An assessment of the impacts of large-scale urban projects on properties values and on urbanization patterns: The case of the North Axis of Belo Horizonte, Brazil

Renan P. Almeida – Professor, DCECO/UFSJ

Marcelo Brandão – PhD Candidate, Cedeplar/UFMG

Pedro Patrício – Master's degree candidate, Cedeplar/UFMG

Ramon Torres - Master's degree candidate, Cedeplar/UFMG

Pedro Amaral – Professor, Cedeplar/UFMG

Abstract

Large-scale urban projects (LSUP) are capable of changing the spatial structure of cities. A consequence is the potential deep impact on land value. Recognizing that these interventions can generate a mass of value is a fundamental point in contemporary land use policy; hence, an adequate assessment of the impact of LSUPs on land value is crucial. This work estimates the impacts of LSUPs implemented in Belo Horizonte, Brazil, on properties values, advancing in the decomposition of macroeconomic effects, neighborhoods' specificities, and the role of zoning. Results indicate that the impacts of LSUPs vary according to the kind of investment (transportation facilities, iconic buildings and shopping malls) and the kind of property considered (vacant land plots, apartments, houses or stores). The role of the macroeconomic cycle is also key to understand the impacts' dynamics. We used an additional dataset to identify a leapfrog urbanization pattern, which is likely to occur when making urban investments on a densely built environment.

Keywords: land markets; large-scale urban projects; differences-in-differences; urban development

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1. Introduction

One reason that justifies the agglomeration forces of cities is the provision of infrastructural urban equipment. On one hand, those who are located close to this equipment can access it at reduced cost; on the other hand, these infrastructures require a large user base to operate efficiently, due to the high fixed costs of its provision (Foldvary and Minola, 2017; Storper, 2013). Large-scale urban projects (LSUP) are large, complex projects involving a myriad of agents, with a long-run horizon and potential impacts on millions of people. Usually, these projects include high amounts of infrastructural investment, including mass transportation and new urban equipment, as well as marketing campaigns aimed at changing the perception about the target area. A key aspect of LSUPs is their capability to change the spatial structure of the area where they are located (Lungo, 2010; Lungo and Smolka, 2010). A consequence of these projects is the potential deep impact on properties' values in the target area. In this sense, recognizing that state interventions can generate such a mass of value is a fundamental point in contemporary land use policy (Foldvary and Minola, 2017; Garza and Lizieri, 2016; Turok, 2016).

In this panorama, this work explores different LSUPs in the North Axis of Belo Horizonte Metropolitan Region (MRBH), Brazil, as a case study to investigate empirical evidence of the relationship between LSUP and property value increments. The MRBH is the third largest urban agglomeration in Brazil, with more than five million inhabitants, and it has undergone rapid urbanization that added irregularly urbanized areas with high social polarization—a typical case of Brazilian and Latin American metropolises. All the LSUPs occurred in a relatively poor and peripheral zone of the MRBH, its northern portion (so-called *North Axis*). It included public investments such as the relocation of the administrative offices of the state government, *Administrative City of Minas Gerais*, creating, in this peripheral poor region, a new iconic building designed by Oscar Niemeyer; and a Bus Rapid Transit (BRT) system, which connected the central area to northern and western zones. One of the main private investments related to these LSUPs is the construction of the shopping mall, *Station Shopping Mall*, located in a hub with access to BRT and metro systems. These LSUPs provide an opportunity to assess the impact of it on

properties prices and urban development having high-quality datasets and the same geography. The study of these investments may be also relevant to the understanding of policies to promote urban development and new centralities in poor peripheral areas.

There is a growing literature on estimating the effects of investment or other relevant urban changes on property values. These urban changes include sport stadia (Ahlfeldt and Maennig, 2010; Ahlfeldt and Kavetsos, 2014); transport facilities and road improvements (Dubé et al., 2014; Hoogendoorn et al., 2017; Maciel and Biderman, 2013); and airport noise and airport net externalities (Tomkins et al., 1998); Winke, 2017). This paper builds on this body of literature, discussing more properly the specific characteristics of each neighborhood—characteristics that go beyond amenities levels; specifying the role of the macroeconomic cycle on property values, and estimating the effects of urban regulation (zoning) on it. Furthermore, we explored the impacts of different kinds of urban equipment and their impacts on property values. We employed a differences-in-differences approach to try to isolate the effects of LSUPs on property prices in a counterfactual strategy. Moreover, although there is evidence that consumers' willingness-to-pay varies across countries facing the same kind of urban amenity, there are few studies of Latin American real estate markets (Garza and Lizieri, 2016).

To assess the impact of LSUPs on property values, we use information from Belo Horizonte's land transfer tax databases (Inter-Vivo Property Transfer Tax, known as ITBI) from 2009 to 2017. This database offers much more accurate information than usual datasets that are constructed using asking prices, since ITBI provides the official price of the sale and covers the entire population of formal transactions, not only an asking price (that may vary due to negotiation). For instance, studies of the United Kingdom use the Nationwide Building Society data, which does not cover the entire population of transactions, with only 10% of the market share; or the Land Registry data, which covers the entire population, but at the cost of fewer properties details (Ahlfeldt and Kavetsos, 2014). Due to the intense real estate boom that occurred in Brazil from 2006 to 2014, we had a very high-quality dataset, with more than 200 thousand observations. This data showed a higher rate of growth in real estate prices in the study area compared to the average of Belo Horizonte. This data, notwithstanding, also showed that other

peripheral areas had higher rates of growth than the study area. We estimated a number of differences-in-differences models to assess the impacts of the major LSUPs on property values within the study area. To check robustness, we tested 15 different models, varying controls and the definition of the study area.

The main results show that the impacts of LSUPs vary according to the kind of investment and the kind of property considered. The shopping mall increased apartments' prices while the BRT system decreased them. The state administrative offices' iconic building had high positive effects on vacant land plots' prices, while the BRT system showed high negative effects on them. Furthermore, we used another dataset, related to new urban land developments, to identify impacts beyond the densely developed area. This dataset brought evidence of a leapfrog pattern of urban development—the emergence of new urban clusters that are not contiguous to the main developed area—when there is available land outside of a consolidated urban area. Altogether, these findings hold strong implications for land use policy, due to the discussion of land value capture as an instrument to finance infrastructural investments, the planning of new urban centralities and to the understanding of urban sprawl in general (Foldvary and Minola, 2017; Medda, 2012; Smolka, 2013).

Besides this introduction, the structure of this work is as follows. The next section contextualizes the literature on urban economics, land use and land value. Section 3 details the LSUP and the study area. Section 4 defines and explains the datasets and the empirical specification. Section 5 explains and discusses the results of the tools used to analyze the impacts of the interventions. Section 6 discusses these results in light of a second group of empirical evidences that clarifies the impacts of the interventions. Finally, the last section concludes and presents a research agenda for a better understanding of the relationship between LSUPs and real estate markets.

2. Agglomeration forces, urban infrastructure, and land value

The fact that urban agglomerations provide more amenities and higher wages to consumers and higher productivity to firms than non-urban areas is well known. Within cities, the two mechanisms of the virtuous spiral of economic development operate as (i) the scale economies, due to the large scale that

economic activities may achieve in the agglomerations, and (ii) the division of labor, due to the diversity that permits specialization. Scale economies allow for lower fixed costs, and division of labor enhances productivity. Furthermore, cities also agglomerate other type of urban advantages, such as synergies forces; easier face-to-face interactions; social and relational proximity; and the sharing of culture and political participation (Beaudry and Schiffauerova, 2009; Jacobs, 1969; Storper, 2013; Storper and Scott, 2003). This stimuli of urban agglomeration—synekism—have been observed in densely settled urban places for centuries (Soja, 2000).

As Foldvary and Minola (2017, p.334) state, "in sparsely occupied places where people live at a subsistence level, such as nomadic tribes in a desert, land generates little or no land rent." Land prices, or urban land premiums, synthesize the net benefits of being in the city. Thereby, "the use of land prices allows a broader perspective on all those advantages associated with an urban location and reach beyond pure productivity gains: synergies; easier contacts; social and relational proximity; sharing commons values and culture" (Caragliu, 2016). Following Cheshire and Sheppard (1995), a house does not represent only a bundle of physical characteristics, but also a set of location specific characteristics.

