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Regional economic growth of the municipalities of the state of Paraná: an approach with the GWR model

Crescimento econômico paranaense: uma abordagem com o modelo GWR

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Abstract
Regional economic growth is a topic that arouses the attention of several researchers, because understanding the way in which it occurs, the way in which the process of interaction between variables occurs, given the characteristics of each region, is essential for it to be possible. Reached. Thus, aiming to analyze what the local behavior of the economic growth variables is, the present study addresses the theme from a broad review, using variables recurrently highlighted in the regional economic growth theories and thus being able to verify, through the Geographically Weighted Regression model (GWR), which in fact affected the growth of municipalities in Paraná. The results indicate that the effects of the variables changed in the period, both in terms of value and regionally. It is noteworthy that the variables of education, municipal structure and agricultural added value played an important role in Paraná's regional economic growth.
Keywords: regional economic growth; spatial regression; model GWR.

Resumo
O crescimento econômico regional é um tema que desperta a atenção entre diversos pesquisadores, pois compreender o modo com este ocorre, a forma como se dá o processo de interação entre as variáveis, dadas as características de cada região, é fundamental para que o mesmo possa ser alcançado. Assim, objetivando analisar qual o comportamento local das variáveis de crescimento econômico, o presente estudo aborda o tema a partir de uma revisão ampla, utilizando variáveis recorrentemente destacadas nas teorias de crescimento econômico regional e assim poder verificar, por meio do modelo *Geographically Weighted Regression* (GWR), o que de fato afetou o crescimento dos municípios paranaenses. Os resultados indicam que os efeitos das variáveis mudaram no período, tanto em termos de valor como regionalmente. Destaca-se que as variáveis de educação, estrutura municipal e valor adicionado agrícola tiveram expressiva importância para o crescimento econômico regional do Paraná.
Palavras-Chave: crescimento econômico regional; regressão espacial; modelo GWR.

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1 INTRODUCTION[3]

The discussion on regional economic growth is an ever-present subject in the field of economic science. This is because these theories started to insert the space variable into their models, thus incorporating not only the importance of the territory's characteristics, but also how they relate to other factors, influencing and being influenced by them; economic growth was then understood as dependent on the local specificities where such models were applied.

In economic science, the debate on growth dates back to Adam Smith's ideas, in the 18th century. However, the first contributions on the influence of spatial dynamics on economic growth start in the 19th, through authors who sought to analyze the criteria that determined how certain productive activities were distributed in a region. These scholars, who later became known as location theorists, represented the first effort to prove that not only certain variables such as investment, education, human capital, depreciation, technology, among others, affect the growth of a region, but that its geographical and spatial characteristics are also part of the dynamic process of economic growth (VIEIRA, SANTOS, 2012).

Among regional growth theorists, a few stand out, such as François Perroux, Gunnar Myrdal, Albert Hirschman and Douglass Cecil North. Through the contributions of these authors, the debate on the subject of economic growth began to incorporate spatial relations as a variable that influences growth in a region. Knowing that economic growth does not occur nor is distributed homogeneously in a territory, as pointed out by Portugal and Souza (1999), Cima and Amorim (2007), and Vieira and Santos (2012), understanding the determinants of regional growth, which are diverse and distinct among regions, is an effective way of directing public policies for both local and regional development.

Thus, this article aimed to verify the local effects of the regional economic growth variables, as well as their behavior in 2006, 2010, and 2016 in the Paraná municipalities, through the Geographically Weighted Regression (GWR) spatial econometric model. The present article has four more sections, besides this introduction. The next section presents the theoretical and empirical research on regional economic growth theories and variables, followed by the methodology and database used. The fourth section focuses on the analysis of the results. Lastly, it presents the final considerations.

2 THEORETICAL FRAMEWORK

Studies on the factors that affect the economic growth of a country, as well as how they interact followed the formation of Economic Science. Since Adam Smith, with his 1776 work "An Inquiry into the Nature and Causes of the Wealth of Nations", the discussion over economic growth has always been present in academic debates.

However, in terms of theoretical contribution, the first researchers who incorporated space into economic models and thus analyzed its influence on growth dynamics became known as the classical in location theories. These theorists began their contributions by raising a criticism to the classical thought by considering it a mistake to build wealth accumulation models from a static criterion through instantaneous adjustments of prices and quantities (SOUZA, 1981; CAVALCANTE, 2007).

Among these location authors, Heinrich Von Thunen (1783-1850) is considered a spatial economics pioneer, for being the first to establish mathematical criteria for maximizing land rent in different

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territories, defined by the distance from the consumer market. The territorial ordering of production would behave starting from a set of concentric circles (called " Thunen's Cicles"), in which places near the consumer market would be destined to highly perishable items, whereas further places would serve items that could endure transporation. In Alfred Weber's (1868-1958) thought, besides transportation costs, there were also labor costs and some local factor, a consequence of pre-existing agglomeration forces. According to Monasterio and Cavalcante (2011), Weber's theory aims to analyze how the industrial location occurs, observing costs with transportation, labor, and local factors, considered agglomerative. Among the various conclusions reached, the author argued that the optimal location would be influenced by minimizing production costs, a direct function of the availability of raw materials, labor, and distance from the consumer market (MONASTERIO; CAVALCANTE, 2011; CAVALCANTE, 2007).

Another classical author of location was Walter Christaller (1893-1969), who devoted his work to understanding which determinants influenced agglomerations in some regions and thus understand how hierarchies are formed, i.e., what affects the number, size, and distribution of cities in a region. His model shows that urban networks form from groups with well-defined characteristics, thus shaping some kind of hierarchy. Thus, in Christaller there is a pattern of concentration in trade relations, with smaller centers being dependent on the larger ones (central) and their agglomeration forming a region for the activities of the poles (ALVES, 2016; MONASTERIO; CAVALCANTE, 2011; THISSE, 2011). For August Losch (1906-1945), the location is determined by the search for profit maximization, as opposed to Weber, who defended the cost of transportation and labor. His model then proposes that companies in the same sector tend to concentrate to minimize production costs and get closer to the consumer market (ALVES, 2016; DALLABRIDA, 2011).

Finishing the approach in location theorists, Walter Isard (1912-2010), considered the founder of Regional Science, who dedicated his studies to understand five points essential to regional economics. These points are i) regional growth through strategic deployment of industry; ii) rise in income and regional employment; iii) interaction and diversification of the regional industrial park; iv) allocation of resources with national planning with a view to the regions and optimal spatial division of labor, and; v) economic activity (SOUZA, 1981; ALVES, 2016; DALLABRIDA, 2011; SOUZA, 2011, THISSE, 2011).

