# URBAN SPRAWL AND THE COST OF PROVIDING LOCAL PUBLIC SERVICES: THE CASE OF BRAZILIAN MUNICIPALITIES

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## RESUMO

Este artigo examina os efeitos do *urban sprawl* sobre o custo da prestação de serviços públicos nas cidades brasileiras. A análise se baseia nas cidades pertencentes a médias e altas concentrações urbanas e utiliza modelos econométricos espaciais para avaliar o efeito do *urban sprawl* sobre o gasto municipal agregado e nove itens de gastos municipais desagregados (administração, saneamento básico, cultura, gestão ambiental, habitação, polícia local, assistência social, esportes e lazer e infraestrutura urbana). Os resultados fornecem evidências de que o *urban sprawl* afeta positivamente o custo per capita de prestação de serviços públicos locais de cidades de alta concentração urbana. Os resultados também sugerem a existência de um efeito threshold entre urban sprawl e o custo dos serviços públicos locais.

**Palavras-chave**: Urban sprawl. Brasil. Finanças públicas municipais.
**Código Jel:** H41, R14, R50.

## ABSTRACT

This paper examines the effects of urban sprawl on the cost of providing public services in Brazilian cities. The analysis is based on cities belonging to medium and high urban concentrations and uses spatial econometric models do evaluate the effects of urban sprawn on one aggregate and nine disaggregate items of local spending (administration, basic sanitation, culture, environmental management, housing, local police, social assistance, sports and leisure, and urban infrastructure). The results provide evidences that the urban sprawl positively affects the per capita cost of provision of local public services of cities from high urban concentration. The results also suggest that there is a threshold effect between urban sprawl and the cost of providing local public services.

**Key-words:** Urban sprawl. Brazil. Local public finances.
**Jel code:** H41, R14, R50.

# 1 INTRODUCTION

The literature of local finance in Brazil has been concentrated in the study of some specific topics such as the decentralization of the responsibilities, the impacts of the tax liability law, and the municipal debts; yet there is a lack of studies that address the determinant factors of the spending on public service. The analysis of these factors is important to provide information about the efficiency of the local spending and the sustainability of local finances in long-term.

Environmental factors such as the population size and the urban areas are determinant factors of the local spending as well as factors prices and quantum of output. Indeed, a growing number of regional and urban researchers have associated the urban sprawl, a specific pattern of urban development, with the allocation, distribution, and volume of spending on local public services. Urban sprawl is a low-density, discontinuous and suburban style development, often characterized as a rapid and unregulated pattern of growth. It is thought to increase the cost of providing public services because it fails to capitalize on economies of scale and/or optimize on facility location (CARRUTHERS; ÚLFARSSON, 2008). For example, the greater the dispersion of population in a municipality the major the investments required for extending the highway network, the water and sewer lines to a small number of residents. By contrast, it is believed that the alternative development pattern of urban sprawl, the compact city, reduces costs by concentrating residents together and creating locational efficiencies in access and delivery (CARRUTHERS; ÚLFARSSON, 2008). Likewise, the compact city model is associated with environmental and social benefits: it encourages the development of more sustainable transport modes, which might reduce the congestion and the pollution; and it reduces the social segregation between the ones living in the suburbs and inner city, diminishing the poverty-related problems such as crime rates and poor quality of public service (HORTAS-RICO, 2014).

Most of the empirical analysis of the relation between urban sprawl and spending on local public service is concentrated in the case of developed countries. An extension of this analysis for Brazil can be valuable for the empirical literature of urban sprawl and its impacts on local spending; it offers a perspective of a country which went through a different urbanization process and presents a distinct local finance system.

The aim of this study is to contribute to the empirical literature on the urban sprawl and its effects on local public finance by offering a perspective of the analysis of a developing country. “Does the positive relation between urban sprawl and the cost of providing local public services stand for the case of Brazilian municipalities?” This is the main question attempted in this analysis, and its answer can be a starting point for discussing the role that the local and regional government should play in regulating the urban sprawl process in Brazil. To the best of our knowledge, this is the first study addressing the role of urban sprawl on provision of public goods in Brazil.

The empirical analysis is based on a per capita local public spending equation both for aggregate spending and nine disaggregated spending categories that could be more influenced by urban sprawl: administration, basic sanitation, culture, environmental management, housing, local police, social assistance, sports and leisure, and urban infrastructure. Other important local public expenditure such as education and health services were not considered since the amount of resources are mandatory accordingly to constitutional rules. Four distinct measures of urban sprawl are considered in this study searching to explore which of them fit better for explaining the cost of provision public services: coefficient of variation, gravitational index, percentage of urban area, and urban population density. All the variables are measures at the municipal level – i.e. where the policy decisions concerning the spending functions are taken.

The paper is organized into six sections. Section 2 briefly reviews previous researches on the relationship between urban sprawl and the cost of providing local public services. Section 3 presents an overview of the Brazilian local finances. Section 4 presents the empirical analysis, including modeling framework, data, and estimation results; the results are discussed in section 5. Section 6 presents the final remarks.

## 2 URBAN SPRAWL AND LOCAL PUBLIC FINANCE

Urban sprawl and its effects on local finances are a trending topic of investigation nowadays mainly because urban sprawl has been associated with negative consequences to the cost of providing public services. Carruthers and Úlfarsson (2003) affirm that urban sprawl is associated with higher providing cost of public goods because of the considerable levels of investment required to expand basic infrastructure and other public services over greater distances so as to reach a relatively smaller number of residents.

Even though urban sprawl is an important issue to local public finance, empirical evidences regarding this topic, in general, are relatively scarce and concentrated primarily on US cities. Many of the empirical studies of this topic have adopted an approach based on econometric techniques to quantify the effects of urban sprawl on per capita local spending. However, the empirical results are still not conclusive and may vary from study-study.

Carruthers and Úlfarsson (2008), for example, pointed out evidence that the density of developed land (an urban sprawl measure) in US cities has a negative effect on five key measures of local government spending: total direct, education, parks and recreation, police protection and roadways; whereas Ladd (1992) found that there is a U-shaped relationship between public spending and density, except in sparsely populated areas, higher density typically increases public sector spending.

According to Hortas-Rico and Solé-Ollé (2010), the empirical results can be influenced by the measures used to account the effect of urban sprawl in the per capita local spending function; more accurate measures lead to better empirical results. Examples of works that used different measures of urban sprawl are Hortas-Rico and Solé-Ollé (2010) and Hortas-Rico (2014), both investigated the effects of urban sprawl on the provision of local public goods by the municipally in Spain. Hortas-Rico and Solé-Ollé (2010) used urbanized area per capita and Hortas-Rico (2014) considered the built-up area per capita as a measure of sprawl. Both papers had the same conclusion: there is a positive effect of urban sprawl on the cost of providing public goods, both aggregated and disaggregated categories (community facilities, basic infrastructure and transport, local police, general administration, and culture and sports).

Nakamura and Tahira (2008) also used a different measure for urban sprawl to evaluate its effect on the cost of public services. They developed an index similar to the Lorenz curve to represent the distribution of the population density within the Japanese municipalities. Their results show that the concentration of population within a city reduces per capita cost of providing the public services, although the results for disaggregated items of expenses are similar to but less obvious than that for the total cost.

## 3 THE BRAZILIAN MUNICIPAL PUBLIC SECTOR: AN OVERVIEW

The administration of the Brazilian public sector is divided into four different levels of government: the federal government, the 26 states, the federal district and 5,570 local governments.

Until the 80s, the provision of public goods in Brazil was concentrated at the federal level. This scenario had changed with the reform promoted by the Brazilian Federal Constitution 1988, which promoted the decentralization of responsibilities among governments. The decentralization increased the responsibilities of the local government, and actually municipalities have played a more prominent role in providing public goods and in promoting regional economic development.

Generally, the local governments are responsible for basic education, urban structure, public transportation, refuse collection, street cleaning, street lighting, among others. The local provision of public services is primarily financed by local taxes, user charges and transfers from others government levels (federal and state). It is worth noting that the smaller the size of the municipality the bigger the dependency of transfers from other government levels.

The distribution of the Brazilian population in its 5,570 municipalities shows a high concentration in large urban centers. Around 56% of the population (114.6 million) live in only 5.5% of the cities (304 cities), which are those with more than 100 thousand inhabitants (IBGE, 2015).

Conversely, only 6.3% of the population (1.4 million) lives in 2,451 Brazilian cities (44%) with up to 10,000 inhabitants.

This unequal population dispersion reflects on the revenues of each city and consequently on the level of public services provided by them. TABLE 1 provides evidence about the inverse correlation between the size of municipalities and the dependence of transfer revenues. Cities less populous have a limited capacity to obtain and handle resources, and are more dependable of transfers from other government levels. Due to it, these cities can face difficulties when trying to meet their expenditure needs. By contrast, cities with a bigger population are less dependable of transfers and hold a better capability to manage their own resources. Nevertheless, populous cities have a great challenge of managing the urban spaces; the public services can be compromised if the resources are not well allocated across the urban space.

