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The Costs of Urban Sprawl on Portuguese Municipalities in 2011

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The Costs of Urban Sprawl on Portuguese Municipalities in 2011

Urban sprawl is a type of urban growth which is generally considered as mainly negative that entails a series of negative impacts. One specific negative impact is the high municipal direct monetary costs associated with it, when compared with other types of urban growth, e.g. compact city¹.

Municipal monetary costs are related with the construction, management, operation and maintenance of infrastructures, such as roads, sewerage, water supply, communications and energy; and services such as garbage collection, recycling, postal service and transportation (including school transport). Usually, these costs are, directly and indirectly, supported by the municipal government².

The association between sprawl and higher municipal costs is related with the over extension of infra-structures and services to serve a fragmented low density urban space. Nevertheless there is a paradox here, since sprawled urban development could act as a source of revenues to a municipality (e.g. urbanization and construction licenses and tax revenues), but in the long term the cost to maintain such paradigm will be higher than the revenue obtained².

The objective of this work is to assess and associate the aforementioned costs to higher levels of and to different manifestations of sprawl. For that we collected data from a sample of 61 municipalities, which are classified as medium cities in Portugal.

For this assessment, a dataset composed by each municipality's census subsections of 2011, containing demographic information, and developed on ARCGIS ®, will be developed.

Sprawl indicators will be built focusing on the following dimensions: population density, building densities and type of urban space, to account for fragmentation and dispersions patterns;

¹ Carruthers, J.I. & Ulfarsson, G.F., 2003. Urban Sprawl and the Cost of Public Services. *Environment and Planning B-Planning & Design*, 30, pp.503–522.

² Carter, N. & Silva, F.N. da, 2001. Recent Changes in Territorial Planning and the System for Controlling Urban Development in Portugal. *Transportation Research Part a-Policy and Practice*, 3, pp.341–370.

Correlation analysis and regression models will be built between the sprawl indicators and the monetary costs of the municipalities, to assess if sprawl is correlated or not with higher costs, while controlling for other aspect like municipal, inter-municipal and private management. These costs are to be extracted from municipal annual budgets, and it will include the budget lines related with the development and maintenance of municipalities infrastructures and services, namely: roads; sewerages; water supply; garbage and recycle recollection; and transportation. The obtained results are discussed both in terms of accordance with previous findings in the literature as well as policy implications.

Introduction

Urban sprawl is a manifestation of urban growth that the current world is constant experiencing. Due to its scale and impacts it is widely researched on all its dimensions, namely its drivers, impacts and costs but also on the most efficient methodologies to measure and analyze it.

The present work aims to analyze the financial costs of 61 municipalities' infrastructures and services and their relation with urban sprawl for 2011. The objective is to assess if municipalities with higher levels of sprawl incur in higher expenditure than the ones with lower levels. The sprawl indicators selected to measure sprawl levels were the following: density population; Moran and Gini coefficients; fragmentation; and dispersion. These were then modelled through a linear regression and a bivariate correlation function with the next municipal financial variables: transports; road network; street light; water and sewer system; and garbage recollection.

The selection of these municipalities as a case study was related to the necessity to enhance the study of Portuguese urban areas beyond its metropolitan areas, namely: Lisbon and Porto. In fact, many of the municipalities, especially the ones located on the interior territory and in the south, possess distinct urban forms quite different from existing ones on the metropolitan areas.

The importance of analyzing the costs of these municipalities and establish a relation with urban sprawl is related with the necessity to improve the present understanding of the Portuguese urban system. With this knowledge other future researches can be justified, local and regional policies can be better reformulated and the scientific gap on the subject can be tightened.

Presently, the concern of Portuguese local authorities with the sprawl is greatly visible on the municipal master plans (PDM) but in reality few has been done to re-orient the existent urban paradigm towards a more sustainable one. Possible, the present work will help boost the change of paradigm with the analysis on the possible extra-costs supported by more sprawled municipalities. This can be especially relevant when one considers that financial and economic crisis of 2009 diminished the revenues of Portuguese national, regional and local authorities and obliged authorities to seek a more sustainable management.

Sprawl can be defined as the development of low-density mono-functional urban forms on rural areas surrounding urban agglomerations, centered on private car and road infrastructure

and without effective spatial planning (Clark 1958; Tsai 2005; Petschel-Held et al. 2007; Bruegmann 2006; EEA 2006; Bhatta 2010).

Common research divides itself in favor or against urban sprawl. The cheaper dwellings and land, liberty of choice, quality of life and contact with nature (Newman et al. 1995; Muñoz 2003; Neumann 2005; Russel 2005) are common arguments of pro-sprawl research. On the other hand, the research against it mainly enunciates sprawl as a financial, economic and environmental unsustainable form (Bhatta 2010) and also entailing social and health impacts (Muñoz 2003). Often, this analysis falls under a comparison with other urban forms, more specifically the compact city which may be described as an urban form with high-medium densities of mixed uses, supported by public transportation and with effective spatial planning (Geurs & van Wee 2006; Couch & Karecha 2006).

