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THE ROLE OF STRUCTURAL CHANGE IN BRAZILIAN STATES' ECONOMIC GROWTH: A SPATIAL APPROACH

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ABSTRACT

The spatial dimension is often overlooked in studies of economic growth, in addition, the effects of structural changes in neighboring regions can spread spatially and affect the growth of states. Taking that into account, this paper aims to make an analysis of the direct and indirect effects of structural change on the economic growth of the Brazilian states in the period from 1970 to 2010. Using a dynamic spatial panel model, this paper provides evidence that the structural change occurred in the country impacts the spatial economic growth of the Brazilian states. Our results confirm the importance of considering the spatial dependency in the model and show that there is a positive impact of structural change on Brazilian states' GDP per capita. Also, we find evidence that there is a positive spatial spillover of structural change, human capital and urbanization on regional growth.

Palavras-chave: Structural change; economic growth; Brazilian states; spatial spillovers; dynamic spatial panel model.

1 INTRODUCTION

Structural change can be defined as the process of sectoral reallocation that occurs in a given economy in a certain period. With the modernization of these economies, the agricultural sector, of low-productivity, loses relative importance, while the more dynamic and technological sectors become more relevant. Some authors suggest that the diffusion of knowledge and technology have high spatial dependence and are possible unobserved determinants of economic growth. Thus, this paper aims to make an analysis of the determinants of Brazilian regional growth, emphasizing the role of structural change, especially the role of more technological and knowledge-intensive sectors, and verify the direct and indirect effects of structural change on the economic growth of the Brazilian states in the period from 1970 to 2010.

The discussion of structural change and its role in economic growth started in the literature with the seminal works of Kaldor (1961), Kuznets (1966, 1971), Chenery and Syrquin (1975) and Chenery *et al.* (1986). From these works, many others appeared in the literature linking structural change and economic growth.

However, most of the papers in the literature use data from developed countries or data panels with many countries at different levels of structural change. As highlighted by Herrendorf *et al.* (2014), more quantitative case studies of structural transformation in currently poorer countries are needed and can help improve the understanding of the forces behind the structural transformation in such countries.

Nevertheless, within a country itself, different processes of structural change may be occurring, especially if countries with continental sizes are considered, as is the case with Brazil. Thus, we understand as extremely important that this spatial issue within a country itself should be considered. Magalhães *et al*. (2005) highlights that the spatial dimension must be considered when dealing with problems involving the economic growth of Brazilian states. Thus, this work seeks to contribute in this area when considering the spatial issue within the study of the role of structural change in Brazilian states' economic growth.

This paper contributes to the literature by: i) analyzing the spatial effect of structural change on the economic growth of the Brazilian states; ii) considering the different stages of structural transformation that the Brazilian states are in and covering a period of 40 years of analysis; iii) expanding on previous work by broadening the analysis by using two measures of structural change, that accounts for the more technological and knowledge-intensive sectors.

More specifically, the study makes a spatial analysis considering the structural transformation as a variable capable of explaining regional Brazilian economic growth and aims to check if there are spatial spillovers of structural change in the growth of neighbors.

Using a data panel for twenty-four Brazilian states and the Federal District covering the period from 1970 to 2010, this work applies a dynamic spatial data panel in order to verify if the economic growth of Brazilian states have spatial dependence and highlights the role of structural change on it. Results corroborated the need to address spatial dependency in the model and showed that states close to others that are experiencing structural change positively impacting their GDP per capita tend to also have their own GDP per capita positively impacted, which means that we confirm the spatial spillover hypothesis. Also, we show that the effect of structural change, human capital and urbanization on GDP per capita is positive both when influencing the growth of these variables in the state itself and when the growth of these variables in the neighboring states spillovers to it, which leads to the growth of the country as a whole.

This study proceeds as follows: section 2 reviews the literature on structural change, economic growth and the spatial issue; section 3 introduces the methodology used in this paper; section 4 presents and discusses the empirical results; finally, section 5 makes concluding remarks about the results found in this paper.

2 LITERATURE REVIEW

In this section, we present a literature review on the process of structural change and its relation with economic growth as well as we emphasize the need to consider the spatial dynamics of economic growth.

2.1 THE PROCESS OF STRUCTURAL CHANGE AND ITS RELATION WITH ECONOMIC GROWTH

The economic growth of countries has been the object of research by many authors in recent decades. Understanding the determinants of economic growth and explaining the differences between countries and regions is important as it can show the paths that decision-makers should take to improve and even boost their growth trajectories. The debate on long-term economic growth determinants started with Solow's (1956) growth model and, over the years, the importance of certain determinants seems to be a consensus in the literature, among these we can mention physical capital, human capital, migration and urbanization. However, a possible determinant, which has been constantly overlooked by the literature, is structural change.

Structural change is a process of reallocating resources through which countries pass over time. As countries develop and get urbanized, the workforce moves away from low-complexity sectors toward relatively more complex production structures and economic activities (Martins, 2019). The important role of structural change in driving economic growth and improving productivity has been the object of literature study since the mid-20th century, as can be seen in classic papers of Kaldor (1966) Kuznets (1966), Kuznets (1971) and more recently in the works of Peneder (2003), Castellaci (2007), Vollrath (2009), Duarte and Restuccia (2010), Adrogué *et al*. (2010), Herrendorf *et al.* (2014) and Nassif *et al*. (2020a).