TABLE 1 - RELATIVE PARTICIPATION OF LOCAL REVENUES ACCORDING TO POPULATION GROUPS IN 2010

| POPULATION GROUPS (PER 1,000) | TOTAL REVENUES | TAXES REVENUES | TRANSFER REVENUES | OTHER REVENUES |
|---|---|---|---|---|
| TOTAL | 1.00 | 0.15 | 0.76 | 0.09 |
| until 2 | 1.00 | 0.03 | 0.93 | 0.04 |
| 2 \|-- 5 | 1.00 | 0.04 | 0.92 | 0.04 |
| 5 \|-- 10 | 1.00 | 0.05 | 0.91 | 0.04 |
| 10 \|-- 20 | 1.00 | 0.06 | 0.90 | 0.04 |
| 20 \|-- 50 | 1.00 | 0.08 | 0.86 | 0.07 |
| 50 \|-- 100 | 1.00 | 0.11 | 0.80 | 0.09 |
| 100 \|-- 200 | 1.00 | 0.15 | 0.73 | 0.12 |
| 200 \|-- 500 | 1.00 | 0.19 | 0.67 | 0.14 |
| 500 \|-- 1000 | 1.00 | 0.22 | 0.63 | 0.15 |
| 1000 \|-- 5000 | 1.00 | 0.28 | 0.57 | 0.15 |
| 5000 and more | 1.00 | 0.45 | 0.40 | 0.15 |

SOURCE: Author's own elaboration based on data from Finbra (2010).

Regarding the composition of local public spending, there are some differences across cities. TABLE 2 shows that expenditure with administration services is bigger in small cities than in big ones. On the other hand, big cities spend more in urban infrastructure than small cities. The spent in health and education is quite similar in all the cities groups, and represents almost fifty percent of the total spending.

TABLE 2 - RELATIVE PARTICIPATION OF LOCAL EXPENDITURE ACCORDING TO POPULATION GROUPS IN 2010

| POPULATION GROUPS (PER 1,000) | TOTAL | ADMINISTRA-TION | HEALTH | EDUCATION | URBAN INFRASTRUCTURE | OTHER SPENT |
|---|---|---|---|---|---|---|
| TOTAL | 1.00 | 0.14 | 0.23 | 0.26 | 0.10 | 0.27 |
| until 2 | 1.00 | 0.18 | 0.21 | 0.24 | 0.08 | 0.29 |
| 2 \|-- 5 | 1.00 | 0.18 | 0.21 | 0.25 | 0.08 | 0.28 |
| 5 \|-- 10 | 1.00 | 0.16 | 0.22 | 0.30 | 0.09 | 0.24 |
| 10 \|-- 20 | 1.00 | 0.15 | 0.22 | 0.32 | 0.09 | 0.22 |
| 20 \|-- 50 | 1.00 | 0.14 | 0.22 | 0.33 | 0.10 | 0.21 |
| 50 \|-- 100 | 1.00 | 0.14 | 0.24 | 0.32 | 0.10 | 0.21 |
| 100 \|-- 200 | 1.00 | 0.16 | 0.23 | 0.27 | 0.11 | 0.22 |
| 200 \|-- 500 | 1.00 | 0.14 | 0.24 | 0.25 | 0.12 | 0.25 |
| 500 \|-- 1000 | 1.00 | 0.12 | 0.30 | 0.22 | 0.11 | 0.26 |
| 1000 \|--5000 | 1.00 | 0.11 | 0.27 | 0.19 | 0.13 | 0.30 |
| 5000 and more | 1.00 | 0.04 | 0.18 | 0.19 | 0.11 | 0.47 |

SOURCE: Author's own elaboration based on data from Finbra (2010).

The expenditures on education and health have some specificities; the Brazilian Federal Constitution establishes a minimum percentage of spending on these two public services. The local governments have to spend a minimum of 25 percent of the total revenue, including taxes and transfers from other government levels, on education, and a minimum of 15 percent of the total revenue on health. Thus, it would not be expected that the per capita spending on education and health are affected by urban sprawl. It is possible that the quality and the level of the final output of these categories of expenditure may be affected by the urban sprawl, but this is a topic that requires more investigation. In this study, we dropped the expenditure of education and health from the analysis and focused on the cost of providing other categories of spending, more likely to be influenced by urban sprawl.

# 4 EMPIRICAL ANALYSIS

## 4.1 EMPIRICAL MODEL

The empirical strategy consists in estimating a public provision equation for each public service searching to achieve a deeper insight about the relationship between urban sprawl and local spending on public services. In each equation, the dependent variable (e) represents the per capita cost of providing some public service and the explanatory variables measure the cost of and the demand for local government spending as well unobserved effects. Generically, the representation of the public provision equation is:

$$e = f(U, D, R, u) \tag{1}$$

Where the explanatory variables are divided into three categories: urban sprawl variables (U); demand variables (D); and revenue variables (R).

### 4.1.1 Urban sprawl variables

Choosing the variables to capture the magnitude of the urban sprawl is the main challenge for the evaluation of the consequences of this phenomenon. One of the most well-known measures for assessing the urban sprawl employs variants of population density or developed areas as proxies. However, the use of this kind of variables has been criticized for two main reasons. First, as pointed out by Hortas-Rico and Solé-Ollé (2010), there is no agreement regarding the right variables to capture density (density of housing units, population or employment), the extent of the space over which density should be characterized (total or urbanized area), and the scale at which density should be measured (metropolitan or municipality). Secondly, the density does not describe the urban areas properly, although it indicates the presence of scale of certain urban services, it fails showing the distribution of the population within the cities (CARRUTHERS; ULFARSSON, 2003).

In our analysis, urban sprawl is considered as a low-density growth pattern characterized by the excessive and continuous spatial expansion throughout the borders of a city and four measures were used to capture its effects. The benefit of using multiple variables is that we can compare the results of each one and indicate the best measure of urban sprawl for the Brazilian municipalities in terms of the significance and fitting adjustment obtained in the estimation process. The selected measures are the percentage of urban area, urban population density, the coefficient of variation (CV), and the gravitational index (GI). A description of each measure follows:

**Percentage of urban area (% Urban Area):** the percentage of urban area is given by the ratio of the urban land to the total land of a municipality. The bigger the percentage of urban land the most sprawled is a municipality.

**Urban population density (UPD):** UPD is given by the ratio of the urban population to the urban area in kilometers. Less dense areas tend to be more sprawled.

**Coefficient of Variation (CV):** The CV is defined as the ratio of the standard deviation to the mean of the urban population density (Equation 2). It shows the extent of variability in relation to the mean of the population density and represents the concentration dimension of urban sprawl. Concentration is the degree to which housing units are disproportionately located in relatively few areas or spread evenly in the urbanized area rather than spread evenly throughout (GALSTER et al., 2001). The higher the CV the most sprawled is a municipality.

$$\mathrm{CV} = \frac{Sd_i}{\mathrm{Me}_i} \tag{2}$$

$Sd_i$= Standard deviation of the urban population density (census tract) of municipally *i*
$Me_i$= Mean of the urban population density (census tract) of municipally *i*

The calculus of the CV is based on the information of the census tract of each city. The census tract is the territorial unit of data collection control, it is made up of contiguous areas and it respects the political and administrative division of others territorial structures of analysis. The census tracts are also classified into rural and urban tracts. In this analysis, only the urban census tract is selected. The population density of each census tract is measured by the ratio of the total resident population to the area of the census tract. The area is estimated by using the shapefile provided by IBGE and by using the software Qgis (QGIS DEVELOPMENT TEAM, 2016).

**Gravitational Index (GI):** the GI shows the concentration of the population at the central area and represents the centrality dimension of urban sprawl. Centrality is the degree to which observations of a given land use are located near the Central Business District (CBD) (GASLTER et al., 2001), usually defined as the city centers. The smaller the GI the less concentrated the population in the central area and the higher the degree of urban sprawl.

The GI was calculated based on the centered index of spatial concentration (CICS) proposed by Campante and Do (2009). The CICS is typically used to measure the concentration around capital cities. In the context of urban sprawl, it measures how concentrated the population is at the city center (CBD).

The GI is defined as:

$$IG(\mu, C) = \int h(|x - C|)d\mu \tag{3}$$

C being the center of interest, in the empirical analysis, it is represented by the city core located at the central area.

$\mu$ being the distribution of the population,

and h(d) = (|x-C|) is a decreasing function of distance (d) with constant coefficient of relative risk aversion; in this analysis the *h(d)* function is given by $h(d)=\alpha \log(d)+\beta$ (plan $\mathbb{R}^2$).

