Romanian Journal of Regional Science
Vol. 19, No. 1, Summer 2025

DOI: https://doi.org/10.61225/rjrs.2025.04

CRIMINALITY AND APARTMENT PRICES: A STUDY FOR RIO DE JANEIRO, BRAZIL

Luiz Andrés Ribeiro Paixão

Federal University of Rio de Janeiro (UFRJ), Brazil./ The Brazilian Institute of Geography and Statistics (IBGE), Brazil

Address: The Brazilian Institute of Geography and Statistics (IBGE), Avenida Pacheco Leão 1235, 5º andar lado A, Rio de Janeiro, Brazil

E-mail: luipai@yahoo.com

Biographical Note

Luiz Andrés Ribeiro Paixão is a substitute professor in Institute of Economics, UFRJ-Brazil, and technologist in Researcher Directorate, IBGE-Brazil. His research interests include urban economics, house price indices, criminality, and art market. ORCID ID: https://orcid.org/0000-0002-6378-9518

Abstract

Violence is one of the biggest problems in Brazilian society, Brazil being one of the most violent countries in the world. Rio de Janeiro is the second largest Brazilian city both in economic and population terms and is the most famous Brazilian city in the world. Measuring the social cost of violence is an important task to understand the Rio de Janeiro reality. There is some consensus in literature that housing prices are very sensitive to environment changes and there is a negative relationship between violence rates and housing price. We developed a hedonic price model to quantitatively determine the effect of violence on apartments price in Rio de Janeiro, using homicide and robbery rates as criminality proxies. A set of control variables were included since these variables were relevant to Rio de Janeiro's apartment market. We used spatial econometric frameworks to deal with the spatial nature of the data. Our results show that the increase in criminal violence is linked to the decrease in apartments prices in Rio de Janeiro.

Keywords: hedonic pricing, spatial econometrics, urban violence, housing Markets, Rio de Janeiro

JEL Classification: R3, R31, C21

1. Introduction

Crime is one of the biggest social problems in the word. In Brazil, the concern is greater since it is one the most violent countries in the world. The crime economics studies appoint that, when crime rates go up, the economic growth goes down, since firms decrease productive investments and individuals decrease their human capital accumulation. Demand for services which are consumed outside home, like leisure and cultural services, tend to decline and the same should occur with activities like tourism. Add to this, crime has consequences, like premature deaths and physical and psychological traumas for the victims, their relatives and friends. Summing up, violence generates economic costs. The violence cost influences politics as well. Candidates use violence as a platform to their election campaign. Politicians and political parties are evaluated for their performance against crime when they are in power.

Measuring the costs of violence is one important task for economists and others social scientists. However, this is not a trivial task. One way to fill this gap is analysing housing market. Housing prices are usually very sensitive to environment changes. In this term, changes in crime rates lead to changes in house prices, in a negative relationship. Since criminality is unequally distributed among the urban space, real estate located in more violent regions of the city tend to exhibit a price discount due to violence. The price discount due to crime rates is one proxy of the social cost of violence. The hedonic price model, usually used in housing price analysis, can be used to measure such cost. This technique consists in a regression between the price of good and its characteristics. To measure the costs of criminality, some violence rate among others housing characteristics is added in a hedonic housing price model.

What is the cost of violence implicit in apartment prices in Rio de Janeiro? This paper aims to answer this question by estimating a spatial hedonic price model for the Rio de Janeiro apartment market. In Brazil, Rondon and Andrade (2005) estimated the crime implicit price in a hedonic price model for Belo Horizonte's apartment rental market. Rondon and Andrade (2005) estimated different models for homicide and robbery rates. Further, Teixeira and Serra (2005) and Pontes, Paixão, and Abramo (2011) extended Rondon and Andrade's (2005) approach to Curitiba's apartment rental prices and Belo Horizonte's apartment sale prices, respectively. All these contributions used the traditional ordinary least squares (OLS) regression technique. Differently from these previous contributions, our analysis will focus on a different housing market (Rio de Janeiro), and we intend to estimate a spatial econometric hedonic model, since the literature points out that house prices are subject to spatial effects. Rio de Janeiro is the second largest Brazilian city in terms of population, and it is an important economic, political, and cultural center in Brazil. Additionally, Rio de Janeiro

is a worldwide famous city and the most important touristic destination in Brazil. So, understanding the relationship between criminality and apartment prices in Rio de Janeiro seems to be an important task.

Frischtak and Mandel (2012) previously estimated the effect of crime on house prices in Rio de Janeiro. Their objective was to evaluate the Peacemaker Police Unit (UPP – Unidade de Polícia Pacificadora) using a quasi-experimental method (difference-in-differences) for average housing sale prices in different districts (bairros). The authors used data from apartment and house listings available on the online classified website platform ZAP. The main results are that the UPP was successful in increasing housing prices due to crime reduction and furthermore, after this policy, housing price inequality decreased in Rio de Janeiro. Our objective is quite distinct from Frischtak and Mandel (2012). In this paper, we aim to measure the effect of crime on apartment price formation in Rio de Janeiro, measuring apartment price depreciation due to criminal activities. Differently from Frischtak and Mandel (2012), we use a database of apartment transactions where each transaction is the unit of analysis, instead of district averages.

It is important to highlight that hedonic spatial regressions are commonly used in Brazilian literature. Macedo (1998), Herman and Haddad (2005), Moreira de Aguiar, Simões, and Golgher (2014), and Campos (2015) are examples of papers in which spatial econometric hedonic models were estimated. The distinction of our contribution is estimating the hedonic spatial regression using Rondon and Andrade's (2005) crime cost estimation strategy. Thus, our results could be directly compared with these previous papers and we can evaluate the gains of using spatial hedonic price model regression instead of the standard OLS.

Recently, some studies have approached Rio de Janeiro's violence with distinct perspectives. Ianchan *et al*. (2023) showed that violence impacts cultural consumption habits. Using a survey conducted in a slum complex (Favela da Maré) the authors measured the violence impact on cultural consumption that takes place in a public space (cinema and music shows) instead of cultural consumption that takes place in a private space (watching movies and listening to music at home). The main result is that the increased of violence decreased the slum inhabitant's propensity to consume culture on public space. The subjective violence, the fear of being victimized by a stray bullet, has more impact on cultural consumption than the objective violence (number of police incursions and gangs' confrontations). Iachan *et al*. (2023) concluded that the violence and cultural consumption are correlated and cultural policies for Rio de Janeiro's poorest population should be thought together with social and security policies.

Others recently studies analyzed the violence in Rio de Janeiro from a regional perspective. These studies focused on Rio de Janeiro state instead of the city. Pio, Brito and Gomes (2021) realized

that UPP had a long run effect on violence decrease in the city in the 2010 and 2020 first year's decades. From a regional perspective, it had a negative spillover effect, since the criminality migrated from the capital to the interior of the Rio de Janeiro state (Carvalho, Montenegro and Martins, 2024). In a sectorial analysis of crime, there was an increasing on cargo theft occurrences from 2014 (Carvalho, Montenegro and Martins, 2024). Almeida and Montes (2021) studied the impact of crime and violence in investment (entrepreneur's expectations), from a regional perspective. The results are interesting for our purpose since it highlights the difference between the impact of violence in business in relation to the individual wellbeing. Almeida and Montes (2021) found that cargo theft is the principal type of crime that concerns Rio de Janeiro state's entrepreneurs. Extortion and commerce theft are the second and the third type of crime that mostly affected the entrepreneur's expectations, the two above homicide rates. From the consumer behavior perspective, homicide rate has more prominence, since this kind of violence has a greater impact on individual wellbeing.

The paper is organized as follows: this section makes an introduction of the thematic. The second section provides a literature review about crime in Rio de Janeiro, focusing on its growth from the 1980s. The methodology, model and variables are presented in the third section. The results are presented and analysed in the fourth section. Finally, the conclusion resumes the main findings of the paper.

2. Literature review

2.1. Hedonic price model and criminality

Thaler (1978) used a hedonic model to estimate the cost of crime in Rochester, New York-USA, being one of the first attempts to use the hedonic approach to violence costs estimation. The author estimated an OLS regression using a linear specification with many control variables and found that a one standard deviation in crime rates devaluated in 3,0% the housing price. Later on, Lynch and Rasmussen (2001) estimated violence cost using a hedonic price model to Jacksonville, Florida-USA. The number of crimes (violent crimes and property crimes) and the cost of crimes (violent crimes and property crimes) are chosen as proxies of violence. The cost of crimes weighted each crime by their seriousness degree. One regression was estimated by each crime proxy. The results showed that the cost of crime performed better than the number of crimes. The results improve when a high crime area was added as dummy variable. The elasticity of violent crime was -1,63% and property crime was -2,89%.

From European reality, Gibbons (2004) studied the impact of criminal damage in dwelling (vandalism, graphite, and arson) and burglary in dwelling in houses prices in London - UK. The two

variables were measured in density by km^2 for London's districts. The results showed that burglary in dwelling is not related with house prices. Criminal damage in dwelling, in its turn, depreciated the house prices. A unit increase in criminal damage in dwelling caused a 26,65% decrease in house prices. Ceccato and Wilhelmsson (2011) applied a hedonic price model analysis to the Stockholm-Sweden apartment market. Choosing a Scandinavian country, according to the authors, is interesting since Sweden is a co-ordinated market economy, which is different from the USA and UK, examples of more liberal market economies. According to the authors, the impact of violence in house prices should be smaller in a co-ordinated market economy with lower income inequality. Using a spatial econometric approach, the authors concluded that apartment prices fall 0,04% when the crimes grow 1%. Comparing this result with the USA and UK, the authors concluded that the crime impact in house prices is lower in a co-ordinated market economy context. However, future researchers should use the same estimation method and the same variables in both contexts for a more robust comparison.