Aforementioned authors did not have a theoretical proposition focused on economic growth itself, they focused on what influenced the distribution of companies and resources in a territory instead. In the wake of their contributions, in the 20th century, works focused specifically on the relationship of space with economic growth emerge; these authors are considered classics in regional economic growth (MADUREIRA, 2015; CORREA, SILVEIRA, KIST, 2019).

Among them, we recall François Perroux (1903-1987) who pointed out that economic growth is neither temporal nor locally homogeneous, since for it to occur there must be some degree of local concentration, a phenomenon later baptized as growth poles. For this reason, the effects of growth are not homogeneous in the economy. These growth poles arise naturally and boost the region through a driving company, which can be a large industry, while having high productive capacity attracts other smaller companies, the driven companies (LIMA; SIMÕES, 2009; PERROUX, 1978).

Gunnar Myrdal (1898-1987), understanding that the economic dynamics cannot be summarized in a stable equilibrium relationship, proposed the existence of a circular causation of cumulative effect in the economy. This would be a negative factor tends to be, by the dynamics of the system itself, increasingly negative, and this circular movement does not lead to any stable equilibrium, given that the change in any direction leads the entire system in the same direction. Such circular causation has two directions, resulting from local characteristics, which are propulsive, which produces positive externalities, and regressive, which produces negative externalities (MYRDAL, 1968).

For Albert Otto Hirschman (1915-2012), economic growth inevitably leads to a situation of disequilibrium. Similarly to Myrdal (1968), Hirschmann (1958) understood that the scarcity of capital resources would impair the capacity for growth and that this would occur when there are investments in sectors considered essential, which can impact the result of others, both upstream and downstream. This sectoral/industrial influence forms the concept of backward linkages and forward linkages, and it is exactly these linkages that generate regional differences given the inhomogeneity in relations and potential linkages between regions (BIANCHI, 2007; NIEDERLE et al., 2016). Douglass Cecil North (1920 - 2015) argued that regional growth occurs through the existence of a sector focused on the external market, based on territorial characteristics, so that the activities of this sector formed the export base. For North (1977), the economic activities would stimulate the emergence of certain allocation channels and new cities that would have their production destined, directly or indirectly, to export. Thus, the diversification of sectors would result from the performance of the export base (NORTH, 1977; ALVES, 2016).

What we verify in the theories of both localization and regional growth is that there is a set of economic (investments, profits, interest, foreign market, income, participation of industries), social (demography, culture, education), and regional (government, institutions, history, and geographic conditions) factors that affect the way it occurs, enabling a greater number of variables used to study it in a given region. In response to this multiplicity of factors, Table 1 presents a summary of the empirical studies that, based on both theoretical and methodological references, analyze regional economic growth.

Table 1 – Summary of methodologies and variables used in empirical research on regional economic growth

Authors	Method	Dependent variable	Independent variable
Montenegro *et al*. (2014)	Spatial panel	GDP *per capita*	Schooling of the population over 25 years old; lagged GDP per capita; average fertility rate; Gross Fixed Capital Formation
Raiher *et al.* (2018)	Data panel	GDP *per capita* growth.	Teachers with degrees; ENEM score; C. H. stock; Average education; Students per class; training/rotation; demographic variables; labor force; physical capital stock
Ribeiro et al. (2017)	Spatial econometric models in cross sections	GDP *per capita*	Institutional variables; government spending
Lazarroto e Lima (2008)	Spatial econometric models in cross sections	GDP *per capita*	Average education; literacy rate; industrial GDP; employment in sectors; government transfers; tax revenue

Carneiro e Silva (2018)	Panel data; spatial econometric models in cross sections	GDP/GDP *per capita*	Average education; GDP growth rate; businesses sizes; demographic variables;
Medeiros e Neto (2011)	Spatial Panel	Poverty rate	Illiteracy rate; dependency rate; formal employment; family structure;
Meiners *et al.* (2013)	Spatial econometric models in cross sections	IDMPE	businesses sizes; institutional variables;
Ferrario et al. (2009)	Spatial econometric models in cross sections	GPD	High school enrollment; population; higher education enrollment; energy consumption

Source: Research results (2020)

3 METHODOLOGY AND DATABASE

As seen in the section above, both from the theoretical and empirical point of view there is a diversity of variables listed that have, directly or indirectly, an effect on the economic growth of a region, either by the distribution of businesses or by their power to affect its growth dynamics. Based on this assumption and the research objective, the methodological approach adopted should be able to capture the impact of a variable on the territory analyzed, which in the present research are the Paraná municipalities, based on the use of variables present in the theoretical and empirical literature on the subject, given data availability.

Thus, to analyze the local effect of certain variables in the Paraná municipalities, the article adopted the Geographically Weighted Regression (GWR) model. This model is defined by means of the Classical Linear Regression Model, through the following expression:

$$y = \beta_0(u_i v_i) + \sum_k \beta_k(u_i v_i) x_{ik} + e_i$$

Where:

$(u_i v_i)$: are the coordinates of point *i* in space;

$\beta_k(u_i v_i)$: local coefficient at point *i*.

e_i: random error term with normal distribution (zero mean and constant variance) (ALMEIDA, 2012).

In the GWR model, the coefficients are not estimated globally, but for each locality of each geographic unit i, which are herein represented by the Paraná municipalities. The GWR, by performing a local estimation, results in linear regressions for each municipality comprehended in the region, Paraná, through subsamples of observations that receive a weight and are, thus, weighted by the geographical distance. To perform this weighting it is necessary to use a spatial Kernel function that uses the distance (d_{ij}) between two geographical points and a parameter that defines the width of the band and thus establish the weight of the two regions, which will be inversely related to the geographical distance (w_{ij}) (BRUNSDON; FOTHERINGHAM; CHARLTON, 1996; ALMEIDA, 2012).

According to Almeida (2012), the employed bandwidth may be of two types: fixed or adaptive. The advantage of adaptive over fixed is that it better adjusts the data to consider the same amount of geographic units of a region. This property of the adaptive band of the Kernel function causes it to expand when there are few observations and contract when there are many. When using the GWR model, we expect an improvement in the results measured by the absence of spatial dependence in the residuals, lower Akaike and Schwarz information criterion in relation to global models (FOTHERINGHAM, BRUNSDON, CHARLTON, 2002).

To define which variables are susceptible to local spatial effects, that is, which present geographical variability, the criterion difference is used, interpreted as follows: variables that in modulus are greater than two, and negative, have variability, the variables that do not fit this criterion are discarded (GWR USER MANUAL, 2016). For Almeida (2012) given the possibility of spatial dependence occurring both in the residual and explained variables, the GWR model can incorporate such dependencies. Thus, considering cross section data for 2006, 2010, and 2016, we used this model to verify which variables had an effect on the economic growth of the Paraná municipalities in these three years, and how was the behavior of such factors in these three years.

