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RAISSA NUMERIANO DUBOURCQ DANTAS

THE EFFECTS OF LAND-USE REGULATION ON LOCAL REAL ESTATE MARKET: EMPIRICAL EVIDENCE FROM BRAZIL

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RAÍSSA NUMERIANO DUBOURCQ DANTAS

A Comissão Examinadora composta pelos professores abaixo, sob a presidência do primeiro, considera a Candidata Raíssa Numeriano Dubourcq Dantas **APROVADA.**

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Conquistar, do latim, conquistare, desde então, tendo semântica de buscar, vencer e procurar juntamente, empregado em sintonia com os verbos querer, dedicar, persistir e perseverar; verbos que refletem uma parcela do meu sentimento ao longo desta jornada. Neste momento, mais um ciclo se conclui; ciclo este marcado não apenas por abdicações e frustrações, mas, também, por superações e alegrias. Este "final" representa a conclusão do segundo capítulo de minha vida acadêmica que, em paralelo à minha formação profissional e ética, paulatinamente construídas, levará escrito consigo sólidas amizades e momentos inesquecíveis.

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"If I have seen further, it is by standing

on the shoulders of giants."

Isaac Newton, 1676

RESUMO

Este trabalho tem como objetivo compreender como restrições do uso da terra, no ambiente urbano brasileiro, podem afetar os preços do mercado imobiliário local. Nós exploramos a heterogeneidade gerada através da promulgação da Lei Municipal nº 16.719; esta, pois, cria limitações na altura dos edificios para alguns, mas não todos, bairros do Recife. Sobre uma base de dados fornecida pela Prefeitura do Recife, usamos uma estratégia de Diferenças em Discontinuidade Geográfica (Diff-in-Geo-Disc) para mostrar que a restrição imposta pela da lei acarretou distorções nos preços dos imóveis. Nossos resultados indicam um aumento significativo dos preços unitários dos apartamentos paralelamente a uma desvalorização das casas pré-existentes. A estratégia utilizada e resultados encontrados são fundamentados por inúmeros testes de robustez.

Palavras-Chave: Mercado Imobiliário. Leis de Restrição do Uso do Solo. Brasil. Differenças em Discontinuidade Geográfica.

ABSTRACT

This paper aims to understand how restrictions to urban land-use could affect Real Estate Market prices in Brazilian urban environment. We explored a heterogeneity arisen from the enactment of a city-level Height-Restriction-Law which limited how tall buildings could get in some, but not all, neighborhoods in Recife, one of the largest cities of Brazil. We used a Differences in Geographic Discontinuity (Diff-in-Geo-Disc) design on a unique data set provided by the Municipal Government to show that the imposed restriction led to an interesting Market Behavior: apartment's unit prices experienced a significant increase in prices meanwhile house's unit prices depreciated value. Our findings rely on empirical models grounded by several robustness checks.

Keywords: Property Values. Height Restrictions; Urban Land-use. Brazil; Geographic Regression Discontinuity Design. Differences in Geographic Discontinuity.

LISTA DE FIGURAS

Figure 1 - Brazil, Recife, and the URA 13
Figure 2 - Areas Specification 23
Figure 3 - Sample Segments..24

LISTA DE TABELAS

Table 1 - Description of the variables 28
Table 2 - Descriptive Statistics - Apartments 29
Table 3 - Descriptive Statistics – Houses 30
Table 4 - Baseline Results 34
Table 5 - Covariates Robustness Checks 36
Table 6 - Treatment Variable Coefficient 38

SUMÁRIO

1 INTRODUCTION 12
2 BACKGROUND 17
2.1. Restrictions on Urban Land Use and Property Prices 17
3 EMPIRICAL FRAMEWORK 21
3.1. Setup and Notation..21
3.2. Model Specification and Identification 24
3.3. Data 26
3.4. Descriptive Statistics 29
4 RESULTS 31
4.1. Basic Results..31
5 ROBUSTNESS CHECKS 33
5.1. Covariates 33
5.2. Polynomial Specification 35
5.3. Year Falsification..37
6 CONCLUDING REMARKS 39
REFERENCES 40

1 INTRODUCTION

Over the past decades, Brazil experienced a steep increase in the proportion of people living in urban areas. In the last forty years, this share increased almost 30% reaching an 85% rate in 2010 (IBGE, 2014). This urban scenario, combined with the macroeconomic stability of the 90's and easier access to credit for housing, increased the demand for living in the few better spots of the country. As a result of this process, Brazil's population ended up unevenly distributed and highly concentrated in few major towns. In 2013, for example, the 10 largest Metropolitan Regions of the country concentrated almost 30% of the national population, however, accounted for 0.7% of the total area of the country (PNAD, 2013).

In Recife, a northeastern city of Brazil, the scenario wasn't different. The urban scenario, economic improvements, access to credit for housing, and the reliance on individual transportation increased the demand for living in some few "better center-situated neighborhoods" of the city which ultimately lead to the construction of taller buildings (da MATA et al., 2007; HENDERSON, 1988; SEPLAN, 2016). Thus, in 1996, due to social demand, it was enacted the Law of Land Use and Occupancy[1] which allowed the construction of skyscrapers in the city as a whole. During this process, a particular set of twelve neighborhoods, located in the Center-North of the city, experienced the highest density growth patterns. In this districts, the verticalization changed the geography of the blocks; "traditional houses" were demolished and were gradually replaced by multi-family buildings (SEPLAN, 2016). This new urban dynamic overloaded the existing infrastructure and reduced green areas extent, which led to a decrease on local inhabitants' welfare and life quality (SEPLAN, 2016).

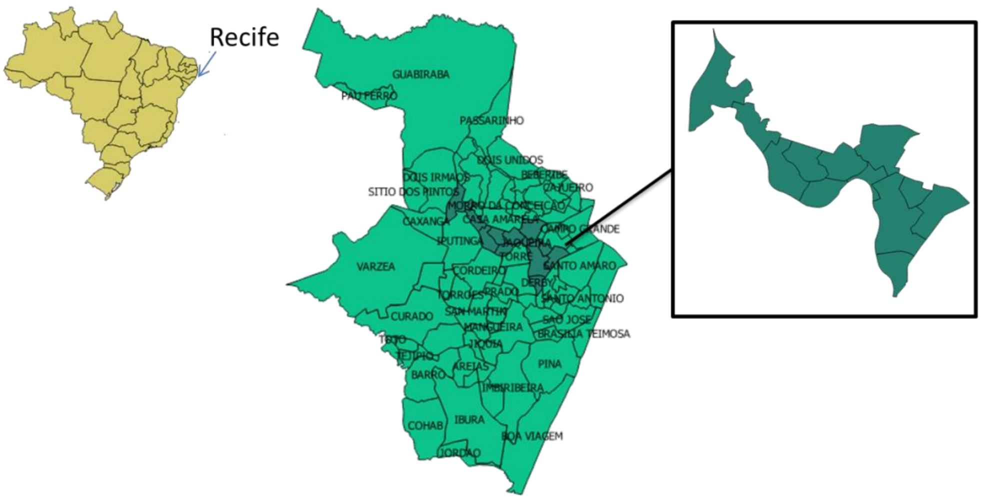
Thereby, following the classical economic argument for zoning, attempting to minimize the consequences of the rampant urbanization, preserve the architectural heritage of the districts and green areas, and attenuate traffic jams and pollution (MCDONALD and MCMILLEN, 2012), some regulatory measures arose. In December 2001, it was announced the Twelve Neighborhoods' Law[2].