The log function incorporates the property of gravity: for any point T, situated at distance *d* from the point of interest *C*, the GI does not change when a uniform subdistribution over a circumference centered at T is squeezed around that point (CAMPANTE, DO; 2009). The property of gravity is important because it separates the impact of the central point of interest from possible local impacts of other points. Considering that the population is symmetrically distributed within each unit of analysis, the property of gravity also allows that population to be represented as a mass point, which guarantees the practical implementation of the index.

In order to shape the GI according to the population size and the area of the city, and to present an easily interpretable scale, it is reasonable to normalize the index. The most simple way is to express the index with the [0, 1] interval, with 0 representing the minimum concentration and 1 the maximum concentration.

Normalizing the index requires two procedures, as described by Campante and Do (2009):

1- Dividing the μ by population size, and
2- Setting

$$(\alpha,\beta) = \left(-\frac{1}{\log(\bar{d})}, 1\right) \quad (4)$$

Where $\bar{d} = \max|x - C|$ is the maximum distance between a point and the center of the city.

The calculation of GI demands the definition of the central point of interest, or the CBD of each city, and the estimation of the distance between each census tract to the CBD. The CBDs are taken from a shapefile (IBGE) which contain the main point of each city in Brazil; these points usually are located at the historical core and represent the city hall. The distance is calculated by using the tools centroid of a polygon and matrix of distance from the software Qgis (QGIS DEVELOPMENT TEAM, 2016).

In order to identify if the effects of urban sprawl (measured by the GI) on the cost of public services differ from cities of high urban concentration to cities of medium urban concentration, a dummy variable was added to the model: the GI is multiplied for a dummy that equals to 0 if the municipality belongs to a high urban concentration and 1 if the municipality belongs to a medium urban concentration. The motivation for this strategy was to capture non linearity in the relationship between urban sprawl and the cost of providing public services.

4.1.2 Demand and revenue variables

The demand function of per capita local spending (Equation 1) depends on a bunch of demand factors, which works as control variables of the model. The selection of these demand variables is based on work done by Carruthers and Úlfarsson (2008), and Hortas-Rico and Sollé-Ollé (2010). It is worth to add that the specification does not match any of these identically, due the data availability and the different purposes of the analysis. Summarily, in this study, demographic, social and economic variables account for the demand factor in the empirical model.

First, we briefly present the demographic variables. In previous studies, the size of the population or the population growth was the most important demographic variable in a model of demand for public services. However, their effects on per capita spending are not clear. According to Ladd (1992), a positive rate of population growth negatively influences per capita spending because the existing population almost always finances new development. Alternatively, bigger population demands more public services, pressing the spending up. We address this question by adding in the model the population size of each municipality in the natural log form.

Other demographic variables that should affect positively the demand for local public services are added to the model: percentage of children below five years old; percentage of people older than 60 years old; percentage of graduate people; and percentage of people without studies.

Regarding the social variables, it should represent the effect of what Hortas-Rico and Sollé-Ollé (2010) call harshness of the environment on local costs. The variable included is the unemployment rate, since it is a measure of disadvantaged people. The higher the number of disadvantaged people in a municipality the higher tends to be the spending on proving public services, especially in some services such as social assistance.

In terms of the economic variables, generally, in previous studies, the main economic variable introduced was the per capita income, usually represented by the Gross Domestic Product (GDP) per capita. Income was tested in the currently empirical analysis, but its inclusion led to a high degree of multicollinearity with some of revenue, demographic and social variables. For this reason, income was rejected as an explanatory variable. Conversely, another variable was introduced to capture the effect of the economic environment on the local spending: the percentage of the industry production on the total production. Given that industries require better infrastructure such as good roads and good sanitation condition to produce, a municipally with more industries will spend more on local public services.

Ultimately, we added a dummy variable in the model in order to measure the effects of the centrality of cities on local public spending. The dummy equals to 1 if the city is a central city with more than 100,000 inhabitants of a population arrangement; and 0 if it is not a central city. Central cities concentrate most part of the population and the jobs of a population arrangement, so it is acceptable to assume that in such cities there are gains of scale in providing public services; and consequently, the spending is lower compared to the cities that are not central.

Turning now to the resources variables, two fiscal capacity variables account for their effects on the demand for local public services. These variables are the local taxes per capita and local fees per capita; both are introduced in the natural log form. It is expected a positive coefficient for the tax per capita (the higher the taxes the higher the spending on public service) and a negative coefficient for the fees because it represents the price of the local public service. Another common resource variable added in models of demand for public service is the per capita government transfers. In the present analysis, this variable was not included in the model for two main reasons. First of all, it is high correlated with other variables and its inclusion led to controversial results; secondly, most of the transfers are linked to specific competencies of the local governments, such as education and health, thus it is expected that transfers do not significantly affect the spending in other public services.

### 4.1.3 Dependent variables

The selection of the local spending variables is based on previous studies that have addressed the effect of the urban sprawl on local public finances (HORTAS-RICO; SOLLÉ-OLLÉ, 2010; CARRUTHERS; ÚLFARSSON, 2008; CARRUTHERS; ÚLFARSSON, 2003; NAKAMURA; TAHIRA, 2008). All these studies focused on the local competencies most directly influenced by the urban sprawl. Thus, we analyze ten expenditure functions of the municipal budget: administration, basic sanitation, culture, environmental management, housing, local security, social assistance, sports and leisure, urban infrastructure; and aggregate spending.

The aggregate spending is the sum of direct expenditures, including salaries and wages, the spending on education and health were excluded from this categories due to the reasons exposed in section 3. TABLE 3 shows the description of each category of local expenditure analyzed empirically.

TABLE 3 - PUBLIC EXPENDITURE VARIABLES

| Variable | Description |
|---|---|
| Aggregate | Sum of direct expenditures, including salaries and wages. |
| Administration | Local spending on general administration, financial administration, management of human resources, among other. |
| Basic sanitation | Local spending on basic sanitation, including the water and sewerage systems. |
| Culture | Local spending on culture. |
| Environmental management | Local spending on environmental management, environmental preservation, and recovery of degraded areas. |
| Housing | Local spending on rural and urban housing development. |
| Local police | Local spending on security and police. |
| Social assistance | Local spending on children, elderly people, disabled people, and community assistance. |
| Sports and leisure | Local spending sports and leisure. |
| Urban infrastructure | Local spending on urban infrastructure, urban services and public transportation. |

SOURCE: Finbra (2010).

Empirical evidences (CARRUTHERS; ÚLFARSSON, 2003; HORTAS-RICO; SOLLÉ-OLLÉ, 2010) show that the effects of urban sprawl on the local cost are distinct, depending on the type of local public services under consideration. The costs of the spending on aggregate, administration, basic sanitation, housing, and urban infrastructure, for example, are positively affected by urban sprawl because higher degrees of population dispersion undermine the use of scale economies on the provision of local public services, leading to an increasing in their costs. It also costs more to local government to expand the roll of public services to achieve a small number of users. On the other hand, the effect of sprawl on the expenditure of environmental management, local police, and social assistance can be positive either negative due to the diseconomies of scale associated with the problems of high degrees of population concentration (poverty, crimes, pollution, and so on). In such cases, the population dispersion can rise and/or reduce the cost of providing these categories of public expenditures because it reduces the impacts of the diseconomies of scale. In the case of the spending on culture and sports and leisure, it tends to be higher where the population is more concentrated and demands more of the services.

## 4.2 DATA AND ECONOMETRIC SPECIFICATION

The local public service demand is estimated by employing a cross-sectional dataset of the Brazilian municipalities for the fiscal year of 2010. A dynamic analysis, which could capture better the process of sprawling, is not possible due to the data availability for Brazilian municipalities. The demand variables of the model and the data used to create the urban sprawl variables are provided by the demographic census, performed every ten years. Thus, in this analysis, the data from the last demographic census (2010) were used.

Due to the fact that urban sprawl is a phenomenon that occurs mainly in areas of high urban concentration such as metropolitan areas, the selection of the cities for the present analysis was based on the definition of population arrangement settled by IBGE (2015). A population arrangement is a group of two or more municipalities with strong population integration due to commuting movements to work or study, or due to the contiguity between the main urban spots. There were 294 population arrangements in Brazil in 2010 composed of 938 municipalities which population represents 55.9% of the overall Brazilian population (IBGE, 2015).

The population arrangements are also classified into some groups according to their population size. Population arrangements with population from 100,000 to 750,000 inhabitants are called medium urban concentrations, and population arrangements or isolated municipality with more than 750,000 inhabitants are called high urban concentration. Each urban concentration has a main city that centralizes the substantial part of the population and jobs of the population arrangement.

The sample is composed by cities of 25[1] high urban concentrations and cities of 79[2] medium urban concentrations. The number of municipalities in the sample differs from model-to-model because municipalities, where no spending took place during the 2010 fiscal year, were dropped in the estimation process.

The municipalities with a population lower than 20,000 inhabitants were excluded from the analysis, due the fact that they do not share the same urbanization process or the finance characteristics of other municipalities in the same population arrangement. TABLE 4 lists the source and descriptive statistics for all the variables of the model.