The studies above concentrated in developed countries, although, following Ceccato and Whilhelmssom (2011), there exist groups of countries with respect of crime influence on housing prices. Since market coordination divided the developed countries in two categories (Ceccato and Whilhenmson, 2011), developing countries could be another category, following a similar approach. Inside this third category, Latin American countries could be another group, characterized by great social inequality and violence rates. Estimating hedonic models to study the costs of violence in house prices in a Latin American and Brazilian context is a significant task. There are some contributions for this group of countries that we will discuss below.

Delgado and Wences (2019) studied the impact of crime in Acapulco, Mexico. It is an interesting exercise, since Acapulco, like Rio de Janeiro, is a touristic place and this activity suffers a lot from a violent environment. The authors used two criminality variables: the number of murders by neighbourhood and a dummy variable that indicated if there were school's closures due to violence in the neighbourhood. Using a bootstrap estimation technique, the authors found a negative relationship between murders and housing price, where each unit increase in murder numbers caused a 0,75% decrease in housing prices, and a positive relationship between no school closures and housing prices, as expected.

Valencia and Sanz (2016) used hedonic model estimating the homicide costs implicit in land prices for Santiago de Cali – Colombia from 2005 to 2012. Cali was the most violent city in Colombia, one of the most violent countries in the world. The authors estimated both ordinary least squares (OLS) and two stages least squares (2SLS), using domestic violence as instrument. According to the authors, the homicides had a statistically significant impact on land prices in Cali. The impact was bigger using the 2SLS estimation method, indicating that OLS models could sub-estimate the

violence impact on real estate price. The land price depreciation of a unit increase in homicide tax was 1,66% using the 2SLS technique.

Regarding the Brazilian reality, there are also some contributions in the literature. Rondon and Andrade (2005) estimated crime costs implicit in apartment prices for a sample of rent apartments in Belo Horizonte in 2002. This was the first contribution for this thematic applied to the Brazilian reality. Homicide rate and armed robbery rate, both per 100.000 inhabitants, were the criminality proxies. The authors estimated two distinct models, one for each crime proxy, using the OLS technique, and using a set of control variables. They justified this procedure since the two kinds of crime are highly correlated. A unit fall in homicide rate would increase the rent prices by 0,61%. The same fall in armed robbery rate would increase apartment's rent in 0,02%. Although the unitary impact of homicide is higher than the armed robbery, the aggregated impact is higher for the latter since there were much more armed robberies than homicides in Belo Horizonte.

Following Rondon and Andrade (2005) strategies, Teixeira and Serra (2006) estimated hedonic price models to measure the crime costs in Curitiba. A sample with apartment and house rents was used for the analysis. Homicides rate and theft and robbery rate were the crime proxies, both for 100.000 inhabitants. Four OLS regressions were estimated one for each kind of real estate – apartments and house – and one for each crime proxy and other control variables. Each unitary decrease in homicide rate would increase the apartment rent in 0,74%, the same decrease in theft and robbery rate would increase the apartment rent in 0,007%.

Comparing with Rondon and Andrade (2005) results, the homicide rate presented a similar result, although the homicide rate had a more important impact in Curitiba's apartment market. Since Rondon and Andrade (2005) used only armed robbery and Teixeira and Serra (2006) used both armed and non-armed infringements, the latter parameter was much lower. In fact, the magnitude of parameters seems to increase with the crime's severity for Brazilian housing rents reality. Theft's rent discount was less than robbery discount, which in turn, was less the homicide's rent discount. Like Rondon and Andrade (2005), Teixeira and Serra (2006) concluded that thefts and robbery had a bigger aggregate impact on Curitiba's rent price, since these kinds of crime were more common than homicides.

Pontes, Paixão and Abramo (2011) built a similar hedonic model to estimate the crime cost implicit in Belo Horizonte's apartment prices, for a sample of apartments sold in 2004. The crime variables were homicide rate and theft and robbery rate by 100.000 inhabitants. Like the studies cited above, two distinct models were estimated for each crime proxy and other control variables. Crime had a significant impact on apartment prices, each unitary fall on homicide rate could increase the

apartment price in 0,05%, the impact for theft and robbery was 0,008%. The latter had a similar value found by Teixeira and Serra (2006) for Curitiba's apartments rent market.

However, the magnitude for the homicide rate estimated parameter was ten times smaller for the Belo Horizonte's apartment price with respect to Curitiba and Belo Horizonte's apartment rent. One explanation is the difference between both markets, where the rent market adjusts more quickly to changes in a violent context (Pontes, Paixão and Abramo, 2011). Other explanations rely on control variable choices. The above authors controlled the crime effects for city zone, age, and human development index (HDI) for each city neighbourhood, absent variables in other papers. Estimating the same homicide model for Belo Horizonte's apartment price without these variables resulted in a homicide rate coefficient much closer to the other studies (0,28%), even though with a smaller value (Pontes, Paixão and Abramo, 2011).

Is noteworthy that the homicide rate impact on housing prices was similar for the Belo Horizonte rent market (0,61%), the Curitiba rent market (0,74%) and the Acapulco housing market (0,75%) (Rodon and Andrade, 2005; Teixeira and Serra, 2006; Delgado and Wences, 2019). This suggests there could be some similitude in housing price formation in a socially unequal and violent context. Even though, this impact was bigger for Cali (1,66%). One explanation could rely on the homicide's extreme high rate in this city.

2.2. Crime in Rio de Janeiro

From the 1980s, the lethal violence strongly increased in Brazil and in the city of Rio de Janeiro in particular. In this period, drug trafficking gangs began to shape Rio de Janeiro's organized crime violence, instead of the illegal gambling lottery (jogo do bicho) gangs, which used to shape this kind of violence before (Misses, 2007). Rio de Janeiro's middle and upper classes fear of violence became relevant already in the 1970s. The cause was not the organized crime violence but the crimes against the patrimony (Misses, 2007). This kind of crime increased and became more violent during the 1970s when robbery became more frequent than theft (Misses, 2007).

The organized crime violence began to scare Brazilian and Rio de Janeiro's population only in the 1980s, when Brazil started to be integrated in the international drug trafficking commerce. Combating drug trafficking gangs became the main target of public security policy and, consequently, there were less resources to deal with other types of crime, like robbery, kidnaps, among other, which also increased from the 1980s (Cerqueira, 2014). Lessing (2012) noted some peculiarity on drug trafficking activities in Rio de Janeiro. According to the author, in Rio de Janeiro, instead of others Brazilian's big cities, the drug trafficking structure is heavily concentrated, an oligopoly with large

firms (drug trafficking gangs) with great market power[1]. The magnitude of the gangs allowed investments in great amounts of guns and weapons[2]. There are two consequences from this reality. First, violent turf wars between gangs are common. Second, the police confrontation strategies were also violence intensive. As a result, the growth of organized crime violence led to the growth in other types of crime, in a vicious circle feeding Rio de Janeiro's population fear of violence.

In intra-urban terms, the lethal violence follows an unequal distribution across the city. Zaluar (2002), in an ethnographic approach, found that, in the affluent and touristic Rio de Janeiro's south zone, both the drug trafficking gangs turf war and the police's confrontation behaviour were not the rule. The drug trafficking gangs do not control the street's drug commerce, which is controlled by many individual agents (steam and planes – vapores e aviões) with little market power. The police round is intense but instead of restraining the drug consume and selling, the main police's target is to avoid violent behaviour[3]. In contrast, according Zaluar (2002), in Rio de Janeiro's periphery (north zone and suburbs), the drug commerce is concentrated on the hills (directly with the drug trafficking gangs) or in the streets, which are directly controlled by the gangs. Then turf wars are constant where each gang seeks to gain more territory. In turn, confrontation rounds are the police behaviour in these areas[4]. As a result, the lethal violence (homicide rates) is much more common in the poor areas of the city with respect to the rich areas, like the south zone.

---

[1] According to Lessing (2008;2012) this high concentrated oligopoly drug trafficking market in Rio de Janeiro was due to the control of the prison system by some criminal syndicates. Comando Vermelho, in the early 1980s, was the first gang to control the prison system. By the middle of 1980s there were few rivals in both control of the prison system and engaged in drug trafficking.

[2] Rio de Janeiro's drug trafficking gangs raised from the bank robber's gang. According to Misses (2007), the bank robber activities provided the drug trafficking's primitive accumulation of capital.

[3] For Lessing (2012), there are two police strategic behaviours face to the high level of violence caused by drug trafficking. The first is the conditional repression, when the police combats gangs in response to some violent behaviour. The second is the unconditional repression, when the police combats gangs aimed to eradicate drug commerce, regardless of the gang behaviour. The conditional repression, according to Lessing (2012), is associated with smaller rates of violence. In these terms, the Rio de Janeiro's police tends to use the conditional repression in the richest parts of the town.

[4] Police uses the unconditional repression in these areas. According do Lessing (2012), unconditional repression leads to more violence, since the gangs tend to react the police incursions. In addition, this kind of repression is associated with the violent corruption model, where the constant combats are a way to adjust bribes value (Lessing, 2012).

In the period covered by this paper, the homicide rates (for 100.000 inhabitants) in Rio de Janeiro fell from 31,7%, in 2008, to 18,9%, in 2012, according to IPP data[5] (Table 1). This was the period of implementation of the Peacemaker Police Unity (UPP – Unidade de Polícia Pacificadora), an innovative approach to deal with the criminality in general, and homicides, in particular. From Lessing (2012) point of view, this politic had a great advantage to be based on the conditional repression approach. The focus was mainly on homicide control and less in drug dealing repression. Since drug gangs do not used children labour, do note sell drugs nearby schools and do not exhibit weapons in the city and slums streets, the police settle in communities, making active policing, but without getting involved in drug selling actives and without making use of violence against the trafficking gangs. The fall in homicide rate in 2012 evidences some relative success of this public policy, even though there was a great difference in the distribution of homicide rates in Rio de Janeiro's territory.