[1] Known in portuguese as "Lei de Sobre o Uso e Ocupacão do Solo"
[2] Municipal Law No. 16.719/2001, known in portuguese "Lei dos 12 Bairros"

The law’s main underlying motivation was the need to preserve the architectural heritage of these districts, to maintain their various green areas and to minimize problems associated with densification in an area with roads of limited capacity (Duarte et al, 2014). For this purpose, the law limited the height of 60 meters for new buildings inside a Urban Restructuring Area (URA)[3], which is represented in darker green in Figure 1 (IBGE, 2000; STORCH, 2000; DUARTE et al, 2014). Hence, due to that height restriction, a composition of effects may have differently affected dwellings’ prices.

In one hand, looking at the apartments’ strand, the restriction implied the construction of lower buildings; thereafter, this would lead to a reduction of apartments’ supplied units, which would push apartment’s price up. Following the same direction, the law “potentially reduces” the overloading of the existing structure, air and sound pollution, which increases the welfare of the residents and give rises to a positive amenity effect and would also push prices up. Nevertheless, on the opposite direction, from the height restriction could also emerge a substitution effect within housing units from other areas in the city (Glaser and Ward, 2009), which could bring push prices down. We hypothesize that the forces that push prices up are much stronger that those pushing prices down, thus, we expect apartments’ prices to decrease.

Figure 1 - Brazil, Recife, and the URA



Source: Elaborated by the author

[3] The URA accounted for 12 of Recife’s 94 neighborhoods: Aflitos, Apipucos, Casa Forte, Derby, Espinheiro, Graças, Jaqueira, Monteiro, Parnamirim, Poço, Santana and part of Tamarineira.

On the other hand, looking at houses, due to the verticalization trend, combined with the income increase and the scarcity of “good places to live”[4], a common practice in Recife is for houses to be demolished to be replaced by buildings (SEPLAN, 2016). Thus, an entrepreneurs who “bought a house”, were not interested in the house itself, but in the economic potential of parcel where the house was built. This relationship is so clear that, most of the times, the entrepreneur does not pay the house owner in the moment of the acquisition, instead he “promises” to share his future profits earned by selling the built units (SILVA, 2008; ZACCHI, 2014).[5] Hence, the price of the house directly depends on the maximum buildable-up area of its parcel, not from the house itself (DAVIS and HEATHCOTE, 2007).

Thus, the reduction of the maximum buildable-up area of the land within the URA reduced the economic potential of the parcel, thereby looking at this effect, we expect houses’ prices to decrease. However, accordingly to the apartments’ prices, an opposite effect may emerge. As the law potentially increases the welfare of the residents and give rises to a positive amenity effect there is an contrary effect which would push prices up. In this case, we hypothesize that the economic reduction of the land is a much stronger effect than the gain in amenities, thus, we expect houses prices to decrease.

The objective of this study is to assess the causal effect of this law on both houses’ and apartments’ prices. According to recent literature, our study reflects a recurrent empirical concern in the field of Urban Economics, it analyzes the impact of different regulations on the urban properties’ market value (SHEPPARD, 2004; QUIGLEY; RAPHAEL, 2005; IHLANFELDT, 2007; GLAESER; WARD, 2009).

To capture the desired causal effect, in the absence of a random experiment, we will “create a Randomized Experiment” from Non-Random Selection. Specifically, adapting Dell (2015) and Grembi et al. (2014) idea, it would be tempting to use a cross-sectional Geographic Regression Discontinuity Design (GRDD), which

[4] Less than 40% of Recife’s population has sanitary or domestic sewage (IBGE, 200).
[5] That way, the house owner do not receive immediately the amount owed by the buyer, instead he owns a share of the builder’s total revenues which would be received by the end of the selling process.

includes two cut-offs (latitude and longitude), seen as a local experiment near the cut-off where treatment status changes. However, as pointed out by Grembi et al. (2014), the standard GRDD assumption of continuity of potential outcomes[6] is not verified in our case, since the threshold created by the law coincides with the neighborhoods' administrative boundary which define intrinsically different neighborhoods' itself.

Thus, aiming to capture part of the non-observables and the preexisting differences, we use a Differences in Geographic Discontinuity (Diff-in-Geo-Disc) design to study the effect of the Twelve Neighborhoods' Law on properties' value. The use of the Diff-in-Geo-Disc design is grounded in the basic ideas of a standard Geographic Regression Discontinuity Design (GRDD) and Differences in Differences (Diff-in-Diff). Hence, in the absence of a randomized control trial, once the mechanism of selection of treatment and control condition is known and observable a Diff-in-Geo-Disc design could provide unbiased estimates of treatment effects on an outcome for units near the geographic boundary. (REARDON et al., 2010; COOK et al., 2008)[7].

Therfore, we hypothesize that the effect was caused through the two strongest channels: houses' prices had fallen due to the reduction of the economic potential of the land and, on the other hand, apartments' prices had increased due to supply restriction and amenities gains. Our findings are robust to different model specifications and placebo tests. Results obtained considering different strategies were quite similar, which only adds credibility to our empirical findings and support our causal claim. Thus, we contribute with the land-use literature that is still, inconclusive and not conducive to generalization, as pointed out by Quigley and Rosenthal (2005), Quigley (2007), and McDonald and McMillen (2012).

From the best of our knowledge, this topic has been virtually unexplored when considering Brazilian cities and is rarely studied for developing countries in general. Furthermore, a method that combines a differences-in-differences approach with a geographic regression discontinuity design, which we call as a

[6] Near the threshold the observations are equal except for the treatment assignment.
[7] This approach was initially popularized by Dell (2010) and with some recent examples such as: Dell, 2015; Keele; Titiunik, 2014; Keele; Titiunik; Zubizarreta, 2015, and Moore, 2015.