To study the structural change of a country or group of countries, therefore, means to study the economic growth of those countries. Economic growth depends on technological progress, which, in turn, is achieved through the continuous shift from low production sectors to sectors with higher productivity. McMillan and Rodrik (2011) have shown that periods of rapid economic growth were those in which the labor force migrated from less productive sectors, such as agriculture, to more productive ones, like the industrial sector. Silva and Teixeira (2011) also highlight the positive effect of technology-intensive industries on productivity growth and, consequently, on the growth of countries. Thus, a hypothesis raised by this work is that the sectors that are more intensive in technology and knowledge are responsible for generating dynamism in the economy in a way that allows for more robust and sustainable growth in the countries.

Teixeira and Queirós (2016) included the variable "share of high-tech/high knowledge-intensive industries in total employment" as a proxy for structural change and verified its impact on the log of GDP per capita in two data panels: one which includes 21 OECD countries and a second which adds to this first nine other European and Mediterranean less developed countries. Using dynamic panel estimations, their results show that, for both groups of countries, structural change contributes to increasing economic growth. The authors highlight that knowledge-intensive activities employ individuals with higher skills and knowledge, which makes these sectors more productive, therefore, countries that observe an increase in specialization in high-level industries tend to achieve higher rates of economic growth.

In the Brazilian literature, we can see recent papers as Adrogué *et al.* (2010), Nassif *et*

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al. (2015) and Nassif *et al.* (2020a), who sought to understand the role of structural change in Brazilian economic growth. Generally, these authors work with employment share or added value share in some specific sector as a proxy for structural change. The general conclusion of these authors is that the structural change that took place in Brazil occurred through the transfer of workers from the agricultural sector to low productivity service sectors, so that, there was little or no increase in labor productivity in the country, therefore, the impact on economic growth is generally small.

Despite this recent effort to understand the role of structural transformation in Brazilian economic growth, much remains to be studied. A possible channel through which the structural change can impact economic growth is the spatial spillover, which it is usually overlooked in works dealing with economic growth. As the aim of this paper is to analyze this subject, the next subsection shows the importance of considering the spatial issue when studying the Brazilian economic growth.

2.2 STRUCTURAL CHANGE AND THE SPATIAL SPILLOVER IN BRAZIL

The use of spatial econometrics has increased in recent decades, a growing number of researchers have considered the spatial dependence in their models. In the analysis of economic growth, it was not different. Many empirical studies have used these techniques to understand the growth processes of several countries or even within a country (e.g., López- Bazo *et al.*, 2004; Magalhães *et al*., 2005; LeSage e Fisher, 2008; Lima and Silveira Neto, 2015).

There are some papers in the literature that evaluated the spatial dynamics of Brazilian economic growth. Mossi *et al*. (2003) highlighted that the spatial pattern of economic growth in Brazilian states cannot be viewed without accounting for spatial spillovers. Magalhães *et al.* (2005) also studied the relationship between spatial dependence and the convergence issue among Brazilian states and concluded that the spatial dimension must be considered when dealing with problems involving the Brazilian states.

Cravo *et al*. (2015) found spatial dependence in the Brazilian economic growth process, as well as they verify that the level of human capital of the entire population is an important determinant of growth, but does not generate positive repercussions among neighbors while SME activity generates positive spatial spillovers. Lima and Silveira Neto (2015) point to the importance of considering the spatial issue in the model and show that investments in both physical and human capital are important for the growth of Brazilian regional economies.

Although the results of dynamic panel regressions are important, Lesage and Fischer

(2008) show that indirect effects or spatial spillovers are perhaps more important than the direct effects since they consider the spread of the effect of explanatory variables in space. Several works in the literature highlight the importance of spatial spillovers when analyzing economic growth (e.g., Ertur and Koch, 2007; Lesage and Fischer, 2008; Tian *et al.*, 2010; Ozyurt and Daumal, 2013; Lima and Silveira Neto, 2015; Resende *et al.*, 2016), with different effects between them. Lesage and Fischer (2008), analyzing the European region, found negative effects for this same variable.

Considering the Brazilian case, Lima and Silveira Neto (2015) found positive effects of human capital and physical capital on per capita income. Ozyurt and Daumal (2013) also found a positive effect of human capital, however, Resende *et al.* (2016) found negative spatial spillovers of human capital and population density on the growth of Brazilian per capita income at the state level.

Although there are no studies that have considered the spatial spillover of structural change on economic growth, some authors have debated the spatial effect of technological development and structural change toward more technology- and/or knowledge-intensive sectors.

López-Bazo *et al*. (2004) argue for the existence of spatial dependence between regions. The authors built a spatially augmented growth model that considers the technological interdependence among economies and applied to the regions of the European Union. They demonstrate that economic growth and initial productivity in other regions drive growth in a given region. Fingleton and López-Bazo (2006) and Resende *et al*. (2016) suggest that variables such as knowledge and technological diffusion have high spatial dependence and be possible unobserved determinants of economic growth, however, they are usually not considered in the models.

