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Crescimento Econômico nos Municípios do Paraná-Brasil: Uma Análise com Econometria Espacial[1]

Economic Growth in the Municipalities of Paraná-Brazil: An Analysis with Spatial Econometrics

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Abstract

This study differs by analyzing the composition of the variables that represent the education and health dimensions, partially present in the concept of human capital, and the aspects of income distribution as elements to explain the municipalities' economic growth in the State of Paraná. For this purpose, spatial econometric models were tested. Durbin's spatial model (SDM) was the most adequate to reinforce the fact that education, health, and income inequality are elements that determine their economic growth. Regarding income distribution, there is a different contribution; that is, there is an indication that economic growth tends to be positively related to the increase in income concentration when analyzed from the municipality's perspective. In contrast, the municipality's economic growth is positively influenced by the better income distribution in neighboring municipalities.

Keywords: Economic Growth; Education; Health; Human Capital; Income Distribution.

Code JEL: R1; R11; I25; C21

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Resumo

Este estudo se diferencia por analisar a composição das variáveis que representam as dimensões educação e saúde, parcialmente presentes no conceito de capital humano, e os aspectos da distribuição de renda como elementos explicativos do crescimento econômico dos municípios do Estado do Paraná. Para tanto, modelos econométricos espaciais foram testados. O modelo espacial de Durbin (SDM) foi o mais adequado para reforçar o fato de que educação, saúde e desigualdade de renda são elementos que determinam seu crescimento econômico. Em relação à distribuição de renda, há uma contribuição diferenciada; ou seja, há indícios de que o crescimento econômico tende a estar positivamente relacionado ao aumento da concentração de renda quando analisado sob a ótica do município. Em contrapartida, o crescimento econômico do município é positivamente influenciado pela melhor distribuição de renda nos municípios vizinhos.

Palavras-chave: Crescimento Econômico; Educação; Saúde; Capital Humano; Distribuição de Renda.

Códigos JEL: R1; R11; I25; C21

1. INTRODUCTION

In the early 1960s, Theodore W. Schultz (1961) realized that the national product's growth was proportionally higher than the increase in the use of production factors, such as land, person-hours, and physical capital. The idea of investment in human capital was used to explain this divergence. This investment was related to direct spending on formal education and training, health, and internal migration to generate advantages regarding better employment opportunities. However, the use of leisure time to improve workers' skills and knowledge is relevant; still, it is not considered and tends to improve the quality of human effort and, as a result, increase labor productivity and real profit per worker.

From this observation raised by Schultz (1961), concerning the importance of human capital for product growth, a fundamental research problem was observed: how to explain why some regions grow at different magnitudes compared to others. In detail, which relevant and significant variables compose the idea of human capital and how much they propagate positive or negative effects on the per capita income growth of some municipalities or regions.

Some articles were proposed by several authors to offer an answer to this question, among which Zhang and Zhuang (2011); Basu and Mehra (2014); and Madsen (2014). The concept of human capital brings together aspects of the education and health dimensions. Those studies seek to use variables representative of these dimensions as somehow relevant to measure the concept of human capital and, later, use this concept as a determining element of a given geographic area's economic growth.

For Barro (2001), assuming a constant physical capital stock, if there is an increase in the human capital stock, this can increase economic growth. Such progress can be transmitted through two channels. The first channel indicates that the greater the share of human capital in a region, the greater its absorption in higher technologies. The second channel is related to the greater flexibility of human capital vis-a-vis physical capital, which allows an area endowed with higher potential in human capital to adjust and recover more dynamically when there are natural or human disasters.

Another relevant and strategic aspect concerns the formation and establishment of conditions to maintain human capital in a given region since this asset is crucial to accelerate local economic growth dynamics. Taylor and Martin (2001) emphasize that the migratory dynamic is a vital aspect to consider because it is influenced by wage differentials and the returns of having migrated to other regions. These wage differentials and the returns obtained in a given area are correlated with capital accumulation and demand for labor; in other words, if there is an increase in labor demand, the positive wage differential will attract labor, that is, human capital from neighboring regions.

In the Brazilian academic field, the component factors of the variables that may represent a human capital perspective have already been analyzed in other articles. In addition to proving the hypothesis of positive causality between human capital and economic growth of the regions through spatial econometrics analysis, these articles also sought to measure how much the first concept produces effects on the second. Among those works, Raiher (2009); Raiher and Dathein (2011); Salgueiro, Nakabashi and Prince (2011); and Dias and Porsse (2016) stand out. Following these studies, this article seeks to confirm the relationship of determination on economic growth (*per capita income*) by analyzing some variables already evaluated in previous studies (*fertility rate*, *illiteracy rate in people over 18*, *percentage of 25 years and older with a college degree*, and *percentage of people in households with an inadequate treated water supply and sanitation*). It also adds different ones (*Gini index*, *formal jobs among 18 years and older*[2], *percentage of people 15-24-year-old who do not study or work and are vulnerable to poverty - Neither-Nor*) to expand the explanatory power of the determination relationship mentioned above.

Spatial econometrics analysis will be used as a methodology to evaluate the municipalities of Paraná in cross-section, for the year 2010, with data obtained from the Brazilian Development Atlas (2013). The choice of these municipalities is justified because Paraná represents the fifth largest GDP share in Brazil in 2010 (IBGE, 2010). This work intends to verify how the variable *per capita income* relates to the selected independent employment characteristics variables. The variable *formal jobs among 18 years and older* is expected to show a positive correlation. Regarding the *Gini index*, it is assumed that there may be a direct or inverse relationship depending on how economic growth occurs, in other words, with an increase or decrease in the inequality gap. A direct relationship is expected between *per capita income* and the *percentage of 25 years and older with a college degree*, and the inverse with the *illiteracy rate in people over 18*, and the *percentage of people 15-24-year-old who do not study or work and are vulnerable to poverty - Neither-Nor*[3] variables. Finally, the variables *percentage of people in households with an inadequate treated water supply and sanitation* and *fertility rate* should have an inverse relationship with the dependent variable.