Diff-in-Geo-Disc design, has never been used for Brazil. Our findings support the evidences for both houses' and apartments' prices analyzed separately unlike most of the studies such as Ihlanfeldt (2007) and Zhou, McDonald and McMillen (2008) who analyzed land parcel and houses' prices, respectively. Furthermore, we are one of the firsts to rely on a non-parametric optimal bandwidth selector[8] using a Local Linear Regression Discontinuity estimator, which estimated two different bandwidths selection for each side of the boundary, as proposed by Catalonico et al (2016).

The remainder of this paper is organized as follows. In the next section we introduce a brief review of literature on land use and regulations, land prices, and housing prices. Section 3 describes our data characteristics; additionally, we show our methodological framework and our empirical application. In Section 4 we present and discuss the main results. In Section 5 we consider different specifications and placebo tests as robustness checks. Finally, in Section 6 we discuss our results and present a brief conclusion.

[8] Which was selected based on the *rdbwselect* from Stata.

2 BACKGROUND

2.1. Restrictions on Urban Land Use and Property Prices

Research on land use regulation in Real Estate Markets dates back to the 1970s (OHLS et al., 1974) and as documented by many urban researchers, urban land regulations are usually enacted to minimize some negative externality, such as unbalanced private use of urban land or the congestion effects of urbanization (BAILEY, 1959; ARNOTT; MACKINNON, 1977; QUIQLEY, 2007; MCDONALD; MCMILLEN, 2012). Regulations governing the use of land have become more numerous and more onerous in recent decades and yet its effects are poorly known given the *continuum* disagreement over the magnitude of its impacts and identification strategies.

Traditional urban models attained mainly to the linkage between public interventions through land use regulation and the welfare of citizens (BRUECKNER, 1998; SHEPPARD, 2004). In the last decade, the relation between land use regulation and housing prices received urban economists' attention (GREEN et al., 2005; HUANG and TANG, 2012; SAIZ, 2010); thereafter, "urban-level" impacts of such restrictions are less clear both theoretical and empirically, particularly in the case of restrictions on the buildings' heights (OHLS et al., 1974; IHLANFELDT, 2007; GLAESER and WARD, 2009; KOK et al., 2014).

In the past, researchers investigating this type of question have estimated hedonic property value models where the regulation was included as an exogenous regressor (GROUT et al., 2011; KNAAP, 1985). Nevertheless, standard hedonic models (SHEPPARD, 1999) considers property's market prices (usually log prices) as a linear combination of property ***observable*** characteristics and their implicit market price (GIBBONS, 2013) as if in an ideal randomized trial where households would be assigned to different dwellings randomly. Notwithstanding, household and governments endogenously choose, their settlement location and law coverage due to their own preferences. Thus, non-observable characteristics could influence both properties' value and government's decision; therefore, the traditional hedonic approach is likely to be invalid leading to omitted variable biases[9](KOK, 2013).

In this sense, at a city-level, one of the first to specifically analyze the impact of height restrictions on property prices recognizing the existence of selection bias, were Pogodinski and Sass (1994). In their paper, they tried to show some preliminary insight about the role of the endogeneity, sometimes inherent to zoning decisions, on the estimated results, thus they illustrate how selection bias is capable of distorting results when models are constructed on a naïve approach. Their findings showed that zoning decisions, such as height and floor size restriction had significant impacts on properties prices located within the restricted if they considered the zoning decision as exogenous and did not control for selection bias. Nevertheless, after "controlling for selection bias"[10] they found that the zoning effect disappeared.

Over the years, new ways of controlling for selection bias and non-observable influence were created and new results emerged. In land-use regulation literature, it had started with the inclusion of many observable characteristics, then, more sophisticatedly, to Instrumental Variables (IV), Differences in Differences (Diff-in-Diff) design, and recently to Regression Discontinuity Design (RDD). Each phase with some specific contributions is going to be succinctly mentioned bellow.

At first, an important empirical study was conducted by Quigley and Raphael (2005), who evaluated whether the degree of regulation in land-use and the growth in housing stocks influenced housing prices using an instrumental variable based on state-level employment trends. They also analyzed the price elasticity of housing supply according to different degrees of regulation. Their results indicate that housing was more expensive in more regulated cities. Ihlanfeldt (2007), studied the effects of land use regulation on houses and vacant

[9] LeSage and Pace (2009) notice that latent unobservable influences related to several factors (urban structure, green areas, amenities or commercial zones, among others) may affect the dependent variable. Urban public interventions can benefit specific segments of the population, affect transport costs and wellbeing, give better access to public spaces; many possible omitted bias.

[10] Due to the lack of instruments, they estimated four different specifications of the tax and zoning equations. They included possible land-use allocation as a function of locational and topographic measures excluding demographic variables.

land prices for cities located in the State of Florida and, as Pogodinski and Sass (1994), he recognized the possibility of endogeneity and selection bias. Thus, to address endogeneity, the author used an instrumental variable approach using jurisdictional variables from the 1990 Census such as: the proportion of adults possessing a college degree. His results indicated that there was a strong linkage between regulation and properties values.

Zhou, McDonald and McMillen (2008) utilized a diff-in-diff approach to access the impact of zoning changes from “hierarchical” to “exclusive” system in Chicago. They analyzed land parcels at the borders between residential and non-residential (commercial or manufacturing) zones. Their results indicated that land values in non-residential zones enjoyed a price increase; however, no significant change was detected in land value in the residential zone. Following a similar strategy, Zabel and Dalton (2011) also accessed the regulatory effect of minimum lot size zoning on house prices. They investigated the impact minimum lot size regulation on house prices controlling for “district non-observable time fixed factors” and found that prices were positively associated with regulation (DUARTE et al., 2014)

In recent years, the impact of regulations on housing prices has received more solid contribution. The access to more detailed and sometimes georeferenced data have led researchers to access better empirical methods and analyses of housing market effects (GLAESER; WARD, 2009; Saiz, 2010; HUANG; TANG, 2012). A recent paper closer to our approach, is Grout, Jaeger and Plantinga (2011). They used a Geographic Regression Discontinuity design to investigate the determinants of urban land prices in Portland. They segmented the Urban Growth Boundary (UGB) in 9 different segments and found significant price differences across it. More recently, Turner et al. (2014) proposed a novel strategy for estimating a possible causal effect in order to evaluate the impact of land use regulation on welfare. Their strategy was based on a decomposition of the regulation effect into three components. They exploited cross-border changes with a Regression Discontinuity design testing different bandwidths. Their findings suggested that there was a large negative effect of regulation on the value of land and welfare in the studied regions.

There is little evidence reported in the literature for developing countries. As for Brazilian related literature, Dantas et al (2007) and Duarte et al (2014) attempted to estimate the effect of the Twelve Neighborhoods' Law for land-lots and apartments, respectively. However, both researches presented potential problems and potentially fail to capture the influences of non-observables characteristics of treated and un-treated. The first used a traditional spatial hedonic pricing model and the second used a diff-in-diff design failing to capture the spatial relations within units[11] and the boundary which we captured by including the coordinates (latitude and longitude). Our paper goes in the same trend of the result of Turner et al (2014); nevertheless, we further analyze changes on the price of apartments and houses using further polynomials specifications for robustness checks and a different empirical strategy; a Differences-in-Geographic-Discontinuity Design.