Table 1. Homicide Rates – Rio de Janeiro , 2008 - 2012

AISP	Region	2008	2009	2010	2011	2012	Mean
Botafogo	South	7,6	14,2	5,0	6,1	2,7	7,2
Méier	Suburb	31,4	32,0	20,8	19,7	18,2	24,1
São Cristovão	North	31,7	27,3	35,9	18,6	24,2	27,4
Centro	Central	150,7	226,4	124,5	26,8	24,2	96,0
Tijuca	North	19,8	14,0	6,9	6,2	3,5	9,9
Madureira	Suburb	52,4	60,3	50,9	27,3	25,7	42,6
Bangú	West	33,7	27,4	16,6	30,6	22,1	25,9
Penha	Suburb	26,8	29,9	20,2	13,4	17,3	21,4
Ilha	Suburb	14,0	14,6	12,0	9,5	10,0	12,0
Jacarepaguá	West	18,1	15,9	10,6	11,9	12,1	13,7
Copacabana	South	2,1	7,3	4,5	1,7	2,8	3,7
Ramos	Suburb	36,0	46,4	31,4	29,4	22,8	33,0
Lagoa	South	11,5	6,6	7,3	5,2	8,0	7,7
Santa Cruz	West	56,7	57,0	46,3	43,8	33,9	47,3
Barra da Tijuca	West	15,7	9,5	13,0	14,9	11,8	13,0
Campo Grande	West	34,7	38,2	29,6	28,2	20,1	30,0
Rio de Janeiro		31,7	32,6	24,4	36,3	18,9	28,6

Source: IPP and own computation

[5] Instituto Pereira Passos (IPP), a local institution, which compiles social and demographic data about Rio de Janeiro's County.

Using the Public Security Integrated Area (AISP – Área Integrada de Segurança) as territory division, the Central (AISP 5) region was the most violent in the city, in 2008, with a homicide rate of 150,7. However, the rate by inhabitant tends to overestimate crimes in regions like the Central AISP region, which are typically commercial with few residents. In absolute terms, conversely, only two AISPs had fewer homicides than the Central AISP, in 2008. Nevertheless, there was a great decrease in Central's homicide rate in the period, which was 24,2, in 2012. Santa Cruz (AISP 27), a distant west zone suburb, and Madureira (AISP 9), a north zone suburb, were the more violent regions, in 2012. The homicide rate in the former was 33,9 and in the second was 25,7. However, there was a significant fall in homicide rates in both regions, since Santa Cruz's rate was 56,7, in 2008, and Madureira's rate was 52,4.

The relative success of the early years of UPP can be attested by the decrease of homicide in all regions of the city except for Copacabana (AISP 19), although the great disparities between regions remained. The homicide rate in Copacabana increased 33,3%, but was the smaller rate in 2008, 2,1. In 2012, the homicide rate (3,7) was only larger than Botafogo's (AISP 2), whose rate was 2,7. Both Copacabana and Botafogo are south zone regions, inhabited by a high-income population. As Zaluar (2002) has described, police's conditional approach was common in Copacabana even before the UPP policy. In general, south zone regions are the safest in the city and the most violent Rio de Janeiro's regions occur in suburbs (north or west).

Table 2. Robbery rates in Rio de Janeiro, 2008 - 2012

AISP	Region	2008	2009	2010	2011	2012	Mean
Botafogo	South	918,6	900,5	845	565,3	368,4	686,1
Méier	Suburb	1019,8	847,3	749,3	594,2	557	737,0
São Cristovão	North	1658,8	1598,5	1491,2	841,8	618,2	1163,1
Centro	Central	9977,6	13232,2	10506,2	2940,2	2443,7	6333,4
Tijuca	North	942,5	846,6	689,7	295,7	226,4	531,8
Madureira	Suburb	904,6	1017,2	833,3	578,8	643,5	780,3
Bangú	West	457,3	490,7	413,2	433,2	404,2	438,8
Penha	Suburb	599,8	540,3	463,9	310	297	428,2
Ilha	Suburb	280,3	206	270,8	264,5	226,8	248,5
Jacarepaguá	West	342,2	347,8	239,6	228,8	200,4	266,8
Copacabana	South	876,2	848,4	559,3	285,6	298,1	522,8
Ramos	Suburb	734,9	669,9	555,8	421,1	286,7	510,7
Lagoa	South	412,5	375,4	338,2	304	243,9	330,8
Santa Cruz	West	161,6	192,3	160,4	124,2	92,3	143,6
Barra	West	375,1	375,9	353,2	505,8	468,9	412,4

Campo Grande	West	239,3	241,8	256,3	259,1	217,9	242,6
Rio de Janeiro		644,1	639,2	543,1	589,6	411,5	559,5

Source: IPP and own computation

The robbery rate also declined in the period (Table 2). From 2008 to 2012 the rate per 100.000 inhabitants fell from 644,1 to 411,5 (36,1%). It seems that UPP had a positive impact in discouraging robbery activities too. The Central region (AISP 5) was the most violent in robbery terms, but as in the homicide rate's case, this index based on number of residents tends to overestimate the crime in this region. Even though, the crimes fell 75,5% in the Central area, form 9.977,6, in 2008, to 2.443,7. From the criminal point of view, commercial areas – where many people circulate every day – tend to concentrate robbery, since there is a smaller probability to get caught (Rondon and Andrade, 2005). Unlike the homicide rates, the west zone suburbs (Santa Cruz and Campo Grande) were the safest regions in robbery terms. This also could be explained by criminal rationality, the major benefit of this type of crime occurs in the richest areas. In addition, Ceccato and Wilhemson (2011) argue that robbery tends to be more denounced to authorities in the richest areas than in the poor areas, and consequently there could be an overestimation of this type of crime in the richest areas of the town, which could in part explain the lower rates in poor areas. Anyway, there was a significant fall in robbery rate in some of the richest Rio de Janeiro's regions (south zone and Tijuca/Vila Isabel in the north zone of city), from 2008 to 2012, except for west zone shoreline's region of Barra da Tijuca, where this rate increased in the period.

3. Methodology

3.1. The hedonic function

Most goods and services can be classified as complex since each unity or model differs from others by the amount or quantity of some characteristics. The relationship between price and characteristics is described by a hedonic function where the good or service price is a function of its characteristics. Assuming the good or service is constituted by N characteristics, the price of good or service (P) is described by a hedonic function (f) as below:

$$P = f\left(\sum_{n=1}^{N} \beta_i x_i\right) \quad (1)$$

Following hedonic assumptions, there is an implicit price (β_i) for each good or service's characteristics (x_i). This implicit price is the first derivative of the hedonic function on the i-th

characteristic direction. If the characteristic evaluated is positive, the increase in its amount (for the quantitative ones) or its presence (for the qualitative ones) has a positive effect, as described below:

$$\beta_i = \frac{\partial P}{\partial x_i} > 0 \tag{2}$$

On the other way, some characteristics are evaluated in negative terms. Consumers preferred to avoid this kind of attributes. As a result, increases in its amount or its presence have a negative impact on price. The implicit price, in this case, will be negative.

$$\beta_i = \frac{\partial P}{\partial x_i} < 0 \tag{3}$$

Griliches (1971) and Rosen (1974) argued that the theory does not specify the form of the hedonic price function or its characteristic vector. For Griliches (1971) the answers for both questions above is more empirical than theoretical. In the following sections, we will justify the function form and characteristics we chose to build our model for the impact of crime rates in apartment prices in Rio de Janeiro.

The semi-log standard hedonic price model estimated by ordinary least squares (OLS) are described below:

$$\ln(\mathrm{P}) = \beta_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \tag{4}$$

Where ln(P) is the natural logarithm of price and ε is the residual term.

$$\varepsilon \sim N(0, \sigma^2) \tag{5}$$

From equation (5), the residual term follows a normal distribution with zero mean and constant variance. Additionally, the OLS assumptions require that ε be homoscedastic and not autocorrelated. However, real estate data have a spatial nature. Neighbouring houses affect both the price and the residuals of each other. As a result, equations 4 and 5 are not well-suited to real estate data as a spatial phenomenon, and spatial econometric techniques seem to be more appropriate for this type of data.

3.2. Spatial econometrics approach

The spatial nature of any house data requires some empirical response to the development of a hedonic model. Neighbouring houses share the same proximity externalities (Basu and Thibodeau, 1998), which could be positives – like local public goods and private goods and services, proximity to parks and commercial centres, affluent neighbourhood etc. – or negatives – like air pollution, criminality, noise, etc. Many of these local characteristics are measurable and could be included in a hedonic model. However, there are no disposable data for all characteristics and many of them are not even liable to measure. For this reason, even when a comprehensive characteristics matrix is added to a house hedonic model, some spatial omitted variable bias persists (Basu and Thibodeau, 1998). To address this issue, the spatial regression approach (Anselin, 1988) appears to be the most appropriate technique. A global spatial autocorrelation model can be written as follows:

$$\ln(p) = \rho W ln(p) + X\beta + \lambda W u + \varepsilon \qquad (6)$$

Where ln(p) is the apartment price logarithm, ρ is the spatial dependency parameter, W is the spatial weight matrix, X is the apartment's characteristics matrix, β is the hedonics' parameters vector, λ is the spatial autocorrelation parameter, u is the spatial autocorrelation error and ε is the independent error term.