The work is structured in five sections. The next section deals with the literature review on the influence of the variables to be analyzed and the regions' economic growth. Also, the methodology will be presented. The Exploratory Analysis of Spatial Data (EASD) and the econometrics estimation models to be tested to obtain the best adherence to reality will be described. In the following section the results will be discussed and, in the last section, the article's main conclusions.

2. LITERATURE REVIEW

The human capital concept encompasses two crucial and complementary dimensions: Education (formal and informal) and Health (sanitation, food, health service infrastructure, etc.). The health dimension inserted in the concept of human capital is discussed by several authors, such as Schultz (1961; 2002); Becker (2007); Howitt (2005); Currie (2007); Cunha, Heckman, and Schennach (2010); and Heckman (2000; 2012). Because of the relevance of such dimensions to help explain economic growth and, mainly, the inequality gap among them, this section discusses the importance of human capital. It also details the inserted dimensions (Education and Health) and the variables that may impact a region's economic growth.

Health is a crucial dimension in ensuring people's welfare and quality of life standards. The risk of death and disease are central issues to form human capabilities and people's behavior. Thus, in theory, a higher health expenditure tends to produce positive effects on human welfare and happiness. According to Bloom and Canning (2003), the most effective methods in developing countries to improve health require the public sector's participation. In these countries, infectious diseases are the leading cause of premature mortality and health problems. These issues are often related to clean water systems deficiencies, lack of basic sanitation, and inadequate large-scale vaccination programs.

2 In the Brazilian Human Development Atlas (2013) formal jobs correspond to employed individuals with formal employment contracts, military personnel from the army, navy, aeronautics, military police or fire brigade, civil servants, as well as employers and self-employed persons who were contributors to an official social security institute.

3 In the Brazilian Human Development Atlas (2013), the Neither-Nor variable comprises the percentage of people between 15 and 24 years old who neither study nor work and are vulnerable to poverty in relation to the total population in this age group. People living in households with a per capita income of less than 1/2 the minimum wage in August 2010 are defined as vulnerable to poverty. Only permanent private households are considered.

According to Turolla (2002), Brazil has a history of change in basic sanitation structure. In the middle of the last century, the news that conveyed information about the country's precarious basic sanitation system was commonplace. Among the relevant items mentioned by users were: lack of chemical treatment, faulty operation, and absence of supervision. However, during the 1960s, as cities' urbanization progressed more rapidly, the sanitation system began to develop with the National Housing Bank's help. It became a resource to attract skilled labor since individuals with higher education would be more likely to migrate to a region with better basic sanitation conditions, positively affecting the region's per capita income.

For Bloom and Canning (2003), there are two direct mechanisms in which health produces positive effects. Firstly, when health is considered a consumer good and has a positive impact on welfare. The second mechanism is when health is considered an investment good and produces a positive result on citizens' future productive power. However, there are indirect mechanisms through which health can also influence labor productivity. The first indirect mechanism is that health can contribute equally to other human capital forms. It has already been empirically proven that productivity and wages are positively related to workers' education and professional experience levels. The indicated complementarity stems from the fact that returns in labor productivity can be higher for healthier workers. Also, poor health and premature death hinder the maximization of gains from investment in human capital and reduce people's incentive to invest. The second indirect benefit arises from increasing the life expectancy of workers. The higher life expectancy generates the need to increase retirement income.

The last indirect mechanism indicates that reductions in mortality rates alter the age structure of the population. Initially, Bloom and Canning (2003) argue that improvements in health conditions tend to reduce the mortality rates of infants and children susceptible to disease. This reduction in infant mortality most often leads to a subsequent drop in the birth rate because families tend to adjust their fertility behavior to the new low mortality regime. The drop in birth rates means that the baby boom phenomenon may be singular. This group of people, representing the "baby boom" phenomenon, can significantly impact a country's economy and must be planned as they will enter the education system, become young adults, enter the labor market and retire. Another relevant point in the relationship between education and health is that reducing mortality rates increases education return. In other words, it extends the useful life in which education can be employed and therefore induces a higher demand for it.

Another author who highlighted the importance of health as a factor closely related to the educational level of a nation was Becker (2007). For this author, there is a direct positive relationship between education and life expectancy through two mechanisms. The first is related to the increase in the number of years of education and the expenditures involved, with the expected future returns. Consequently, it generates a wealth effect that tends to increase health expenditures and reinforce survival potential in subsequent years. The second mechanism comes from the direct impact of education on life expectancy. By increasing health expenditures, individuals tend to become more productive. The higher the person’s education level, the greater his ability to obtain information on a healthy lifestyle and better health professionals to provide for his needs[4].

Concerning life expectancy, an estimate made by Bils and Klenow (2000) indicated that for each additional year of life expectancy, there would be an increase of ¼ in years of education. In another study, Barro and Sala-I-Martin (1995) demonstrate that estimates suggest that the effect of health, observed as life expectancy, on the GDP is exceptionally relevant. Such estimates indicate that an extra year of life expectancy increases the steady-state GDP by about 4%. However, education is an asset capable of boosting labor productivity only if workers are somehow inserted into the labor market. Otherwise, it is being used inefficiently. Thus, such a relationship contributes to explain why education levels are higher in developed countries than in developing countries.

Another essential aspect of human capital is that it can self-reproduce, generating more human capital. An initial investment can cause a cascading effect on other investments, which can influence a person's migration from one city to another more advanced in human capital, considering not only the technology but also health and education. In this case, according to Heckman (2000), it is estimated that the average return on investment in human capital is approximately 10%. Still, in the

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4 The causality relationship is discussed in two different directions. Some authors argue that higher education levels generate positive effects on health, while others affirm the reverse causation, i.e., an improvement in health produces or supports a higher and/or better education level. It is worth mentioning that the authors of this article understand that causality relationships can occur in both directions.

case of less qualified people, this average is less than 10%. The study estimated that to restore the 1979 school dropout loss in the United States, it would be necessary to invest $25 in the U.S. labor force for each escaped student ten years later.