From the best of our knowledge, this paper is a new departure from the literature, since this topic has been virtually unexplored when considering Brazilian cities and is rarely studied for the case of developing countries in general. Furthermore, a Diff-in-Geo-Disc design has never been used for studying Brazilian urban questions. The chosen approach allows us to use non-parametric bandwidths selection methods, which could capture a better matching within treated and untreated units. In addition, it also eliminates potential results' contamination given by the arbitrary definition of neighborhoods' and law's boundaries.

[11] Neighboring relations and Amenities effects which are captured once the geographical coordinates are included in the model.

3 EMPIRICAL FRAMEWORK

3.1. Setup and Notation

When studying the causal impact of land-use restrictions on property values, a major methodological concern is that the enactment of the law may not be orthogonal to unobserved factors that also affect property prices. As in any other identification approach, we adopt a binary potential outcomes framework. We are interested in the effect of treatment for unit i, $ζi = Y_{i1} - Y_{i0}$, where Y_{i1} corresponds to the transacted value of a treated unit, i.e. the unit that is inside the Urban Restructuring Area (URA) which was transacted after the law had been enacted and Y_{i0} would be the outcome of the unit *i* if it had not been treated. As we cannot observe both Y_{i1} and Y_{i0} simultaneously for any given unit, we are going to use a Diff-in-Geo-Disc design approach to recover the effect of the law ζi.

Following Keele and Titiunik (2014), Dell (2010), Dell at al. (2015), and Grembi (2014), similarly to a standard GRD “plugged in” a diff-in-diff approach, in a Diff-in-Geo-Disc design, we compare treated and untreated units which are within a certain distance to the cut-off given a specific time, as if the geographic boundary had split units into treated and control areas randomly in two periods of time. Additionally, in this case, the geographic boundary is simply represented by the coordinate systems: latitude and longitude. Our approach is going to be a sharp Diff-in-Geo-Disc design, since the treatment assignment is considered a deterministic function and the probability of treatment jumps from 0 to 1 discontinuously along the boundary with the enactment of the law in December 2001. Formally, treatment assignment is given by:

$$\tau_{it} = \begin{cases} 1 \text{ if } i \in \text{URA } \textbf{and} \text{ T} > \text{December 2001} \\ 0 \text{ if } i \notin \text{ URA } \textbf{or} \text{ T} < \text{December 2001} \end{cases}$$

Thereby, a unit is considered to be treated if it is inside the treatment area and was transacted after the enactment of the law. An additional assumption for the employment of Diff-in-Geo-Disc design is that there cannot exist selective sorting across the geographical boundary. We controlled for this problem since the law hadn’t provoked substantial out-migration from the URA, leading to a larger indirect effect. In addition, following Keele et al. (2015), we assumed that near the boundaries potential outcomes and treatment assignment are conditionally independent given predetermined covariates.

Importantly, note that in our empirical analysis, the boundary created by the law coincides with the administrative boundaries of the neighborhoods thus there could be a “contamination” effect that existed before the law’s enactment which wouldn’t be captured with a simple cross-sectional GRDD. Thus, as suggested by Grembi et al. (2014), in order to minimize the “compound treatment” issue and make inferences about the effect of the law separately, i.e. despite any other administrative influence, we use a Differences in Discontinuity (Diff-in-Disc). As our boundary is *geographic*, we are going to call it a Diff-in-Geo-Disc design.

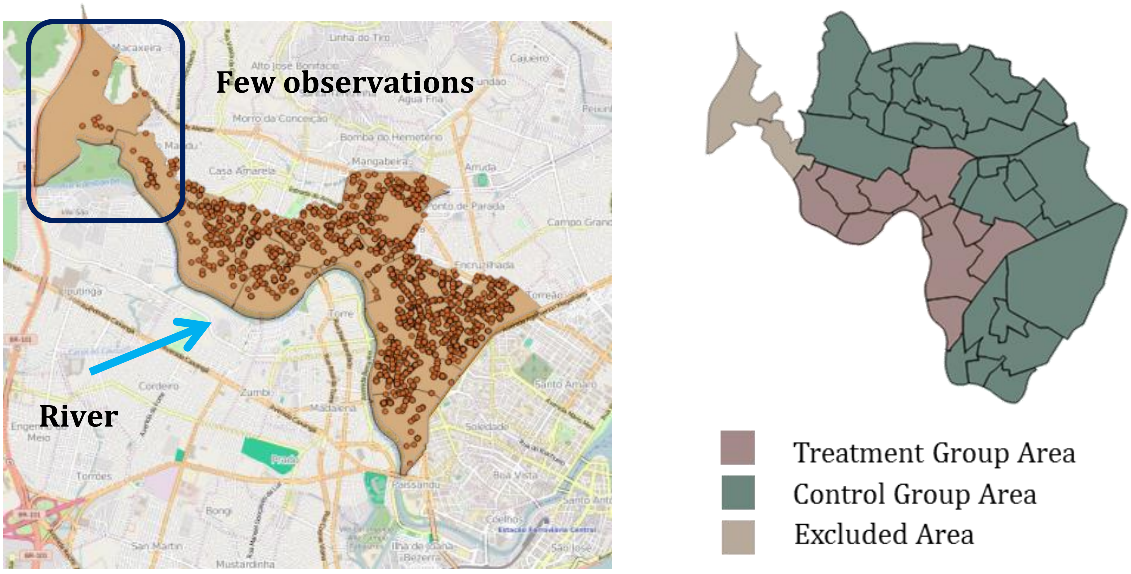
In a Diff-in-Geo-Disc design, treated and control groups near the boundary are good counterfactuals since we consider as if the treatment was random environs the boundary. We restricted our potential control group to the northeast region, as we can see in Figure 2. We excluded the southwest frontier because it borders an important river for the city (Capibaribe River), thus, in this case, we wouldn’t be able to separate the effects from the policy and the effects of the river. We also excluded the northwestern neighborhoods (represented in Figure 2 in orange) due to the lack of a sufficient number of observations to make our estimates credible since the region mainly consists in a forest reserve. Therefore, our treated units were considered the neighborhoods in red transacted after the law’s enactment and the control units the observations in the green area.