The exact nature (shape) of the relationship between urban sprawl development pattern and public services expenditure is not well defined. Hortas-Rico and Solé-Ollé (2008) considered the log-log function the best specification to describe the relation between urban sprawl and per capita public spending. However, Carruthers and Úlfarsson (2003) found that neither linear nor log-linear forms are appropriated; they adopted the semi-log form by taking the log of the dependent variable only. In the current study, some of these functional forms were tested and the one that best fits the data from the Brazilian municipalities is the log-linear form and it is estimated by Ordinary Least Square (OLS), which presentation is defined as follow:

$$\text{Ln } e = \alpha + U + \beta_1 D + \beta_2 \ln R + \varepsilon \tag{5}$$

[1] There are 26 high urban concentrations in Brazil; the concentration of Brasília was not included in the analysis.
[2] In this analysis, we selected only the medium population arrangements in which the central city has more than 100,000 inhabitants.

TABLE 4 - DESCRIPTIVE STATISTICS

| **Dependent variables** | Mean | Standard deviation | Maximum | Minimum | Data sources |
|---|---|---|---|---|---|
| per capita aggregated expenditure (R$) | 934.933 | 684.737 | 6122.500 | 286.002 | Brazilian Mystery of Finance (Finbra,2010) |
| per capita spending (R$) on | | | | | |
| Administration | 271.397 | 250.133 | 2410.340 | 5.067 | |
| basic sanitation | 81.942 | 113.087 | 876.164 | 0.004 | |
| Culture | 21.449 | 42.891 | 644.108 | 0.036 | |
| environmental management | 23.593 | 48.858 | 507.432 | 0.002 | |
| Housing | 30.861 | 93.474 | 846.334 | 0.002 | |
| local police | 27.184 | 36.904 | 304.296 | 0.005 | |
| social assistance | 53.067 | 53.416 | 623.490 | 2.383 | |
| sports and leisure | 21.442 | 28.869 | 300.964 | 0.040 | |
| urban infrastructure | 215.085 | 192.848 | 2106.117 | 1.822 | |
| **Urban sprawl variables** | | | | | |
| % Urban area | 0.839 | 0.226 | 1.000 | 0.004 | Author's own elaboration; Census 2010, IBGE |
| Coefficient of variation (CV) | 1.061 | 0.669 | 7.648 | 0.352 | |
| Gravitational index (GI) | 0.590 | 0.170 | 1.000 | 0.099 | |
| Urban population density (UPD) | 2271.953 | 2012.221 | 13018.414 | 82.781 | |
| **Demographic, economic and social variables** | | | | | |
| Population | 291997 | 776605 | 11253503 | 20029 | Census 2010, IBGE |
| % Graduates | 10.222 | 5.802 | 33.700 | 1.810 | |
| % Without studies | 45.414 | 8.918 | 72.900 | 22.000 | |
| % Population <5 | 9.034 | 6.717 | 95.100 | 5.530 | |
| % Population >60 | 9.894 | 2.395 | 19.160 | 4.370 | |
| % Unemployed | 8.243 | 3.343 | 25.300 | 1.700 | |
| % Industry production on total | 0.283 | 0.136 | 0.838 | 0.059 | |
| **Resources variables (per capita R$)** | | | | | |
| Taxes | 325.678 | 331.792 | 2536.375 | 14.408 | Finbra, 2010 |
| Fees | 31.539 | 31.189 | 212.036 | 0.000 | |

SOURCE: IBGE (2010); Finbra (2010).

Nevertheless, accordingly to Sollé-Ollé (2005) and Carruthers and Úlfassson (2008), this econometric specification is not complete. These authors maintain that there is a strategic interaction among local government of neighboring municipalities, which means that the per capita expenditure on public services in a jurisdiction *i* depends on per capita expenditure or other factors of surrounding jurisdictions.

As noted by Carruthers and Úlfassson (2008), the strategic interaction needs to be accounted in the framework of the empirical model for two main reasons. First, "to recognize the presence of an underlying behavioral model of public finance; and secondly to avoid an econometric misspecification that does not account for the spatial dependence introduced by various forms of strategic interaction" (CARRUTHERS; ÚLFASSSON, 2008).

We accounted for the strategic interaction framework by using the technique of spatial econometric (described in APPENDIX 1). The diagnostics for spatial dependence (see TABLE 1.A in APPENDIX 1) indicate that there is spatial dependence in the error term of some competences of local spending (aggregate, basic sanitation, housing, social assistance, sports and leisure, and urban infrastructure) and spatial dependence in both the dependent variable and the errors in the local police spending. Thus, for local police, we estimated the Spatial Autocorrelation Model (SAC) (Equation 7) and for the other spending functions with spatial dependence, the model estimated is the Spatial Error Model (SEM) (Equation 6).

$$\ln e = \alpha + U + \beta_1 D + \beta_2 \ln R + \nu \quad (6)$$

$$\ln e = W\ln e + \alpha + U + \beta_1 D + \beta_2 \ln R + \nu \quad (7)$$

where $\nu = \lambda W \nu + \varepsilon$ (W is the queen contiguity matrix)

The SEM is essentially a generalized normal linear model with spatially autocorrelated disturbances. Assuming independence between X and the error term, least squares estimates for β are not efficient, but still unbiased. Because of that, the SEM was estimated by the Method of Moments Estimators (MME)[3] developed by Kelejian and Prucha (1998). The SAC contains spatial dependence in both the dependent variable and the errors and it is estimated by a spatial two-stage least square (S2SLS)[4] strategy, also developed by Kelejian and Prucha (1998).

## 4.3 ESTIMATION RESULTS

TABLE 5 shows the results estimated by OLS (Equation 5) for per capita local spending functions that do not present spatial dependence (administration, culture and environmental management), and TABLE 6 presents the results from the estimation of the spatial models, given by equations (6) and (7), for the categories of spending that have spatial dependence. Four estimations were performed for each spending category using the same model; the only difference is the urban sprawl variable inserted in each estimation. Thereby, in columns (1), (2), (3) and (4) we introduced as a measure of urban sprawl the variables percentage of urban area, coefficient of variation (CV), gravitational index (GI) and the dummy for medium concentration (GI Medium), and the urban population density (UPD) respectively.

The econometric specification enables the identification of the specific effects of urban sprawl on local spending since other municipal characteristics are controlled by a set of control variables. The following paragraphs summarize the results in a general way; a discussion of the findings and its implications is done in the next section.

Before presenting the estimations results, a note should be made about the estimations from the categories of spending that have spatial dependence. Comparing the estimated parameters from the OLS and the SEM and SAC estimations, we noted that the values of the parameters have a small decrease, and the sign and the level of significance of each parameter do not vary when a spatial component is added. Seeing that, we only present the spatial results for the categories of spending that have spatial dependence.

To begin with, we present the results from the parameters of the urban sprawl variables. The percentage of urban area carries a positive sign in the local security and urban infrastructure and a negative sign in all other categories; it is significant only in the administration spending, indicating that the bigger the proportion of urban area in a city the lower its spending on administration services. Regarding the estimation results of the models with the CV, the estimated parameters of this variable are not significant in all the spending functions analyzed, pointing out that the dimension of urban sprawl represented by the CV is not correlated with the cost of providing the categories of spending analyzed in this study. On the other hand, the estimated results of the GI indicate that there is a correlation between the degree of concentration around the city center and the cost of some categories of local expenditures. The estimated parameters for aggregate spending and spending on administration and environmental management are large and significant, additionally, it has a negative sign in the aggregate and administration spending, and a positive sign in the environmental management; in other expenditure categories, the estimated parameters are large, but not statistically significant. Additionally, the estimated parameters of the dummy for medium concentrations show that the GI is not a determinant factor of the spending on administration and environmental management for cities of medium urban concentrations, suggesting that the effects presented by the GI are strictly related to cities of high urban concentrations;

[3] Anselin (2001) presents the details of the MME estimator.
[4] Anselin (2001) presents the details of the S2SLS estimator.

however, the estimated parameter for the aggregate spending and spending on social assistance are positive and statistically significant. Lastly, the UPD has a positive and highly significant coefficient in the culture and sports and leisure spending; it also has a positive sign but not statistically significant parameter in housing and local security; in all other cases, the parameters are negative and statistically insignificant.

The control variables also show important elements of the per capita spending on local public services. The statistically significant parameters of these variables change according to the category of spending. Moreover, when the urban sprawl variable differs, the sign and the level of significance of each parameter do not alter in most cases and the values have a small change.

The population is one of the most important explanatory variables of the per capita expenditure function. It has a negative and statistically significant parameter in the aggregate, administration, culture, social assistance, sports and leisure, and urban infrastructure expenditure functions. As the population is in the log form, its coefficient can be interpreted as elasticity. Then, a 1 percent increases of the population decreases local spending by around 0.096[5] percent the aggregate spending (the lowest value) and by around 0.347 percent the spending on sports and leisure (the highest value). The results of the population also evidence the role that the economies of scale exert on the cost of provided some categories of local expenditure. The bigger the population the lower the per capita cost of providing local public service. This evidence indicates that big cities can be more efficient in the provision of public services than medium or small ones: the services can reach more people with a smaller per capita cost, especially in the expenditure categories that have high fixed costs, like the administration and urban infrastructure spending.