W defines which observations could be considered neighbourhoods. The spatial autoregressive model (SAR) is defined when ρ is different from zero and λ is equal to zero. If a hedonic model follows a SAR pattern, it means that the price of one apartment is in part determined by the price of the apartments nearby. Although ρ could be positive or negative, in housing market, we expected $\rho > 0$, so the price of an apartment will be higher when the price of its neighbours increases.

The spatial error model (SEM) is defined when $\rho = 0$ and $\lambda \neq 0$. In this case, we cannot define or model the spatial autocorrelation process, differently from the SAR model where we know the source of the spatial autocorrelation. Finally, there are some spatial phenomena for which the spatial effects are both autoregressive and in the error term. These kinds of models are called spatial autoregressive combined model (SAC). In SAC's models, both ρ and λ are different from zero.

The Lagrange multiplier (LM) diagnostic for spatial dependence is used to test for the presence and type of spatial dependence in the data. The LM estimation consists of maximizing a log-likelihood (logL) function as follows:

$$\log L = L(\lambda, \rho, \beta, \sigma^2) \quad (7)$$

If the spatial autoregressive term (ρ) is statistically significant, this indicates a strong neighbourhood interaction between the apartment prices. Similarly, if the spatial autoregressive error parameter (λ) is also statistically significant, this indicates the presence of spatial autocorrelation in the error term. If only ρ is significant, the phenomenon is better described as SAR; if only λ is significant, it is better described as SEM; if both parameters are significant, it is better described as SAC. If neither parameter is significant, OLS regression is a better fit for the data.

3.3. The variables

The dependent variable in hedonic models' applications is some measure of the price or value of the good or service. In housing price analysis, the explained variable is the sale or rent price. Thus, the first problem the hedonic price researcher must deal concerns about which independent variables must be included in the model. Both Griliches (1971) and Rosen (1974) were sceptical about some theoretical response for this kind of question. For Griliches (1971), a variable should be added on a hedonic regression if it exerts some influence in a relevant share of the market. In housing market services, there are two sets of independent variables: the capital (K) applied in a land, also known as physical variable, and location related variables (L), including the distance in relation to some important urban points, like the central business district (CBD) or recreational places (like a beach, for example) and the location's amenities. Following Griliches (1971) recommendations, we will choose as independent variables in our model, those variables included in the dataset that capture some relevant share of Rio de Janeiro's apartment market.

The data come from the Caixa Econômica Federal (CEF), a public bank, which is an important real estate credit provider in Brazil, and from Instituto Pereira Passos (IPP), a local institution, which compiles social and demographic data about Rio de Janeiro's County. The apartment's prices and physical characteristics data come from on survey conducted by CEF with real estate agents from august 2008 to November 2012. This survey serves as a source of information about financed properties contract analysis. The data consists of 1.693 observations covering the role Rio de Janeiro's municipality. The physical characteristics vector, set K, comes from this same database, and is described in table 3.

The major difficulty building a hedonic price model is to choose the location variables set (L). This vector could be subdivided in distance and amenities variables. The distance variables are easier

to get since the apartments addresses are available in CEF's database. From the new urban economics (NEU), also known as the Alonso-Muth models, the price of urban land decreases with the CBD distance. Thus, the distance to CBD (t_c) is included in the L set. Knetch (1963) pointed out the role of distance to a great leisure place, like a beach or a park, in housing price. There are transport and time costs to achieve some leisure place (t_b) for the family. Since Rio de Janeiro is a coastal city, with some worldwide famous beaches, and the beaches are not far away from the city centre, there exists one trade-off between living near the CBD or near the beach from the family point of view. In these terms, t_b was included in the model. Table 3 resumes the distance subset vector.

To measure the impact of crime rates in the apartment price, we included both homicide and pedestrian theft rates as explanatory variables. Following the previous literature (Rodon and Adrade, 2005; Teixeira and Serra, 2006; Pontes, Paixão and Abramo, 2010), we estimated two distinct models, one using homicide rates as crime rate proxy and another using pedestrian thefts. The data, available at IPP's Data Rio database, was provided by Instituto de Segurança Pública/Public Security Institute (IPS) from the Civil Police's data and consisted of the rate per 100.000 habitants. The regional unity of analysis of the data is the Delegacia de Policia/Police Station (DP). Since each DP is associated with one or more city district, we use the city district information at the CEF's data to input the criminal rate for each observation. Table 3 resumes the crime rates variables.

The natural and social configurations of Rio de Janeiro's urban space follow an uneven shape. The south zone's space is characterized by a peculiar combination of mountains and sea, with bay and ocean beaches, a lagoon and green areas that make its landscape and its environment very attractive. As a result, living in an apartment with a view for some of these landscapes is a unique experience. Exemplifying, Villaça (1998) argued that a view which combines the Pão de Açúcar hill and Botafogo bay's cove is the monopoly of few front apartments located in Rui Barbosa Avenue. The same could be said for apartments with sea and/or lagoon and/or mountains and/or Cristo Redentor views.

Table 3. Variables

Variable	Type	Description	Expected signal
Age	Discreet	Building age in years	+
Parking Space 1	Dummy	One car parking space	+
Paking Space 2	Dummy	Two cars parking space	+
Parking Space 3	Dummy	Three or more cars parking space	+

Studio	Dummy	Studio apartment	-
Bedroom 2	Dummy	Two bedrooms	+
Bedroom 3	Dummy	Thre bedrooms	+
Bedroom 4	Dummy	Four or more bedrooms	+
Area	Continuous	Apartment's area is square metes	+
Elevator	Dummy	Building with elevator	+
CBD	Continuous	Distance from CBD	-
Beach	Continuous	Distance forom the nearest ocean beach	-
Robberies	Continuous	Robber rate per 100.000 ihabitants	-
Homicides	Continuous	Homicide rate per 100.000 inhaibitants	-
Line 1	Dummy	Apartment nearby metro line 1	+
Line2	Dummy	Apartment nearby metro line2	+
Culture	Continuous	Cultural equipaments per 100.000 inhabitants	+
Cinema	Dummy	Neighbourhood with movie theatres	+
Green	Continuous	Green area acre per 100.000 ihabitants	+
PCI	Continuous	Per capita income of each district	+
Time	Discret	Time dummy (Zero in the first month)	+

Source: own representation

Over time, the south zone attracted the top income inhabitants of the city, and includes most places where tourists stay. Consequently, this area concentrates high-quality services and most social urban amenities in town. As Villaça (1998) pointed out, over decades a great amount of public and private investments endowed Rio de Janeiro's south zone with proper infrastructure. Some expensive public expenditures, like building tunnels across mountains, landfill, and subway constructions, helped to improve the urban life's quality in this already privileged place. As a result, it is expected that apartments located in some specific Rio de Janeiro's micro-areas have increased value due to their peculiar locations.

Rio de Janeiro is also an uneven city in both social and urban terms. Except for the south zone and the coastal neighbourhoods of Barra da Tijuca and Recreio dos Bandeirantes in the west zone, there is no landscape differential on the other regions. Contrariwise, the central, north, and west regions districts serve as residency for the lower income populations with less presence of any urban, natural, or social amenities. Many of these places, especially some suburbs of the north and west zone, lack some basic urban infrastructure like sanitation and transports facilities. Furthermore, in some of those areas, there is such a lack of state presence that the territory is controlled by paramilitary groups, like drug dealers or militia. To deal with these peculiarities of Rio de Janeiro's urban space, the personal per capita income (PCI) of each district was included in our model. The PCI acts as proxy for services quality and natural, leisure and landscape amenities. The PCI treats each city district as a package of these amenities and consequently it measures how these amenities are

important to Rio de Janeiro apartment price formation. Since some regions of Rio de Janeiro are recognized for their amenities, it is important to control the model for PCI[6]. The PCI data comes from the Data.Rio platform, which compiles the IBGE Census data for each Rio de Janeiro's district.

Lastly, some specific urban amenities or facilities in our data seem to exert influence in Rio de Janeiro's real estate prices. Since metro lines were available only in a small part of the city, in 2012, high prices in apartments located near subway stations are expected. There were two subway lines in Rio de Janeiro, lines 1 and 2, at the time, so we measured a hedonic parameter for each line. Green areas represent the environmental amenity and cinema, and cultural variables represent the cultural amenities. Finally, a monthly temporal tendency variable (time) was included to control the model from apartments prices inflation.

4. Results

4.1. Descriptive statistics

Table 4 presents the descriptive statistics for our Rio de Janeiro's apartment market data. The CEF data contain 1.693 observations, the mean apartment price was R$ 224.511 (U$ 108.041[7]) and the mean area was 74,40 square meters. Most apartments contained one car's parking space, two bedrooms, one bathroom and no elevator. Almost 23% of the apartments were located near a subway station (most near Line 1, 16%). The distance from CBD and beach (ocean beach) were similar, 18,77 km and 18,21 km respectively. Almost one third of the sample was near some movie theatre and the most part were in Rio de Janeiro's north zone.

The mean per capita income was R$ 2.001,62 (US$ 963,24) and its standard deviation was R$ 1,379,65 (US$ 663,93). Lagoa (R$ 7.239,50/US$ 3.483,85), Ipanema (R$ 6.323,26/US$ 3.042,93), Barra da Tijuca (R$ 5.940,31/US$ 2.858,64), Leblon (R$ 5.805,42 /US$ 2.793,73), Flamengo (R$ 4.796,83 / US$ 2.3808,37) and Humaitá (R$ 4.162,33/ US$ R$ 2.003,03) were the districts with more than double of the mean per capita income. Except for Lagoa and Humaitá, all other are coastal districts with landscape, leisure, and urban services amenities. All districts were in

[6] In an earlier version of the paper, we added specific locations dummy. Instigated by one of the paper's referees, we exchanged the set of dummies variables by the per capita income (PC|I). The advantage to use PCI instead a set of dummies is that PCI represents each city district as a package of urban services, natural, leisure and landscape amenities. Therefore, the result is more accurate than to choose a few *ad hoc* location dummies variables. We take this opportunity to thank the referees for the valuable suggestions.