Another result presented is that a woman's higher primary education positively impacts economic growth because it reduces the region's birth rate. Schultz's study (1994) points out that a 2.2% increase in a woman's education would generate a reduction in both the birth rate (4.7%) and the infant mortality rate (2%). Additionally, if family planning is considered, the decrease in the birth rate becomes 7.8% and, as such, has a direct impact on human capital.

In a further study by Balassiano, Seabra, and Lemos (2005), it was detected that it is possible to observe higher wages for people with higher education, which generates a specific influence on the individual's employability. However, considering the other groups, it presented a low significance in the salary discrepancy of the less educated. Moreover, another result was that an increase in education would only significantly impact income if the individual has more years of study. Among people with the least number of school years, this change in schooling will not considerably affect earnings. The study showed a 5.4% difference in employability between those with a college degree and those who only had completed high school. The wage difference between the two groups was three times greater for the group with higher education in one of the regions.

When analyzing the studies carried out in Brazilian municipalities by Salgueiro, Nakabashi, and De Prince (2011), a spatial correlation is confirmed, and the importance of physical and human capital to explain economic growth is highlighted. The study by Raiher (2009); and Raiher and Dathein (2011), conducted for the micro-regions of Paraná, also found results indicating that the increase in human capital caused positive impacts on the productivity of the State's economy and, consequently, on the economic growth of the region. That was also confirmed by Dias and Porssé (2016), in their study on the evidence of income convergence between 2000-2010, for the municipalities of Paraná. They also verified a positive effect of human capital on economic growth.

Based on the theoretical and applied results presented in this section, the next step will be to explain the methodology used to ascertain the spatial dependence and demonstrate whether the hypothesis of positive causality between human capital and economic growth is verified in the municipalities of Paraná.

3. METHODOLOGY

The data used in this article were collected from the Brazilian Atlas of Human Development (2013). This section presents the variables and their respective descriptive statistics in Table 1[5]. The statistical data used to test and select the spatial econometrics models were transformed using a natural logarithm to obtain the best spatial econometrics model and, therefore, a better reality approximation.

The variables *Fertility rate* (FECTOT), *Illiteracy rate in people aged 18 and over* (T_ANALF18M), *% of people in households with an inadequate treated water supply and sanitation* (AG_ESG), *% of people 15-24-year-old who do not study or work and are vulnerable to poverty - Neither-Nor* (T_NES_MEIO) are expected to constitute an inverse relationship with the dependent variable.

On the other hand, it is expected that variables *% of 25 years and over with a college degree* (T_SUPER25M) and *Formal jobs among 18 years and older* (P_FORMAL) will have a direct or favorable relationship with the economic growth represented by the variable per *capita income*. Concerning formal employment, according to Ulyssea (2006), there are well-established stylized facts about the existence of significant wage differentials between formal and informal work in the literature.

5 The following variables showed no significant results: Life expectancy at birth (ESPVIDA), Mortality up to 5 years of age (MORT5), Probability of survival up to 40 years (SOBRE40), Years of study expectancy (E_ANOSESTUDO), percentage from 15 to 17 years in secondary education without delays (T_ATRASO_0_MED). Therefore, they were excluded from the model.

Table 1- Presentation of the study variables

Variable	Variable Description	Expected Signal	Average	Median	Mode	Standard deviation	Coefficient of variation (%)	Sample variance	Kurtosis	Asym-metry	Interval	Mini-mum	Maxi-mum	Confi-dence level (95.0%)
R_CAP	Per capita income		610.22	592.27		150.29	24.63	22585.97	4.76	1.24	1303.71	277.33	1581.04	14.79
FECTOT	Fertility rate	(-)	2.05	2.04	2.10	0.32	15.74	0.10	-0.39	0.24	1.61	1.35	2.96	0.03
T_ANALF18M	Illiteracy rate in people aged 18 and over	(-)	11.14	11.02	13.78	4.17	37.43	17.40	-0.55	0.12	19.91	1.32	21.23	0.41
T_SUPER25M	% of 25 years and over with a college degree	(+)	6.72	6.00	5.56	2.89	43.04	8.35	6.50	1.79	24.08	1.87	25.95	0.28
GINI	Gini index	(-) or (+)	0.4657	0.4700	0.48	0.0571	12.26	0.0033	0.1035	0.2333	0.33	0.33	0.66	0.0056
P_FORMAL	Formal jobs among 18 years and older	(+)	56.02	56.52	64.71	11.47	20.47	131.49	-0.18	-0.43	64.39	15.86	80.25	1.13
AG_ESG	% of people in households with an inadequate treated water supply and sanitation	(-)	1.55	0.61	0.00	2.34	150.31	5.46	11.48	2.84	19.02	0.00	19.02	0.23
T_NES_MEIO	% of people 15-24-year-old who do not study or work and are vulnerable to poverty - Neither-Nor	(-)	8.36	7.86	6.41	4.11	49.11	16.86	0.27	0.71	21.70	0.00	21.70	0.40

Source: Prepared by the authors with data from the Brazilian Development Atlas (2013).

Finally, the variable *Gini index* (GINI) can influence in both directions since economic growth may improve or worsen income inequality. Also, it is possible to occur an increase in *per capita* income due to a rise in the unemployment rate. Bresser-Pereira (2017) argues that this can be caused, for example, by an improvement in productive technology in a region, which, in turn, triggers a labor factor economy or an increase in *per capita* income, resulting from a drop in the occupation rate, a situation with apparent positive effects resulting from a cycle of expansion of productive activity.

After describing the variables to be used to estimate the model (Table 1), the next step is to specify the spatial econometrics models to be tested to choose the one with greater adherence to the assessed reality.