The demographic variables which represent the preferences of the individuals for public services (percentage of graduate and percentage of no educated people) are determinant factors of per capita spending on basic sanitation, culture, local security and social assistance. The parameter of the percentage of graduate is positive and significant in the basic sanitation, culture, and social assistance; the percentage of people without education is significant and carries a negative sign and in the local security and a positive sign in the spending on social assistance. Regarding the remaining demographic variables, the percentage of the population that is less than five years old is mostly insignificant, the exception is in the social assistance function, in which the parameter is negative and significant; the percentage of people older than 60 years old has a positive and significant coefficient in the basic sanitation equation; and negative and significant coefficient in the local police spending equation. The unemployment rate has a highly and significant coefficient in eight categories of spending, but the direction of the effect varies according to the spending; it is positive in aggregate, administration, culture, and housing spending; and it is negative in basic sanitation, environment management, local security, and sports and leisure spending.

Concerning the revenue variables, as expected, the coefficient of the per capita taxes is positive, large and highly significant in most of the categories of spending; the higher the taxes in a city the higher its spending on public services. Fees per capita parameters are positive and statistically significant in the environmental management; and negative and statistically significant in the culture spending function estimated by model 3.

The percentage of industry production appears to be an important element of the per capita local spending on public services. As shown by the estimation results, it has a high and positive effect on the cost of proving the aggregate spending and the spending on administration, culture, environment management, local police, and sports and leisure. This means that, with all other variables keep unchanged, the more industrialized a municipality is the higher its spending on these public services.

The dummy that represents the centrality indicates that the fact of a city been or not a central city does not influence the cost of providing public services, the exceptions are the spending on culture, in which the coefficient is large and positive; and the spending on housing, in which the coefficient is positive and significant (in the model 4). These results indicate that in central municipalities the spending on culture and on housing is bigger than the spending on not central municipalities. In a population

[5] This value is the average of the estimated parameters of each models estimated.

arrangement, the cultural activities are concentrated in the central city, where the population is bigger and demands more of this kind of activities, for this reason, the spending on culture tends to be higher in central cities than in not central cities; similarly, in central cities the urban area is also higher and may demand more housing planning, this can explain the fact that the spending on housing is higher in this kind of municipalities.

Moving on to consider the spatial variables (see Table 6). As indicated previously, the SEM was estimated for per capita spending on basic sanitation, housing, social assistance, sports and leisure, urban infrastructure, and aggregate spending; the SAC was estimated for per capita spending on local police. The coefficient of the spatial error term (λ) is positive and highly significant in all the disaggregated measures of spending and in the aggregate spending. This evidence suggests that some factors of a municipality *i* that are not specified in the models, positively affect the cost of providing public services in a municipality *j*. This result also indicates that the strategic interaction among the municipalities in a region is a fact that accounts for the per capita spending on local public services. With respect to the spatial variables in the spending on local police function, with the exception of the function estimated by model 1, both the λ and the *We* are statistically significant and have a considerable value. This implies that the per capita spending on local security in a municipality is affected by the spending on local security and other not identified characteristics of the surrounding municipalities.

TABLE 5- OLS ESTIMATION RESULTS

continued

| MODEL | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| **ADMINISTRATION** (n=326) | | | | | | | | |
| Constant | **5.194*** ** | (6.270) | **4.943*** ** | (5.954) | **5.571*** ** | (6.061) | **4.887*** ** | (5.705) |
| % Urban area | **-0.295*** | (-1.837) | - | - | - | - | - | - |
| CV | - | - | -0.089 | (-1.701) | - | - | - | - |
| GI | - | - | - | - | **-0.568*** ** | (-2.349) | - | - |
| GI Medium | - | - | - | - | 0.198 | (1.427) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (-0.879) |
| Central | 0.019 | (0.192) | 0.035 | (0.353) | 0.047 | (0.425) | 0.055 | (0.552) |
| Population | **-0.199*** ** | (-4.756) | **-0.201*** ** | (-4.788) | **-0.23*** ** | (-4.818) | **-0.189*** ** | (-3.973) |
| % Graduates | 0.005 | (0.402) | 0.011 | (0.892) | 0.011 | (0.872) | 0.008 | (0.668) |
| % Without studies | -0.004 | (-0.555) | -0.002 | (-0.245) | -0.003 | (-0.409) | -0.003 | (-0.399) |
| % Population <5 | 0.002 | (0.470) | 0.003 | (0.602) | 0.003 | (0.619) | 0.003 | (0.642) |
| % Population >60 | 0.003 | (0.209) | -0.001 | (-0.031) | 0.000 | (-0.026) | -0.001 | (-0.042) |
| % Unemployed | **0.044*** ** | (3.818) | **0.045*** ** | (3.903) | **0.054*** ** | (4.434) | **0.0467*** ** | (4.028) |
| % Industry production on total | **0.763*** ** | (2.957) | **0.727*** ** | (2.826) | **0.713*** ** | (2.771) | **0.708*** ** | (2.734) |
| Taxes | **0.4192*** ** | (7.340) | **0.414*** ** | (7.267) | **0.395*** ** | (6.804) | **0.406*** ** | (7.110) |
| Fees | -0.011 | (-0.256) | -0.008 | (-0.182) | -0.012 | (-0.273) | -0.017 | (-0.380) |
| $R^2$ | 0.357 | | 0.356 | | 0.362 | | 0.351 | |
| **CULTURE** (n=318) | | | | | | | | |
| Constant | 0.337 | (0.233) | 0.074 | (0.051) | -0.525 | (-0.326) | 0.859 | (0.577) |
| % Urban area | -0.443 | (-1.583) | - | - | - | - | - | - |
| CV | - | - | -0.065 | (-0.714) | - | - | - | - |
| GI | - | - | - | - | 0.453 | (1.042) | - | - |
| GI Medium | - | - | - | - | -0.020 | (-0.081) | - | - |
| UPD | - | - | - | - | - | - | **0.0000649*** | (1.869) |
| Central | 0.288 | (1.641) | **0.344*** ** | (1.992) | **0.341*** | (1.764) | **0.465*** ** | (2.692) |
| Population | **-0.237*** ** | (-3.236) | **-0.247*** ** | (-3.357) | **-0.216*** ** | (-2.568) | **-0.328*** ** | (-3.951) |
| % Graduates | **0.054*** ** | (2.427) | **0.062*** ** | (2.763) | **0.059*** ** | (2.631) | **0.060*** ** | (2.725) |
| % Without studies | 0.016 | (1.262) | 0.018 | (1.474) | 0.018 | (1.470) | 0.019 | (1.524) |
| % Population <5 | -0.006 | (-0.699) | -0.005 | (-0.587) | -0.006 | (-0.643) | -0.006 | (-0.664) |
| % Population >60 | -0.012 | (-0.409) | -0.020 | (-0.704) | -0.027 | (-0.913) | -0.029 | (-1.021) |
| % Unemployed | **0.065*** ** | (3.195) | **0.067*** ** | (3.296) | **0.064*** ** | (2.909) | **0.063*** ** | (3.066) |
| % Industry production on total | **1.261*** ** | (2.790) | **1.203*** ** | (2.663) | **1.187*** ** | (2.618) | **1.274*** ** | (2.823) |
| Taxes | **0.653*** ** | (6.524) | **0.639*** ** | (6.397) | **0.657*** ** | (6.423) | **0.644*** ** | (6.482) |
| Fees | -0.114 | (-1.476) | -0.114 | (-1.467) | **-0.130*** | (-1.667) | -0.116 | (-1.502) |
| $R^2$ | 0.314 | | 0.310 | | 0.3115 | | 0.317 | |
| **ENVIRONMENTAL MANAGMENT** (n=282) | | | | | | | | |