As the purpose of the article was to evaluate the economic growth of municipalities in Paraná, the proxy used for growth was the natural logarithm of GDP per capita. We divided the explanatory variables into seven large groups, namely: i) education: Firjan Index of Municipal Development (IFDM) education dimension and percentage of population with high school education; ii) health: Firjan Index of Municipal Development (IFDM) health dimension, vehicular density and number of hospitalizations in SUS per capita; iii) economic: Gross Value Added of industry, agriculture and retail and services; iv) structural: Firjan Index of Municipal Development (IFDM) employment dimension, population density, residential energy, water supply and altitude; v) financial: Number of bank branches: vi) fixed capital: industrial energy; vii) public management: investment ratio public revenues, Municipal Participation Fund and Gross Value Added of the sector. We used the Instituto Paranaense de Desenvolvimento Econômico e Social (IPARDES) database.

4 RESULTS

To begin the analysis of the GWR model, the first step is to evaluate whether it presents a better adjustment than the global model. For this, Table 2 presents the results for estimating the GWR with and without the spatial dependence of the dependent and independent variables, comparing with the estimates at the global level for all years. To evaluate the best adjustment, Almeida (2012) indicates checking the lowest Akaike's information criterion (AIC), the highest coefficient of determination and the non-spatial dependence in the residual, obtained by Moran's I (ALMEIDA, 2012).

Table 2 - GWR model results for the Paraná municipalities

2006					
Model specifications	Regressão	AIC	R^2	F-test	Moran's I
GWR without the spatial component	Global	136,9856	0.5123		
	Local	57,7680	0.6958	3.2551**	-0.0434*
GWR SAR	Global	127,7399	0.5261		
	Local	55,2782	0.7039	3.0721***	-0.3840
GWR SDM	Global	136,1672	0.5646		
	Local	87,9991	0.7074	2.5863***	-0.0357

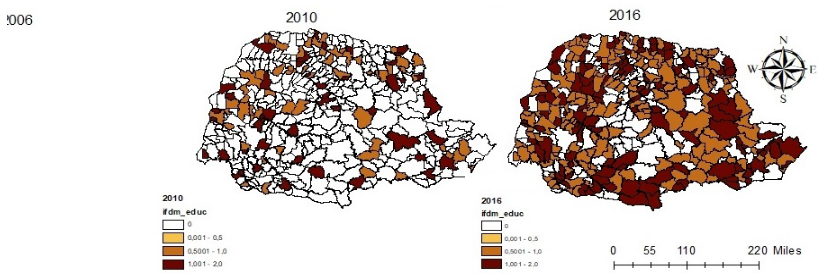
		2010			
GWR without the spatial component	Global	194,7778	0.4769		
	Local	38,7503	0.7422	4.8154***	-0.0424*
GWR SAR	Global	191,3129	0.4843		
	Local	40,0207	0.7484	4.5934***	-0.0453*
GWR SDM	Global	208,2942	0.5159		
	Local	74,1423	0.7787	4.0227***	-0.0196
		2016			
GWR without the spatial component	Global	156,5853	0.4951		
	Local	67,4155	0.7109	3.2977***	-0.0251
GWR SAR	Global	147,7850	0.5088		
	Local	67,2550	0.7188	3.0964***	-0.0208
GWR SDM	Global	167,7877	0.5355		
	Local	141,8778	0.6861	2.1646***	-0.0102

[1]Adaptive bandwidth size:: 377, [2]Adaptive bandwidth size: 399, [3]Adaptive bandwidth size: 395; [4]Adaptive bandwidth size: 399, [5]Adaptive bandwidth size: 399, [6]Adaptive bandwidth size:399; [7]Adaptive bandwidth size: 399, [8]Adaptive bandwidth size: 399, [9]Adaptive bandwidth size:399.
Note:* significant at the 0.01 level ** significant at the 0.05 level*****

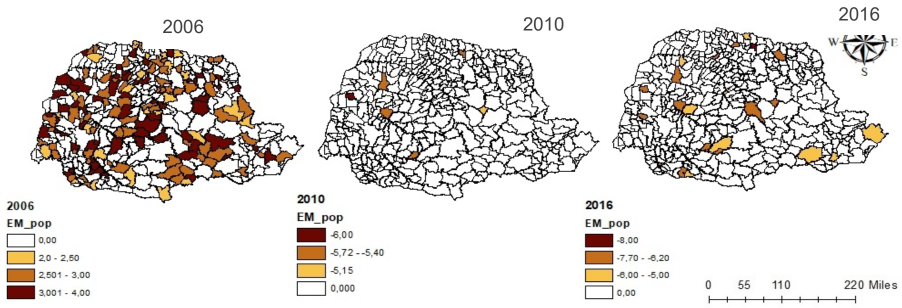
As shown above, for the entire period, the models obtained by GWR were the ones with the best adjustment, given that they had the lowest AIC information criterion, absence of spatial dependence in the residual and the highest coefficient of determination. Such results show that, in fact, the local estimation has better quality than the global one (ALMEIDA, 2012). Among the GWR models tested, the one we chose to analyze the results was those considering the existence of a spatial relationship in the dependent variable, that is, the Spatial Autoregressive Model (SAR), since it presented the best adjustment in the years 2006 and 2010 in terms of Akaike's criterion, even though it was not the best in 2016. Table A1 of the Appendix presents the description of the variables used in the model, the local coefficients, the mean, and the difference of criteria, a method used to obtain the variables with geographic variability and thus capture the effect of local municipal coefficients. From Figure 1 onwards, we present how the variables used in the GWR model affect economic growth in Paraná. The municipalities in white are those that were not significant at the 0.05 level, and the darker the shade of brown, the greater the value of the estimated coefficient and with the intervals presenting the same values for the three years, except when not possible given the incompatibility of the parameters obtained between one year and another. It is noteworthy that the major purpose of the analysis is to verify the variable's behavior in the period, not aiming at a more detailed study about the particularities of each municipality.

Figure 1 – Local effects of the educational variables

IFDM education dimension



Secondary education attainment



Source: Research results, Author's own elaboration.

Note: Considering Test t_c=1.96, at the significance level of 0.05; missing maps refer to the years in which the variable presented no geographic variability.

When verifying the impact of the variable IFDM education in 2006, we notice that it had no statistical significance. However, for the year 2010 this fact changes, because in some regions of the state, especially in the North Central, Center Eastern, Metropolitan Curitiba, and Western Paraná portions, there was a high impact of the IFDM education dimension, since in those regions the parameter found ranked in the last two quartiles. As the value intervals of the estimates are the same for all years, we see that, in the year 2016, the number of municipalities that had the GDP per capita positively influenced by the IFDM education increased, maintaining the trend around the regions already mentioned, but with a greater regional scope. This result matches, although in a general way given the methodological approach used, Medeiros and Neto (2011), Fontenelle et al. (2011), Pereira et al. (2012), Montenegro et al. (2014), Firme and Filho (2014), Irffi et al. (2016), Meyer and Shera (2016), Loures and Figueiredo (2017), Raiher et al. (2018), and Carneiro and Silva (2018).

