happening is that people living outbound had accessibility advantages from the new beltway, such as new routes to commute to the CBD, while people inbound had not the same.

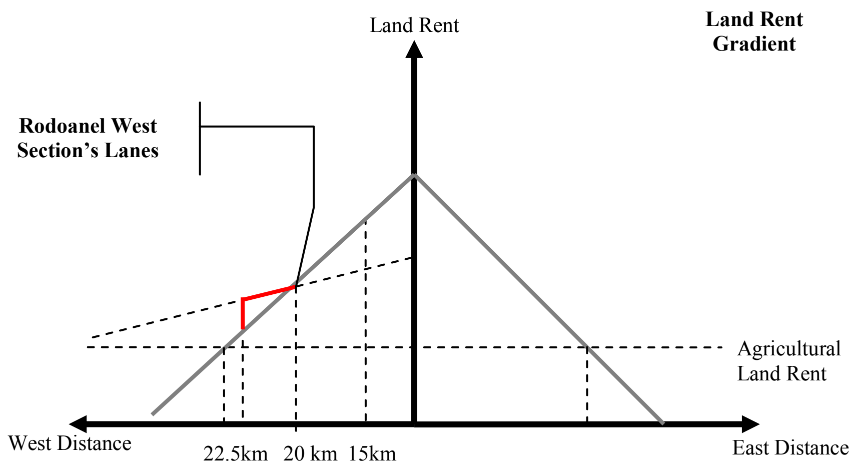

Figure 7 – Illustration of the Main Results from the Hedonic Price Equation

These short-run effects tend to vanish over the years as residential and commercial location decisions are made. Also the better level of commuting service brought by Rodoanel will tend to diminish as the demand for the beltway goes up. Whereas changes on density seem to be plausible around the new beltway, there is no reason to believe that it can have enough power to contribute to increasing urban sprawl.

These findings would suggest taxation possibilities for purposes of urban policy. The economic rent created by Rodoanel could be taxed to fund the next branch of the beltway or to cover its operational expenses. On the other hand if a tax is levied, that could reduce any advantage for new residential developments located far from the CBD.

The problem is that property taxes in Brazil are the responsibility of municipalities and the Rodoanel investment is funded by the state and the national government. Moreover, the eventual capturing of the incremental land value through property tax and the corresponding increase in municipal tax revenue can only be realized by the municipalities on the west of the beltway since, as we have seen, parcels on the east side experienced a decline in land values. Consequently the municipality of São Paulo, located on the east side of the beltway, would face a decline in property tax revenues from parcels located near the beltway.

A broader implication of this analysis relates to regional and local policies and their effects. In a general Keynesian framework, new infrastructure investment always increases income by virtue of its multiplier effects. But if we look at the micro level, these effects do not always hold. There are redistributive gains and losses for different private agents located in the area of influence of the investment and also different effects for the municipalities involved. Although at the state and national levels the benefits are great, for some neighbourhoods or municipalities the impact may be small or even negative.

But the main issue is the appropriation for commuting use of a road designed for cargo traffic, as is the case of Rodoanel, and the potential rent generated by this behaviour is reflected in the congestion observed near the intersections of the beltway with radial highways in the peak-hours. It concerns to our main hypothesis.

To be successful as a 'logistic infrastructure' Rodoanel needs more than its deployment. The results imply a need for 'demand management' – congestion tolls for automobiles and urban traffic should be implemented. Nowadays tolls are set in order to recover the cost of investment in a Public-Private Partnership (PPP) framework. Rodoanel should priory pass-through and cargo traffic. The relative cost for Rodoanel usage for logistic purpose should be less than the usage of metropolitan avenues or the first beltway of SPMA. The inefficiency in the current tolling is shown by local policies. For example, the City Hall of São Paulo imposed restriction for cargo traffic in the first beltway in order to re-direct it to Rodoanel and to reduce peak-hour traffic conflicts.