Initially, following Almeida (2012) indications, the model to be used will be the classical ordinary least squares (OLS), which represents the aspatial process; in other words, it does not consider the spatial effects. This model can be represented by equation (1).

$$\boldsymbol{y = \alpha_n + X\beta + \varepsilon}$$
$$\varepsilon \sim N(0, \sigma^2, I_n) \qquad (1)$$

Then, based on Lasage and Pace (2009) indications, the occurrence of spatial dependence will be tested using Moran's I. This test verifies the occurrence of spatial autocorrelation of the regression residues; for this, the spatial weights matrix (W) best adapted to verify the spatial dependence between the regions will be chosen. The spatial weights matrix (W) corresponds to a square matrix of dimension n x n. The spatial weights w_{ij} correspond to the degree of connection between the regions guided by some proximity criterion, revealing the interference of region j in region i. Therefore, the spatial weights matrix establishes the weighting of the regions' influence among themselves.

Equation 2 represents Moran's I:

$$\boldsymbol{I = \frac{n}{S_0}\left(\frac{e'We}{e'e}\right)} \qquad (2)$$

Where, according to Arbia and Baltagi (2009), $e = y - X\hat{\beta}$, $\hat{\beta}$ is the OLS estimator for β, and S_0 represents $\sum_i \sum_j w_{ij}$, corresponding to a standardization factor. As the matrix W is normalized in the line, S_0 equals n (number of regions), and this produces equation 3.

$$\boldsymbol{I = \frac{e'We}{e'e}} \qquad (3)$$

Contiguity matrices (Queen, Rook), and five neighbors, will be tested to prove if there is spatial dependence using Moran's I. These matrices were previously selected based on Stakhovych and Bijmolt (2008) because these authors tested several matrices with different numbers of neighbors and with the inverse of the distance. They found the best results in the matrices above, and, therefore, they were selected to perform the estimates in this article.

According to Lesage and Pace (2009); and Almeida (2012), it is necessary to use the robust tests of the Lagrange Multiplier (ML) to select the spatial econometrics model with the most significant explanatory power of the relationship between the dependent variable and the independent variables. If these tests show substantial results, the model of spatial econometrics to be chosen will be the one with the highest statistically significant value.

Among the possible spatial models to be tested, the following were selected: (1) Spatial Autoregressive - SAR; (2) Spatial Error Model – SEM; (3) Spatial Autoregressive Model with Autoregressive Errors – SARAR; (4) Spatial Cross-Regressive Model – SLX; (5) Durbin spatial (SDM) or (6) Durbin error (SDEM) models.

The first spatial model to be tested will be the Spatial Autoregressive Model (SAR). According to Lesage and Pace (2009), this model incorporates the spatially lagged dependent variable to capture the "neighborhood" effect of the phenomenon under analysis. Equation (4) represents this model:

$$\boldsymbol{y = \rho Wy + \alpha_n + X\beta + \varepsilon} \qquad (4)$$
$$\boldsymbol{\varepsilon \sim N(0, \sigma^2, I_n)}$$

Vector n x 1 corresponds to the dependent variable (y), and ρ is the spatial autoregressive coefficient, with W representing the n × n spatial weight matrix. It is assumed that ε follows a normal multivariate distribution with mean zero and the diagonal scalar constant variance-covariance matrix $\sigma^2 I_n$.

The second model to be tested will be the Spatial Error Model (SEM). From Almeida (2012), this model reveals that spatial dependence is present in the error term. This model's implicit idea is that the spatial pattern represented by the error term is displayed by effects not modeled due to the inadequate form of measurement, which, in turn, are spatially self-correlated. However, they are not correlated with the explanatory variables used in the regression model. This model can be formally expressed by equation 5.

$$\begin{aligned} \boldsymbol{y} &= \boldsymbol{\alpha_n} + \boldsymbol{X\beta} + \boldsymbol{u} \\ \boldsymbol{u} &= \boldsymbol{\lambda W u} + \boldsymbol{\varepsilon} \\ \varepsilon &\sim N(0, \sigma^2, I_n) \end{aligned} \quad (5)$$

$W\lambda$ represents the spatial lag, and λ represents the parameter of spatial autoregressive error.

The third model is the spatial lag model with a spatial autoregressive error (SARAR or SAC). For Lesage and Pace (2009); and Arbia and Baltagi (2009), this model includes both the spatial lag coefficient (ρ) and the regressive author error term parameter (λ), represented by equation (6).

$$\begin{aligned} \boldsymbol{y} &= \boldsymbol{\alpha_n} + \boldsymbol{\rho W y} + \boldsymbol{X\beta} + \boldsymbol{u} \\ \boldsymbol{u} &= \boldsymbol{\lambda W u} + \boldsymbol{\varepsilon} \\ \boldsymbol{\varepsilon} &\sim \boldsymbol{N}(\boldsymbol{0}, \boldsymbol{\sigma^2}, \boldsymbol{I_n}) \end{aligned} \quad (6)$$

The fourth model to be tested will be the Spatial Cross-Regressive Model, which incorporates the explanatory variables' spatial lags (WX). However, it is possible that the spatially lagged explanatory variables (WX) are correlated with the lagged dependent variable (Wy). If this occurs and the appropriate model is the SDM, the Wy variable's omission will bias the model estimates and make them inconsistent. The SLX model is represented by equation (7):

$$\begin{aligned} \boldsymbol{y} &= \boldsymbol{\alpha_n} + \boldsymbol{X\beta_1} + \boldsymbol{WX\beta_2} + \boldsymbol{\varepsilon} \\ \boldsymbol{\varepsilon} &\sim \boldsymbol{N}(\boldsymbol{0}, \boldsymbol{\sigma^2}, \boldsymbol{I_n}) \end{aligned} \quad (7)$$

Based on Lesage and Pace (2009); and Almeida (2012), the Lagrange Multiplier (ML) tests will be used to select the type of models to be used (SAR or SEM), then the Durbin spatial (SDM) or Durbin error (SDEM) models will be tested. The SDM model contains, in addition to the lagged dependent variable (Wy), the spatial lags of the explanatory variables (WX). As in the SAR model, in SDM models, attention should be paid to the existence of spatial endogeneity related to Wy. The model is represented by the equation below:

$$\begin{aligned} \mathbf{y} &= \boldsymbol{\rho}\mathbf{Wy} + \boldsymbol{\alpha}_{\mathbf{n}} + \mathbf{X}\boldsymbol{\beta} + \mathbf{WX}\boldsymbol{\theta} + \boldsymbol{\varepsilon} \\ \varepsilon &\sim \mathrm{N}(0, \sigma^2, \mathrm{I_n}) \end{aligned} \quad (8)$$