TABLE 5- OLS ESTIMATION RESULTS

continued

| MODEL | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| Constant | **-4.523*** | (-1.686) | **-4.751*** | (-1.766) | **-7.296*** | (-2.447) | **-5.277*** | (-1.919) |
| % Urban area | -0.298 | (-0.589) | - | - | - | - | - | - |
| CV | - | - | -0.087 | (-0.543) | - | - | - | - |
| GI | - | - | - | - | **1.759**** | (2.132) | - | - |
| GI Medium | - | - | - | - | -0.188 | (-0.408) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (-1.037) |
| Central | 0.027 | (0.085) | 0.037 | (0.118) | 0.006 | (0.017) | -0.005 | (-0.017) |
| Population | 0.104 | (0.781) | 0.103 | (0.771) | 0.219 | (1.452) | 0.167 | (1.114) |
| % Graduates | -0.005 | (-0.126) | 0.002 | (0.042) | -0.005 | (-0.124) | -0.002 | (-0.058) |
| % Without studies | 0.024 | (0.996) | 0.026 | (1.070) | 0.030 | (1.251) | 0.023 | (0.971) |
| % Population <5 | -0.012 | (-0.826) | -0.012 | (-0.783) | -0.014 | (-0.912) | -0.011 | (-0.741) |
| % Population >60 | 0.034 | (0.632) | 0.028 | (0.544) | 0.011 | (0.205) | 0.034 | (0.654) |
| % Unemployed | **-0.124***** | (-3.210) | **-0.123***** | (-3.191) | **-0.14***** | (-3.409) | **-0.117***** | (-3.015) |
| % Industry production on total | **1.851**** | (2.273) | **1.822**** | (2.242) | **1.793**** | (2.216) | **1.744**** | (2.141) |
| Taxes | **0.684***** | (3.807) | **0.676***** | (3.781) | **0.756***** | (4.140) | **0.664***** | (3.718) |
| Fees | **0.249*** | (1.763) | **0.255*** | (1.795) | 0.217 | (1.530) | **0.243*** | (1.724) |
| $R^2$ | 0.224 | | 0.223 | | 0.236 | | 0.226 | |

Note: *** denotes two-tailed hypothesis test significant at p <0.01; ** denotes two-tailed hypothesis test significant at p <0.05; * denotes two-tailed hypothesis test significant at p <0.10. T-value is in parentheses. Statistically significant parameters are in bold.
SOURCE: Estimation results.

TABLE 6 - SPATIAL MODEL ESTIMATION RESULTS

continued

| MODEL | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| **AGGREGATE (**n= 326) | | | | | | | | |
| Constant | **4.737***** | (10.861) | **4.675***** | (10.657) | **4.562***** | (9.708) | **4.593***** | (10.361) |
| % Urban area | -0.106 | (-1.325) | - | - | - | - | - | - |
| CV | - | - | -0.007 | (-0.254) | - | - | - | - |
| GI | - | - | - | - | **-0.208*** | (-1.723) | - | - |
| GI Medium | - | - | - | - | **0.236***** | (3.182) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (-1.064) |
| Central | 0.031 | (0.625) | 0.046 | (0.943) | -0.014 | (-0.276) | 0.037 | (0.764) |
| Population | **-0.099***** | (-4.577) | **-0.101***** | (-4.673) | **-0.091***** | (-3.831) | **-0.091***** | (-3.836) |
| % Graduates | **0.012*** | (1.806) | **0.014**** | (2.081) | **0.015**** | (2.311) | **0.013**** | (2.036) |
| % Without studies | 0.004 | (1.080) | 0.005 | (1.278) | 0.005 | (1.287) | 0.005 | (1.205) |
| % Population <5 | -0.002 | (-0.854) | -0.002 | (-0.759) | -0.003 | (-1.037) | -0.002 | (-0.723) |
| % Population >60 | 0.007 | (0.805) | 0.005 | (0.579) | 0.004 | (0.446) | 0.006 | (0.710) |
| % Unemployed | 0.010 | (1.590) | **0.011*** | (1.653) | **0.018***** | (2.640) | **0.012*** | (1.765) |
| % Industry production on total | **0.550***** | (4.178) | **0.537***** | (4.081) | **0.510***** | (3.924) | **0.524***** | (3.964) |
| Taxes | **0.480***** | (16.208) | **0.475***** | (16.109) | **0.481***** | (16.213) | **0.473***** | (16.079) |
| Fees | -0.002 | (-0.102) | -0.003 | (-0.13) | -0.010 | (-0.440) | -0.005 | (-0.218) |
| $\lambda$ | **0.220***** | (3.905) | **0.220***** | (3.933) | **0.219***** | (3.814) | **0.222***** | (3.976) |
| Pseudo-$R^2$ | 0.685 | | 0.683 | | 0.694 | | 0.684 | |
| **BASIC SANITATION (**n=238) | | | | | | | | |
| Constant | -2.569 | (-0.762) | -2.465 | (-0.725) | -3.126 | (-0.843) | -2.786 | (-0.805) |
| % Urban area | -0.360 | (-0.563) | - | - | - | - | - | - |
| CV | - | - | 0.098 | (0.473) | - | - | - | - |
| GI | - | - | - | - | 0.203 | (0.194) | - | - |
| GI Medium | - | - | - | - | 0.085 | (0.137) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (-0.193) |
| Central | -0.229 | (-0.600) | -0.123 | (-0.328) | -0.210 | (-0.508) | -0.182 | (-0.481) |
| Population | -0.008 | (-0.045) | -0.032 | (-0.182) | 0.009 | (0.965) | -0.004 | (-0.020) |
| % Graduates | **0.099*** | (1.903) | **0.101**** | (1.964) | **0.103**** | (2.015) | **0.103**** | (2.027) |
| % Without studies | 0.047 | (1.571) | 0.048 | (1.582) | 0.048 | (1.618) | 0.048 | (1.610) |
| % Population <5 | -0.002 | (-0.130) | -0.002 | (-0.090) | -0.002 | (-0.122) | -0.001 | (-0.082) |
| % Population >60 | **0.147**** | (2.049) | **0.133*** | (1.929) | **0.132*** | (1.882) | **0.138**** | (1.974) |

TABLE 6 - SPATIAL MODEL ESTIMATION RESULTS

continued

| MODEL | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| % Unemployed | **-0.124**** | (-2.382) | **-0.120**** | (-2.311) | **-0.121**** | (-2.159) | **-0.121**** | (-2.316) |
| % Industry production on total | 1.348 | (1.250) | 1.299 | (1.207) | 1.294 | (1.196) | 1.285 | (1.189) |
| Taxes | 0.388 | (1.602) | 0.364 | (1.516) | 0.386 | (1.569) | 0.368 | (1.532) |
| Fees | -0.021 | (-0.116) | -0.040 | (-0.217) | -0.035 | (-0.193) | -0.030 | (-0.164) |
| λ | **0.123*** | (1.675) | **0.127*** | (1.732) | **0.125*** | (1.696) | **0.124*** | (1.677) |
| Pseudo-$R^2$ | 0.176 | | 0.175 | | 0.175 | | 0.175 | |
| **HOUSING (**n=234) | | | | | | | | |
| Constant | **-6.138*** | (-1.916) | **-6.089*** | (-1.895) | **-6.535*** | (-1.843) | **-5.469*** | (-1.692) |
| % Urban area | -0.359 | (-0.662) | - | - | - | - | - | - |
| CV | - | - | 0.102 | (0.583) | - | - | - | - |
| GI | - | - | - | - | -0.262 | (-0.261) | - | - |
| GI Medium | - | - | - | - | 0.338 | (0.571) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (1.359) |
| Central | 0.421 | (1.186) | 0.551 | (1.581) | 0.396 | (1.021) | **0.604*** | (1.757) |
| Population | 0.182 | (1.140) | 0.165 | (1.035) | 0.199 | (1.099) | 0.073 | (0.416) |
| % Graduates | 0.019 | (0.395) | 0.018 | (0.379) | 0.023 | (0.484) | 0.026 | (0.545) |
| % Without studies | 0.015 | (0.509) | 0.015 | (0.496) | 0.015 | (0.506) | 0.018 | (0.614) |
| % Population <5 | -0.012 | (-0.773) | -0.011 | (-0.725) | -0.012 | (-0.772) | -0.012 | (-0.759) |
| % Population >60 | -0.056 | (-0.890) | -0.070 | (-1.138) | -0.066 | (-1.081) | -0.075 | (-1.219) |
| % Unemployed | **0.098**** | (2.037) | **0.101**** | (2.128) | **0.111**** | (2.164) | **0.096**** | (2.035) |
| % Industry production on total | 1.285 | (1.246) | 1.255 | (1.221) | 1.202 | (1.165) | 1.514 | (1.457) |
| Taxes | **0.769***** | (3.490) | **0.744***** | (3.427) | **0.752***** | (3.400) | **0.749***** | (3.465) |
| Fees | 0.058 | (0.330) | 0.047 | (0.265) | 0.062 | (0.354) | 0.082 | (0.467) |
| λ | **0.167*** | **(1.870)** | **0.155*** | (1.757) | **0.159*** | (1.790) | 0.148 | (1.644) |
| Pseudo-$R^2$ | 0.170 | | 0.171 | | 0.171 | | 0.178 | |
| **LOCAL SECURITY** ( n=251) | | | | | | | | |
| Constant | 3.076 | (1.082) | 3.431 | (1.239) | 3.595 | (1.181) | 4.010 | (1.425) |
| % Urban area | 0.745 | (1.303) | - | - | - | - | - | - |
| CV | - | - | 0.063 | (0.417) | - | - | - | - |
| GI | - | - | - | - | 0.294 | (0.350) | - | - |
| GI Medium | - | - | - | - | -0.383 | (-0.871) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (1.287) |
| Central | -0.077 | (-0.235) | -0.056 | (-0.171) | 0.069 | (0.183) | 0.120 | (0.382) |
| Population | -0.125 | (-0.879) | -0.132 | (-1.020) | -0.157 | (-1.047) | -0.225 | (-1.504) |
| % Graduates | 0.012 | (0.278) | 0.003 | (0.078) | 0.002 | (0.049) | 0.009 | (0.234) |
| % Without studies | **-0.054**** | (-2.121) | **-0.055**** | (-2.227) | **-0.054**** | (-2.174) | **-0.050**** | (-2.106) |
| % Population <5 | 0.005 | (0.352) | 0.003 | (0.222) | 0.002 | (0.044) | 0.002 | (0.149) |
| % Population >60 | **-0.093*** | (-1.797) | **-0.080*** | (-1.648) | -0.073 | (-1.486) | **-0.085*** | (-1.817) |
| % Unemployed | **-0.125***** | (-2.747) | **-0.106**** | (-2.457) | **-0.117**** | (-2.544) | **-0.102**** | (-2.459) |
| % Industry production on total | **1.428*** | (1.722) | **1.382*** | (1.714) | **1.445*** | (1.787) | **1.411*** | (1.799) |
| Taxes | **0.516 **** | (2.525) | **0.534***** | (2.662) | **0.536***** | (2.647) | **0.530***** | (2.722) |
| Fees | 0.161 | (1.090) | 0.134 | (0.935) | 0.149 | (1.043) | 0.133 | (0.965) |
| *We* | 0.165 | (1.386) | **0.232**** | (1.950) | **0.234**** | (1.969) | **0.289**** | (2.574) |
| λ | -0.125 | (-0.969) | **-0.226*** | (-1.821) | **-0.235**** | (-1.904) | **-0.294**** | (-2.523) |
| Pseudo-$R^2$ | 0.247 | | 0.261 | | 0.262 | | 0.260 | |
| **SOCIAL ASSISTANCE (** n=322) | | | | | | | | |
| Constant | **2.190***** | (2.617) | **2.031**** | (2.426) | **1.577*** | (1.761) | **2.106**** | (2.493) |
| % Urban area | -0.037 | (-0.251) | - | - | - | - | - | - |
| CV | - | - | -0.068 | (-1.400) | - | - | - | - |
| GI | - | - | - | - | 0.019 | (0.085) | - | - |
| GI Medium | - | - | - | - | **0.324**** | (2.226) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (-0.448) |
| Central | 0.143 | (1.551) | 0.119 | (1.302) | 0.046 | (0.472) | 0.141 | (1.548) |
| Population | **-0.205***** | (-4.979) | **-0.198***** | (-4.803) | **-0.169***** | (-3.768) | **-0.198***** | (-4.429) |
| % Graduates | **0.043***** | (3.400) | **0.046***** | (3.672) | **0.045***** | (3.596) | **0.043***** | (3.488) |
| % Without studies | **0.0286***** | (3.941) | **0.030***** | (4.155) | **0.029***** | (4.030) | **0.029***** | (3.979) |
| % Population <5 | **-0.012***** | (-2.607) | **-0.012***** | (-2.609) | **-0.013***** | (-2.890) | **-0.0112***** | (-2.582) |