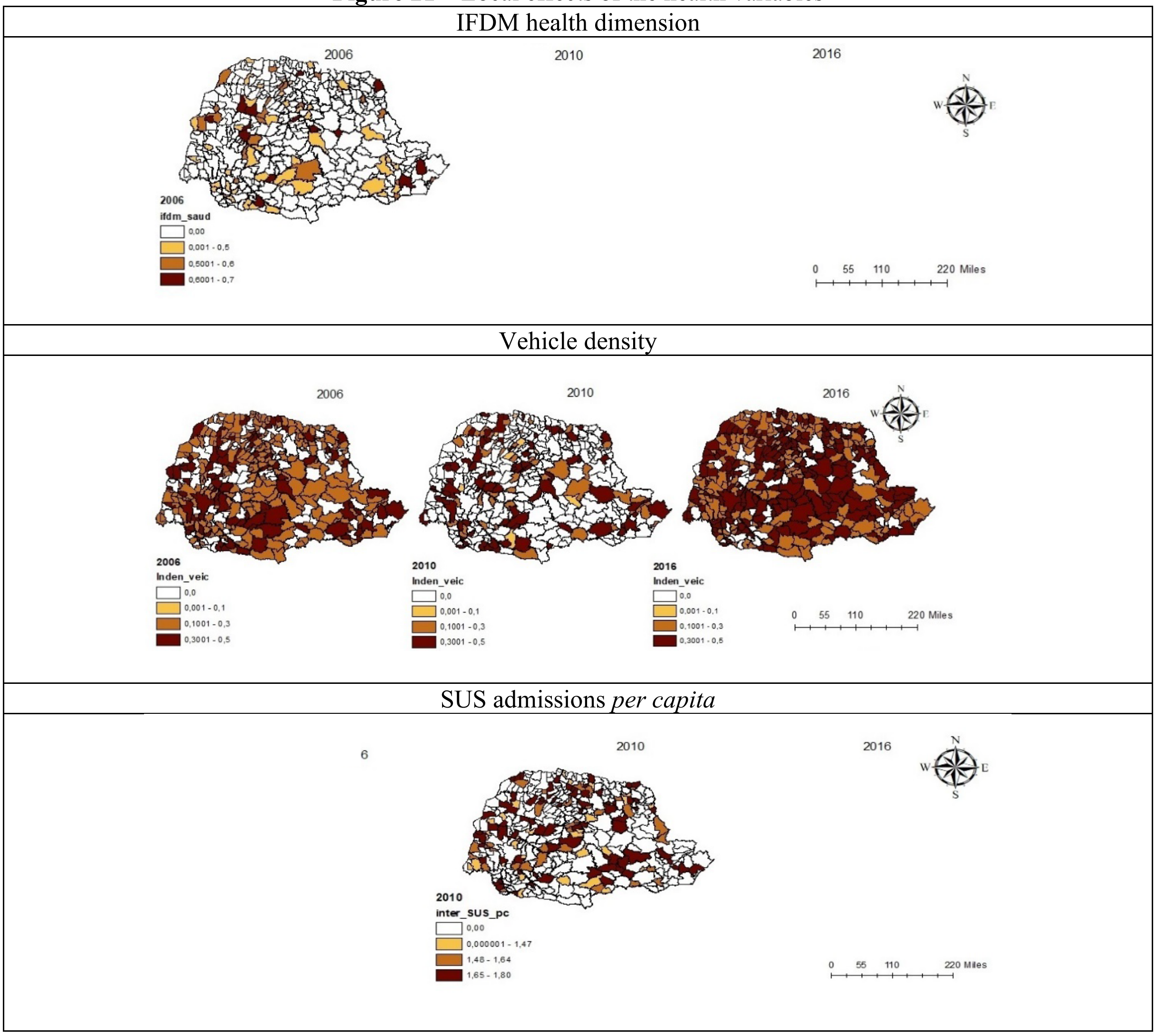
The percentage of the population who attained secondary education, also a proxy for education, did not have the same local behavior as the IFDM education dimension. In the year 2006, a little over half of the municipalities were affected, with a positive effect on the state's economic growth. Nevertheless, in the years 2010 and 2016, most municipalities did not show statistical significance at the level of 0.05, and of those that did, their effect was negative, albeit very small.

Of the variables in the health set, the IFDM health dimension only showed statistical significance at the 0.05 level in 2006, presenting a positive impact for few municipalities, while there was no regional pattern in the way that the variable affected the state's growth. As Ribeiro et al. (2019) argued, vehicle density directly relates to air quality, since large urban centers, by having a high degree of pollution due to traffic, have a significant impact on the health of the population exposed to this problem.

However, the effect of the variable was positive throughout the period, although in 2010 there was a reduction in the number of municipalities affected by this variable, a reduction later reversed in 2016, where in addition to increasing the number of municipalities that were influenced, the impact rose, especially in the Central region of the state.

Such fact can be explained, as Cacciamali et al. (2009) and Portillo (2019) argue, because the automotive sector has great influence on the generation of employment and income in Brazil, as it demands a large amount of labor, directly and indirectly, both in production and in the marketing, and other services linked to it. For the number of SUS admissions per capita, the increase in the number of admissions increases economic growth. This fact can be explained because admissions to the SUS are not limited to the municipality demanding the service, since the regional trend is that there is a migration of patients who use SUS services and, for this, go to other regions, better economically developed, and thus with better resources available.

Figure 21 – Local effects of the health variables



Source: Research results, Author's own elaboration.