In this panorama, we can understand infrastructure and urban equipment in the same vein, offering higher levels of amenities for consumers and higher productivity for firms. The higher levels of amenities imply a higher willingness-to-pay (WTP) for urban housing, while agglomeration economies imply higher commercial real estate prices. Therefore, property prices may reflect changes in the provision of public goods and services, and in the civic pride of an area, such as those promoted by an LSUP. Increases in commercial properties may reflect new firms and new jobs and increases in residential properties may reflect higher levels of amenities in the region. In the short-run, infrastructure investment may have positive effects through multiplier effects, and in the long-run, the effects may be related to increases in capabilities, productivity, and competitiveness (Ball and Nanda, 2014).

3. The large-scale urban projects and the affected area

The study area is composed of neighborhoods in the northern portion of the municipality of Belo Horizonte, Minas Gerais, Brazil. According to Table 1, the total number of inhabitants of the study area is 255,800 people, while Belo Horizonte (without the study area) has more than 2 million inhabitants. In addition, Table 1 shows that the average income of the head of household of Belo Horizonte is 72% higher than the study area.

Table 1

Population and income—study area and control group (2010).

Areas	Population	Monthly Average Income (US$)*
Study Area	255,800	1,136.45
Belo Horizonte**	2,111,429	1,961.88

*BRL/USD exchange rate of July 2010. **Belo Horizonte without the study area

Source: own elaboration from the 2010 Census - IBGE.

There are about 5 million residents in the MRBH. It is the seventh most populous metropolis in Latin America and the third in Brazil. MRBH is composed of 34 municipalities, including the capital, Belo Horizonte, and its area encompasses 9,640 km.

Table 2 describes the subsequent main interventions that the state government and the private sector developed in the area. Based on the criteria of relevance, location, and data availability, we modeled three main investments detailed in Table 2[1].

[1] It is worth to note that other LSUPs occurred in the North Axis of Belo Horizonte in the last decade. Nonetheless, some of these were impossible to be modeled due to the lack of data (they were delivered before the begging of the time series) and others were just announced but the works did not start. Potentially, this fact could make the estimated coefficients presented in the next section higher than they would be if the other LSUPs were modeled, which do not generate misunderstandings to our conclusions because we interpreted these impacts as relatively low – it means, we already employed the most conservative interpretation.

Table 2

Selected LSUP.

	Cost (billion US$*)	Delivery	Beginning	Description
***Administrative City of Minas Gerais* (CAMG)**	0.95	2010	2005	The *CAMG*, enhanced by the Brazilian architect, Oscar Niemeyer, is the new headquarters of the government of Minas Gerais, and its structure is composed of six buildings, totaling about 270 thousand mi^2 of constructed area. It is located in the Serra Verde neighborhood, Belo Horizonte, where it borders two other municipalities, Vespasiano and Santa Luzia. The state government's initial decision was to locate it on the west side of the city, but due to problems with land acquisition, it opted for the Serra Verde neighborhood.
BRT (*MOVE*)	0.59	2014	2012	The *MOVE* corridor is mainly along avenues Antônio Carlos, Cristiano Machado, Pedro I, Paraná, Santos Dumont and Vilarinho, connecting the center of Belo Horizonte to the northern portion of the city. It is worth mentioning that the system also has extensions that have stations in eight other municipalities of the MRBH.
Shopping Estação	0.12	2012	2010	*Shopping Estação* is a large mall located in the Venda Nova region, Belo Horizonte. It has a strategic position, located in a confluence of three great avenues; Cristiano Machado, Pedro I, and Vilarinho. It also integrates a transport hub with the subway terminal, buses, and the BRT system. It is located 13 km from downtown. The construction area is 33.982 mi^2 and has 206 stores.

*BRL/USD exchange rate of July 2010.

Source: Authors' elaboration based on research (see references).

4. Empirical specification and data

To identify the specific impacts of the LSUP on real estate prices, we run an econometric analysis using software R and ordinary least squares (OLS) as the estimation method. We did not identify strong reasons to suppose the presence of endogeneity *a priori*, hence, the use of Generalized Moments Method (GMM) was discarded. Due to intuition and the Breusch-Pagan heteroscedasticity test, we used heteroscedasticity-robust standard errors for both groups of regressions.

A key aspect of this analysis is that the dataset does *not* have the *same* properties being sold throughout the study time. In other words, contrary to the typical US dataset, we *do not have repeated sales*. Our datasets are composed of unique sales—maybe a few properties were sold more than once during the seven years we analyzed, but these properties are impossible to identify (there is not a fixed "ID" for each property). Maciel and Biderman (2013) used a dataset with similar characteristics to assess the impacts of the Beltway construction on properties value in the São Paulo metropolitan region. One of the implications of this type of dataset is that *we do not have a panel data*, but a cross-sectional one, in which we used the year of transaction as an individual characteristic of the properties and, as suggested by Dubé et al. (2014), the dummies coefficients work as a price index. We used dummies variables to capture individual effects related to unobservable variables for each neighborhood[2]—average opinions on the statuses of the neighborhoods,[3] for instance. Therefore, the potential benefits of a panel data fixed-effects approach are also present in this cross-sectional approach.

The econometric analysis is a counterfactual exercise in which we estimated differences-in-differences (DID) models to test if the LSUPs had significant effects over properties prices. The comparison included the entire city, which provided more than 200 thousand observations using pooled data from January 2009 to May 2017. This approach appears frequently in the literature,

[2] The typical hedonic price model approach does not capture this kind of effect, because it captures only physical changes, reflected by the changes in the level of amenities in a neighborhood.

[3] For a detailed discussion, see Abramo (2007, 1994). See also Furtado (2011) on the role of neighborhoods in Urban Economics modeling.

such as Maciel and Biderman (2013). We tested the effects of three main investments over prices: the *CAMG* (Administrative City), the Station Mall ("*Shopping Estação*") and the BRT system ("*MOVE*"). We selected these investments because they have a large scale and they are among the most cited by residents and land developers.

We did not model the anticipated effects of announcement of each LSUP, because we did not have available data and there was uncertainty about the delivery of these investments. Even in the Global North, real estate markets may have problems anticipating urban investment externalities due to uncertainty. Nevertheless, the level of uncertainty tends to be higher in the Global South. We employed a careful analysis of newspapers to identify whether anticipation effects might be severe. Furthermore, the macroeconomic cycle also suggests that the real estate markets capitalized the main effects after 2010. Still, real estate markets may capture the effects in anticipation and in delay.

The DID methodology requires that the parallel trends assumption hold true—although it is an untestable assumption (Ahlfeldt, 2018). It means that in the absence of the studied interventions, the two regions would have evolved similarly after those interventions. As Figure 2 depicts, the property prices in our samples verify this assumption.

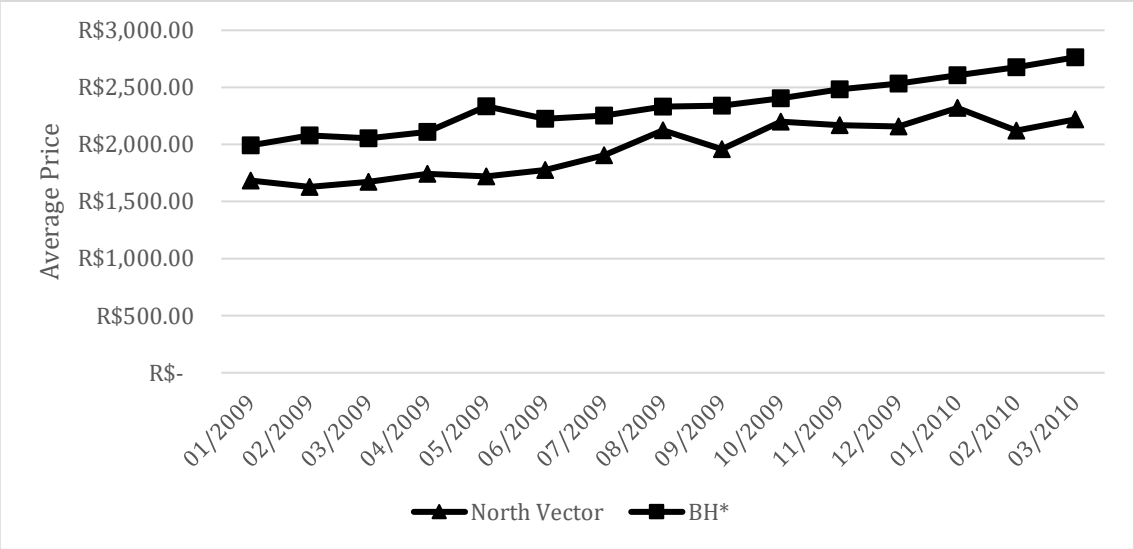


Fig. 2. Real estate's average prices before deliveries of LSUP**.**

North Vector = study area. BH* = Belo Horizonte without study area. Source: Authors' elaboration based on ITBI data.