[7] December 2012 exchange rate.

the South Zone, expect for Barra da Tijuca, which is in West Zone. Despite not being a coastal district, Lagoa has landscaped and leisure amenities (Rodrigo de Freitas Lagoon and Corcovado view) and urban services amenities like high quality restaurants, bars, cafes and clothing stores. Finally, Humaitá is not a coastal district too, but there are many high-quality services in this district and it is also near the Lagoa district.

On the other hand, the poorest districts in our sample were Caju (R$ 505,50/ US$ 243,26), Inhoaíba (R$ 506,05/US$ 243,53), Vigário Geral (R$ 508,27/ US$ 244,59), Santa Cruz (R$ 509,71/ US$ 245,29) and Paciência (R$ 517,56/ US$ 249,16). Two of these poorest districts are North Zone Suburbs (Caju and Vigário Geral) and three are distant West Zone districts (the former Rural Suburbs), like Inhoaíba, Santa Cruz and Paciência. It is worth noting that the per capita income in Lagoa, the richest district in the city, is more than 14 times the per capita income of Caju, the poorest district in our sample. This figure shows how income inequality is a social characteristic of Brazilian society and how it shaped the Rio de Janeiro's urban space[8].

Table 4. Descriptive Statistics

Variable	Mean	Standard Deviation	Variable	Mean	Standard Deviation
Price	224.511,00	218,621,00	Homicides	24,01	16,51
Age	26,24	16,68	Line 1	0,16	0,37
Parking Space1	0,52	0,50	Line 2	0,07	0,25

[8] Rio de Janeiro, like many latin american cities, has a large informal real estate market and for this reason there are no apartments located in slums (favelas) in our sample. In 2010, 1,4 million people lived in slums, according to IBGE Brazilian census, which corresponds to 22,2% of the 6,3 million residents of Rio de Janeiro. The poorest districts in Rio de Janeiro are slum complexes, like Barros Filho and Costa Barros (R$ 366,90/ US$ 188,13), Alemão (R$ 390,93/ US$ 188,13), Jacarezinho (R$ 405,49/US$ 195,13), Manguinhos (R$ 439,96/US$ 211,72), Rocinha (R$ 455,67/US$ 219,28), and. Maré (R$ 456,72/US$ 219,79). Except for Rocinha, which is in the South Zone, the other slum complexes are all in North Zone suburbs. It deserves attention that the per capita income in the richest district in Rio de Janeiro (Lagoa) was almost 20 times the per capita income of the poorest district (Barros Filho and Costa Barros).

Parking Space2	0,09	0,29	Culture	18,45	26,25
Parking Space3	0,01	0,09	Cinema	0,29	0,45
Studio	0,001	0,02	Green	0,003	0,003
Bedroom2	0,65	0,48	PCI	2.001,66	1.362,62
Bedroom3	0,20	0,40	Elevator	0,49	0,50
Bedroom4	0,02	0,14	CBD	18,77	10,90
Bathroom2	0,29	0,45	Beach	18,21	8,86
Bathroom3	0,06	0,23	Robberies	870,09	1.148,39

Source: own calculations from CEF and IPP data.

4.2. Results

The results of the OLS regressions follow the theory's prediction for most variables, as seen in Table 5. For example, like the New Urban Economics predictions, distance from CBD was negative in the two models, but was not significant in the homicide OLS regression. Following the Knetche's approach, distance from the beach was significant and its sign was negative, as expected, in both OLS models. The impact of income per capita (IPC) was positive and significant in all OLS regressions. The violence proxies – homicide and robbery taxes – have both the negative sign, as expected, and were significant. A one-point growth in the homicide rate corresponds, on average, to 0,20% of apartments price depreciation. For robbery, the same rates growth is correlated, on average, to a 0,01% depreciation. Although the OLS regressions gave results that are in line with the theories postulates, their results don't take the spatial dimension of the phenomenon into account. Additionally, there could be some kind of endogeneity between the crime rates and apartments prices. Using a spatial autoregressive regression contributes to deal with this question (Brasington and Haurin, 2006). Anyway, before testing for spatial autocorrelation it is not possible to conclude

anything from the OLS regression (Dantas, Magalhães and Vergolino, 2007). Table 6 resumes the Lagrange multiplier diagnostic for spatial dependence (spatial error, spatial lag or both).

The LM tests suggested spatial autoregressive dependence (lag), spatial dependence in error term (error) and both at the same time (sac). From these results, the following analysis will be done using the SAC model. The spatial econometrics SAC model is estimated by a maximum likelihood (ML) method. The hedonic SAC model is described in equation 8 below:

$$\ln(p) = (I - \rho W)^{-1} X\beta + (I - \rho W)^{-1}(I - \lambda W)^{-1}\varepsilon \qquad (8)$$

The results suggested the existence of both lag and error spatial effects (Table 7). The spatial autoregressive parameter (ρ) is positive and statistically significant in both models. There is a strong interaction between neighboring apartments prices. The ρ parameter is a proxy to unobserved spatial amenities. The autoregressive error parameter (λ) is statistically significant in both models, and in these terms, there is the existence of spatial autocorrelation in the error term in our data. All estimated parameters for physical characteristics have the expected sign and are statistically significant in both models. Except for the studio's parameters, which exhibited the negative expected sign but were not statistically significant in the robberies model and were significant only at the 10% level in the homicides model.

There are few differences between the homicides and robberies models for both OLS and SAC regressions. The main differences between OLS and SAC models in both models concentrated on bedroom4. The OLS regression seems sub-estimate the implicit price for four or more bedrooms. Using homicide regressions as an example, the implicit price for a four or more bedrooms was 14,8% in the OLS regression and 20,5% in the SAC regression. The parameter differences for Line 1 was significant only in the robberies regression,

Analyzing the urban economics variables, CBD was negative and significant in both models, at 5% level in homicide regression and at 1% level in robberies regression. This result is in line with the New Urban Economic theory for which the land price decreases with the distance from the CBD. Each kilometer far from the city center decreases the apartment price in 0,24%, at homicide regression, and 0,32% at robberies regression. Using spatial econometrics techniques was important, since in OLS regressions CDB was not significant in the homicide regression and was significant in OLS robberies regression, but the impact was slightly less, each kilometer far form CBD decreasing the apartment price in 0,30%. Beach was statistically significant and had the expected negative sign in all models, highlighting that the estimated parameters were smaller on SAC models. From SAC regressions, each kilometer added from the nearest ocean beach devalued on average the apartments

prices in 1,04% (model I) or 1,07% (model II). From Villaça's (1998) point of view, along the XX century the beach became the landmark for the Rio de Janeiro's elite location choices. This kind of behavior follows the Knetch (1963) approach, where environmental and leisure amenities coordinate the urban location preferences.

Table 5. OLS regression on homicides and robbery taxes

Variable	Estimate Model I	Estimate Model II	Variable	Estimate Model I	Estimate Model II
Intercept	11,0100***	11,0800***	CBD	-0,0011	-0,0030**
Age	-0,0042***	-0,0045***	Beach	-0,0140***	-0,0147***
Parking Space1	0,1481***	0,1458***	Line1	0,1272***	0,1071***
Parking Space2	0,2349***	0,2391***	Line2	0,0040	0,0072
Parking Space3	0,2110***	0,2258***	Culture	0,0030***	0,0061***
Studio	-0,5075*	-0,4028	Cinema	0,0138	0,0311
Bedroom2	0,1989***	0,1941***	Green	5,1820	10,6100***
Bedroom3	0,2698***	0,2647***	Time	0,0201***	0,00195***
Bedroom4	0,1478**	0,1435**	IPC	0,0002***	0,0001***
Bathroom2	0,1301***	0,1347***	Homicides	-0,0020***	-
Bathroom3	0,1088***	0,1035***	Robberies	-	-0,0001***
Area	0,0057***	0,0057***	Adjusted-R^2	0,83	0,84
Elevator	0,0788***	0,0997***	F-statistic	387,7***	411,7***

*Significant for 10%

*Significant for 5%

*Significant for 1%

Source: own calculation from CEF and IPP data

Table 6. Lagrange multiplier diagnostic for spatial dependence

Test	Degree of freedom (Model I)	Estimate (Model I)	Probability (Model I)	Degree of freedom (Model II)	Estimate (Model II)	Probability (Model I)
LM (error)	1	30,94	0,0000	1	19,95	0,0000
LM (lag)	1	53,82	0,000	1	63,51	0,0000
LM (sac)	2	260,97	0,0000	2	237,43	0,0000

Source: own calculation from CEF and IPP data

The per capita income (PCI) acts as a proxy variable to measure services, leisure and landscape amenities. Since these aspects are difficult to be measured in each city district, they can be associated as a package with PCI representing this package. PCI was significant and its signal was positive, as expected, in all models. For Rio de Janeiro apartment markets, each R$ 100,00 in a PCI increased the apartment price in 1,3% in model I and in 1,0% in model II. The SAC results were lower than the OLS regressions. Theses results were expected since the spatial weight matrix captures some neighbourhood interaction that could not be measured in OLS regressions.