The higher financial and economic costs of sprawl enumerated by authors (Board 1998; Coyne 2003) are, more or less, common, being related with investment, provision and maintenance of infrastructures and services. The higher amounts of area consumed by sprawl along with their low-density population increase these infrastructures and services. Simplifying, one kilometer of road serving one thousand people is clearly different from serving one hundred.

Besides these implications, tax revenues originated from sprawled population are the same as population living on urban agglomeration. At first sight it may be seen as advantageous for sprawled population, yet in many cases the heavy financial burden for municipalities causes higher taxes for all municipality population. The infrastructures and services managed by the local power and that are usually focused of researchers are: road network, public transportation, water and sewerage systems, garbage recollection, urban cleaning, mail delivery and street light (Petschel-Held et al. 2007).

Authors (Camagni et al. 2002; Petschel-Held et al. 2007) also count other type of costs, namely environmental (destruction of agricultural, forest and open-space areas, higher fuel emissions and greenhouse gases and aesthetic degradation of landscape), social (higher disparities on wealth and loss of sense of community) and health impacts (higher percentages of heart conditions and obesity). Despite not being on focus on the current work, these costs can also be counted and monetized as shown on the work of (Wu 2006).

There are already research on the financial costs supported by the local and regional authorities on sprawled areas. For example, Board (1998) made a short report regarding the costs of sprawl in its all dimensions while analyzing different studies on the subject. Coyne (2003) wrote on important policies findings of how sprawl is subsidized and how it burdens

municipalities budgets. Solé-Ollé and Hortas-Rico (2010) through a linear function model assessed the impacts of urban sprawl on the municipal budgets concluding that indeed sprawl leads to higher costs of public services.

In Portugal, exists already some research on the subject. DGT ((2013) elaborated a project where costs were counted by pre-defined urban forms and typologies through standard indicators. Danko et al (2009) analyzed the costs of wastewater infrastructure and the relation with sprawl on the Douro region, with costs extracted from different sources. This assessment was also made with linear regression models giving the conclusion that denser areas have lower costs than more sprawled areas. Some master dissertations also reflects on the subject, with analysis on sprawl costs regarding public infrastructures (Dias 2010) or the relation between sprawl and the sewage system (Salvação 2012).

On next chapter, a characterization of the methodology applied and the aspects of the Case Study are elaborated, followed by the discussion of the results on section 4. Finally, on section 5 the key points of the work are resumed and compared with the initial objectives.

Methodology and Case Study

Sixty one municipalities where selected when they possessed a medium city as their main urban center. They were extracted from the Portuguese City Atlas (INE (2002), with the double condition of having more than 7500 inhabitants and being located outside the metropolitan areas of Lisbon and Porto. The dataset was based on the 2011's census dataset (INE 2015) at subsection level (census block) which included the number of population and dwellings and was worked on the ArcGIS® software.

Five indicators where established to measure the dimension of sprawl in the sixty one municipalities, namely density population, Moran and Gini coefficients, fragmentation and dispersion. For the first three indicators no substantial changes were made. Regarding fragmentation and dispersion, they focus specifically on urban areas and therefore the dataset was modified. The urban areas were created with the following rules: (1), selection of the subsections with more than 700 dwellings/km² OR with more than 2000 inhabitants/km²; (2), aggregation of all subsections (including non-urban) in a distance of 400 meters from the previous step; (3), inclusion of non-urban areas to eliminate possible interstices inside the urban areas; (4), classification of the urban areas between central and secondary areas, with the

intersection of the centroid of the main city center to define the first ones. The formulation of each indicator is presented as follows:

- Density population, a well-known used indicator which measures the concentration of population in a determined area (Galster et al. 2001)

$$d_{b_i} = \frac{Pop_i}{A_i}$$

Pop_i – population

A_i – area

- Moran coefficient, applied to assess the distribution patterns of spatial units (subsections) with different densities, in another words, to measure their level of clustering (Tsai 2005)

$$Moran = \frac{N \sum_{i=1}^N \sum_{j=1}^N W_{ij} (X_i - X)(X_j - X)}{\left(\sum_{i=1}^N \sum_{j=1}^N W_{ij} \right) (X_i - X)^2}$$