We run the DID models using samples for apartments (147,670 observations), houses (26,705), commercial real estate (19,053), and land plots (11,590).

The regression equation has the following format.

$$\log(Y_i) = \beta_0 + \sum_{j=1}^{J} \beta_j Z_{ji} + \sum_{n=1}^{N} \theta_n W_{ni} + \sum_{u=1}^{U} \propto_u T_{ui} + \gamma_1 SA_i + \sum_{f=1}^{F} \delta_f \left(T * SA_{fi}\right) + \mu_i \quad (1)$$

where, for our purposes:

$$\log(price_i) = \beta_0 + \beta_1 construction.year_i + \sum_{j=2}^{9} \beta_j year.sold_{j,i} + \beta_{10} plot.area_i + \sum_{j=11}^{14} \beta_j P_{j,i} + \sum_{j=15}^{33} \beta_j zoning_{j,i} + \beta_{34} CAMG_i + \beta_{35} MOVE_i + \beta_{36} SHOP_i + \beta_{37} SA_i + \beta_{38} (SA * CAMG)_i + \beta_{39} (SA * MOVE)_i + \beta_{40} (SA * SHOP)_i + \sum_{j=41}^{J} \beta_j neighborhood_{j,i} + \varepsilon_i \quad (2)$$

- Log of the real estate price (log$(price_i)$) is the logarithm of the deflated price per square meter. Similar to much of the literature on estimation of linear hedonic land price model, we adopted a log-linear specification.[4]
- Construction year variable (*construction.year*) indicates when the real estate was built.
- Year of transaction (year.sold) indicates when the sell/buy transaction of the property happened.
- The *plot.area* variable indicates the total area of the plot where the real estate is located.
- Construction Quality (*P*) is a categorical variable. Belo Horizonte's city hall classifies real estate accordingly with the number of rooms, number of bathrooms, parking spaces, construction material, painted area, etc. It varies from Pattern 1 (P1), the lowest rank, to Pattern 5 (P5), the highest rank. A P1 dwelling is a very modest house, while P4 and P5 are luxury houses.
- *Zoning* (ZAP, ZAR2, ZEIS1, etc.,) indicates the zoning parameters that govern the potential for construction in each land parcel. Belo Horizonte's zoning law defines land

[4] Authors' make this suggestion because the errors may be non-normal in the estimation of hedonic land price models.

use homogeneous zones. Zoning restrictions may affect real estate prices due to the effects on land rent, which, net present value, forms the land price.[5]

- We modeled each neighborhood as a factor (*neighborhood*). Drawing on Abramo (1994, 2007) and Furtado (2011), the average price within each neighborhood varies according to the level of neighborhood externalities, which the theory explains based on the concept of urban convention (an average collective opinion on that neighborhood). This concept advances the spatial representation of cities from a monocentric-ring structure to a kaleidoscope of externalities, where the distance from Central Business District (CBD) or the level of amenities is not the main explanatory variable of real estate prices. Besides this theoretical basis, we also have empirical evidence that Belo Horizonte has a spatial representation more adherent to a mixture of externalities than to a monocentric city with respect to real estate prices (Almeida et al., 2017; Furtado, 2011, 2009, 2007). Furthermore, the level of amenities did not change significantly in the time-period analyzed, except for the urban investments we modeled.

As typical in DID models, we used a time-specific variable for each new intervention (*CAMG*, *MOVE* BRT, and *SHOP*). Moreover, we used a *dummy* to capture whether the real estate is located within the study area or not (*SA*). The DID coefficients are obtained by estimating the joined effect of being in the study area and each intervention (*Intervention*SA*).

Among the Brazilian municipal laws, taxation affects all transactions of real estate and property. This tax, called "Inter-Vivo Property Transfer Tax" (ITBI), defines the tax collected by the municipal authority based on the value of the property in question. This database is useful for analyzing the real estate dynamics of the region and capturing aspects of the land value increase in the area.

ITBI is not appropriate to evaluate repeated sales, as is the usual practice in empirical housing market studies in the United States, because it does not provide information on the same property over time. On the other hand, it offers much more accurate information than

[5] For a detailed discussion on this, see Guigou (1982) and Almeida and Monte-Mór (2017).

usual datasets that are constructed using asking prices, since ITBI informs the real price of the sale and covers the entire population of transactions, not only an asking price that may vary due to negotiation. The study area analysis concerns the Transactions Report, where all characteristics of the transmitted properties are recorded, such as the zoning code for the area where it is located, as well as the neighborhood, transaction value, month, prevailing construction type, and the construction quality.

With this information, it was possible to draw an analysis of the local real estate market, observing the neighborhoods' dynamics and comparing them to the situation of the city as a whole. Comparing the evolution of areas affected by "treatment" (LSUP) with non-impacted areas promotes "quasi-experimental" aspects to the research.

The data is available only for Belo Horizonte, not the entire metropolitan region. The observation period corresponds to the transactions of properties registered in the municipality from 2009 to 2017. There are approximately 220 thousand recorded transactions from January 2009 to May 2017; an average of 26 thousand transactions per year. It is also relevant that this dataset does not provide the precise location of each property; hence, we could not use GIS tools to spatialize the information. We had only the street and the neighborhood, which makes it impossible to use distance measures from each property to the LSUP. Despite this limitation, we defined a treatment area that follows the main transport axes and the LSUP proximity, based on the neighborhoods.

We used a second dataset to understand what happened with the metropolitan region's surrounding lands, since LSUPs are close to the borders of other municipalities. This dataset brings evidence of the leapfrog pattern of urbanization that may be correlated with the LSUPs discussed in this paper and it is different from the land transaction tax data, which was available only for Belo Horizonte and not to the metropolitan area. This second dataset was provided by the Belo Horizonte Metropolitan Development Agency (*Agência de Desenvolvimento da Região Metropolitana de Belo Horizonte* or AMRBH), a state autarchy created on January 12, 2009. Public and private land developers operate pursuant to the MRBH's land regulation institution. For every new land development project with certain characteristics, such as subdividing farms

into lots with large sizes and level of impacts, developers need to obtain the "*Anuência Prévia*" (prior consent), an official document authorizing the project and requiring a tax payment collected by the AMRBH. It means that the property is not rural anymore and it will be converted for housing, industrial or commercial purpose. Due to this tax, AMRBH provided a dataset for this research listing all the new land development projects that required *Anuência Prévia* from 2011 to 2016. Herein, we used three types of projects: *Guidelines ("Diretrizes,"* the early stage of land development); ("*Loteamentos*," land development involving the opening of new roadways or the restructuring of existing ones); and *Parceling Out* (*"Desmembramentos,"* land development not involving new roadways or the restructuring of existing ones). For all these types, we do not have access to the monetary values of the transactions, but we identified the size, the location and the stage of land development. It sheds light in the following question: did the peripheral LSUPs studied here may be correlated to the dynamics of metropolitan urban sprawl? Is it reasonable to suppose that a portion of the land value created was privately captured by land developers in other municipalities?

5. Descriptive analyses and DID results: Effects of LSUP on properties value

Figure 2 depicts the real estate price cycle from 2009 to 2017. It also depicts the number of sales (columns). Both prices and the number of sales show the effects of the Brazilian economic and political crisis after 2014. For 2017, data was available only up to May.