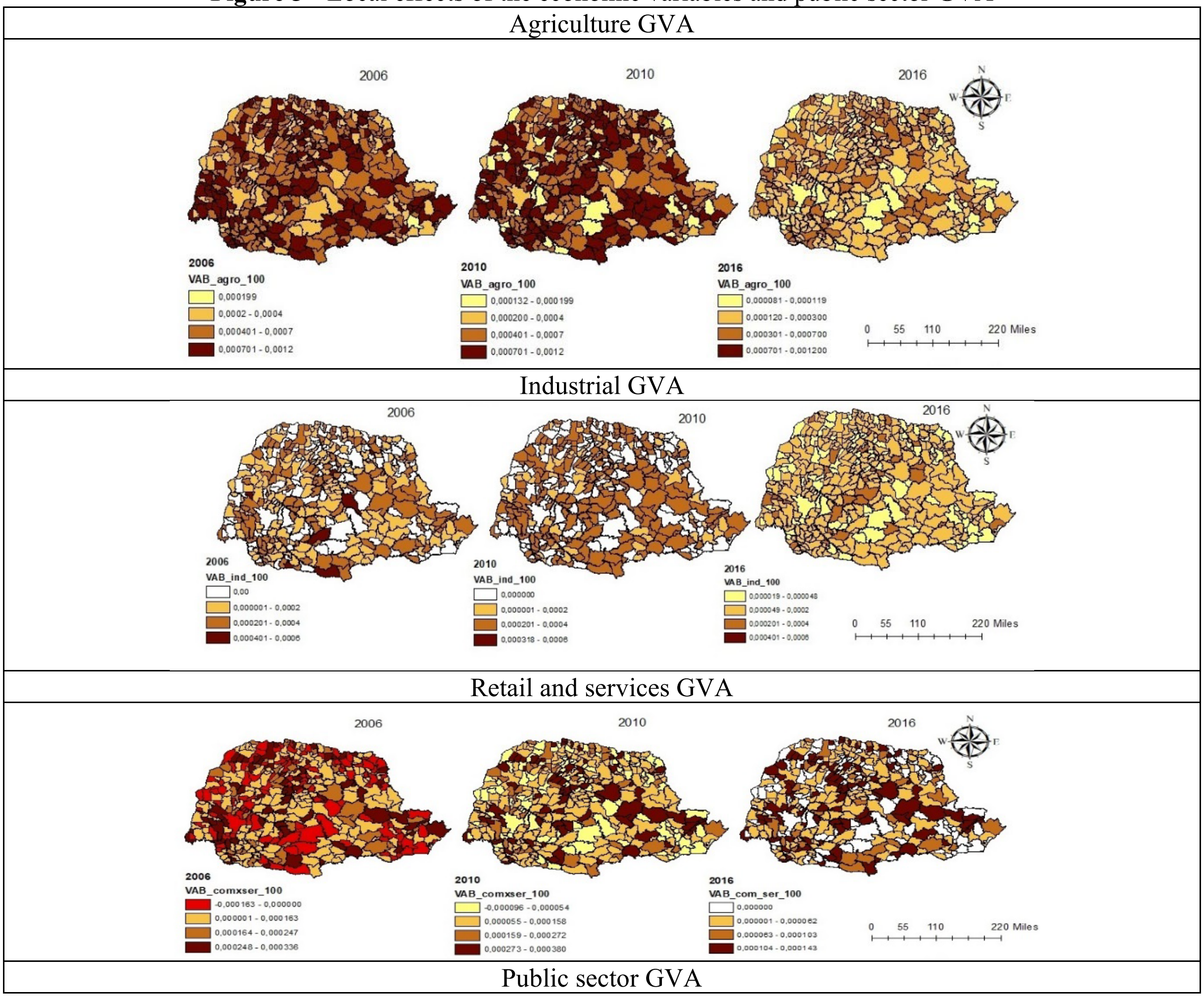
Note: Considering Test t_c=1.96, at the significance level of 0.05; missing maps refer to the years in which the variable presented no geographic variability.

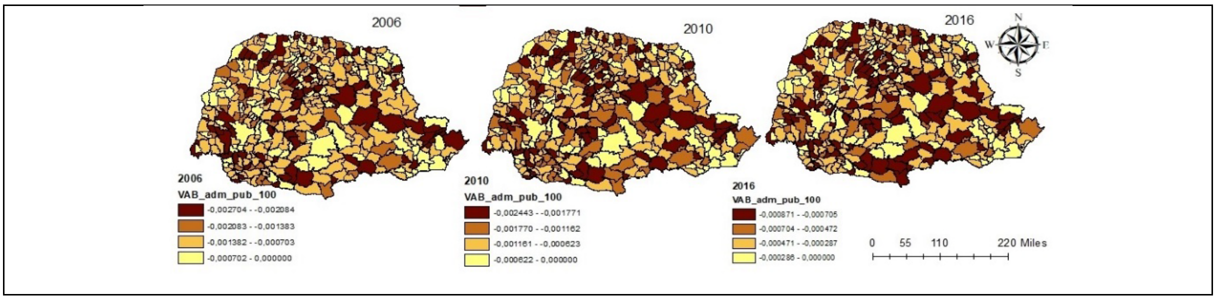
Analyzing in Figure 3 how the sectors impact the state growth, given the agricultural sector had a strong influence on the formation of Paraná, being responsible for explaining a large part of its current sector configuration, it was expected to be influential on its economic growth (SCHMIDT, FILIZOLA, 1998; CANCIAN, 1981). We see that municipalities in the South, Center-East, West, and North of Paraná were strongly impacted by agricultural GVA. In 2016, the effect of the variable decreased significantly, but the most affected regions maintained the trend of the previous two years.

. The behavior of the industrial GVA was different from the agriculture GVA. In the years 2006 and 2010, a large part of the municipalities suffered no effect from this variable. Yet, in 2010 presents homogeneity in the GVA effect of this sector. In 2016, its effect influenced all municipalities in the state, although with a low parameter value.

For the tertiary sector, the behavior of the retail and services GVA variable had an effect on growth in all municipalities, although with a negative sign for some in the year 2006 (represented by the municipalities in red). In turn, the effect of the GVA of public administration was negative and significant for all periods and municipalities. What is also evident in the maps is that there was no expressive regional variation in how it affected municipal GDP *per capita.*

Figure 3 - Local effects of the economic variables and public sector GVA



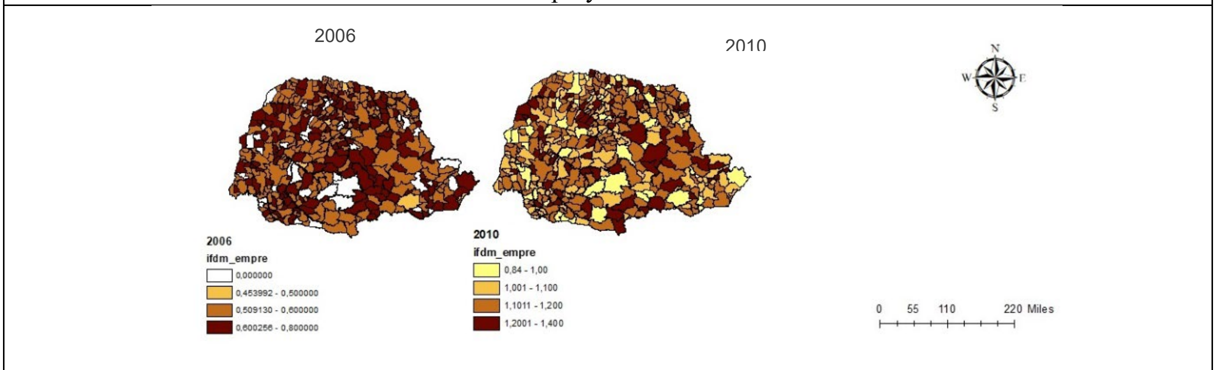


Source: Research results, Author's own elaboration.
Note: Considering Test t_c=1.96, at the significance level of 0.05; missing maps refer to the years in which the variable presented no geographic variability.