We had restricted our visual analysis to the 2,000 meters buffer since that beyond two kilometers the buffer crosses the city limit. However, in order to find the best confounders, in these two potential regions, we relied in a non-parametric optimal bandwidth selector[12] using a Local Linear Regression Discontinuity estimator as proposed by Catalonico et al.. (2016).[13] which do not suffer from bias when the explanatory variable is not uniformly distributed and are based on locally fitting a line rather than a constant, thus it is considered to be superior in terms of bias performance than Kernel regressions. Due to the number of observations, we had to define the parameter of pre-treatment and

[12] Which was selected based on the *rdbwselect* from Stata.
[13] The procedure was implemented using a *msetwo* which defines two different mean square error optimal bandwidths (below and above) the cutoff for the RD treatment effect.

post-treatment as: from January 2000 to November 2001 and from December 2001 to December 2003, respectively.

Figure 2 - Areas Specification



Source: Elaborated by the author

In addition, as proposed by Grout et al. (2011), to allow us to capture the heterogeneity within the study are, we divide both treatment and control groups in four segments. We chose 4 segments to our baseline specification seeking to equalize political boundaries and number of observations; however, other specifications, such as one, two and three segments were also tested. In Figure 3 it is illustrated how the four segments section were divided and how the units, represented by dots, were “evenly” split.[14] We reiterate that we split our boundary into these four segments seeking to equalize political boundaries, the number of observations and heterogeneity within segments. In the Figure 3 (a) treated area is represented in darker gray, while control area is represented in medium gray. Figure 3 (b) and (c) represent how control and treated units were distributed, respectively.

[14] Each color is attached to one segment.

Figure 3 - Sample Segments

(a) Treated and non-treated areas

(b) Non-treated units distributed by segments

(c) Treated units distributed by segments

Source: Elaborated by the author

3.2. Model Specification and Identification

From the best of our knowledge, there has not being applied any other political or administrative measure to our study area during the observed period. However, by estimating a standard cross sectional GRDD someone might argue that the Compound Treatment Irrelevance Assumption did not hold, i.e., that the effect that we are measuring could be driven by other political or geographical factors which coincide with our boundary.

As suggested by Grembi (2014), in those cases under appropriate assumptions, we could estimate a difference-in-discontinuity. The intuition behind this strategy is simply that, we create an estimator that takes the difference between two cross-sectionals Standard Geographic Regression Discontinuity Design, one before December 2001 (when all the "others features" but the law took place) and the other cross-sectional discontinuity at the boundary after December 2001 (when both the law and potentially "others features" took place). That way, it is a sort of difference-in-differences (diff-in-diff) approach and therefore the assumptions for applying a diff-in-diff strategy are required. We consider that the Diff-in-Geo-Disc is a more "complete model" and we are going to report all the estimates and robustness checks for this specification. Based on Grembi (2014), our baseline specification consists on the Equation (1):

$$\begin{aligned} y_{imctbs} = \alpha_0 + \alpha_1 Dist_i + URA_i(\gamma_0 + \gamma_1 Dist_i) \\ + T[\delta_0 + \delta_1 Dist_i + URA_i(\beta_0 + \beta_1 Dist_i)] \\ + X'_i\beta_2 + f(geographic_i) + \phi_m + \phi_c + \phi_t + \phi_b + \sum_{s=1}^{S} \phi_s^i \\ + \varepsilon_{imctbs} \end{aligned} \quad (1)$$

Where y_{imctbs} represents the outcome variable of interest, price per square meter of the units for observation *i* at month *m* according to its' typology *b* along the segment *s* of the URA boundary in the census tract *c* at year *t*. In both cases, houses and apartments, the dependent variable was the logarithm of the price per square meter to avoid capturing differences in sizes. URA_i represents an indicator function which equals to 1 if unit i was inside the URA and 0 otherwise; $Dist_i$ is a vector which contains the distance to the boundary. Distances inside the URA_i are considered positive, while distances outside the URA_i are considered negative. *T* represents an indicator function which equals to 1 if unit *i* was transacted after the enactment of the law (after December 2001) and 0 otherwise. X_i is a vector of covariates that includes the characteristics of properties differing between the two regions other than the treatment of interest that are presented in detail at the Table 2 and Table 3.

In addition, we split our boundary into four segments seeking to equalize political boundaries and number of observations. $\sum_{s=1}^{S} \phi_s$ represents a set of boundary segments fixed effects. It is an indicator function ϕ_s^i that equals 1 if the unit *i* is closest to the segment *s* and zero otherwise. As Dell (2015) and Grout et al. (2011), we are aware that since latitude-longitude polynomials are included, they already control for geographic location, segment fixed effects has little impact on our estimates. In fact, we included segments fixed effects in all our specifications as an attempt to capture some heterogeneity throughout the border (Grout et al., 2011; Dell, 2010).

The other fixed effects were represented by ϕ_m which controls for months/seasonal fixed effects; ϕ_c that controls for the census tract with the average income of the head of households at a census tract level; ϕ_b which controls for the typology of the building, since that building with less than four floors, are called "coffin buildings" which characteristics differ from higher buildings; and ϕ_t controls for the fixed effects of the year of transaction. Unbiased estimation of β_0, the parameter of interest, requires, among other assumptions, that URA_i is uncorrelated with ε_{imctbs}.

The multidimensional RD polynomial $f(geoghaphic_i)$ used is similar to the ones proposed by Dell (2010) and Dell et al. (2015), which controls for smooth functions of geographic location. Often in the GRD design, the score is defined as the shortest distance to the boundary; so, equally distant unit are taken as a valid counterfactual for each other. However if this concept is used alone, it could mask boundary heterogeneity since that this measure of distance ignores the spatial nature of geographic locations. As our border could be considered a long one, this "naïve" implementation would probably lead to misleading results since is does not take into account geographic heterogeneity considering distant observations with the same distance to the border as equal. Thus, in such cases, the inclusion on a $f(geoghaphic_i)$ polynomial is crucial for getting accurate results.

Therefore, following Dell et al. (2015) and in contrast with Dell (2010), our specifications do not include high order polynomial such as cubic or quartic. Using high order polynomials for local linear regressions could lead to very sensitive results and misrepresented confidence intervals (Gelman and Imbens, 2014). Therefore, our approach focuses on linear and quadratic cases. Hence, trying to capture both heterogeneities, our estimates represent the "complete" version of the multidimensional RD polynomial where, besides latitude and longitude, we include the "shortest distance" to the boundary polynomial where the distance is by construction $d > 0$ for units within the URA and $d < 0$ otherwise.

3.3. Data

Recife is a coastal city in the northeast of Brazil founded in 1537, during the early Portuguese colonization. Initially, the urban occupation of Recife was concentrated near the center[15] around the harbor; later on, due to urban transportation system and technology the city expanded hinterland. Given job

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[15] Neighborhoods of Boa Vista, São José and Santo Antônio.

opportunities, attached to the port and tourism, Recife has developed both in population and in density. As a result of this process, the city has a population of approximately 1.6 million inhabitants distributed over 217 km^2 in 94 neighborhoods (IBGE, 2014). Currently it is the capital of the state of Pernambuco and it is one of the most important capitals of Brazil having the fourth highest population density (IBGE, 2014). Recife's occupation is distributed into flats' and hills' areas; however, our study is going to be concentrated in a flat area which allows us to estimate the Cartesian distance between units.