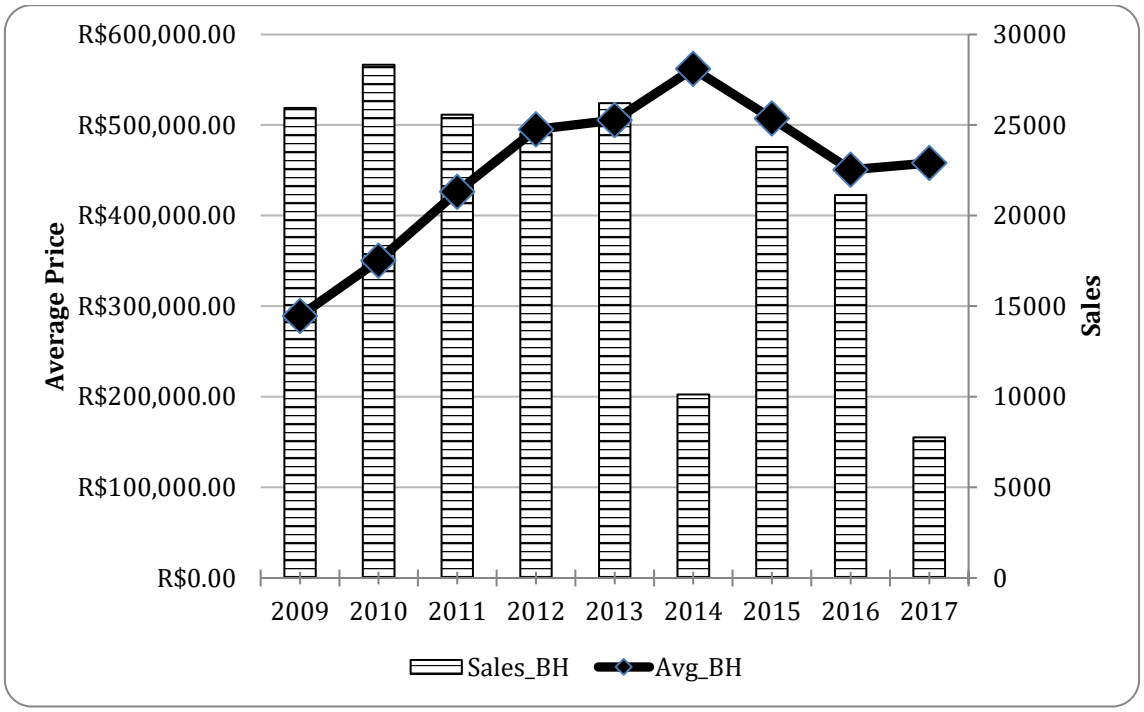


Fig. 2. Average price and number of sales in Belo Horizonte (Jan. 2009–May 2017).

Source: Authors' elaboration using ITBI data.

Figure 3 depicts a comparative exercise, comparing average prices and the number of sales for the study area and Belo Horizonte (without the study area). We constructed time series for residential and commercial real estate using (2009 = 100), and deflating monetary values using the Brazilian Price Index (*IGP-M*).[6] For 2017, we extrapolated the number of sales (for the second semester).

[6] General Average Price Index, which is calculated by Fundação Getúlio Vargas (FGV), is the most used index for the real estate market in Brazil.

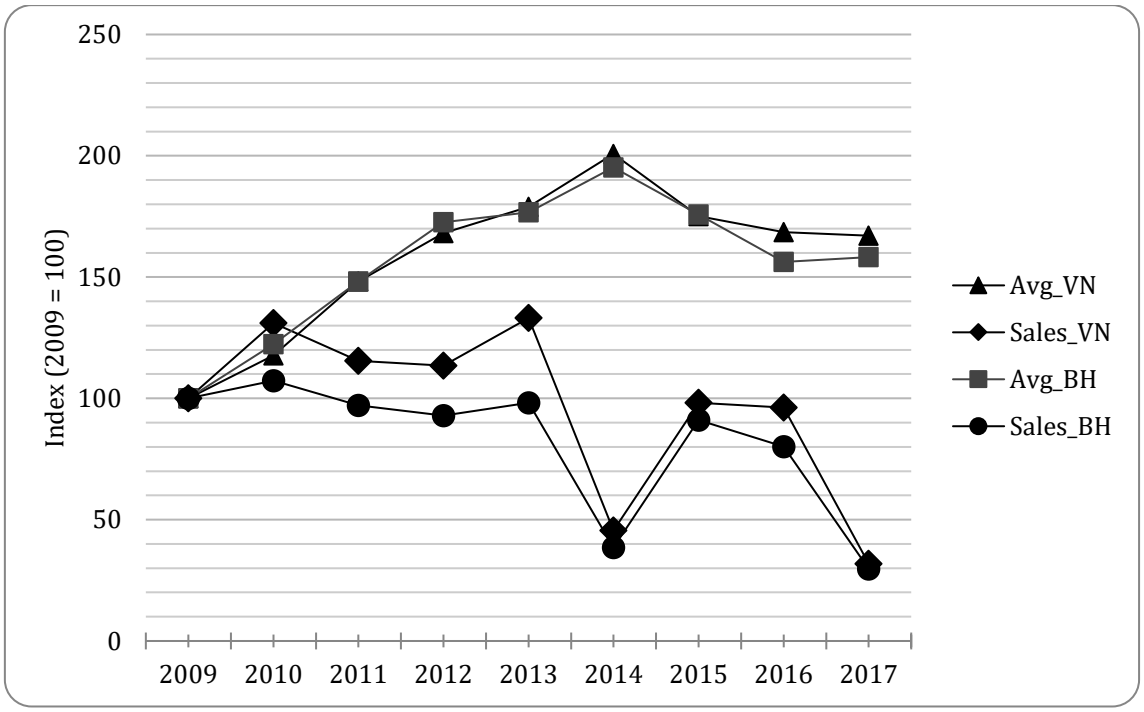


Fig. 3. Average price growth and transactions growth – Study area and BH (2009–2017).

Source: Authors' elaboration based on ITBI data.

The real growth rates of the study area's average prices, considering residential and commercial real estate, are about the same as the average of BH, although they decreased a little less from 2014 to 2017. The prices indexes increased around 100% from 2009 to 2014. From 2014 to 2017, these indices fell around 30–40%.

The growth rates of the study area's property sales essentially followed the same trends of BH. However, sales grew more in the study area than in BH from 2009 to 2014, and fell more from 2013 to 2017. This data shows evidence of the typical low-price elasticity of the real estate supply (Foldvary and Minola, 2017), with prices varying more than quantities.

Comparing the study area with other peripheral and low-income areas helps to check robustness. We observed similar trends in the Barreiro region, located in the south-west periphery of BH. Nonetheless, in Barreiro, the average prices grew more (2009–2014) and fell less (2014–2017). This fact may be interpreted as evidence that the LSUPs in the study area were not the key determinant for the real estate dynamic in the region—a result that the regression coefficients also corroborate. Furthermore, Figure 4 shows evidence that the study

area is a peripheral area with higher land supply than the Barreiro region (an old blue-collar neighborhood).