Demand management is a necessary condition but it is not sufficient. A rail beltway and additional intermodal infrastructure are also necessary. These are the conditions for Rodoanel to be the logistic infrastructure and not just one more expressway in a hyper-congestioned metropolitan area.

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APPENDIX

Table A1 – Estimated coefficients for the regressions

Dependent Variable: *Ln (p)*	**Regression 1**	**Regression 2**	**Regression 3**	**Regression 4**	**Regression 5**	**Regression 6**
Constant	6.3157***	6.3392***	6.3676***	6.2731***	14.4167***	14.1118***
	(0.3160)	(0.3137)	(0.3145)	(0.3448)	(2.6929)	(2.6959)
ln of useful area	-0.6868***	-0.6356***	-0.6354***	-0.6186***	-0.8842***	-0.8854***
	(0.0468)	(0.0470)	(0.0474)	(0.0527)	(0.2068)	(0.2063)
# of bedrooms	-0.0766***	-0.0920***	-0.0932***	-0.0757***	-0.0660	-0.0933
	(0.0212)	(0.0216)	(0.0216)	(0.0245)	(0.1062)	(0.1082)
# of bathrooms	0.1537***	0.1428***	0.1436***	0.1189***	0.3130***	0.3299***
	(0.0225)	(0.0229)	(0.0230)	(0.0257)	(0.0922)	(0.0940)
# of parking places	-0.0085	-0.0264	-0.0262	-0.0332	-0.1493*	-0.1427*
	(0.0195)	(0.0196)	(0.0197)	(0.0220)	(0.0809)	(0.0808)
# of elevators	-0.0011	-0.0031	-0.0025	-0.0008	0.1108***	0.1152***
	(0.0058)	(0.0061)	(0.0061)	(0.0073)	(0.0342)	(0.0348)
# of floors	0.0639***	0.0654***	0.0658***	0.0654***	0.0507***	0.0498***
	(0.0019)	(0.0020)	(0.0020)	(0.0023)	(0.0102)	(0.0104)
penthouse	0.0322***	0.0362***	0.0365***	0.0328***	0.0491*	0.0496*
	(0.0062)	(0.0064)	(0.0064)	(0.0070)	(0.0276)	(0.0284)
percentage of dwellings with sewage coverage	-0.1092	-0.1575	-0.1638	-0.2035	-0.2684	-0.2683
	(0.1166)	(0.1225)	(0.1191)	(0.1289)	(0.2079)	(0.2070)
percentage of dwellings without bathrooms	-1.8126	-1.6787	-1.8362	-0.5558	-6.4494	-7.8416
	(2.0933)	(2.1472)	(2.1507)	(2.1785)	(6.2692)	(6.6370)
percentage of dwellings with garbage services coverage	0.0884	0.0690	0.0611	0.1577	0.9216	0.8895
	(0.1520)	(0.1503)	(0.1501)	(0.1582)	(0.6683)	(0.6738)
percentage of dwellings with water system coverage	0.0722	-0.0136	0.0068	0.0261	-0.7474	-0.7903
	(0.2516)	(0.2559)	(0.2565)	(0.2730)	(0.7173)	(0.7231)
ln of income	0.0071	-0.0080	-0.0034	-0.0123	-0.0936	-0.0757
	(0.0153)	(0.0113)	(0.0113)	(0.0132)	(0.0738)	(0.0769)
ln of population density in sector	-0.0355***	-0.0388***	-0.0414***	-0.0414***	-0.0399	-0.0299
	(0.0121)	(0.0124)	(0.0123)	(0.0138)	(0.0539)	(0.0543)
municipality of Sao Paulo	0.1062***	0.1416***	0.1717***	0.1783***	0.1209	0.1608
	(0.0295)	(0.0300)	(0.0295)	(0.0324)	(0.1213)	(0.1299)
ln of distance from Sao Paulo downtown	-0.0619***	-0.0623***	-0.0714***	-0.0695***	-0.7316***	-0.7145***
	(0.0118)	(0.0118)	(0.0118)	(0.0124)	(0.2167)	(0.2167)
Rodoanel west branch: announcement	-0.3021***					
	(0.0285)					
Rodoanel west branch: construction	-0.3780***					
	(0.0357)					
Rodoanel west branch: delivery	-0.7116***					
	(0.0268)					
near till 2500m outbound from Rodoanel	-2.3469***	-2.3013***	-2.2954***	-2.3141***	-2.3443***	-2.3399***
	(0.1355)	(0.1329)	(0.1388)	(0.1402)	(0.2155)	(0.2209)
near till 2500m inbound from Rodoanel	0.1421	0.0540	0.0694	0.0603	-0.3879	-0.6101*
	(0.1933)	(0.1588)	(0.1588)	(0.1607)	(0.2436)	(0.3536)
near beyond 2500m outbound from Rodoanel	-0.0254	0.0174				
	(0.1677)	(0.1667)				
near between 2500m and 5000m inbound from Rodoanel	-0.1670	-0.0905				
	(0.1313)	(0.1111)				
announcement*proximity 2500m outbound	0.0000					
	(0.0000)					
announcement*proximity 2500m inbound	-0.1043					
	(0.3176)					
announcement*proximity beyond 2500m outbound	0.0000					
	(0.0000)					
announcement*proximity 2500m-5000m inbound	0.3246					
	(0.2154)					
construction*proximity 2500m outbound	1.3266***					
	(0.1498)					
construction*proximity 2500m inbound	-1.0506					
	(0.6404)					