Our data consists on property sales records obtained from the base of the City Hall - Property Transfer Tax database (ITBI) - which provides monthly information on properties transactions in the city of Recife from January 2000 to December 2003. Additionally, we geocoded all units' zip codes; that way, we've recovered georeferenced data in unit level which gave us a number of advantages. Besides the information on the transaction value of each property, this dataset provides some property's characteristics, such as: number of floors of building, number of units in the building, building floor space, construction standard, among a few others as described in Table 1.

Our data accounts for all transactions recorded in Real Estate Registries, excluding houses and apartments in favelas and under R$ 9,999.00 (brazilian currency)[16], practically covering the entire city. For the purpose of this study, we restricted our sample within *treat* and *control areas,* as illustrated in Figure 2, keeping nearly 7,700 apartments and 1,800 houses transacted within a two kilometer distance to the boundary[17].

Following Kok et al. (2014), aware that the price of a property reflects the economic value of a specific site and of the amenities available at that location, in our model, we tried to capture this effect including the distance to some of the most important amenities in the city. Kok et al. (2014) also point out that

[16] Because this is not a reasonable amount of transaction, we assumed this value as a "fill in" error.
[17] The non-parametric boundary selected was much smaller which led to a fewer number of observations that had to aggregate our data before and after law's enactment from January 2000 to November 2001 and from December 2001 to December 2003.

demographics are strongly related to the price of land, that way; we tried to capture this effect including neighborhood population.

Table 1 - Description of the variables

Variable name	Description
Price-BRL[18]	Transaction Property Price
Area (m^2)	Private built area of the property
+4Floors	buildings with 4 floors or more
Low standard	Low construction standard (dummy)
Medium standard	Medium construction standard (dummy)
High standard	High construction standard (dummy)
Year of Construction	Year the Property was Build
Regular	Property considered to have fair conservation conditions (dummy)
Good	Property considered to have good conservation conditions (dummy)
Excelent	Property considered to have excellent conservation conditions (dummy)
Law - dummy	Indicates whether the property is located in the affected
E	Latitude
N	Longitude
d	Distance to the Boundery

Our data format, not aggregated and geo-referenced, allows us to precisely estimate how the dwellings' prices vary around the boundary of interest (KEELE; TITIUNIK, 2014). We considered that prices provided in this dataset are a fair approximation to the actual amount paid given that, in on hand, undervaluation is economically discouraged due to the incidence of taxes on the gains of capital appreciation that the buyer would incur in a future sale (long term loss); on the other hand, overvaluation would incur losses for the buyer due to higher IPTU (Urban Property Tax) value (short term loss), (DUARTE et al. 2014).

We used Geographic Information Systems (GIS) software to process the data before the final statistical analysis. Without a GIS analysis, a Diff-in-Geo-Disc design would be significantly weakened (KEELE; TITIUNIK, 2014). First, we geocoded all unit's zip codes[19] which allowed us to calculate many unit relations such as distance to the boundary of interest. We are aware that the calculation of Euclidean distances could be a naïve strategy since that using this measurement

[18] Brazilian currency.

[19] Geocoding means to convert addresses into a coordinate system, in our case latitude and longitude.

for rugged and bumpy lands could severely underestimate distances (BANERJEE, 2005). Nevertheless, our study area is composed by a flat region where short distances would be calculated, which makes using Euclidean distances non-problematic.

3.4. Descriptive Statistics

Descriptive statistics report were generated for treatment and control groups for both houses and apartments and are show in Table 2 and 3. Some of the numbers show a slight difference between Treatment and Control Group; however it is necessary to remember that the numbers presented consist for years before and after the enactment of the law, thus, a hasty inference about the behavior of this numbers could be misleading. Notwithstanding, if there is a remaining discrepancy we intend to capture it using our Diff-in-Geo-Disc design. From the tables 2 and 3 it is possible to infer that observable characteristics between Treatment and Control Group, for houses and apartments, are very similar.

Table 2 - Descriptive Statistics – Apartments

	Control Group			Treatment Group		
VARIABLES	N	mean	sd	N	mean	sd
Year of Transaction	3,456	2,001	1.067	1,792	2,002	0.555
Month of Transaction	3,456	6.555	3.383	1,792	6.915	3.392
Valuation Price (R$/m^2)	3,456	82,21	59,82	1,792	123,04	72,15
Number of Stages	3,456	5.955	5.315	1,792	7.874	5.841
Land Area (m^2)	3,456	1,755	1,791	1,792	1,730	1,620
Private Area (m^2)	3,456	136.1	85.11	1,792	163.1	87.24
Year of Construction	3,456	1,986	13.94	1,792	1,992	11.25
+4Floors	3,456	0.760	0.427	1,792	0.912	0.284
Low Standard	3,456	0.341	0.474	1,792	0.14	0.347
Medium Standard	3,456	0.440	0.496	1,792	0.427	0.495
High Standard	3,456	0.219	0.413	1,792	0.432	0.496
Good Conservation	3,456	0.016	0.127	1,792	0.004	0.062
Excellent Conservation	3,456	0.982	0.132	1,792	0.996	0.062
Age of the Building	3,456	14.78	13.98	1,792	10.36	11.28
Population of the Census Tract in 2000	3,456	1,070	326.9	1,792	1,165	266.5

Table 3 - Descriptive Statistics – Houses

	Control Group			Treatment Group		
VARIABLES	N	mean	sd	N	mean	sd
Year of Transaction	820	2,001	1.079	159	2,003	0.561
Month of Transaction	820	6.212	3.410	159	6.899	3.415
Valuation Price (R$/m^2)	820	77,69	86,42	159	129,03	91,43
Number of Stages	820	0.006	0.175	159	0.013	0.159
Land Area (m^2)	820	469.1	839.1	159	729.7	1,179
Private Area (m^2)	820	172.3	132.8	159	204.7	112.9
Year of Construction	820	1,964	19.59	159	1,968	21.29
Low Standard	820	0.761	0.427	159	0.616	0.488
Medium Standard	820	0.206	0.405	159	0.327	0.471
High Standard	820	0.033	0.179	159	0.057	0.232
Good Conservation	820	0.082	0.274	159	0.107	0.31
Excellent Conservation	820	0.890	0.313	159	0.893	0.31
Age of the Building	820	37.20	19.64	159	34.89	21.33
Population of the Census Tract in 2000	820	1,114	306.6	159	1,213	260.2

4 RESULTS

4.1. Basic Results

Most studies show a positive association between more restrictive zoning and property value, when “aggregated”; however, our findings support the evidence that, when analyzed separately, houses’ unit prices decreased while apartments’ unit prices increased, as showed in the Table 4. The reported results consider price per square meter, which is called unit price, in order to avoid capturing differences in house sizes.