TABLE 6 - SPATIAL MODEL ESTIMATION RESULTS

continued

| MODEL | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| % Population >60 | -0.023 | (-1.314) | -0.022 | (-1.292) | -0.028 | (-1.636) | -0.023 | (-1.305) |
| % Unemployed | 0.012 | (0.933) | 0.012 | (0.895) | 0.020 | (1.493) | 0.100 | (0.399) |
| % Industry production on total | 0.117 | (0.467) | 0.108 | (0.434) | 0.078 | (0.317) | 0.013 | (0.985) |
| Taxes | **0.458***** | (8.178) | **0.461***** | (8.303) | **0.479***** | (8.502) | 0.455 | (8.180) |
| Fees | -0.032 | (-0.763) | -0.026 | (-0.620) | -0.046 | (-1.104) | -0.033 | (-0.801) |
| $\lambda$ | **0.304***** | (5.005) | **0.301***** | (4.990) | **0.298***** | (4.850) | **0.305***** | (5.017) |
| Pseudo-$R^2$ | 0.376 | | 0.381 | | 0.390 | | 0.376 | |
| **SPORTS AND LEISURE (**n=308) | | | | | | | | |
| Constant | 2.860 | (1.692) | 2.627 | (1.549) | 1.771 | (0.949) | 3.738 | (2.201) |
| % Urban area | -0.194 | (-0.627) | - | - | - | - | - | - |
| CV | - | - | -0.064 | (-0.651) | - | - | - | - |
| GI | - | - | - | - | 0.039 | (0.082) | - | - |
| GI Medium | - | - | - | - | 0.451 | (1.636) | - | - |
| UPD | - | - | - | - | - - | | **0.000101**** | (2.558) |
| Central | -0.031 | (-0.165) | -0.030 | (-0.160) | -0.167 | (-0.817) | 0.127 | (0.685) |
| Population | **-0.333***** | (-4.013) | **-0.33***** | (-3.965) | **-0.276***** | (-2.945) | **-0.446***** | (-4.910) |
| % Graduates | 0.033 | (1.293) | 0.037 | (1.487) | 0.036 | (1.454) | 0.035 | (1.414) |
| % Without studies | 0.002 | (0.138) | 0.004 | (0.276) | 0.003 | (0.210) | 0.004 | (0.284) |
| % Population <5 | -0.009 | (-1.008) | -0.009 | (-0.962) | -0.011 | (-1.134) | -0.010 | (-1.060) |
| % Population >60 | -0.012 | (-0.355) | -0.014 | (-0.416) | -0.025 | (-0.746) | -0.028 | (-0.857) |
| % Unemployed | **-0.068***** | (-2.768) | **-0.068***** | (-2.755) | **-0.057**** | (-2.266) | **-0.074***** | (-3.066) |
| % Industry production on total | **1.398***** | (2.781) | **1.375***** | (2.741) | **1.312***** | (2.623) | **1.480***** | (2.973) |
| Taxes | **0.673***** | (6.011) | **0.669***** | (6.007) | **0.708***** | (6.252) | **0.684***** | (6.229) |
| Fees | -0.043 | (-0.498) | -0.039 | (-0.453) | -0.061 | (-0.715) | -0.032 | (-0.372) |
| $\lambda$ | **0.133**** | (2.260) | **0.133**** | (2.292) | **0.112*** | (1.900) | **0.111**** | (1.881) |
| Pseudo-$R^2$ | 0.352 | | 0.352 | | 0.360 | | 0.367 | |
| **URBAN INFRAESTRUCTURE** (n=322) | | | | | | | | |
| Constant | **4.878***** | (4.832) | **4.831***** | (4.759) | **5.386***** | (4.854) | **5.033***** | (4.896) |
| % Urban area | 0.068 | (0.360) | - | - | - | - | - | - |
| CV | - | - | -0.040 | (-0.652) | - | - | - | - |
| GI | - | - | - | - | -0.139 | (-0.485) | - | - |
| GI Medium | - | - | - | - | -0.122 | (-0.712) | - | - |
| UPD | - | - | - | - | - | - | 0.000 | (0.584) |
| Central | 0.060 | (0.515) | 0.027 | (0.232) | 0.107 | (0.847) | 0.064 | (0.558) |
| Population | **-0.143***** | (-2.842) | **-0.136***** | (-2.685) | **-0.170***** | (-2.989) | **-0.155***** | (-2.787) |
| % Graduates | -0.013 | (-0.822) | -0.012 | (-0.803) | -0.014 | (-0.898) | -0.013 | (-0.886) |
| % Without studies | -0.010 | (-1.192) | -0.010 | (-1.179) | -0.011 | (-1.267) | -0.010 | (-1.214) |
| % Population <5 | -0.008 | (-1.405) | -0.008 | (-1.436) | -0.008 | (-1.319) | -0.008 | (-1.454) |
| % Population >60 | -0.015 | (-0.719) | -0.012 | (-0.607) | -0.020 | (-0.494) | -0.015 | (-0.732) |
| % Unemployed | 0.012 | (0.802) | 0.011 | (0.755) | 0.010 | (0.617) | 0.011 | (0.717) |
| % Industry production on total | -0.179 | (-0.584) | -0.174 | (-0.568) | -0.149 | (-0.486) | -0.153 | (-0.499) |
| Taxes | **0.519***** | (7.576) | **0.525***** | (7.690) | **0.507***** | (7.272) | **0.525***** | (7.701) |
| Fees | -0.074 | (-1.423) | -0.070 | (-1.348) | -0.065 | (-1.239) | -0.072 | (-1.378) |
| $\lambda$ | **0.154**** | (2.306) | **0.159**** | (2.376) | **0.150**** | (2.288) | 0.152 | (2.258) |
| Pseudo-$R^2$ | 0.280 | | 0.280 | | 0.283 | | 0.281 | |

Note: *** denotes two-tailed hypothesis test significant at p <0.01; ** denotes two-tailed hypothesis test significant at p <0.05; * denotes two-tailed hypothesis test significant at p <0.10. T-values are in parentheses. Statistically significant parameters are in bold.