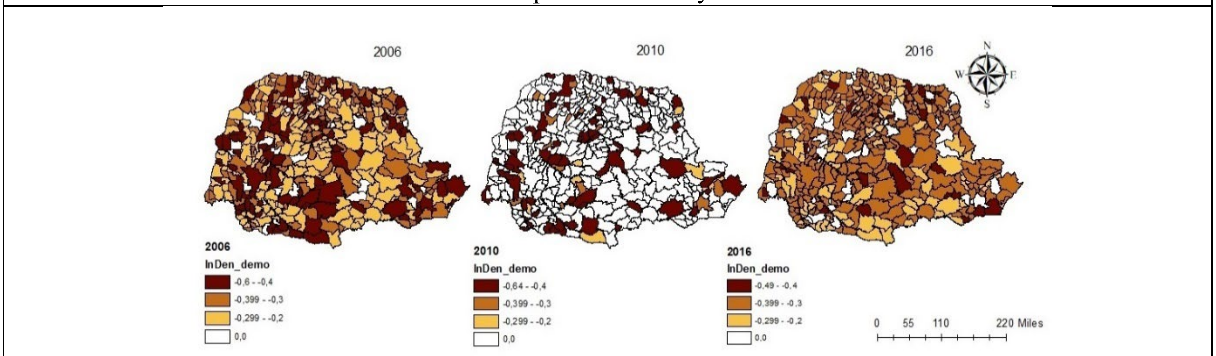
When analyzing characteristics related to the structure of the Paraná municipalities, and because the variable IFDM employment and income dimension directly relates to the generation of income and formal jobs, although it has not shown geographical variability in 2016, in 2006 and 2010 most municipalities were affected by this variable. The effect of demographic density was significant in all three years and with a negative sign. In 2006, a large part of the municipalities responded negatively to demographic density and with expressive impact on the reduction of GDP per capita. Nevertheless, its influence reduced in the year 2016, compared to 2006, since few municipalities were in the last quartile in the value obtained in the parameter. According to McNicoll (1984), Kelley (1988), and Paiva and Wajnman (2005) there is no obvious relationship in how population density can affect economic growth, and it can be either positive or negative, depending on the socioeconomic context of the region, or it can be negative in the short term and positive in the long term.