More specifically, for our baseline result, we consider both distance and latitude and longitude second degree polynomials and include the fixed effects and observable characteristics. Due to the number of observations, we had to aggregate the period after the treatment from December 2001 (immediately after the treatment) until December 2003, thus our sample consists in two years before and two years after the treatment. Results show that after the enactment of the law, house prices decreased by 25.2%, while apartment prices increased by 7.2%. Those values, thereby, are plausible and aligned with, for example, Ihlanfeldt (2007) and Grout et al. (2011) expectations. We hypothesize that the effect was caused through two different channels: houses’ prices had fallen due to the reduction of the economic potential of the land; on the other hand, apartments’ prices had increased due to supply restriction.

Table 4 - Baseline Results

Second Degree Polynomial		
	Apartments	Houses
	(1)	(2)
Bureaucratic	0.072*	-0.252*
	(-1.78)	(-1.65)
Locational Variables	YES	YES
Observable Characteristics	YES	YES
Intrinsic	YES	YES
Fixed Effects	YES	YES
R^2	0.7682	0.4751
Obs.	1422	821
F	163.94	21.19
Prob>F	0,0000	0,0000

OBS: t statistics in parentheses; Coefficients different from zero are denoted by: * p<0.10, ** p<0.05, *** p<0.01; Private Area, in Logarithmic scale, Standard of the construction and distance to de beach were considered intrinsic characteristics of the unit. Locational Characteristics: Distance to the Center Business district; Distance to the park, Distance to green areas, distance to Capibaribe river, and Distance to ZEIS. Observable Characteristics include: Launching, Conservation, Demographic Population, and the age of the building. Fixed effects: Seasonal, Segment, Typology, Census Tract and year of transaction effects. The optimal bandwidths were created using the rdbwselect from Stata using the option *msetwo*.

In the next section, we evaluate the validity of our results considering a variety polynomials' specification, inclusion or exclusion of covariates, falsification tests, and model specification.

5 ROBUSTNESS CHECKS

In order to provide additional support to our findings, we run some robustness checks and placebo tests to investigate if there was something other than the treatment itself being captured by our result. Given the nature of our empirical exercise, our robustness checks consist in testing for the inclusion and exclusion of covariates to check if our results are sensitive to observable characteristics. We also test for different polynomial specification to check for the sensitivity of our results to the geographical polynomials, for year falsification where we chance the actual date of the enactment of the law to a “placebo” date, and, finally, before and after tests to verify for the irrelevance of the treatment before the law.

5.1. Covariates

According to Keele, Titiunik, and Zubizarreta (2015), the assignment of the treatment via geographic location should create one “as-if random variation” in treatment status, thus covariates shouldn’t be necessarily included in our model to infer the treatment effect. In other words, the treatment variable should not be affected by the inclusion or exclusion of covariates. Thus, to determine whether someone had or had not estimated the effect of interest, one of the most common robustness checks is to drop and addback covariates and see the behavior or the treatment coefficient. If the coefficient changes significantly, probably there is something else determining the treatment effect apart from the treatment itself. Ideally, in different scenarios, the coefficient should be the identical, however, in practice, due to correlations between variables, they usually differ a little.

As pointed out by White and Lu (2010), robustness is necessary to a valid causal inference, so at least two alternate choices of covariates, e.g. X1 and X2 should be provided to ensure the validity of the estimated treatment effect. In our paper we present, in Table 5, four different specifications of X_i for the Quadratic Polynomial in Latitude and Longitude and Quadratic Polynomial in Distance to the Boundary.

Without any covariates, just including the Intrinsic Characteristics of the dwelling and the fixed effects, results show that after the enactment of the law, house prices decreased 32.2%, while apartment prices increased 11.4% which are much higher than our baseline results; hence, corroborating with our causal explanation. In addition, as a robustness check we drop and addback “Blocks of Covariates” to show that the results do not change much. The first column refers to our baseline results, thus includes all possible the blocks of variables. In the second column of results, the blocks of Locational Variables and Observable characteristics had been suppressed. In addition, on the third column, only Observable Characteristics were not included on the estimation, and finally, on the last column, Locational Variables were not considered. This procedure illustrates that our results are not significantly sensitive to the inclusion or exclusion of covariates, thus the effect found is not driven by specific covariates inclusion. Furthermore, different polynomial specifications were tested; however, due to limited space are not going to be presented[20].

Table 4 - Covariates Robustness Checks

	(1)	(2)	(3)	(4)
HOUSES				
Bureaucratic	-0.252*	-0.322**	-0.296*	-0.253
	(-1.65)	(-1.98)	(-1.90)	(-1.62)
APARTMENTS				
Bureaucratic	0.0720*	0.114**	0.117***	0.0805**
	(-1.78)	(-2.58)	(-2.61)	(-2.01)
Locational Variables	YES	NO	YES	NO
Observable Characteristics	YES	NO	NO	YES
Intrinsic	YES	YES	YES	YES
Fixed Effects	YES	YES	YES	YES

OBS: t statistics in parentheses; Coefficients different from zero are denoted by: * p<0.10, ** p<0.05, *** p<0.01. Private Area, in Logarithmic scale, Standard of the construction and distance to de beach were considered intrinsic characteristics of the unit. Locational Characteristics: Distance to the Center Business district; Distance to the park, Distance to green areas, distance to Capibaribe river, and Distance to ZEIS. Observable Characteristics include: Launching, Conservation, Demographic Population, and the age of the building. Fixed effects: Seasonal, Segment, Typology, Census Tract and year of transaction effects.The optimal bandwidths were created using the rdbwselect from Stata using the option *msetwo*.

[20] These results could be provided by the authors upon request

5.2. Polynomial Specification

As pointed out by Del (2010), there is no a priori reason why a particular polynomial specification should be the most appropriate to a Diff-in-Geo-Disc design model. Thus, there is not a predetermined optimal interaction between longitude, latitude, and distance to the boundary. Given these concern, we estimate the effect considering both distance and latitude and longitude polynomials, jointly and separately, as presented in the Tables 6. In this paper we limit our estimations to first and second degree polynomial, both in distance and in latitude and longitude following Gelmans and Imbens (2014)[21].