In case the SEM family models are more appropriate, according to Lesage and Pace (2009), the SDEM model considers the spatial lag of the explanatory variables (WX) and the spatial lag of the error term. The following equation 9 represents this model:

$$\begin{aligned} \mathbf{y} &= \boldsymbol{\alpha}_{\mathbf{n}} + \mathbf{X}\boldsymbol{\beta} + \mathbf{WX}\boldsymbol{\theta} + \mathbf{u} \\ \mathbf{u} &= \boldsymbol{\lambda}\mathbf{Wu} + \boldsymbol{\varepsilon} \\ \varepsilon &\sim \mathrm{N}(0, \sigma^2, \mathrm{I_n}) \end{aligned} \quad (9)$$

The models described will be estimated by maximum likelihood, and the results found will be analyzed and interpreted in the next section of this article.

4. RESULTS

This section will be subdivided in two sections. In the first one, an analysis will be performed to verify if the explanatory variables in the neighboring municipalities have global spatial dependence concerning the dependent variable *per capita* income. The Moran's I will be used to verify if there is global autocorrelation multivariate (see equation 2). Subsequently, since the global analysis cannot capture particularities between the municipalities, it is essential to apply the Local Indicators of Spatial Association (LISA) to verify if there is no local spatial correlation (see equation 3). After performing the mentioned analysis, in the second part of this section, the spatial econometrics results required to achieve this article's proposed objectives will be presented.

4.1 Global Analysis

Table 2 presents the results of the global Moran's I statistics for the correlation of the *per capita* income of municipality *i* with the *per capita* income of municipality *j* in univariate analysis, and also the correlation of the *per capita* income of municipality *i* with the explanatory variables in municipality *j* in bivariate analysis. The Moran's I dispersion diagram corroborates the analysis.

Table 2 – Univariate and bivariate global analysis

Analysis	Variables	Moran's I	Correlation
Univariate	*Per capita* income	0,275*	Positive
Bivariate	*Per capita* income and illiteracy rate	-0,253*	Negative
Bivariate	*Per capita* Income and college degree	0,165*	Positive
Bivariate	*Per capita* income and Gini index	-0,178*	Negative
Bivariate	*Per capita* income and formal jobs percentage	0,294*	Positive
Bivariate	*Per capita* income and inadequate treated water and sewage	-0,189*	Negative
Bivariate	*Per capita* income and Neither-Nor	-0,289*	Negative
Bivariate	*Per capita* income and fertility rate	-0,255*	Negative

Source: Prepared by the authors with data from the Brazilian Atlas of Human Development (2013) and using the Geoda software.

It is observed that the *per capita* income in a municipality has a positive correlation with the *per capita* income in the neighboring municipality. This can be explained by the fact that there are people who live in the neighboring municipality and maintain income-generating economic activity relations in the municipality in question, which as a result, causes an overflow of income.

Also, as expected in theory, per capita income positively correlates with the number of people with a college degree and the percentage of formal work in the neighboring municipality. In detail, municipalities with a higher *per capita* income tend to offer or concentrate a more significant number of vacancies in undergraduate courses. This fact tends to encourage a direct relationship between municipalities because, in general, people tend to move to study. Concerning the percentage of formal jobs, municipalities with higher income tend to have a more dynamic labor market and, therefore, with a higher proportion of people formalized in the labor market.

Otherwise, as expected in theory, municipalities with higher *per capita* income levels tend to have an inverse relationship with the variables illiteracy rate, number of people in the Neither-Nor situation, fertility rate, Gini index, and access to inadequate water and sewage services.

4.2 Local Analysis

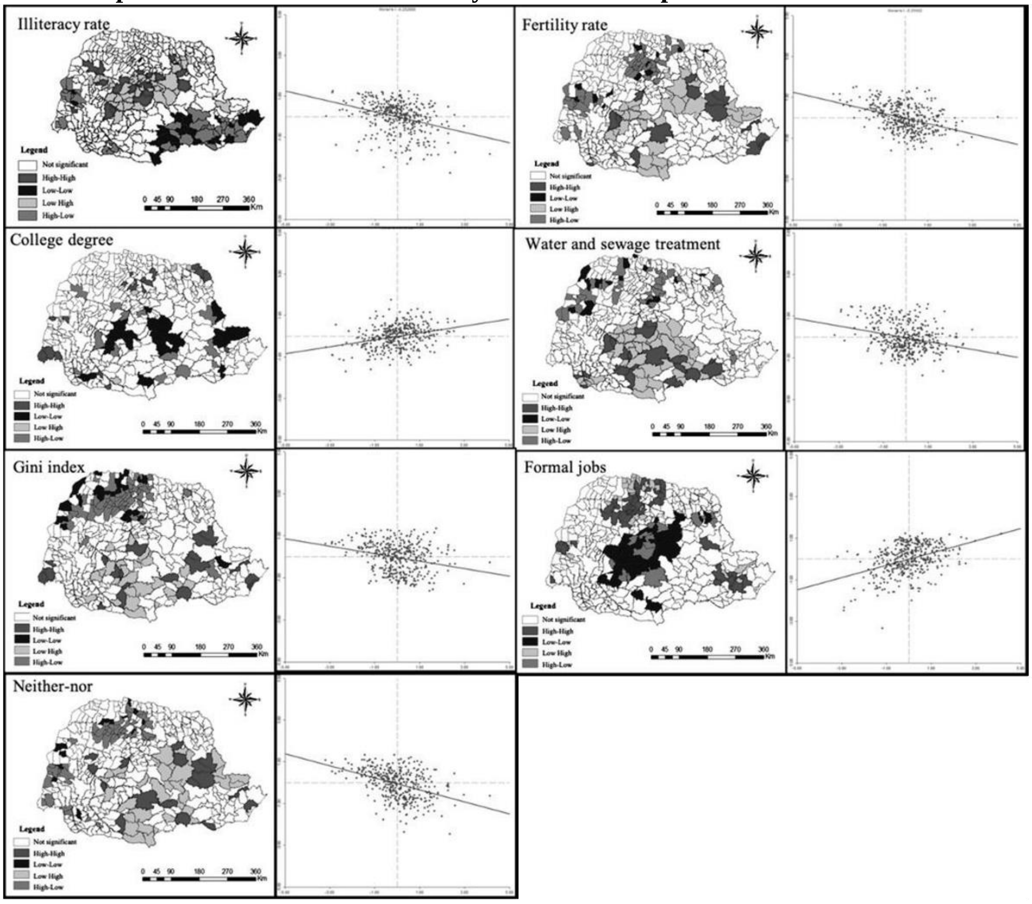
Initially, based on Almeida (2012), the bivariate analysis will be applied to previously assess the spatial relationship between the dependent variable and the independent variables to be used in spatial econometric models.