From others urban amenities and facilities, culture was significant and positive in all regressions. On the other hand, cinema was not significant in all regressions, although the signal was positive in the four models[9]. Green areas were positive in all regressions but was only significant in robberies regressions (at both OLS and SAC). As expected, Line 1 was positive and significant in all regressions. To live near a Line 1 metro station added 10,4% in apartment price, in SAC regression of model I, and 8,1% in SAC regression of Model II. The impact measured by OLS regressions was higher for the two models, and adding the W matrix is important to not overestimate the Line 1 impact. Surprisingly, Line II was not significant in all regressions, although its parameter was positive. Line II stations are located in North Zone suburbs while the Line I stations are located in South Zone, Central Zone and North Zone, encompassing some of the richest districts in the city. Finally, time was positive and statistically significant in all regressions, so the results were controlled by inflation impacts.

[9] Ianchan *et al*. (2023) for a sample in the Maré slum complex show a tendency for people to consume music and cinema at home. Although this result is for a low income and high violent district, we can infer that theses facts are a general tendency. In this context, living near cinemas is not valuable in real estate market.

Table 7. SAC spatial regression on homicides and robberies

Variable	Estimate Model I	Estimate Model II	Variable	Estimate Model I	Estimate Model II
Intercept	8,8901***	8,8527***	Beach	-0,0104***	-0,0107***
Age	-0,0043***	-0,0044***	Line1	0,1038***	0,0081***
Parking Space1	0,1347***	0,1332***	Line2	0,0090	0,0137
Parking Space2	0,2101***	0,2121***	Culture	0,0029***	0,0056***
Parking Space3	0,2125***	0,2160***	Cinema	0,0190	0,0343*
Studio	-0,4731	-0,3879	Green	3,7522	8,2568***
Bedroom2	0,2076***	0,2028***	Time	0,0207***	0,0201***
Bedroom3	0,2857***	0,2802***	RPC	0,0001***	0,0001***
Bedroom4	0,2054***	0,2000***	Homicides	-0,0016***	-
Bathroom2	0,1616***	0,1212***	Robberies	-	-0,000084***
Bathroom3	0,0826**	0,0794**	ρ	0,1818***	0,1900***
Area	0,0054***	0,0054***	λ	0,1501***	0,1138***
Elevator	0,0755***	0,0802***	AIC	348,17	284,03
CBD	-0,0024**	-0,0032***			

*Significant for 10%

*Significant for 5%

*Significant for 1%

Source: own calculation from CEF and IPP data

Measuring the effect of crime rates in Rio de Janeiro's apartment price is our primary interest. Both crimes variables proxies, homicide, and robbery rates, are statistically significant and the sign was negative, as expected, in all four regressions. Therefore, the data confirm our hypothesis that violence represents a social cost and the apartment's prices devaluation reveals this reality. The magnitude of estimated parameters was larger in OLS regressions for both homicide and robbery rates. Controlling for non-observable spatial variables is an important task to avoid overestimated

apartment's value depreciation due to criminality rates. If the homicide rate increases by one unit, prices are expected to drop by 0,20%, in OLS model I. Assuming an average apartment price of R$ 224.511,00, each homicide rate unity increase implies in a decrease of R$ 449,02 in its price. In the SAC regression, the marginal increases in homicide rate causes decreases of 0,16% in the apartment price or R$ 359,22, taking the average apartment price into account. In robbery rate models, model II, like in the homicide case (model I), the estimated parameter for SAC regression was smaller. From the OLS regression, the marginal impact of robbery rate in apartment price was 0,0097% or R$ 21,78 for an average price apartment. From model II SAC regression, this marginal effect was 0,0081% or R$ 18,19 for an average price apartment.

We suppose that every district has an apartment whose price is R$ 224.511,00 (the sample average price) and initially there is no criminal violence. This initial price is a price without criminal violence impact. In a second time, we included in each district a criminal violence average rate in the SAC parameter and estimated the monetary impact of each criminal violence type in the apartment price for each selected district. The results are on table 9.

Centro is a predominant commercial district, although there are some residential properties. Consequently, the number of inhabitants in Centro is relatively small compared to the people who commute there every day for work, and the crime rates tend to be overestimated for this district. Because of this, the impact of crime rates is higher for Centro, and we will focus our analysis on the other districts.

For Rio de Janeiro as whole, the homicide and robbery impacts were of the same magnitude. The homicide discount 4,6% and the robbery was 4,7%. In general, in the richest population districts, the robbery impact was bigger. The contrary occurred in the poorest population districts, where homicides had more impact on apartment prices[10].

Table 9. Impact of crime tax on mean price apartments for Rio de Janeiro

District	Region	Homicides		Robberies	
		Tax	Price reduction	Tax	Price reduction

[10] Ceccato and Wilhelmsson (2011) pointed out that the robbery police complaint tended to be more common in higher income locations. Rodon and Andrade (2005) underlined that thieves tend to act in richer neighbourhoods where the revenue of this criminal activity is expected to be higher.

Botafogo	South	7,2	1,2%	686,06	5,8%
Meiér	Suburb	24,1	3,9%	737,04	5,8%
São Cristovão	North	27,4	4,4%	1.163,11	9,8%
Centro	Central	96,0	15,4%	6.333,35	53,2%
Tijuca	North	9,9	1,6%	531,78	4,5%
Madureira	Suburb	42,6	6,8%	780,31	6,6%
Bangu	West	25,9	4,1%	438,82	3,7%
Penha	Suburb	21,4	3,4%	428,23	3,6%
Ilha	Suburb	12,0	1,9%	248,49	2,1%
Jacarepaguá	West	13,7	2,2%	266,83	2.2%
Copacabana	South	3,7	0,6%	522,80	4,4%
Ramos	Suburb	33,0	5,3%	510,70	4,3%
Lagoa	South	7,7	1,2%	330,77	2,8%
Santa Cruz	West	47,3	7,6%	143,64	1,2%
Barra	West	13,0	2,1%	412,38	3,5%
Campo Grande	West	30,0	4,8%	242,56	2,0%
Rio de Janeiro		28,6	4,6%	559,51	4,7%

Source: own calculation from CEF and IPP data

In Copacabana, the district with the lowest homicide rate in our sample (3,7), the hypothetical apartment suffers 0,6% price discount due homicide tax. By contrast, in Santa Cruz, where the homicide rate was 47,3, the hypothetical apartment lost 7,6% in value. Analysing the impact of robbery, Santa Cruz had the smallest robbery rate (143,64), it decreased the apartment price in 1,2%. On the other hand, São Cristovão, where the robbery rate was 1.163,11, the price reduction was 9,8%.

To evaluate a public policy, quasi-experimental methods are recommended. Frischtak and Mandel (2012), using a difference-in-difference method, showed that the UPP policy was successful. By comparing the average district housing prices before and after the policy implementation, the authors found that housing price inequalities between districts decreased after the treatment. From

Frischtak and Mandel's (2012) findings, we can use our spatial hedonic estimated parameters to illustrate the UPP effects using an apartment sales database. Between 2008 and 2012, when the state implemented the UPP program, criminal violence rates decreased, as we have seen above. Both homicide and robbery rates experienced a significant decline. We can use the average price of a hypothetical apartment approach to check if Frischtak and Mandel's (2012) conclusions are corroborated by our model by comparing the impact of crime rate in house prices in 2008 and 2012.

The decrease in homicide rate was bigger in the poorest part of town, therefore the apartment price increased more in the poor districts. The price of a hypothetical apartment in Madureira would grow 4,7%, in real terms, in Santa Cruz this growth would be 4,0% and in Campo Grande 2,5%. The richest neighbourhoods would present a smaller increase: 0,6% in Lagoa and Barra da Tijuca and 0,8% in Botafogo. In Copacabana, the safest Rio de Janeiro district in homicide rate terms, exceptionally the homicide rate increased in the analysed epochs, from 2,1 to 2,8, and the hypothetical apartment would have depreciated by 0,1%. From this evidence, almost the entire city benefited from the UPP's homicide reduction policy, and the growth for the whole city would be 2,2%. This kind of policy benefited the poorer areas of the town more, since the homicide reduction was larger in the north and west zone suburbs, as Frischtak and Mandel (2012) highlighted.

Table 10. Impact of crime tax decrease on a hypothetical price apartment – 2008-2012

District	Region	Growth crime rate between 2008/2012		Growth Price Rate due to Crime reduction	
		Homicide	Robberies	Homicide	Robberies
Botafogo	South	-64,5%	-59,9%	0,8%	5,0%
Meiér	Suburb	-42,0%	-45,4%	2,2%	4,3%
São Cristovão	North	-23,7%	-62,7%	1,3%	10,2%
Centro	Central	-83,9%	-75,5%	26,7%	390,9%
Tijuca	North	-82,3%	-76,0%	2,7%	6,5%
Madureira	Suburb	-51,0%	-28,9%	4,7%	2,4%
Bangu	West	-34,4%	-11,6%	2,0%	0,5%
Penha	Suburb	-35,4%	-50,5%	1,6%	2,7%
Ilha	Suburb	-28,6%	-19,1%	0,7%	0,5%

Jacarepaguá	West	-33,1%	-41,4%	1,0%	1,2%
Copacabana	South	33,3%	-66,0%	-0,1%	5,2%
Ramos	Suburb	-36,7%	-61,0%	2,2%	4,1%
Lagoa	South	-30,4%	-40,9%	0,6%	1,5%
Santa Cruz	West	-40,2%	-42,9%	4,0%	0,6%
Barra	West	-24,8%	25,0%	0,6%	-0.8%
Campo Grande	West	-42,1%	-8,9%	2,5%	0,2%
Rio de Janeiro		-40,4%	-36,1%	2,2%	2,1%

Source: own calculation from CEF and IPP data

The robbery rates were bigger in the richest districts and in the districts near the city center. The biggest impact of robbery rate decrease was in São Cristovão, a north zone district very close to city center, where the hypothetical apartment value increases in 10,2% in real terms. The Upper middle-class districts like north zone district of Tijuca (6,5%) and south zones districts of Copacabana (5,2%) and of Botafogo (5,0%) stranded out in apartments valuation due to a decrease in robbery occurrences. The impact was smaller in the west zone districts of Campo Grande (0,2%) and of Bangu (0,5%) and in Ilha do Governador (0,5%), a big island in Guanabara's bay on the north zone of the city. Barra da Tijuca, an upper middle-class district in the west zone, was an exception because the robbery tax increased between 2008 and 2012. Summing up, the UPP's robbery reduction benefited Rio de Janeiro as a whole (2,1% growth rate), but its impact was more evident in districts near the city center and some relatively rich districts in the north and south zones.