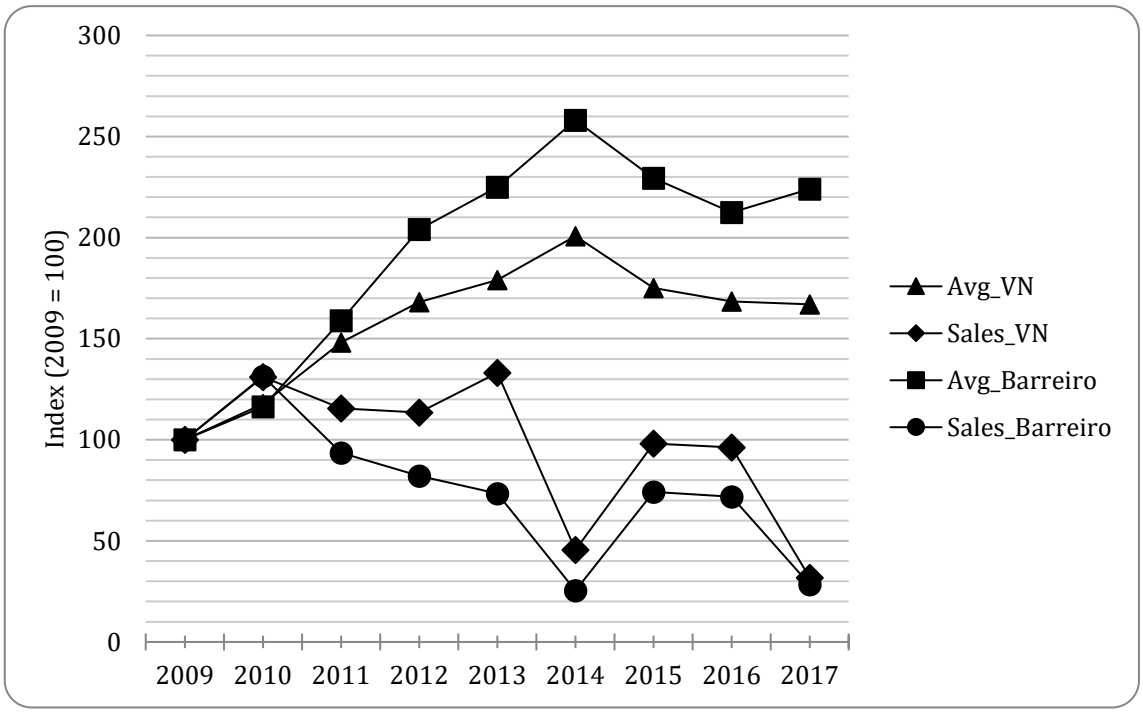


Fig. 4. Average price growth and transactions growth – study area and Barreiro (2009–2017). Source: Authors' elaboration based on ITBI data.

After 2010, there was a very significant increase of real-estate activity, with prices peaking in 2014 and the number of sales peaking in 2010. The estimated coefficients in the DID models corroborated this result.

With this descriptive information on hands, we discuss the econometric results. In general, the variables had the expected sign and most of them were statistically significant at a 1% level. Moreover, we tested 15 different specifications to check robustness. The main results stand on all the specifications, and the magnitude of the coefficients is similar.

As Table 3 shows, in the sample for apartments, the DID coefficient was statistically significant at 1% for the inauguration of the Station Mall and the *MOVE* BRT, and at a 10% level for the *CAMG*. The estimated impact of the Shopping's inauguration over apartment prices within the study area is around 4%; this sample's higher DID coefficient. The estimated impact

of the *CAMG* was around 3%, while *MOVE* BRT decreased average prices within the study area by nearly -2%.

Table 3

Regression results of log price for apartment, houses and commercial real estate.

	(1) Apartments	(2) Houses	(3) Commercial
(Intercept)	6.19E+00***	4.31E+00**	2.44E+00
	(<2.2E-16)	(1.98E-03)	(1.49E-01)
construction.year	6.24E-04.	1.47E-03*	2.28E-03**
	(6.91E-02)	(3.61E-02)	(7.14E-03)
year.sold2010	1.46E-01***	2.55E-01***	1.30E-01***
	(<2.2E-16)	(<2.2E-16)	(4.36E-05)
year.sold2011	2.91E-01***	4.51E-01***	1.77E-01***
	(<2.2E-16)	(<2.2E-16)	(1.57E-06)
year.sold2012	3.84E-01***	5.32E-01***	3.55E-01***
	(<2.2E-16)	(<2.2E-16)	(<2.2E-16)
year.sold2013	4.71E-01***	6.43E-01***	5.47E-01***
	(<2.2E-16)	(<2.2E-16)	(<2.2E-16)
year.sold2014	5.00E-01***	6.63E-01***	6.75E-01***
	(<2.2E-16)	(<2.2E-16)	(<2.2E-16)
year.sold2015	4.49E-01***	6.40E-01***	6.35E-01***
	(<2.2E-16)	(<2.2E-16)	(<2.2E-16)
year.sold2016	3.47E-01***	5.74E-01***	4.85E-01***
	(<2.2E-16)	(<2.2E-16)	(1.32E-10)
year.sold2017	3.74E-01***	5.43E-01***	5.32E-01***
	(<2.2E-16)	(<2.2E-16)	(3.35E-12)
plot.area	6.24E-07***	2.86E-05***	1.77E-06
	(1.33E-10)	(<2.2E-16)	(6.99E-01)
P2	7.92E-03	-1.18E-01***	2.15E-01***
	(5.24E-01)	(4.60E-12)	(9.81E-09)
P3	1.08E-01***	-1.10E-01***	5.51E-01***
	(<2.2E-16)	(2.40E-09)	(<2.2E-16)
P4	2.01E-01***	-2.15E-01***	8.41E-01***
	(<2.2E-16)	(<2.2E-16)	(<2.2E-16)
P5	4.07E-01***	-2.47E-01***	1.12E+00***
	(<2.2E-16)	(3.28E-14)	(<2.2E-16)
zoning.ZAP	-1.76E-02**	3.53E-02	-1.06E-01*
	(7.46E-03)	(2.72E-01)	(2.53E-02)
zoning.ZAR1	4.14E-03	1.42E-02	-8.56E-02
	(7.09E-01)	(7.87E-01)	(3.53E-01)
zoning.ZAR2	-4.81E-02***	-7.06E-02*	-3.03E-01***
	(4.15E-12)	(3.78E-02)	(2.39E-06)
zoning.ZCBA	-3.37E-02	3.97E-01***	1.26E+00***
	(1.65E-01)	(4.44E-04)	(<2.2E-16)

zoning.ZCBH	1.95E-01***	9.92E-01***	5.85E-01***
	(<2.2E-16)	(<2.2E-16)	(3.34E-08)
zoning.ZCVN	1.32E-02	-1.16E-01	-9.80E-01***
	(3.80E-01)	(2.43E-01)	(<2.2E-16)
zoning.ZE	1.78E-02.	-5.61E-02	1.05E-01
	(9.93E-02)	(3.93E-01)	(4.81E-01)
zoning.ZEENG	x	x	x
zoning.ZEIS1	5.51E-02	-6.02E-01***	-3.06E-01
	(4.39E-01)	(4.21E-10)	(1.59E-01)
zoning.ZEIS2	-2.09E-01***	-4.47E-02	-2.47E-01
	(<2.2E-16)	(8.25E-01)	(5.49E-01)
zoning.ZEIS3	x	-5.27E-01***	x
		(4.56E-06)	
zoning.ZEJAT	x	x	1.26E+00***
			(<2.2E-16)
zoning.ZEPIL	x	x	x
zoning.ZESFR	4.12E-02	-6.09E-02	-6.43E-03
	(1.42E-01)	(8.87E-01)	(9.83E-01)
zoning.ZHIP	-6.21E-02***	-2.50E-02	9.08E-01***
	(2.76E-04)	(9.29E-01)	(2.50E-15)
zoning.ZP1	-1.77E-01***	-2.37E-01.	-1.45E+00
	(2.49E-08)	(6.34E-02)	(1.17E-01)
zoning.ZP2	1.15E-01***	1.02E-01.	-2.85E-01*
	(3.44E-10)	(6.79E-02)	(4.58E-02)
zoning.ZP3	-3.51E-01***	x	-6.09E-02
	(4.63E-15)		(7.67E-01)
zoning.ZPAM	3.42E-01***	-2.80E-01.	5.98E-02
	(<2.2E-16)	(9.91E-02)	(8.35E-01)
CAMG	6.46E-02***	2.91E-02	2.51E-01***
	(<2.2E-16)	(2.09E-01)	(3.47E-14)
MOVE	-6.08E-03	-2.60E-02	5.19E-03
	(3.16E-01)	(4.85E-01)	(9.32E-01)
SHOP	7.18E-03*	3.87E-02*	8.00E-02**
	(4.78E-02)	(4.06E-02)	(1.18E-03)
StudyArea	-1.59E-02	2.46E-02	4.27E-03
	(1.94E-01)	(4.21E-01)	(9.68E-01)
DID*CAMG*	2.40E-02*	-6.55E-03	1.80E-02
	(4.07E-02)	(8.14E-01)	(8.47E-01)
DID*MOVE*	-1.71E-02**	-3.53E-03	-1.08E-01
	(3.80E-03)	(8.92E-01)	(2.58E-01)
DIDSHOP	3.79E-02***	4.31E-02	3.73E-02
	(6.60E-08)	(1.03E-01)	(7.16E-01)
Neighborhoods[t]	...	...	...
N	147,669	26,705	19,053

Adjusted R-squared	0.4994	0.3755	0.705
F-Statistic	525.2***	45.1***	169***
	(df = 281; 147,387)	(df = 364; 26,340)	(df = 271; 18,781)

Notes: Heteroscedasticity-robust standard errors clustered at postcode in parentheses, with . for p < 0.05; * for p < 0.01; ** for p < 0.001; and *** for p = 0. [t]Neighborhoods coefficients were omitted due to their very large number.