Figure 1 shows that some municipalities in the State, even with high per capita incomes, are surrounded by neighboring municipalities with high illiteracy rates, Neither-Nor, fertility rates, inadequate treated water and sewage, and high Gini index. This result shows that the worst health and education situations in the municipalities are an indication that explain their worst level of income inequality. Furthermore, corroborating Turolla's (2002) research, the results obtained in this article indicate a positive relationship between the level of income and better levels of adequate basic sanitation.

It should also be noted that the health and education variables used are interconnected and, according to Schultz (2002); Currie (2007); and Heckman (2012), this is because the health and education tend to reinforce each other both ways. In detail, the best sanitary conditions tend to produce positive effects on education. Individuals with higher education levels tend to earn higher incomes and tend to invest, or demand, a better health infrastructure.

Another aspect to be mentioned stems from the fact that an inadequate health system compromises the potential for maximizing gains from investment in human capital. Health throughout academic life, especially in childhood, is a crucial factor in forming human capital. According to Currie (2007) and Heckman (2012), the problems caused in childhood by inadequate sanitation conditions are essential factors to help explain the intergenerational transmission of education and socioeconomic status. The analysis between regions' economic, educational, and health status, especially the relationship between children's health and education and adults' income, is an important feature and partially helps explain the sustained economic growth of regions and countries6.

Figure 1 – *Per capita* income local bivariate analysis and the independent variables to be tested.



Source: Prepared by the authors with data from the Brazilian Atlas of Human Development (2013) and using the Geoda software.

Regarding the percentage of formal jobs variable, Ulyssea (2006) argued that there is no consensus on the influence of this type of employment on wage income. Thus, locations where there is a more significant share of formal jobs tend to have higher per capita income levels. Figure 1 shows the positive relationship between the mentioned variable and per capita income. In this case, part of the municipalities of Paraná had worse levels of formal employment linked to worse levels of per capita income. They tended to present worse education and sanitary conditions, as represented by the central region of Paraná.

Still, in **Figure 1**, the clusters represented by the variable 'Neither-Nor' constitute a relevant problem regarding potential human capital formation. The explanation is that these young people did not absorb formal educational knowledge or knowledge resulting from the experiences obtained by executing tasks in the work environment. Thus, in the municipalities that form these clusters, there is a need to understand why these young people do not seek education or work. This problem occurs in municipalities with high and low levels of per capita income, which does not satisfactorily explain

6 The objective of this study is not to discuss public policies carried out by municipalities. This will be the object of future research.

the levels above and below the average of the Neither-Nor variable presented by neighboring municipalities.[7]

Therefore, the maps presented in Figure 1, show a strong spatial correlation between the explanatory variables and the dependent variable. These results demonstrate that the regions gave the expected correlation between per capita income and the education, health, and participation in formal work variables. Only the income inequality variable presented a controversial result: the highest income concentration is positively related to per capita income. Consequently, the next section aims to establish and evaluate the causal relationship between the explanatory variables presented and the dependent variable, per capita income, in the municipalities of Paraná.

4.3 Econometrics Results

In this second part of the results section, the estimated models and the selected model will be presented as the most adequate to assess the causality relationship between human capital and economic growth. And the interpretation of the econometrics results found.

Table 3 - Results of OLS regressions and tests

ORDINARY LEAST SQUARES			
Dependent Variable:	R__cap	Number of Observations	399
Variable average:	6.3854	Number of Variables	4
Standard Deviation:	0.2380	Degrees of Freedom	395
R^2	0.6791	F Statistics	208.5
R^2 Adjusted	0.6759	Prob (F)	0.0000
Akaike Criterion	-455.8846	Schwarz Criterion	-423.996
MULTICOLLINEARITY			
Condition Number: 28.286			
Variance Inflation Factor (VIF)			
AG__ESG	1.295	T_ANALF18M	1.303
GINI	1.172	T_SUPER25M	1.475
DIAGNOSTICS FOR NORMALITY			
Test	DF	Value	p-values
Jarque-Bera	2	141.23	0.000
DIAGNOSTICS FOR HETEROSKEDASTICITY			
Test	DF	Value	p-values
Breusch-Pagan test	4	20.572	0.000385

Source: Prepared by the authors with data from the Brazilian Atlas of Human Development (2013) and R software.

The classic linear regression model (OLS) is the first to be estimated. In Table 3, the Condition Number indicates the non-suspicion of multicollinearity between the explanatory variables because the value 28.29 is less than 30. In complementarity, the Variance Inflation Factor (VIF) showed a value of less than 10 for all independent variables used in the model. Therefore, this reinforces the argument that there is no excess multicollinearity acting on the model. Thus, only the percentage variable of formal jobs was excluded due to its multicollinearity concerning the dependent variable. However, the Jaques-Bera test indicates no normal error, and the Breusch-Pagan test suggests the presence of heteroscedasticity in the residues in this model.

7 There are a number of questions about the reasons why these individuals are not encouraged by economic incentives to participate in the educational training process or in the production process. However, this is not the objective of this article, but an important issue for a future research agenda.

Table 4 – Spatial weighting matrix selection.