From this perspective, our spatial hedonic price model indicates that well-being increased in Rio de Janeiro due to decreases in robbery rates. Unlike the homicide rate, the richest districts seem to benefit the most. This evidence is quite different from the conclusion by Frischtak and Mandel (2012) that housing price inequalities decreased. However, their analysis did not include robbery rates. Further studies should use quasi-experimental analysis to evaluate the UPP or other public safety policy results in terms of robbery rates. Still, when analyzing the robbery rate results, it is worth recalling Ceccato and Wilhelmsson's (2011) argument that robbery rates tend to be underestimated in the poorest districts. To our knowledge, there is no evidence if this kind of phenomenon occurs in Rio de Janeiro. If Ceccato and Wilhelmsson's (2011) hypothesis applies to the reality of Rio de Janeiro, the well-being increases from a decrease in robbery rates should be bigger than our estimates

for the poorest districts. Consequently, the inequality in apartment prices tends to increase less than it appears in our previous analysis.

We compared our results with other Brazilian literature contributions. Analysing homicide rates, Teixeira and Serra (2006) estimated -0,74% as a marginal effect for Curitiba's apartment rent market. Rondon and Andrade (2005) estimated -0,61% for the same effect using a sample for Belo Horizonte's rent market. Nevertheless, Pontes, Paixão and Abramo (2011) found -0,05% as homicide rate parameter for Belo Horizonte's sale market, which is closer to our OLS effect of -0,20%. Teixeira and Serra (2006) and Rondon and Andrade (2005) did not control for district effects and estimated a bigger marginal impact than us. Applying our OLS model without control for IPC (the district characteristics variable), like Teixeria and Serra (2006) and Rondon and Andrade (20025) did, we found a similar marginal effect (-0,60%)[11]. We can infer that control for district variables is an important task to not overestimate the homicide effect on the real estate market. Since Pontes, Paixão and Abramo (2011), controlling to district effects, found a lower effect value, we ca infer that homicide in Rio de Janeiro had a more marginal effect on apartment market compared to Belo Horizonte reality. Controlling for the spatial effects, like we did in the SAC regression, the marginal effect was -0,16%, showing that using spatial regression is important too to avoid super estimate the homicide effects on apartment prices.

Compared with other Latin American cities, the marginal discount on housing prices due to homicide rates was smaller in Rio de Janeiro (-0,16%) than in Acapulco (Delgado and Wences, 2019), Mexico (-0,75%) or Cali (Valencia and Sanz, 2016), Colombia (-1,66%). The homicide tax was higher in Acapulco (104,2) and Cali (79,0) in relation to Rio de Janeiro (28,6). In part this explains the smaller homicide marginal effect on apartment prices in Rio de Janeiro. In contrast, none of these studies control the housing prices with respect to the district characteristics effect or use the spatial econometric techniques. When we removed the IPC variable in the SAC model, the homicide marginal effect rises to -0,41% and when we used the OLS regression without the IPC variable, the same effect rises to -0,60%. If the same model was used for the three different locations, we can infer that the marginal effect on Rio de Janeiro was a little smaller than in Acapulco and Cali, probably because Rio de Janeiro is a less violent city compared with the others two. Our results highlight the importance of controling the hedonic price for district characteristics and using spatial econometric models.

[11] The regression output is on the appendix.

Analysing the robbery rates, we can compare our results with Teixeira and Serra (2006) and Ponte, Paixão and Abramo (2011), which used the same variables. Teixeira and Serra estimated as robbery marginal effect of -0,007% for Curitiba rent market and Pontes, Paixão and Abramo (2011) estimated -0,008% for Belo Horizonte's sale market. Since the parameter for our SAC regression was -0,008% it seems that robbery marginal effects are similar in different Brazilian contexts[12].

4.3. Some further discussion

Our sample deals with a specific period that coincided with the UPP program first years (2008-2012). The success of this politics was highlighted by our results, unfortunately our dataset is limited from 2008 to 2012, when the homicide rate reduced from 33,2 to 18,9. Between 2013 and 2019, the average homicide rate was 19,7. Pio, Brito and Gomes (2021) estimated that there is a long run effect of the UPP in Rio de Janeiro's criminality decay both for homicides and robbery, using a vector error correction (VEC) model. Although there are some events which contribute to crime rate reduction like the politics related to disarmament status and investment for football Fifa World Cup (2014) and Rio de Janeiro Olympics Games (2016), Pio, Brito and Gomes (2021) found the UPP was prominent to Rio de Janeiro long run crime reduction. Between 2020 and 2022 there was a fall in homicide rates (average 12,7), and this was the period of the social distancing measures due the Covid-19 pandemic. From the crime rate point of view, we observed there were no substantial changes from 2012 to 2019, so although our data do not coverage more recent periods, there was no significant crime rate variations until the Covid-19 pandemic.

From the real estate market point of view, some urban investments due to the Rio de Janeiro 2016 Olympic Games could impact some specific regions of the city. Barra da Tijuca, a shoreline district in West zone of the city, received major investments, mainly one subway station. In intra-urban terms, Barra da Tijuca is now more accessible for the rest of the city in relation to its situation in the 2008-2012 period. We expected that being in Barra da Tijuca now is more valuable than it was in our sample data. On the other hand, the other urban investments due to Rio de Janeiro 2016 Olympic Games did not modify the Rio de Janeiro urban social fabric. In these terms, we could infer that the Olympic Games had a limited effect on Rio de Janeiro's apartments price formation.

Although it is still early to analyse the long-run impact of Covid-19 and the remote work on Rio de Janeiro's urban structure and apartment price formation, we could infer that one effect could

[12] Since Rondo and Andrade (2005) used armed robbery and robbery in general like the other papers, their results are not comparable with the other studies.

be to reinforce Barra da Tijuca apartment prices appreciation. The main attractions of Barra da Tijuca are the beach, parks and a great provision of commerce and services. By contrast, the main disadvantage of Barra da Tijuca was its great distance for the CBD. Remote work, in its turn, could make shorelines west zone distant districts like Barra da Tijuca and Recreio dos Bandeirantes more suitable as a place of residence. Some Rio de Janeiro residents could prefer to live in other cities in Rio de Janeiro metropolitan area (like Niteroi) or in other cities of Rio de Janeiro state, like the coastal cities or mountain cities. On the other hand, some Rio de Janeiro non-residents can be attracted due to natural and cultural amenities of the city, which are concentrated in the South zone districts as well as West zone coastal districts. Further studies are important to measure the arrival and departure of residents due to remote word and to estimate its impact on apartments price formation.

5. Conclusion

Our goal in this paper was to estimate the effect of criminal violence on apartments prices in Rio de Janeiro, based on urban economics theory and a hedonic price model. We used the homicide rate and robbery rate as alternative measurements of criminal violence. The criminal violence effects were estimated separately for each variable, following Rondon and Andrade (2005) approach, since the nature of each criminal variable is different, like the population fear for each of these types of crimes. There is evidence that in housing market some unobservable spatial variables affect housing prices. For these cases, the literature recommends using spatial regression techniques. We estimated the OLS standard hedonic regression and tested for spatial dependence and error for both violence criminal variables. The tests suggested both spatial dependence and spatial error, so we chose the SAC hedonic regression, since its method estimated the hedonic model controlling for spatial dependence and error at the same time.

We chose as criminal violence variables the homicide rates and robbery rates, both measuring the number of crimes for 100.000 inhabitants. The estimated parameters for the criminal violence variables were statistically significant and had the expected negative sign for both homicide and robbery rates and before and after control for spatial effects. Homicide rate parameters are larger than the robbery parameters, meaning that, for the Rio de Janeiro apartment market, the marginal impact of homicide is higher. On the other hand, there are more robberies than homicides in absolute terms. The monetary impact of each type of crime on apartments price changes from one neighbourhood to another. In districts inhabited by more affluent people, the monetary impact of robbery is higher than the monetary impact of homicides. Moreover, in the poorest districts, homicides have higher monetary impact than robbery. For the whole city, the monetary impact of homicide is bigger, which

highlights the dual pattern of Brazilian's big cities, where the social inequalities stand out and the poor people must live in extreme violent environments.

Between 2008 and 2012, our sample period, the state of Rio de Janeiro implemented the UPP program to reduce the violent criminality. The program had a short run of success reducing both homicide and robbery rates. Using our SAC regressions results to test the impact of violent criminal rates on apartments prices for different Rio de Janeiro's districts, we concluded that almost the whole city benefited from the criminal violent reduction. The homicide reduction had more effect in poor districts, whereas the robbery reduction was more outstanding in some rich districts and near the city centre.