These coefficients make sense in light of both theory and fieldwork experience. Citizens evaluate the BRT system poorly, and its stations lack an appealing aesthetic. Many local bus routes that connect neighborhoods to downtown no longer exist, forcing users to take two buses instead of one. This may have increased the travel time and, in many cases, the tariffs.

On the other hand, it is easy to justify why the Station Shopping generated a 4% increase in apartments' prices in the study area. The Shopping Station provided a number of services and retail options to residents, strengthening the urban centrality of the area. Moreover, Shopping's accessibility increased due to its physical integration with the terminal metro and bus station (*Vilarinho* Station).

The iconic building of the administrative state offices (*CAMG*) may have affected the perception of the area; a result also found by Ahlfeldt and Kavetsos (2014) when analyzing whether the form of urban facilities has more impact than function on property values. *CAMG* also had a significant and positive impact on apartments' prices in the study area, although less than the Station Shopping's impacts. One possible explanation is that most of the residents do not interact with *CAMG*, and most of the public servants and technocrats who work there do not live in the study area. Therefore, it is harder for the real estate market to capitalize on the potential benefits of *CAMG*, due to its disconnection with the surrounding area. Nevertheless, the enormous public area for outdoor activities, the aesthetic aspect, and the expectations that *CAMG* created may be enough to explain the 2.4% price increase that it promoted in the study area.

We also tested a different definition of the study area. One may argue that the LSUP had a wider territorial impact, such as in the preliminary study conduct by Nabuco et al. (2017). Adopting the city's regions *Norte*, *Venda Nova*, and *Pampulha* as the study area, the DID coefficients were not statistically significant for *CAMG* and *MOVE* BRT. It was still statistically

significant at a 1% level for the Station Shopping. The estimated effect was a 1.1% apartment price increase. Therein, it shows the geographically limited impact of *CAMG* and *MOVE* BRT on apartments' prices, at least in the Belo Horizonte municipality.

As mentioned before, the dummies variables that capture the macroeconomic cycle is significant and had the expected sign. If a household bought an apartment in 2014, for instance, it was 50% more expensive than a similar apartment in 2009. The magnitude of the macroeconomic cycle was higher than many variables related to urban amenities.

Table 3 also shows the DID coefficients for the house and commercial samples. In these samples, DID coefficients were not statistically significant. Thereby, we can infer that these three LSUPs had different impacts, depending on the kind of market. The commercial real estate market in Belo Horizonte is still highly concentrated in the center-south region. The housing market is more spread, but the main concentrations of high-priced houses are not within the study area.

We also directly estimated LSUP effects on land value. Table 4 shows the DID coefficients for this estimation. We tested two study area definitions; one using the previously studied area described throughout this work, and a second for an expanded study area, composed of *Pampulha*, *Venda Nova*, and *North* regions.

The estimated impacts of the *CAMG* and *MOVE* BRT on land values were statistically significant at a 1% level, and had the same sign as in the apartments' sample. However, the impacts were higher for land markets, in which the *CAMG* increased the average prices by 17% and *MOVE* BRT decreased by 14%. In the expanded study area, *CAMG* had an almost 10% impact, and *MOVE* BRT had a negative 6% impact (although statistically significant only at 10% level). The Station Shopping's effect was not significant in the first definition of the study area and was significant only at 10% in the expanded area.

Table 4

Regression results of log price for land plots sample - study area and expanded study area.

	(1) Study Area	(2) Expanded Study Area
(Intercept)	6.43E+00***	5.94E+00***
	(<2.2E-16)	(<2.2E-16)
year_sold2010	1.33E-01***	1.31E-01***
	(1.36E-06)	(1.55E-06)
year_sold2011	4.63E-01***	4.60E-01***
	(<2.2E-16)	(<2.2E-16)
year_sold2012	7.30E-01***	7.25E-01***
	(<2.2E-16)	(<2.2E-16)
year_sold2013	8.78E-01***	8.71E-01***
	(<2.2E-16)	(<2.2E-16)
year_sold2014	9.96E-01***	9.86E-01***
	(<2.2E-16)	(<2.2E-16)
year_sold2015	9.77E-01***	9.71E-01***
	(<2.2E-16)	(<2.2E-16)
year_sold2016	9.31E-01***	9.24E-01***
	(<2.2E-16)	(<2.2E-16)
year_sold2017	8.90E-01***	8.80E-01***
	(<2.2E-16)	(<2.2E-16)
terrain.area	-4.66E-06**	-4.72E-06**
	(6.11E-03)	(4.72E-03)
zone.fZAP	-7.30E-02	-7.39E-02
	(4.87E-01)	(4.76E-01)
zone.fZAR1	-4.10E-01***	-4.08E-01***
	(2.93E-04)	(2.66E-04)
zone.fZAR2	-3.62E-01***	-3.63E-01***
	(5.88E-04)	(4.90E-04)
zone.fZCBA	2.56E-01.	2.59E-01.
	(9.55E-02)	(8.64E-02)
zone.fZCBH	1.33E+00***	1.32E+00***
	(1.12E-08)	(6.64E-09)
zone.fZCVN	-1.53E-01	-1.45E-01
	(4.08E-01)	(4.19E-01)
zone.fZE	-5.08E-01***	-5.10E-01***
	(4.75E-06)	(3.11E-06)
zone.fZEENG	-1.26E-01	-1.30E-01
	(3.16E-01)	(2.95E-01)
zone.fZEIS1	-1.31E+00***	-1.32E+00***
	(<2.2E-16)	(<2.2E-16)
zone.fZEIS2	-4.28E-01***	-4.33E-01***
	(2.19E-04)	(1.52E-04)
zone.fZEIS3	-3.02E-01	-2.92E-01

	(3.48E-01)	(3.65E-01)
zone.fZEJAT	-3.63E-01**	-3.75E-01**
	(4.24E-03)	(2.81E-03)
zone.fZEPIL	-2.99E-01	-3.16E-01
	(2.38E-01)	(2.06E-01)
zone.fZESFR	1.46E-01	1.85E-01
	(3.53E-01)	(2.42E-01)
zone.fZHIP	5.56E-01*	5.70E-01**
	(1.30E-02)	(9.35E-03)
zone.fZP1	-1.03E+00***	-1.03E+00***
	(<2.2E-16)	(<2.2E-16)
zone.fZP2	-5.55E-01***	-5.58E-01***
	(3.01E-07)	(1.74E-07)
zone.fZP3	7.66E-01***	7.66E-01***
	(1.16E-09)	(8.65E-10)
zone.fZPAM	-1.30E+00***	-1.30E+00***
	(<2.2E-16)	(<2.2E-16)
CAMG	-4.03E-02	-6.24E-02*
	(1.61E-01)	(3.40E-02)
MOVE	-1.02E-02	-3.00E-03
	(8.08E-01)	(9.43E-01)
SHOP	-2.61E-02	-7.44E-03
	(2.60E-01)	(7.67E-01)
StudyArea	-4.18E-02	4.63E-01*
	(2.13E-01)	(1.27E-02)
DID*CAMG*	1.73E-01***	8.65E-02***
	(1.86E-06)	(9.37E-05)
DID*MOVE*	-1.47E-01***	-4.65E-02*
	(6.80E-06)	(4.81E-02)
DIDSHOP	-4.58E-02	-4.35E-02*
	(1.74E-01)	(4.41E-02)
Neighborhoods[t]	...	...
N	11,590	11,590
Adjusted R-squared	0.7487	0.7486
F-Statistic	107.9***	108.1***
	(df = 323; 11,266)	(df = 322; 11,267)

Notes: Heteroscedasticity-robust standard errors clustered at postcode in parentheses, with . for p < 0.05; * for p < 0.01; ** for p < 0.001; and *** for p = 0. [t]Neighborhoods coefficients were omitted due the very large number of them.