Variable	Coefficient	Standard Error	Statistics t	p-values
CONSTANT	6.433811	0.093913	68.5078	0.0000
T_ANALF18M	-0.192150	0.019376	-9.9169	0.0000
T_SUPER25M	0.296103	0.022106	13.3949	0.0000
GINI	0.192353	0.063457	3.0312	0.002596
AG_ESG	-0.040358	0.005937	-6.7977	0.0000
TESTED SPACE WEIGHTING MATRICES				
Moran Index Tests		**MI/DF**	**standard deviate**	**p-values**
5 neighbors		0.1375	4.8137	0.00000074
Queen		0.1279	4.3954	0.000006
Rook		0.1270	4.3414	0.0000071
DIAGNOSTICO DE DEPENDENCIA ESPACIAL USANDO A MATRIZ DE PONDERAÇÃO SELECIONADA 5 VIZINHOS				
Lagrange Multiplier Tests		**MI/DF**	**standard deviate**	**p-values**
Lagrange multiplier (lag)		1	27.485	0.00000016
Robust LM (lag)		1	8.931	0.002804
Lagrange multiplier (error)		1	20.664	0.0000055
Robust LM (error)		1	2.1106	0.1463
Lagrange Multiplier (SARMA)		2	29.595	0.00000038

Source: Prepared by the authors with data from the Brazilian Atlas of Human Development (2013) and R software.

Based on Table 4, the fertility rate and Neither-Nor variables were excluded from the analysis because they are not statistically significant. When using the same OLS estimator to test the three different weighting hues, the one selected was the matrix with five neighbors, since the obtained Moran I showed the highest statistically significant value in comparison to the other tested matrices [Queen (0.1279) and Rook (0.1270].

After choosing the five neighbors matrix as the most appropriate, we tested which types of spatial econometric models are most suitable and adherent to the available data (models of the SAR or SEM family). For this purpose, after the diagnosis of spatial dependence using Lagrange Multipliers (ML), robust version, the Robust LM (lag) (Value = 8,931; p-values = 0.0028) presented the highest statistically significant value. The SAR type models offered the best fit (see Table 4). As a result, spatial econometrics regressions were estimated using the SAR, SARAR, SLX, and SDM models. The SEM model was also assessed for comparison purposes.

The following criteria were used to select the regression model: Akaike information criterion (AIC: -524.54), Bayesian information criterion (BIC: -480.67), and Log-likelihood (273.27). Based on them, the Durbin model (SDM) was chosen, shown in Table 5, as the most appropriate. It minimizes the possibility of no bias in relevant variables that are spatially omitted and autocorrelated.

Also, the Hausman test (test = 23,245, df = 5, p-value = 0.0003031) indicated that the OLS and SEM estimates are significantly different, suggesting that the Spatial Error Model is capturing the effect of the omitted variables and the latter are correlated with the variables included. Therefore, this indicates that the appropriate model to be used is the SDM.

As expected and supported by the results of Schultz (1961; 2002); Becker (2007); Howitt (2005); and Cunha, Heckman, and Schennach (2010), in this model, it is observed that the signs of the variables AG__ESG and T_ANALF18M, representing the interrelationship between health and education, in the composition of part of the human capital measure, are inversely related to per capita income. In comparison, the other two variables that infer inequality in income and the importance of higher education were directly related to per capita income.

Table 5 – Spatial models analyzed

Weights matrix File: 5 Neighbors					
Dependent Variable per capita income					
	SEM	SAR	SARAR	SLX	SDM
(Intercept)	6.6962594	4.704.860	5.4897909	6.104429	4.3124915
	(2.2e-16)	(2.2e-16)	(2.2e-16)	(2.0e-16)	(2.2e-16)
T_ANALF18M	-0.2004898	-0.151112	-0.1722243	-0.221902	-0.2204221
	(2.2e-16)	(2.2e-16)	(1.13e-14)	(2.3e-14)	(2.2e-16)
T_SUPER25M	0.2550546	0.291415	0.2800448	0.235204	0.2289364
	(2.2e-16)	(2.2e-16)	(2.2e-16)	(2e-16)	(2.2e-16)
GINI	0.4116763	0.292104	0.3559590	0.484822	0.5277549
	(5.29e-11)	(3.54e-7)	(5.94e-09)	(1.43e-12)	(2.2e-16)
AG_ESG	-0.0317027	-0.034037	-0.0338071	-0.024800	-0.0231924
	(8.963e-08)	(6.421e-09)	(1.30e-08)	(5.59e-05)	(7.46e-05)
Lambda (λ)	0.46543		0.1649		
	(2.4e-14)		(0.026064)		
rho (ρ)		0.26923	0.24767		0.28854
		(2.0e-8)	(0.0149)		(0.0000512)
lag.T_ANALF18M				0.013434	0.0709885
				(0.695)	(0.049)
lag.T_SUPER25M				0.120977	0.0376188
				(0.00242)	(0.392)
lag.GINI				-0.623330	-0.6368806
				(1.00e-08)	(5.04e-10)
lag.AG_ESG				-0.014398	-0.0030286
				(0.21572)	(0.79164)
Wald statistic	58.171	31.618			17.122
	(2.398e-14)	(1,88e-08)			(3,51e-05)
Log-likelihood	247.82	247.43	248.83	265.07	273.27
AIC:	-481.64	-480.86	-481.65	-510.14	-524.54
BIC	-453.72	-452.94	-449.74	-470.25	-480.67
BP	12896	16.067	14.675	21.036	19.841
	(0.01179)	(0.00293)	(0.005425)	(0.0071)	(0.01096)
Moran I	-0.027952	0.030192	-0.012989	0.12857	-0.0075362
	(0.787)	(0.146)	(0.642)	(0.001)	(0.598)

Source: Prepared by the authors with data from the Brazilian Atlas of Human Development (2013) and R software.