This study makes three contributions to the Brazilian debate about violent crimes impacts on house prices. The first one is methodological. Using spatial regression, as we propose, shows that traditional OLS regression tends to overestimate the violent crime impact on house prices. The former Brazilian papers used standard OLS regressions and they could have overestimated the violence rate impacts on apartments prices. Secondly, it is important to control for districts intrinsic characteristics – like services quality, leisure and landscape – to avoid overestimating the impact of violence in apartments price. Thirdly, we estimated the violent crime impact for the Rio de Janeiro market, the second largest Brazilian city in population and in economics terms. Rio de Janeiro is also the most popular Brazilian city in the word and the biggest tourist destination in Brazil. Finally, this kind of study has important public policies implications. The hedonic regression can be used to highlight the impacts of public safety policies. The hedonic model parameters related to crime rates are one measure of the social cost of crime. Since Brazil is one of the most violent countries in the world, testing the implicit cost of crime on housing prices is an important task. In our paper, we corroborated Frischtak and Mandel's (2012) finding that the UPP safety policy was successful in reducing Rio de Janeiro's hosing prices inequalities. In terms of robbery rates, the UPP also seems to have been successful, although the impact was more pronounced in the richest districts, where the robbery rate was higher in the initial period.

Finally, comparing to other Brazilian studies, the impact of homicides in apartment price are lower in our analysis. There are two reasons for this result. The first is that the other Brazilians contributions did not used spatial econometric techniques. The second is that there was no control to intrinsic district characteristics in the most of the papers. Combining spatial regressions and control to districts characteristics is important to avoid overestimating the homicide impact. When we calculated an OLS model without district characteristics, the results were with the other Brazilian studies. Comparing our results to others from highly violent Latin America cities – Cali, in Colombia, and Acapulco, in Mexico – the homicide impact on apartment prices is lower in Rio de Janeiro, even

when we estimated OLS regression without district characteristics control variable. Further studies could compare the violence impact in house prices in international perspectives.

References

Almeida, E., 2012. *Econometria Espacial Aplicada*. Campinas: Editora Alinea.

Almeida, A., Montes, G., 2020. Effects of crime and violence on business confidence: evidence from Rio de Janeiro. *Journal of Economic Studies*, 47, pp. 1669-1688. https://doi.org/10.1108/jes-07-2019-0300

Anselin, L., 1988. *Spatial Econometrics:* methods and models. Kluwer Academic.

Basu, S., Thibodeau,T.G., 1998. Analysis of spatial autocorrelation in house prices. *Journal of Real Estate and Economics*, 17, pp.61-85. https://doi.org/10.1023/A:1007703229507

Brasington, D., Haurin, D.R., 2006. Educational outcomes and house values: a test of the value added approach. Journal of Regional Science, 46(2), pp. 245-268. https://doi.org/10.1111/j.0022-4146.2006.00440.x

Campos, R., 2017. O mercado imobiliário residencial no município de São Paulo. *Nova Economia*, 27(1), pp. 307-337. https://doi.org/10.1590/0103-6351/2441

Carvalho, L.D.S., Montenegro, R.L., Martins, M.A., 2024. Effects of crime in Rio de Janeiro: a spatial analysis of the period between 2014 and 2016. *Gestão & Regionalidade*, 40. https://doi.org/10.13037/gr.vol40.E20248232

Ceccato, V., Wilhelmsson, M., 2011. The impact of crime on apartment prices: evidence from Stockholm, Sweden. *Geografiska Annaler*, 93(1), pp.81-103. https://doi.org/10.1111/j.1468-0467.2011.00362.x

Cerqueira, D.R.C., 2014. *Causas e consequências do crime no Brasil*. Rio de Janeiro: BNDES.

Dantas, R.A., Magalhães, A.M., Vergolino, J. R., 2007. Avaliação de imóveis: a importância dos vizinhos no caso de Recife. *Economia Aplicada*, 11(2), pp.231-251. https://doi.org/10.1590/S1413-80502007000200004

Delgado, J., Wences, G., 2019. A hedonic approach to the valuation of the effect of criminal violence on housing prices in Acapulco City. *Empirical Economics*, 59, p. 2999-3018. https://doi.org/10.1007/s00181-019-01804-3

Frischtak, C., Mandel, B.R., 2012. Crime, house prices, and inequality: the effect of UPPs in Rio (Staff Report no. 542). Federal Reserve Bank of New York.

Gibbons, S., 2004. The costs of urban property crimes. *The Economic Journal*, 114, pp. 441-463. https://doi.org/10.1111/j.1468-0297.2004.00254.x

Griliches, Z., 1971. Introduction: hedonic price indexes revisited. In: Griliches, Z (ed). *Prices indexes and quality change*: studies in new methods of measurement. Cambridge: Havard University Press.

Herman, B., Haddad, E., 2005. Mercado imobiliário e amenidades urbanas: a view through the window. *Estudos Econômicos*, 35(2), pp. 237-269. https://doi.org/10.1590/S0101-41612005000200001

Iachan, L., Moreau, F., Heritage, P. *et al*., 2023. How does urban violence impact choices of cultural participation? The case of Maré *favela* complex in Rio de Janeiro. *Journal of Cultural Economics* 47, pp. 609-641. https://doi.org/10.1007/s10824-022-09465-4

Kennedy, P., 1981. Estimation with correctly interpreted dummy variables in Semilogarithmic Equations. *American Economic Review*, 74(1), pp.801.

Knestch, J.L., 1963. Outdoor recreation demands and benefits. *Land Economics*, 39(4), pp. 387-396.

Lessing, B., 2008. As facções cariocas em perspectiva comparativa. *Novos Estudos*, 80, pp. 43-62. https://doi.org/10.1590/S0101-33002008000100004

Lessing, B., 2012. *The logic of violence in criminal war:* cartel-state conflict in Mexico, Colombia and Brazil. Thesis (Doctor of Philosophy in Political Science). Graduate division of University of California, Berkeley. University of California, Berkeley.

Lynch, A.K., Rasmussen, D.W., 2001. Measuring the impact of crime on house prices. *Applied Economics*, 33(15), pp. 1981-1989. https://doi.org/10.1080/00036840110021735

Macedo, P.B., 1998. Hedonic price models with spatial effects: an application to the housing market of Belo Horizonte, Brazil. *Revista Brasileira de Economia*, 52(1), pp.63-81.

Misses, M., 2007. Mercados ilegais, redes de proteção e organização do crime no Rio de Janeiro. *Estudos Avançados*, 21(6), pp. 139-157. https://doi.org/10.1590/S0103-40142007000300010

Moreira de Aguiar, M., Simões, R., Golgher, A.B., 2014. Housing market analysis using a hierarchical-spatial approach: the case of Belo Horizonte, Minas Gerais, Brazil. *Regional Studies, Regional Science*, 1, pp. 116-137. https://doi.org/10.1080/21681376.2014.934391

Pio, J.G., Brito, A.C.S., Gomes, A.L., 2021. Criminalidade na cidade do Rio de Janeiro (RJ): as influências das políticas públicas e as relações de curto e longo prazos. *Revista Brasileira de Ciências Sociais*, 36(106). https://doi.org/10.1590/3610601/2021

Pontes, E., Paixão, L.A., Abramo, P., 2011. O mercado imobiliário como revelador das preferências pelos atributos espaciais: uma análise do impacto da criminalidade urbana no preço de

apartamentos em Belo Horizonte. *Revista de Economia Contemporânea*, 15(1), pp. 171-197. https://doi.org/10.1590/S1415-98482011000100007

Rosen, S., 1974. Hedonic price and implicit markets: product differentiation in pure competition. *Journal of Political Economy*, 82(1), pp. 35-55.

Rondon, V.V., Andrade, M.V., 2005. Uma estimação dos custos da criminalidade em Belo Horizonte. *Ensaios FEE*, 26(2), pp. 830-854.

Teixeira, E.C., Serra, M.A., 2006. O impacto da criminalidade no valor da locação de imóveis: o caso de Curitiba. *Economia e Sociedade*, 15(1), pp. 175-207.

Thaler, R., 1978. A note on the value of crime control: evidence form the property market. *Journal of Urban Economics*, 5, pp. 137-145.

Valencia, J.B.V., Sanz, M.I.Z., 2017. Homicide and land prices: a spatial analysis in Santiago de Cali. *Cuadernos de Economia*, 40(4), p.147-159. https://doi.org/10.1016/j.cesjef.2016.06.001

Villaça, F., 1998. *Espaço intraurbano no Brasil*. São Paulo: Studio Nobel.

Zaluar, A., 2002. A guerra sem fim em alguns bairros do Rio de Janeiro. *Ciência e cultura*, 54(1), pp. 32-38.

Appendix

Table A1. OLS (AI) and SAC (AII) regressions on homicides taxes without IPC

Variable	Estimate Model A1	Estimate Model AII	Variable	Estimate Model AI	Estimate Model AII
Intercept	11,518***	8,2588***	CBD	0,0037***	0,0005
Age	-0,0037***	-0,0040***	Beach	-0,0280***	-0,0189***
Parking Space1	0,1560***	0,1371***	Line1	0,0727**	0,0633*
Parking Space2	0,2676***	0,2240***	Line2	0,00879***	0,0612*
Parking Space3	0,2415***	0,2262***	Culture	0,0055***	0,0044***
Studio	-0,7413**	-0,5660**	Cinema	0,1156***	0,0858***
Bedroom2	0,2081***	0,2124***	Green	1,0632	1,0086
Bedroom3	0,2734***	0,2878***	Time	0,0188***	0,0202***
Bedroom4	0,1561**	0,2197**	Homicides	-0,0060***	-0,0041***
Bathroom2	0,1745***	0,1371***	ρ		0,242***

Bathroom3	0,1524***	0,0972**	λ		0,1685***
Area	0,0062***	0,0056***	Adjusted-R^2	0,80	
Elevator	0,0678***	0,0685***	F-statistic	324,4***	

*Significant for 10%

*Significant for 5%

*Significant for 1%

Source: own calculation from CEF and IPP data