SOURCE: Estimation results.

## 5 DISCUSSIONS

The first argument to point out regards the estimated results is the effectiveness of the measures of urban sprawl. The population density and the percentage of urban area, the two most used measures of urban sprawl, do not seems to be correlated with the cost of providing public service in Brazilian municipalities; the parameters estimated, in most cases, are statistically insignificant and/or have a small value. By its turn, the CV, which shows the dispersion of the population in the urban area, is insignificant in all the estimated equations. Whereas the gravitational index appears to be the best measure (in terms of fitting to the model) to account the effects of urban sprawl on local public spending for Brazilian municipalities.

Contrary to expectations, none of the urban sprawl measures is statistically significant in the urban infrastructure per capita spending function, indicating that urban sprawl is not an important impacting factor on the cost of providing this public service. Similar result was found by Hortas-Rico and Sollé-Ollé (2010) in a cross-sectional analysis of the Spanish municipalities spending functions. A possible explanation for this might be that investments on urban infrastructure demand time to be done, in other words, the local governments do not respond to the urban sprawl at the same time it is identified, thus the cross-section analysis is not able to capture the effects of urban sprawl on the infrastructure expenditure. Furthermore, some important variables, like political issues and/or the spending on infrastructure by other government levels, not added in the model, can influence the effects of the urban sprawl. These explanations can also be extended to other expenditure items in which the parameters of urban sprawl are not statistically significant.

Focusing now on the aggregate per capita spending, the GI shows that municipalities that have a small degree of sprawl have lower aggregate spending on public services. Accordingly to this empirical evidence, urban sprawl, characterized as an expansion through the borders of a city, increases the cost of providing local public services. Although, the positive relation between urban sprawl and the cost of providing aggregate spending presented by the estimation results only holds for municipalities of high urban concentration. Concerning the cities of medium concentration, the total effect of urban sprawl on their aggregate spending is given by the sum of the coefficients of the GI and the GI Medium; as can be seen on the estimation results, the total effect is very small, indicating that urban sprawl is not a determinant factor of the aggregate spending of medium cities. This result may support the hypothesis that there is a threshold effect in the relation between urban sprawl and aggregate expenditures; which means that the pattern of urban sprawl meaningly press up the cost of local public services only after it achieves a certain degree.

Defining the degree of sprawl that is harmful to cities is one of the main challenges nowadays for the analysis of urban sprawl, mainly because empirical evidences to determinate it are scarce, and there is no theoretical consensus among the researchers about this degree. With regard to the Brazilian municipalities, the investigation of this issue is important especially for the medium cities. It is expected that such cities grow faster than the cities of high urban concentration in the next years; thus, promoting a strategy of urban planning that accounts for the impact of the sprawling process in medium cities is a key action to avoid the negative consequences of urban sprawl, already existing in big cities.

On the question of the effects of urban sprawl on disaggregated expenditure items; the results for the GI indicated that urban sprawl affects the per capita spending on administration and environmental management. In the administration spending, which includes financial and human resources expenditures and represents the third biggest spending of local governments, the effect is negative and significant for municipalities of high urban concentrations. A scale gain can explain the result; it cost less to main the local administration if the population is more concentrated close to the central area than sprawled in the urban area. Regards to the result of the environmental management, the effects of urban sprawl on this spending item is positive, the more concentrated the population the higher the per capita spending. This result indicates that more people living close to the central area causes more environment degradation, so the spending on preservation and recovery is higher. It worth to add that the coefficients of the GI Medium in the spending on administration and environmental management equations have the opposite sign of the coefficients of the GI. Although they are not statistically significant, they are in line with the relationship described in the last two paragraphs. Regards to the social assistance spending, there is a positive effect of sprawl on this category of spending, measured by the GI Medium. In medium cities, the concentration of people in the central area increases the per capita spending on social assistance.

Lastly, the findings of this study also evidence that the strategic interaction among the municipalities has an important role in the per capita cost of public service. As could be seen, the spatial component is a determinant factor of the per capita expenditure of seven items of spending. The direct implication of this evidence is that any politics that aims to reduce the cost of providing local public services should be taken at the regional level, notably at each urban concentration.

## 6 FINAL REMARKS

This paper set out to examine the consequences of the urban sprawl on the local public finances in Brazilian municipalities. Multiple regression analysis revealed the importance of testing new measures to evaluate the effects of urban sprawl on the cost of providing local public services. As shown by the estimation results, the gravitational index is the most correlated measure with the Brazilian local finances.

The findings of the empirical analysis also allow us to answer the question made in the introduction section. The estimation results suggest that there is a positive relation between urban sprawl and the cost of providing the aggregate spending and spending on administration, which stands for cities of high urban concentrations. This finding, while preliminary, proposes that the urban patterns of growth should be addressed in politics of promotion the long-term local finance sustainability.

Additionally, the empirical results suggest an interesting fact regarding the effects of urban sprawl in big and medium cities of Brazil. The effect of urban sprawl on the spending is not linear and it is characterized as a threshold effect: the sprawling process is harmful to the local spending only after it achieves a high degree. This evidence is quite important to medium cities since their degrees of urban sprawl are not high nowadays, but it is expected that this scenario changes in the next years, as medium cities expand in terms of population size and urban area. Thus, investigating the pattern of urban land occupation is necessary to the promotion of an urban pattern of growth consistent with a sustainable local finance system and with a high level of welfare of the population.

Some of the issues emerging from the empirical findings relate specifically to the current limitations of the analysis of urban sprawl and its effects. Until which limit is the process of urban sprawl acceptable? What is the best measure to account urban sprawl? The answers to these questions are two of the keys elements to the literature of urban economics and to urban planners and policy-makers; therefore, they should be contemplated in further studies.

The present study has raised important insights regarding the phenomenon of urban sprawl in Brazil, but yet there are many unanswered questions about it. To develop a full picture of this phenomenon in Brazilian municipalities, additional studies are needed to investigate the factors behind the causes of urban sprawl and its consequences other than financial.

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## APPENDIX 1 – DIAGNOSTIC OF SPATIAL DEPENDENCE

The detection of spatial dependence of a model and the choice of the most appropriated spatial model consist of the following steps[6]:

-Chose a matrix of spatial weights.

-Estimate the proposed model by OLS (equation 5).

-Test the spatial dependence of the error terms of the models estimated by OLS with the Moran's I statistic.

-If Moran's I is not statistically significant, there is not spatial dependence and the model can be estimated by OLS.

-If Moran's I is statistically significant, there is spatial dependence and a spatial model is more appropriated to the data.

-The choice of the spatial model can be done by the Lagrange Multiplier (lag) and Lagrange Multiplier (error). The most statistically significant indicate the type of the spatial dependence. Other spatial models can the tested to check the most appropriated.

In this analysis, the spatial matrix used was the queen contiguity: two regions are neighbors in this sense if they share any part of a common border, no matter how short.

The diagnostic for spatial dependence of each spending category with the model varying the urban sprawl variables is shown in TABLE 1.A.

TABLE 1.A: MORAN'S I ESTIMATION RESULTS

| Dependent variable | Urban sprawl variable in the model | | | | Model |
|---|---|---|---|---|---|
| | %Urban Area | CV | GI | UPD | |
| Aggregate | **0.188*** ** | **0.187*** ** | **0.186*** ** | **0.190*** ** | SEM |
| Administrations | 0.025 | 0.031 | 0.035 | 0.029 | OLS |
| Basic sanitation | **0.141*** | **0.121 ** ** | **0.118*** | **0.115*** | SEM |
| Culture | 0.028 | 0.026 | 0.017 | 0.014 | OLS |
| Environmental management | 0.023 | 0.019 | 0.009 | 0.028 | OLS |
| Housing | **0.129** ** | **0.119*** | **0.122** ** | **0.114*** | SEM |
| Local Security | **0.144** ** | **0.137** ** | **0.133** ** | **0.121** ** | SAC |
| Social Assistance | **0.237*** ** | **0.236*** ** | **0.235*** ** | **0.237*** ** | SEM |
| Sports and leisure | **0.111** ** | **0.112** ** | **0.090*** | **0.092 *** | SEM |
| Urban infrastructure | **0.114** ** | **0.116** ** | **0.111** ** | **0.112** ** | SEM |

Note: *** denotes two-tailed hypothesis test significant at p <0.01; ** denotes two-tailed hypothesis test significant at p <0.05; * denotes two-tailed hypothesis test significant at p <0.10.
Statistically significant parameters are in bold.
Source: Estimation results.

[6] Description based on Almeida (2012).