Table 6 – Impacts of Spatial models

Variables	Impacts SAR			Impacts SDM		
	Direct	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**
T_ANALF18M	-0.15318344	-0.05360022	-0.20678366	-0.22001376	0.009975178	-0.2100386
	(2.22e-16)	(6,0e-06)	(2.22e-16)	(2.22e-16)	(0.783)	(4.32e-13)
T_SUPER25M	0.29540988	0.10336649	0.39877637	0.23466692	0.139993643	0.3746606
	(2.22e-16)	(5,1e-05)	(2.22e-16)	(2.22e-16)	(0.0066)	(6.96e-11)
GINI	0.29610818	0.10361083	0.39971902	0.50096965	-0.654352893	-0.1533832
	(3,0e-07)	(0.002223)	(0.000003)	(1.78e-15)	(8.2e-07)	0.258
AG_ESG	-0.03450395	-0.01207323	-0.04657718	-0.02372969	-0.013125605	-0.0368553
	(6,0e-09)	(0.00034)	(0.00000002)	(5.57e-05)	(0.388)	0.027

Source: Prepared by the authors with data from the Brazilian Atlas of Human Development (2013) and R software.

Table 6 shows the impacts of the independent variables used on the per capita income of municipalities of Paraná. The variables used as representatives of the education dimension in the concept of human capital were: illiteracy rate (T_ANALF18M) and percentage of people aged 25 or older with a college degree (T_SUPER25M). This last variable indicated that if there is an increase of 1%, it will cause a total impact of 0.375% (direct impact 0.235, and indirect impact 0.14) on per capita income. Additionally, if there is a 1% increase in the illiteracy rate, this will have a direct adverse effect of 0.22% on per capita income. This fact corroborates the results obtained by Balassiano, Seabra and Lemos (2005); Zhang and Zhuang (2011). It confirms the importance of education and its positive relationship with the generation of per capita income, as demonstrated by the authors Schultz (1961); Becker (2007); and Cunha, Heckman and Schennach (2010).

Regarding the Gini variable that showed a positive relationship with the dependent variable, according to Bresser-Pereira (2017), the plausible explanation is that the municipalities may be saving on the labor factor during the process of productive sophistication. Still, concerning the Gini variable and its positive correlation with per capita income, it can be corroborated by the hypothesis that the Kuznets (1955) curve is occurring. Based on the results presented in Table 6, an increase of 1%, on average, in this variable, causing a worsening in the municipality's income distribution, will generate a 0.50 direct impact and a -0.65 indirect impact in per capita income. This result indicates an unusual aspect of this variable because it induces the conclusion that the municipalities of Paraná grow economically with an increasing income concentration, and income deconcentration, among its neighbors throughout economic development.

The results presented in Table 6 confirm those obtained by Bloom and Canning (2003) because the variable inadequate treated water and sewage (AG_ESG) indicates that if there is a reduction of 1% on average, the per capita income will suffer a direct effect increase in the magnitude of 0.024%, and a total effect of 0.037% (significant to 5%), a result also consistent with Turolla (2002). This causality is evident since, especially in developing countries, infectious diseases are premature mortality and health problems leading cause. Such issues are often related to drinking water systems, lack of basic sanitation, and inadequate large-scale vaccination programs. Thus, corroborating Sala-I-Martin (1997) arguments, the results point to the fact that the health factor is still one of the most robust predictors of future economic growth. The variable inadequate treated water and sewage indicates, even partially, the relevance of this variable to explain the economic growth of the municipalities of Paraná.

In summary, the causal relationships between human capital, represented by the independent variables shown in Table 6, indicate the importance of health, education, and income distribution to determine the economic growth, via per capita income, of the municipalities. However, the development of these municipalities has occurred with income concentration (increase in the Gini index) in the municipalities themselves and, conversely, with positive spillover effects, resulting from the better distribution of income in the neighbors.

5. CONCLUSION

This study reached the proposed objective of analyzing some human capital components and their causal relationship with economic growth. The main conclusion of this study and its academic contribution is to confirm the relevance of education, health, and income distribution as determining elements of the process of local economic growth. The spatial econometrics model that showed greater adherence to the data used in the research to estimate the impacts of the representative variables, in part, of human capital on economic growth was the Durbin spatial model (SDM).

The difference of this study concerning others, including those used in it for theoretical and applied foundation, is in the variables composition used to represent economic growth determinants. Partially, the variables representing the education and health dimensions help explain the constitution of human capital involved in wealth production. The variable representing income distribution presented different determinations and directions in establishing the largest generation of income per capita in the municipalities and neighbors.

These independent variables presented the expected results in terms of the direction of causality. However, the Gini index, which deserves a greater degree of detail, should be highlighted. This variable showed a positive causal relationship with per capita income. It infers the possibility that the economic growth process in Paraná has been occurring with an increase in the concentration of income degree, but with positive spillover effects causing the better distribution of income among neighboring municipalities. This result is interesting to induce future research with the following question: if lower income inequality in neighboring municipalities generates positive local effects, why does the increase in the local concentration of income still directly correlate with local economic growth? Does the Kuznets curve hypothesis hold?

However, the results found limitations, these limitations stem from the fact that methods were not used to control heteroscedasticity in the models. Additionally, it is essential to mention that the variables fertility rate and the variable "Neither-Nor" did not show statistical significance in the estimated models. They are variables with relevant information to help explain the determinants of local economic growth, although they were not determinants for the municipalities of Paraná. Regarding the percentage of formal jobs, the fact that this variable has multicollinearity with the variable per capita income made us exclude it, which does not make this variable less relevant for future studies, since Brazil has a considerable number of informal workers and this characteristic can be significant to explain the differences between economic regions.

In conclusion, the results indicate that if the municipalities in Paraná aim to accelerate their economic growth, they should institute public policies in the following areas: 1) improve basic sanitation in households, since this problem is still current and hinders economic development; 2) reduce the illiteracy rate, increase access to higher education, and improve its quality. This could reduce the fertility rate, which is still very high and affects, mainly, people inserted in the lower social strata; 3) sponsor new research to investigate why the worst levels of income inequality, and the lowest income inequality in their respective neighbors, positively affect economic growth. How and what characteristics produce this process of draining income towards the interior of this type of locality?

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