Source: Authors.

It is also worth mentioning that our estimation using the sample for Belo Horizonte showed that the other controls are key explanatory variables for the property prices in the city. The coefficients related to location, zoning, and construction quality have high magnitudes and are

statistically significant at a 1% level, in general. The coefficients for construction quality in the residential samples are similar to those found by Furtado (2007), who also studied the housing market in Belo Horizonte. Regarding neighborhoods' coefficients, location in a neighborhood such as Belvedere (7 km south of the CBD[7]) results in a more than 70% price increase for apartments, while location in very poor neighborhoods (slums), such as Alto Vera Cruz or Nazaré, may result in more than a 55% price decrease for apartments.[8] The São Luiz neighborhood (9 km north of CBD) also showed one of the highest positive and significant coefficients, demonstrating evidence of relevant suburbanization of wealth in Belo Horizonte (see Almeida et al., 2017). On the other hand, there is still a very relevant agglomeration of high-priced neighborhoods in the center-south portion of the city, in neighborhoods such as Lourdes, Santo Agostinho, Savassi, Anchieta, Sion, and Santo Antônio (around 20–30% estimated coefficients for apartments). These results indicate that distance to the CBD does not explain residential prices in these samples. Moreover, one of the reasons for the limited impact of the LSUP on land value in the northern portion of the city is likely related to the collective opinion: investments were unable to change urban conventions in the area and attract high-income groups to the northern portions of the city.

Zoning variables brought evidence that the higher the restriction (or the lower the floor–area ratio), the lower the price. This result is line with the theoretical prediction (Foldvary and Minola, 2017). As mentioned previously, this result is very relevant for zoning law debates. For instance, being located in a ZEIS-2 (low-income social protection zone) may result in a 20% price decrease, while location in a ZAR-2 (restricted density zone) may result in a nearly 5% price decrease for apartments. Obviously, these coefficients change according to the definition of dummies variables. Herein, the main relevance regards the significance and the sign of these variables, and not to the specific coefficient magnitudes, which certainly deserves another study.

[7] Considering the "*Praça 7 de Setembro"* as the CBD.

[8] Selecting only neighborhoods whose coefficients were statistically significant at less than a 1% level.

Construction quality showed expected results. If an apartment has the construction quality classified as “P4” (high quality), it represents a 20% average price increases. If it is a “P5” (luxury quality), the estimated result is around 40%.

As is natural with any econometric estimation, all these results demand further investigation and cautiously interpreted. Due to the relevance of the *MOVE* BRT investment, this LSUP certainly requires more research on its effects in the city structure and real estate markets.

6. What did happen to the metropolitan region? Leapfrog urbanization evidence

Table 5 depicts the dynamics of land development in MRBH by showing the number of land development processes registered within the responsible bureau (ARMBH).

Table 5

Land development in MRBH (2012–2016).

	Processes		
	MRBH	**Study Area**	
2012	2	1	50%
2013	221	95	43%
2014	237	91	38%
2015	191	82	43%
2016	65	28	43%
Total	**716**	**297**	**41%**

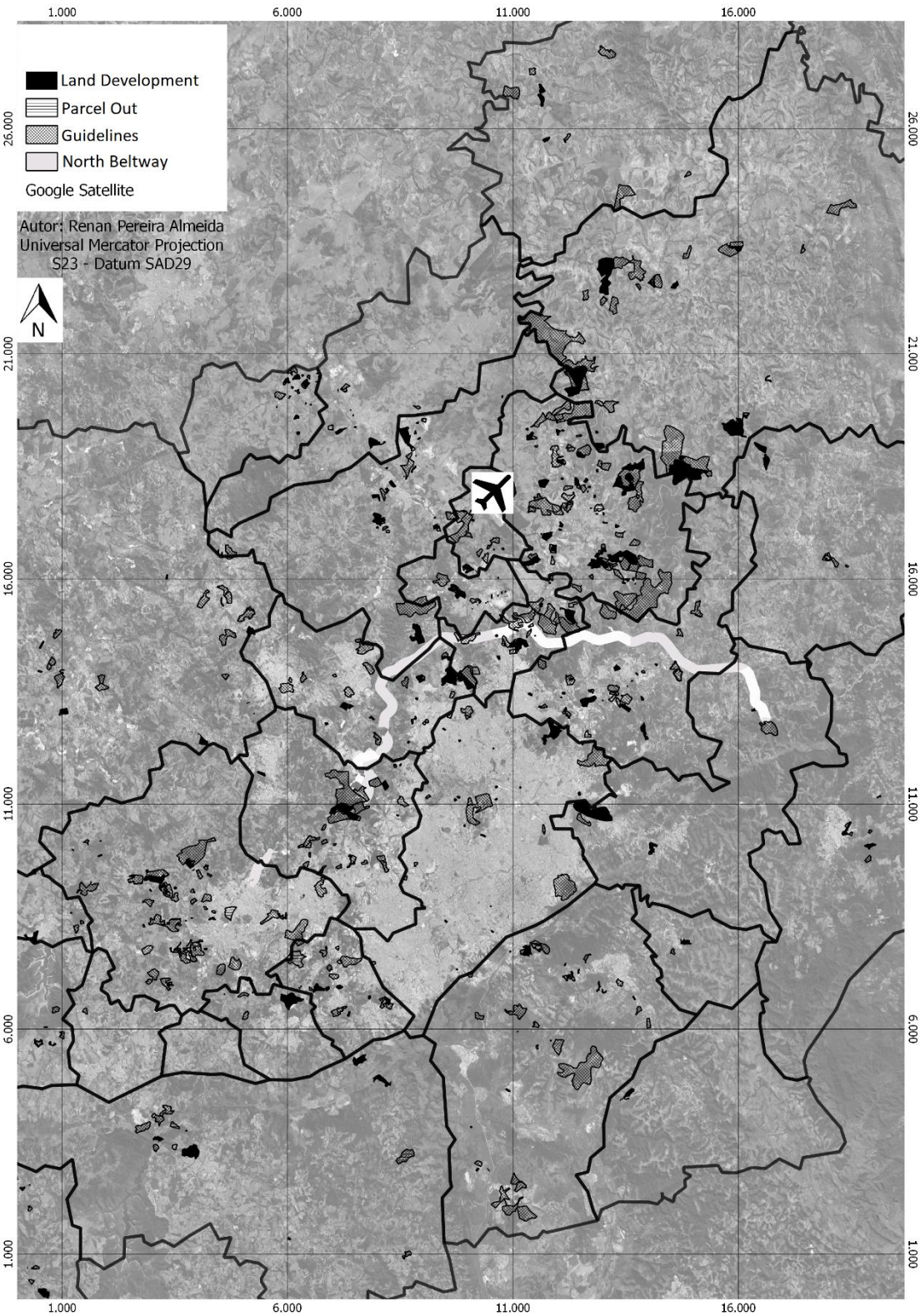
Source: Authors’ elaboration from AMRBH´s data.

The year 2012 remained irrelevant for the analysis due to the very small number of observations—AMRBH was a new autarchy (created in 2009), and this data reflects this fact. The AMRBH’s analyst, who provided the data, confirmed it. From 2013 to 2016, it shows cyclical behavior, as do the other dataset in this work. In 2014, the series peaked, and since 2015, the Brazil’s huge economic crisis deeply affected land developers. More importantly, Table 5 shows that the studied area accounts for more than 40% of all the land development projects from 2012 to 2016.