Figure 4 – Local effects of the municipal structure variables

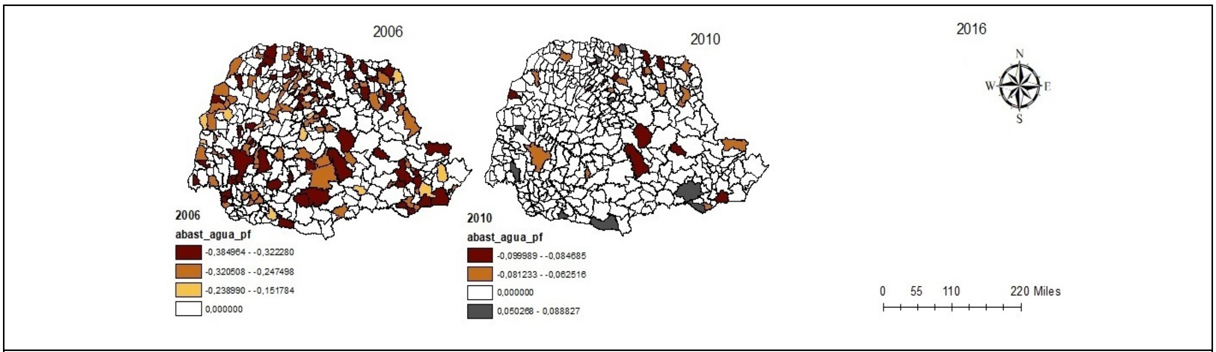
IFDM employment dimension



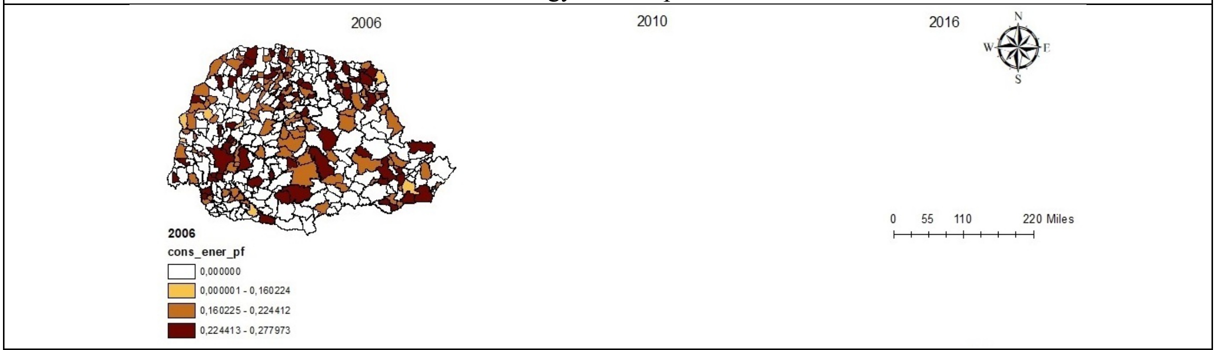
Population Density



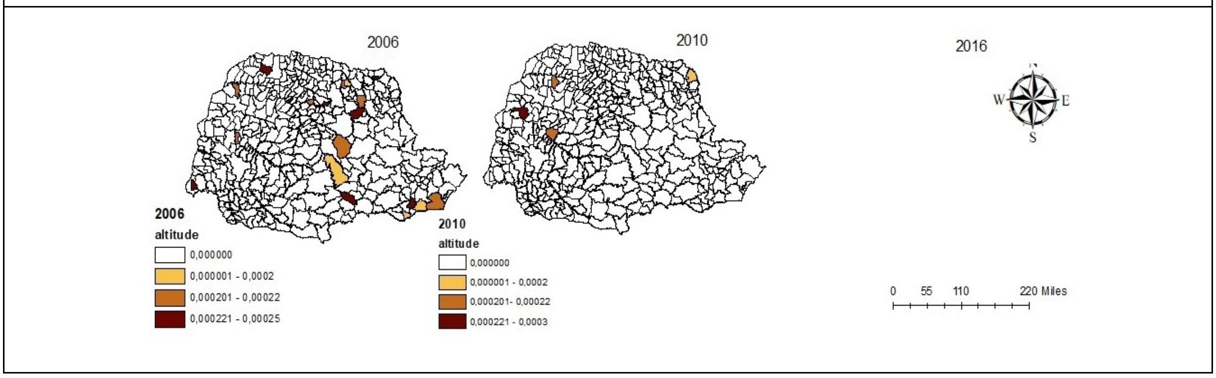
Households' water supply



Energy consumption



Altitude

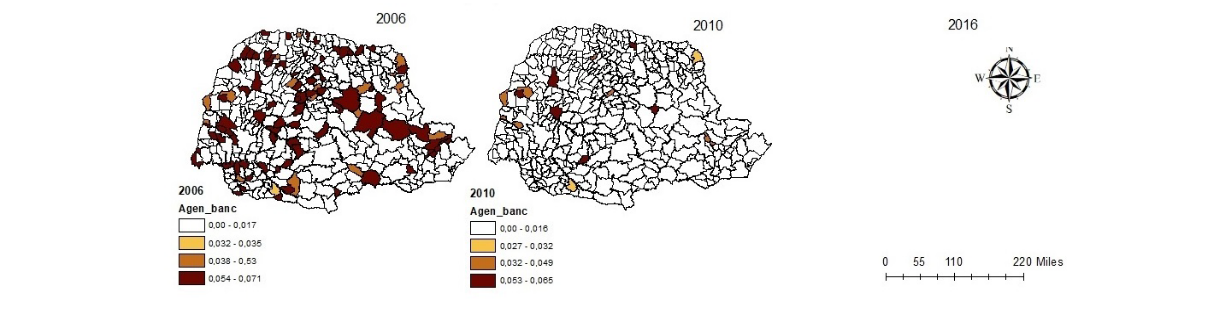


Source: Research results, Author's own elaboration.
Note: Considering Test t_c=1.96, at the significance level of 0.05; missing maps refer to the years in which the variable presented no geographic variability.

The household water supply presented a negative sign, an unexpected result, since, as pointed out by Ottonelli et al. (2013) and Firme and Filho (2014) this had a positive sign. The impact of the variable was smaller in the state in 2010 than in 2006 and, in some municipalities in 2010, its effect was positive (indicated by those in gray), while in 2016 the variable showed no geographical variability. Whereas household energy consumption only showed geographic variability in the 2006, and few municipalities had statistical significance and positive sign. The altitude variable was used with the purpose of capturing whether any geographic attribute could influence the state's economic growth, as did Loures and Figueiredo (2017) in their research and the classical authors of location. We found that in the state, in 2016, the variable showed no geographical variability, while in the other years, few municipalities were affected by altitude.

Figure 5 – Local effects of the number of bank branches

Number of Bank Branches

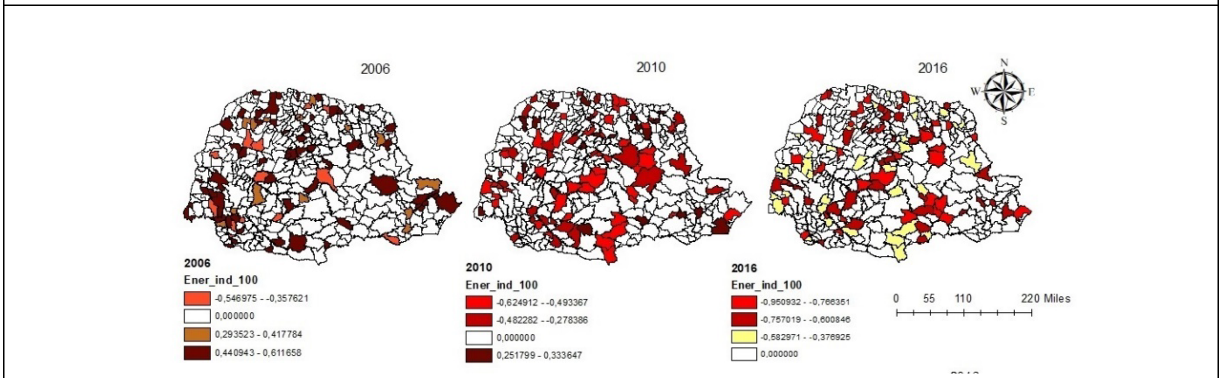


Source: Research results, Author’s own elaboration.
Note: Considering Test t_c=1.96, at the significance level of 0.05; missing maps refer to the years in which the variable presented no geographic variability.

The variable number of bank branches presented a positive sign, indicating that the increase in this variable had a positive effect, in 2006 and 2010, on the per capita GDP of Paraná municipalities, even though it did not present geographic variability in 2016. In 2006, in most municipalities, the variable did not present statistical significance, but in the few that did, its effect was significant. When considering 2010, however, there was a reduction in the number of municipalities influenced by this variable, but maintaining the positive sign, results similar to those of Meiners et al. (2013) and Carneiro and Silva (2018).

Figure 6 - Local effects of industrial energy consumption per 100,000 inhabitants

Industrial energy consumption per 100,000 thousand inhabitants

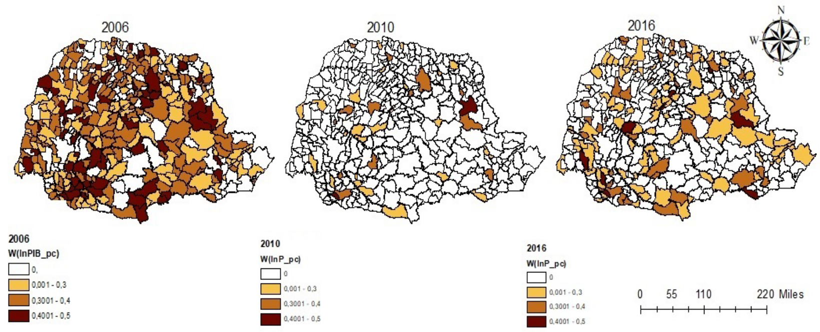


Source: Research results, Author’s own elaboration.
Note: Considering Test t_c=1.96, at the significance level of 0.05; missing maps refer to the years in which the variable presented no geographic variability.

The local effect of industrial energy consumption per 100,000 inhabitants, proxy for fixed capital was controversial, in terms of both the expected sign and the effect on regions. Initially, it shows that throughout three years, few municipalities had their GDP per capita influenced by this variable. It is also noteworthy that in the year 2006, of the municipalities in which industrial energy consumption was significant at the 0.05 level most were positively influenced by it, while a small part of them were negatively influenced by the variable. In 2010, however, this scenario changed, given those that were significant, the greatest impact was negative on growth with a small minority affecting positively. In 2016, the negative effect of the variable was predominant. Results that go against those of Montenegro et al. (2014), Raiher et al. (2018), and, especially Ferrario et al. (2009) who used this same variable, however with a distinct methodological approach.

Figure 7 - Local effects of spatially lagged GDP per capita

Spatially lagged GDP *per capita*



Source: Research results, Author's own elaboration.
Note: Considering Test t_c=1.96, at the significance level of 0.05; missing maps refer to the years in which the variable presented no geographic variability.