Dependent Variable: ***Ln (p)***	**Regression 1**	**Regression 2**	**Regression 3**	**Regression 4**	**Regression 5**	**Regression 6**
construction*proximity beyond 2500m outbound	-0.8552** (0.3855)					
construction*proximity 2500m-5000m inbound	0.0889 (0.4594)					
delivery*proximity 2500m west	0.5434 (0.4753)					
delivery*proximity 2500m east	-0.3324 (0.2179)					
delivery*proximity beyond 2500m west	-0.6044*** (0.2073)					
delivery*proximity 2500m-5000m east	-0.3397* (0.1957)					
after construction has started		-0.5047*** (0.0227)	-0.5143*** (0.0226)	-0.5610*** (0.0252)	-0.9013*** (0.1535)	-0.8750*** (0.1613)
after*proximity 2500m east		-0.4671* (0.2407)	-0.4461* (0.2400)	-0.3998* (0.2401)	0.3357 (0.2831)	0.3177 (0.3578)
after*proximity 2500m-5000m east		-0.3889** (0.1871)				
after*proximity 2500m west		0.6227 (0.4133)	0.6666 (0.4146)	0.7217* (0.4140)	0.9496** (0.4317)	0.9084* (0.4701)
after*proximity beyond 2500m west		-0.7335*** (0.2031)				
R-squared	0.43	0.41	0.40	0.42	0.58	0.58
N	7212	7212	7212	5833	502	493

*Robust standard errors in parethesis. * p<0.10, ** p<0.05, *** p<0.01*

Table A2 – Variations on housing land parcels caused by Rodoanel West Branch (summary)

Treatment Group	**Compared to the rest of the land parcels of SPMA**	**Compared to the rest of the land parcels of SPMA (collapsing time variables into one major event: construction and delivery)**	**Compared to sites with no relevant investment in transport**	**Compared to sites with no relevant investment in transport and more than 15.5km far from the CBD**	**Compared to sites with no relevant investment in transport, more than 15.5km far from the CBD and more than 1km far from the Rodoanel**
Group 1 (outbound till 2500 m)	133% during construction		72% during deployment	95% during deployment	91% during deployment
Group 2 (inbound till 2500 m)		-45% during deployment	-40% during deployment		