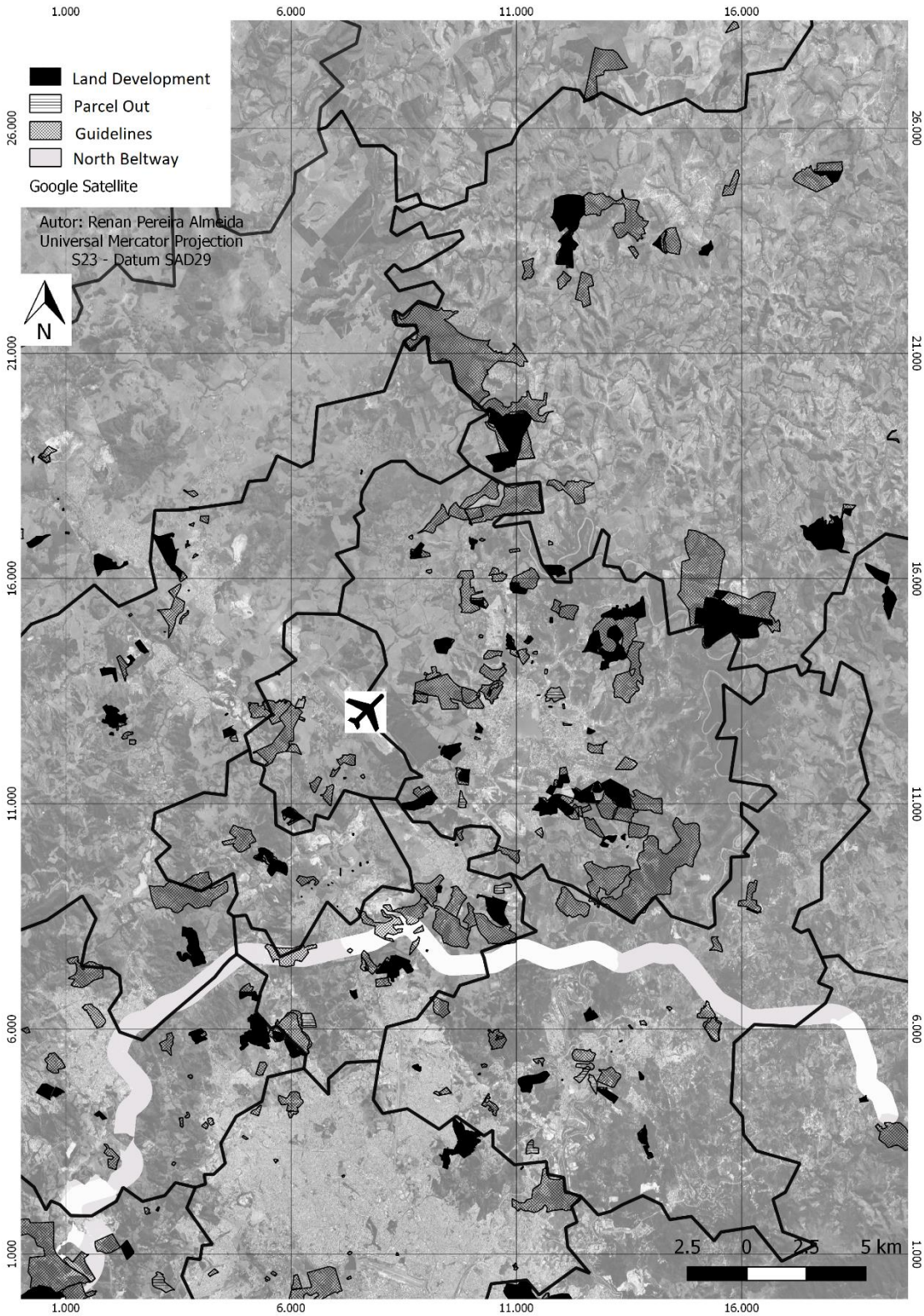
Maps 1 and 2 spatialize this phenomenon. Three main aspects must be grasped: the northern region (where the previously discussed LSUPs are located) is clearly the main axis of expansion in the metropolitan region; the land developments within the study area follow the Green Line

corridor (MG-010); and the land development showed a leapfrog pattern, “leaping” over the densely developed area and reaching northern portions of the MRBH (especially the municipality of Lagoa Santa). At this point, for the land development that occurred before or together with the delivery of the LSUPs (2010, 2012 and 2014), all we may affirm is that there is a correlation between these land developments in the northern region and the LSUPs discussed here. Future works may employ a DID model to test the causality of this relationship, when transaction data will be available for municipalities other than the capital city, Belo Horizonte. However, for the land development that occurred in 2015 and 2016, we may establish a relationship between the LSUPs implemented in the northern region of Belo Horizonte and these land developments, which occurred in the same axis (the North axis). The three LSUPs previously describe can be easily accessed by car from these new land developments. The data indicate that most of the large parcels and land developments are destinated for housing purposes – gated communities for middle and high-income groups.

These data also demonstrate the major trend related to the type of land development in the area. Most new projects are still in the Guidelines phase (“*Diretrizes*”), meaning the early stage. Developments (“*Loteamentos*”), when subdividing real estate into lots requires new motorways, representing the most dramatic change, accounts for less than 50%. It opens possibilities for tremendous changes in land use in the metropolitan region in the next decade, depending on the degree and speed of Brazil’s economic recovery, as well as the region’s own dynamic.



Map 1. New land development in the MRBH.
Note: Black lines define municipalities' borders. North Beltway is only planned so far.
Source: Authors' elaboration with ARMBH's data.



Map 2. New land developments in the MRBH (zooming).
Note: black lines define municipalities' borders. North Beltway is only planned so far. Source: authorship with ARMBH's data.

7. Concluding remarks

Large-scale urban projects can change cities' spatial structures. This fact notwithstanding, academics and policy makers need to consider local contingencies. The impacts may vary a lot according to the type of urban equipment and the surrounding built area.

The LSUPs implemented by the state government of Minas Gerais and by private investors in Belo Horizonte significantly increased property values in the affected area. Therefore, a part of these investments could have been financed through land value capture and betterment levies. The state government spent more than R$ 3 billion (more than US$ 1 billion) on these LSUPs. Nonetheless, the land value generated varies according to the type of urban investment. As our regression results indicate, iconic buildings and shopping malls may have positive effects on property values, while poorly evaluated transportation facilities may have negative effects. Therefore, land use policy must be aware of the limited capacity to finance investments using land value capture instruments.

Some of these investments may play a relevant role in promoting a new urban centrality in this peripheral poor region of Belo Horizonte, promoting job opportunities and avoiding commuting to the central city, as proposed by the Metropolitan Plan.[9] The *CAMG* already (re)located thousands of jobs from the central city. Despite its problems, the BRT is still a relevant mass transportation option in many Latin American cities (Rodriguez and Mojica, 2008; Rodriguez and Tovar, 2013). Its success depends fundamentally on the way it operates, on tariff levels, and on the possibilities of integration with other models. A deeper evaluation of BRT's impacts is necessary to provide a better understanding of transportation investment in Latin American cities, which daily have been facing huge problems with congestion. Further research may investigate in more detail whether the BRT's impacts on land value were, indeed,

[9] The Metropolitan Plan of Belo Horizonte—PDDI/RMBH, elaborated by the UFMG—Universidade Federal de Minas Gerais, between 2009–2011, inaugurating a planning process still in progress, proposes three new metropolitan centralities of the RMBH, one of them in the northern region. See www.rmbh.org.br for further information.

negative. Also needed are datasets that provide sufficient information to estimate anticipated effects. Regarding transportation, it is relevant to assess whether the LSUP discussed here had a significant impact on land value near previously existing metro stations. There is some preliminary reasoning on that.

The empirical results of this work highlight the role of the macroeconomic cycle and the specificities of neighborhoods and zoning on real estate pricing. These three key variables may be better predictors of real estate prices than usual levels of amenities. Future research may improve the estimations, specifically including spatial lags and spatial errors effects.

Our findings help to understand the effects of LSUPs on consolidated areas. The study area is a consolidated region, and if real estate developers attract high-income groups to the area, they will probably favor gated communities. These small islands of wealthy residents in the midst of seas of poverty are unlikely to displace low-income residents (Betancur, 2014; Sabatini et al., 2009), but increase the inequality within the region.

Finally, this work opens some research avenues. A significant part of the land value generated by these LSUPs probably "leaped" over the low-income areas and was privately captured by real estate developers in northern municipalities. Therefore, a future research may assess these impacts on municipalities other than Belo Horizonte. A detailed study on how exactly to recover the land value created is also necessary.

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