N – number of sub-areas

X_i – population in sub-area *i*

X_j – population in area *j*

X – mean of population

W_{ij} – weighting between sub-areas *i* and *j*

- Gini coefficient, to measure the inequality of population distribution in terms of their spatial distribution (Tsai 2005)

$$Gini = 0.5 \sum_{i=1}^N |X_i - Y_i|$$

X_i – the proportion of land area in a sub-area *i*

Y_i – proportion of population in sub-area *i*

- Fragmentation, which measures the weight of non-central areas (secondary type) to the respective total urban space of each municipality (Frenkel & Ashkenazi 2008)

$$F_i = \frac{A_{nci}}{A_i}$$

A_{nci} – non-central area

A_i – total urban area

- Dispersion, similar to fragmentation measuring a theoretical distance between secondary areas with the respective central area (Meneses 2010)

$$DSP_i = \sum \frac{A_{ncij}}{A_{c_i}} \times d_j$$

A_c – central urban area

d – Distance between a secondary urban area centroid and their respective central urban area centroid, with the subtraction of the radius of the circles with equivalent area of the considered areas

The financial costs of the municipalities were individually extracted from each 2011 budget by taking in account the budget items related with transports, road network, street light, water and sewer system and garbage recollection, from the chapters capital acquisition and leasing (Table 1). Transports included the expenditure with scholar and general transportation despite in the majority of the cases there wasn't distinction between both. Road network included the items viaducts, streets and complementary works, rural road and signaling and transit. Street light was an item itself, while the water and sewer system encompassed the costs with wastewater treatment plants, sewerage systems and collection and distribution of water. Finally, the garbage recollection included infrastructures for treating solid waste and the service of solid waste itself.

Table 1 – Variables and Related Budget Items

<i>Cost Variables</i>	<i>Items</i>
Transports	Scholar
	General
Road Network	Viaducts, streets and complementary works
	Rural road
	Signalling and transit
Street Light	Street light
Water and Sewer System	Wastewater treatment plants
	Sewerage systems
	Collection and distribution of water
Garbage Recollection	Infrastructures for treating solid waste
	Solid waste

The authors has some difficulties in the collection of data due to several reasons. Lack of quality and availability of data was an initial problem. Also, despite following a general norm to account their revenues and expenditure, municipalities tend to distribute the costs in different manners and sometimes in generic and general items. From here, it was difficult to distinguish between investment and maintenance costs in the overall items. Besides, the management of the Water and Sewer System and of the Garbage Recollection are mostly in hands of municipal, inter-municipal or private companies which makes even harder to account for these types of expenditure. Usually, the transference of money from the municipality for these companies it is not discriminated and in the specific case of inter-municipal and private companies these values are not shown.

Still, for the transports and road networks it was possible to obtain values for the 61 municipalities, for street light 55, for water and sewer system 51 and for garbage recollection only 20. These numbers could be improved but due to time constrains obtaining them would be too time consuming.

Results

The resulting values were divided by the population thus creating variables *per capita* which were applied into the models as dependent variables while sprawl indicators were introduced as independent ones. To extend the field of possibilities all variables were replicated on their natural logarithm (Ln) form. Dummy variables were created to represent the municipal (ME), inter-municipal (IE) and private enterprises (PE) managing the water and sewer systems as well the garbage recollection. Finally, it were formed five bivariate correlations analysis and five linear regression models on SPSS® which are presented below. The tables presented are the final versions of each model with all the valid variables.

Transports Model

There is correlation between the independent variables and the dependent one (table 2). Moran with a value of 0.223 and the dispersion of 0.250. The Dispersion is also correlated with Moran with a negative value of -0.065. Higher dispersion suggests less cluster patterns (Moran) which still are dependent of other variables as density population or Gini.

Table 2 - Correlations on Transports Model

Correlations				
Variables		LnTransports (<i>per capita</i>)	Moran	Dispersion
Moran	Pearson Correlation	.223	1	
	Sig. (2-tailed)	.084		
Dispersion	Pearson Correlation	.250	-.065	1
	Sig. (2-tailed)	.052	.620	

On table 3, the most significant value is from Moran which influences positively (2.995) the costs with the natural logarithm of the transports per capita. Higher value of Moran with more dispersion (0.000027) may incur on higher costs. Still, the model had a lower efficiency with an R Square of 0.119.

Table 3 - Coefficients on Transports Model

R	R Square	Adjusted R Square		
0.346	0.1197249	0.089371		
Variables	Coefficient	t stat	p-value	
Moran	2.995	1.945	.057	
Dispersion	0.000027	2.148	.036	

Dependent Variable: LnTransports (*per capita*)

Road Network Model

There is a negative correlation between the LnDensity Population and the Road Network (per capita) of -0.244 (table 4). The coefficient of the independent variable on the model (table 5) is around -.34.5, and taking in account literature, suggest that higher densities will decrease road costs. The quality of the model was smaller than before with an R Square of approximately 0.065.