Lastly, Figure 7 presents how spatially lagged GDP *per capita* affected the growth dynamics. As already showed in the empirical works of Ferrario et al. (2009), Ferrario et al (2009), Montenegro et al. (2014), Reis (2014), Dias and Porsse (2016), Carmo et al. (2017), and Carneiro and Silva (2018), it was expected that economic growth would be influenced by several variables and, among them, the regional dynamics itself. For Paraná, the lagged GDP per capita presented a positive influence in all study years on some municipalities, although not in all.

From the 2006, 2010, and 2016 analysis, we see that, of the variables used in the research as determinants of regional economic growth of the Paraná municipalities, which represented, as possible, the variables present in the economic theories addressing this topic, had mostly the expected effects. However, some presented no statistical significance or an effect contrary to the expectation (specifically the industry energy consumption). We also found that throughout the period certain variables were important and consistent with the theory, as is the case of the agriculture GVA, the education IFDM, while others had changes, being significant in only one period, or losing it throughout the period. Such was the case of the variables number of hospitalizations in the SUS, employment IFDM, energy consumption and household water supply. In this way, the GWR model can show at the local level the impact of each variable on the municipality, indicating in which regions the effect was greater, which ones gained (or lost) explanatory power over the state's economic growth.

5 FINAL CONSIDERATIONS

In general, given that the objective of the research was to analyze which were the determinants of economic growth in the Paraná municipalities in 2006, 2010 and 2016, diverse results were obtained. The advantage of using the GWR model is that it allowed verifying how a variable affects, at the local level, the growth in each geographical unit under analysis, which was for this research, the municipalities of the state of Paraná. Among the selected determinants, we may observe the existence of a certain pattern, since variables related to education, municipal structure, and economics were responsible for the increase in the state's municipal GDP *per capita*. The results showed that the variables used with the intention of evaluating the importance of the territory, as advocated by both classics of the location theory and authors of regional economic growth; we observed that in Paraná, the spatially lagged GDP per capita positively affected economic growth. These findings match those in the works of Pereira et al. (2012) and Firme and Filho (2014).

As seen, the education, municipal structure and economic variables, especially the agriculture GVA, were fundamental to the economic growth of the Paraná municipalities. The GWR model allowed us to verify that the effect of some variables changed over the period. This happened either by changing the sign of the parameter, as in the case of the retail and services GVA and the industry energy consumption, or by gaining or losing explanatory power in the municipalities, especially the education IFDM, health IFDM, demographic density and industry GVA, given that the first gained explanatory power throughout the years while the second lost. Furthermore, the demographic density was limited to a few municipalities in 2010 and the industrial GVA became increasingly greater, affecting an increasing number of municipalities in the state.

It is noteworthy that education, measured by the IFDM education, although had not presented geographical variability in 2010, gained increasing proportions both in the value of the parameter obtained and the ability to influence an increasing number of municipalities, thus showing that investments in this area have the greatest potential to raise the economic level of Paraná. Similarly, the agriculture GVA showed high explanatory power for the economic growth of Paraná, a result expected because agricultural production has followed and influenced the historical, political, social, and economic formation of the state, as pointed out by Trintin (2006).

Thus, even with the article's limitations for not considering other regional growth theories, or for not detailing each of those presented, or even for the limitation of variables used, since several other proxies could be used. In general, the article showed that certain variables, especially the IFDM education dimension, the agriculture and industry GVA, the demographic density, and the IFDM employment dimension were relevant to increase the economic level of the municipalities of Paraná between the years under study. The article contributes to the subject because, by considering a non-negligible amount of variables and theories, it evidenced which factors actually affected the municipal GDP of Paraná. Thus, its results can be useful for public managers to better understand the dynamics of the municipal economic growth process in the state, serving as a means of guidance for decision making regarding the allocation of public resources.

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APPENDIX

Table A1 - Local coefficients and criterion difference of the SAR model estimated by GWR for 2006, 2010, and 2016

Variables	2006		2010		2016	
	Mean	Difference in Criteria	Mean	Difference in Criteria	Mean	Difference in Criteria

Intercept	6.266.27	**-2,058,723,912**	74.302	**-635,027,553**	7.726.142	**-714,868,373**
W(lnGPD *per capita*)	0.27288	**-896,349,731**	0.083018	**-332,462,979**	0.136945	**-337,359,607**
IFDM education	0.10423	**-29,669,876**	0.678864	**-272,119,648**	1.009.339	**-149,865,142**
IFDM employment	0.5748	**-3,463,448**	1.124.513	**-31,956,643**	0.691873	4,442,045
IFDM health	0.2816	**-56,444,153**	0.098672	**-100,012,834**	-0.091411	**-16,609,255**
Agriculture GVA100,000 inhabitants	0.0005	**-7,969,236**	0.000636	**-26,811,993**	0.000242	**-13,805,936**
Industry 100,000 inhabitants	0.0001	**-112,439,307**	0.000156	**-213,019,445**	0.000093	**-79,526,465**
Retail and services GVA 100,000 inhabitants	0.0001	**-207,597,302**	0.000136	**-281,302,227**	0.000056	**-151,688,987**
GVA Public administration100,000 inhabitants	-0.0012	**-87,053,895**	-0.001129	**-57,424,705**	-0.000472	**-31,703,506**
Ln(population density)	-0.3300	**-294,417,06**	-0.174083	**-266,592,821**	-0.32206	**-134,482,351**
Number of bank branches	0.0258	**-140,446,92**	0.011513	**-3,397,268**	0.012687	8,059,531
Ln(population density)	0.2411	**-87,180,127**	0.153561	**-35,512,562**	0.287797	**-139,480,392**
Population with Higher Education	2.122.65	**-23,719**	-0.784932	**-8,563,131**	-0.541811	**-3,914,193**
Household energy consumption	0.137542	**-191,701,104**	-0.008642	0,848612	0.06651	0,852228
Households water supply	-0.1832	**-131,951,095**	0.001513	**-7,871,295**	-0.102514	13,577
Industrial energy consumption per 100,000 inhabitants	0.1856	**-15,556,216**	-0.10372	**-42,404,157**	-0.154548	**-15,064,379**
SUS admissions *per capita*	-0.1384	3,558,526	0.678888	**-2,749,211**	0.02338	3,958,273
Public Revenue Investment Ratio	0.8290	3,002,667	0.215047	3,062,622	0.67329	1,111,649
Altitude	0.0001	**-11,428,123**	0.000072	**-12,175,904**	0.000059	285,074
Municipal Participation Fund *per capita*	0.00003	2,217,313	0.000095	241,249	0.000054	5,006,537

Source: Research results, Author's own elaboration.
Note: The coefficients presenting geographical variability are highlighted in bold.

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