In this section, with our baseline model specification, we vary our $f(geoghaphic_i)$. The column 1 of the Table 6 we represent the baseline model with a Linear Polynomial in Distance to the Boundary; in column 2, we change this specification to a Linear Polynomial in Latitude and Longitude; in column 3, we change this specification to a Linear Polynomial in Distance to the Boundary and Linear Polynomial in Latitude and Longitude; in the column 4, we change this specification to a Quadratic Polynomial in Latitude and Longitude; and finally, in the column 5, we change this specification to a Quadratic Polynomial in Distance to the Boundary and Quadratic Polynomial in Latitude and Longitude.

[21] Who suggest not considering high order polynomials in our f(geographic) polynomial

Table 5 – Polynomial Specification Robustness Checks

	Base Line Model Results				
	(1)	(2)	(3)	(4)	(5)
	APARTMENTS				
Bureaucratic	0.0615 (-1.5)	0.0743* (-1.8)	0.0712* (-1.74)	0.0768* (-1.89)	0.0720* (-1.78)
	HOUSES				
Bureaucratic	-0.280* (-1.75)	-0.274* (-1.72)	-0.276* (-1.71)	-0.319** (-1.99)	-0.322** (-1.98)
Locational Variables	YES	YES	YES	YES	YES
Observable Characteristics	YES	YES	YES	YES	YES
Intrinsic	YES	YES	YES	YES	YES
Fixed Effects	YES	YES	YES	YES	YES

OBS: t statistics in parentheses; Coefficients different from zero are denoted by: * p<0.10, ** p<0.05, *** p<0.01; Column's meaning: (1) Linear Polynomial in Distance to the Boundary (2) Linear Polynomial in Latitude and Longitude (3) Linear Polynomial in Distance to the Boundary and Linear Polynomial in Latitude and Longitude (4) Quadratic Polynomial in Latitude and Longitude (5) Quadratic Polynomial in Distance to the Boundary and Quadratic Polynomial in Latitude and Longitude. Private Area, in Logarithmic scale, Standard of the construction and distance to de beach were considered intrinsic characteristics of the unit. Locational Characteristics: Distance to the Center Business district; Distance to the park, Distance to green areas, distance to Capibaribe river, and Distance to ZEIS. Observable Characteristics include: Launching, Conservation, Demographic Population, and the age of the building. Fixed effects: Seasonal, Segment, Typology, Census Tract and year of transaction effects.The optimal bandwidths were created using the rdbwselect from Stata using the option *msetwo*.

From the Column (1) we infer that, as pointed out by Dell (2010), the distance to the boundary alone is, sometimes, not enough to capture the wanted effect, since characteristics and heterogeneities vary with latitude and longitude. From Column (2) on we include latitude and longitude in our f(geographic) specification attempting to capture the locational heterogeneities. Following Dell (2015) with her baseline model[22], we see that after the enactment of the law, house prices decreased 27.6%, while apartment prices increased 7.12%.

Hence, Table 6 shows that results do not change much, illustrating that our findings are not significantly sensible to the variation of the Geographical Polynomial Specification. In addition, different polynomial specifications were tested; however, due to limited space are not going to be presented[23].

[22] A Linear Polynomial in Distance to the Boundary and Linear Polynomial in Latitude and Longitude.
[23] These results could be provided by the authors upon request

5.3. Year Falsification

We also consider a placebo test considers a “placebo” law, faking the actual date of treatment. This involves re-estimating our model over the pre-treatment period, with the assumption that the treatment happened at a date other than the actual enactment date. Presumably, since the treatment should have happened in the actual date without anticipatory effects, the estimates under this placebo date treatment should be insignificant.

Due to the delay between the enactment of the law and the approval of a building project, our chosen placebo dates were one year before the treatment, i.e. on December 2000. Our results are shown in the Table 7 and in order to add even more credibility to our findings, from Column (1) to (4), we follow the same strategy of our covariates robustness checks. Thus in Table 7 we bring a simultaneous covariate and placebo date of treatment robustness check. Coefficients remain insignificant throughout the table illustrate, which corroborates with our causal inference that nothing else happened other than the law’s enactment. In addition, different polynomial specifications were tested; however, due to limited space are not going to be presented[24].

[24] These results could be provided by the authors upon request

Table 6 - Treatment Falsification Robustness Checks
Different Models specifications

	(1)	(2)	(3)	(4)
HOUSES				
Treatment at December of 2000				
Bureaucratic	-0.009	-0.079	-0.049	-0.006
	(-0.05)	(-0.42)	(-0.28)	(-0.03)
APARTMENTS				
Treatment at December of 2000				
Bureaucratic	-0.01	-0.061	-0.049	-0.014
	(-0.30)	(-1.51)	(-1.22)	(-0.40)

OBS: t statistics in parentheses; Coefficients different from zero are denoted by: * p<0.10, ** p<0.05, *** p<0.01; Intrinsic Characteristics Include: Private Area, in Logarithmic scale, Standard of the construction and distance to de beach; Locational Characteristics include: Distance to the Center Business district; Distance to the park, Distance to green areas, distance to Capibaribe river, and Distance to ZEIS. Observable Characteristics include: Launching, Conservation, Demographic Population, and the age of the building. The optimal bandwidths were created using the rdbwselect from Stata using the option *msetwo*. Fixed effects: Seasonal, Segment, Typology, Census Tract and year of transaction effects. The original treatment date was on December 2001. Column (1) considers Locational Characteristics, Observable Characteristics, Intrinsic Characteristics, and Fixed Effects. Column (2) considers Intrinsic Characteristics and Fixed Effects. Column (3) considers Locational Characteristics, Intrinsic Characteristics, and Fixed Effects. Column (4) considers Observable Characteristics, Intrinsic Characteristics, and Fixed Effects.

6 CONCLUDING REMARKS

By using an empirical strategy that combines GRD and Diff-in-Diff approaches, we intend to generate credible evidences about the impact of urban land use restriction on properties values. Such kind of evidences have not being further explored in developing countries, in addition, this is the first time that a Diff-in-Disc design is used in urban literature in Brazil.

Usually, most studies show a positive association between more restrictive zoning and property values when “aggregated[25]”; however, our findings provide new insights to the literature as we go further and analyze the effect of the regulation on houses and apartments, separately.

Our set of evidences support that when analyzed separately houses’ prices decreased, while apartments’ prices increased due to the height restriction of the buildings. We hypothesize that the effect was caused through two different channels: reduction of the economic potential of the land and supply restriction, respectively. Empirically, our results show that houses’ prices decreased on average 25.2%, while apartments’ prices increased on average 7.2%. Therefore , our results are consistent with our initial hypothesis and are aligned with the land use regulation literature.

In addition, Robustness Checks add credibility to our empirical findings and support our causal claim. They confirm that our results are not driven by a unique choice of covariates or polynomial specification, furthermore, when we used a year falsification and results are shown as insignificants, it also corroborates with our initial hypothesis that the effect captured is driven by the enactment of the law.

[25] Houses and apartments evaluated together.

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