Table 4 - Correlations on Road Network Model

Correlations		
Variables	Road Network (<i>per capita</i>)	
LnDensity Population	Pearson Correlation	-.244
	Sig. (2-tailed)	.058

Table 5 - Coefficients on Road Network Model

R	R Square	Adjusted R Square		
0.255	0.0652151	0.049371		
Variables	Coefficient	t stat	p-value	
LnDensity Population	-34.455742	-2.029	.047	

Dependent Variable: Road Network (per capita)

Street Light Model

The only valid variable on this model was the dispersion, with a minimum positive correlation of 0.064 (table 6) with the dependent variable of the street light logarithm (per capita).

Table 6 - Correlations on Street Light Model

Correlations		
Variables	LnStreet Light (<i>per capita</i>)	
Dispersion	Pearson Correlation	.252
	Sig. (2-tailed)	.064

Its coefficient on the regression (table 7) was minimal positive, although with a p-value slight above the interval of 5%. Despite the low value, more dispersion usually implies higher efforts on providing street light. Again, the general efficiency of the model was low with an R Square of 0.063

Table 7 - Coefficients on Street Light Model

R	R Square	Adjusted R Square	
0.252	0.063391	0.045719	
Variables	Coefficient	t stat	p-value
Dispersion	0.000028	1.894	.064

Dependent Variable: LnStreet Light (per capita)

Water and Sewer System Model

The model with more valid variable, namely the density population logarithm and the dummy variables of the Municipal and Inter-Municipal Enterprises. The correlation (table 8) was negative between all three (-0.325, -0.389 and -0.153 respectively) and the water and sewer system logarithm. ME and IE had positive correlation with the LnDensity Population (0.90 and 0.01 respectively) although was negative (-0.257) between each other.

Table 8 - Correlations on Water and Sewer System Model

Correlations					
Variables		LnWater and Sewer System (<i>per capita</i>)	LnDensity Population	ME	IE
LnDensity Population	Pearson Correlation	-.325	1		
	Sig. (2-tailed)	.020			
ME	Pearson Correlation	-.389	.090	1	
	Sig. (2-tailed)	.005	.532		
IE	Pearson Correlation	-.153	0.01	-.257	1
	Sig. (2-tailed)	.284	0.942	.068	

On table 9, the three variables, as expected according to the previous table, influence negatively the costs of water and sewer management. LnDensity Population with a value of -0.51503, ME -1.796 and IE -1.1440. Similar to table 5, there is the suggestion of higher densities may signify lower financial costs. Important also to notice the fact that the transference of management to external enterprises (municipal and inter-municipal) will have a negative influence on the costs although additional work is necessary to infer more information. The current model is the most suitable one with an R Square of 0.300.

Table 9 - Coefficients on Water and Sewer System Model

R	R Square	Adjusted R Square	
0.548	0.300296	0.255634	
Variables	Coefficient	t stat	p-value
InDensity Population	-0.51503	-2.318	.025
ME	-1.796	-3.399	0.001
IE	-1.440	-2.066	0.044

Dependent Variable: LnWater and Sewer System (per capita)

Garbage Recollection Model

Finally, the garbage recollection model was the one less informative. The only valid variable was the ME with a negative correlation of -0.485 (table 10) with the natural logarithm of the Garbage Recollection (per capita) as shown on table 10. The same negative direction is replied on its coefficient (table 11) with a value of -1.541. As on the previous model, extra assessment will be needed to understand the existent relation. It was the second most suitable model with an R Square of 0.236.

Table 10 - Correlations on Garbage Recollection Model

Correlations		
Variables		InGarbage Recollection (per capita)
ME	Pearson Correlation	-.485
	Sig. (2-tailed)	.030

Table 11 - Coefficients on Garbage Recollection Model

R	R Square	Adjusted R Square	
0.485	0.235535	0.193065	
Variables	Coefficient	t stat	p-value
ME	-1.54189	-2.355	.030

Dependent Variable: InGarbage Recollection (per capita)

Conclusions

The objective of this work was to assess the relation between municipalities and sprawl levels with their financial costs. The costs considered were transports, road network, street light, water and sewer system and garbage recollection of 61 Portuguese municipalities, which are classified as medium cities.

Despite the lack of suitability of the models the preliminary results shows some relations that sprawl influence the costs. Moran and dispersion had positive influence on the transports costs; the density population negative influence on the road network and water and sewer system costs; and the dispersion positive influence on the street light costs. Dummy variables such as municipal and inter-municipal enterprises also influenced negatively the water and sewer system as well the garbage recollection. The latter was the one with less clear results.

Supporting the preliminary results with literature, despite the low suitability of the models, it is possible to confirm that sprawl patterns are associated with higher costs. Nevertheless, it is necessary more efforts to collect and systematize the data between all costs variables. Also, the period of time under analysis should be extended beyond 2011. This is to balance punctual investments and detect a more realist pattern on the expenditure of the municipalities. Therefore other years should be includes, more specifically 2010 and 2013 and with the average of the three years data replicate the same indicators.

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