Rey and Montouri (1999) reach a similar conclusion. The authors emphasize that the theory suggests that mechanisms such as technological diffusion, mobility factor and payment transfers can have spatial effects and, therefore, boost regional growth, however, the analysis of these effects is usually ignored in the empirical literature. Ertur and Koch (2007) found that the speed of convergence of economies becomes greater as the technological interdependence between economies is taken into account.

Considering the important role played by the economic structure in regional economic growth and that there is no paper in the literature, at least as far as we are aware, that has worked on the relationship between structural change and Brazilian economic growth considering the spatial issue, we understand that this is a gap in the literature to be filled, given the amount of work that emphasized the need to consider spatial dependence in economic growth studies and the spatial spillover effect that the structural transformation may have.

3 METHODOLOGY

Whereas there is a gap in the literature regarding the inclusion of the spatial issue in studies on structural change and economic growth, and as the current paper aims to study the role of structural change in Brazilian states' economic growth, we propose two approaches to achieve this objective: first, an exploratory spatial data analysis is conducted to verify whether the data are spatially dependent, as well as whether they have spatial heterogeneity, if the answer is positive, we move on to the second phase: running spatial econometric regressions. Each of these steps are presented in detail below.

3.2 REGRESSION MODEL AND ESTIMATION METHODS

The first step in choosing the most suitable model is to define the most appropriate spatial weight matrix and run an Ordinary Least Squares (OLS) regression. After that, the presence of spatial autocorrelation should be tested using Moran's I (equation 1) and Pesaran's CD (equation 2) tests.

$$I = \left(\frac{e'W_e}{e'e}\right) \tag{1}$$

where $e = y - Xb$, b being the OLS estimator for β. If the test result is significant, the presence of spatial autocorrelation is confirmed, therefore, the model should not be estimated using the Ordinary Least Squares (OLS) method because the estimates generated may be biased and inconsistent (if the correlation occurs in the dependent variable) or are no longer the most efficient (when the correlation is present at the error term).

The Pesaran's CD test was proposed by Pesaran (2004) and can be represented by equation (2):

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i=1}^{N}\hat{\rho}_{ij}\right) \tag{2}$$

where N is the sample size and T is the time. $\hat{\rho}_{ij}$ is the sample estimate of the pairwise correlation of the residuals. Pesaran's statistic follows a standard normal distribution and can handle balanced and unbalanced panels. The null hypothesis is of no cross-sectional dependence, if it is rejected, it is understood that there is spatial autocorrelation.

After running the OLS model and verifying that there is spatial autocorrelation through the Moran's I and Pesaran's CD tests, a fixed effects panel and a random effects panel should be run in order to choose the most appropriate model, this choice it is done via the Hausman test, which allows us to select between the model in which the individual effects are not correlated with the covariates and the model in which this correlation can exist. Mutl *et al.* (2011) found that the Hausman test does not lose its properties when working with spatial regressions, thus, the test is performed considering the estimates produced by the fixed spatial effects estimator (FE) and the random spatial effects estimator (RE). Thus, the spatial Hausman test is given by equation (3):

$$H\ test = NT\left(\hat{\beta}_{RE} - \hat{\beta}_{FE}\right)'\left(\hat{\Sigma}_{FE} - \hat{\Sigma}_{RE}\right)^{-1}\left(\hat{\beta}_{RE} - \hat{\beta}_{FE}\right) \quad (3)$$

where $\hat{\beta}_{RE}$ and $\hat{\beta}_{FE}$ are the estimates of the parameters obtained respectively by the model of random effects and fixed spatial effects, while $\hat{\Sigma}_{FE}\ e\ \hat{\Sigma}_{RE}$ are the variance-covariance matrices of the two estimates. If the null hypothesis is rejected, there is evidence that the fixed effects model is the most appropriate, so it must be the one used during the analysis. In addition, the choice of the final specification is made using the lowest information criterion, based on the Akaike Information Criterion (AIC).

After performing all these tests, the general empirical model that we use in this research is given by equation (4):

$$y_t = \tau y_{t-1} + \psi W y_{t-1} + \rho W y_t + X_t\beta + W X_t\gamma + \mu + \varepsilon_t \quad (4)$$

where $y_t = (y_{1t}, \dots, y_{Nt})'$ is the linearized GDP per capita for the n states in the t years, the lagged variable y_{t-1} it is included to capture the unobserved effects of other variables that may influence GDP per capita growth and which were not included in the model and τ is the parameter that represents these effects. Wy_{t-1} is the lagged vector of the dependent variable spatially lagged and ψ is the parameter of the autoregressive lag of the dependent variable lagged (-1< ψ <1). Wy_t is the vector of the dependent variable spatially lagged and ρ is the parameter of the autoregressive lag of the dependent variable (-1< ρ <1). $\beta = (\beta_1, \dots, \beta_K)'$ is the vector of coefficients to be estimated; $X_t = (X_{Kt}, \dots, X_{Nt})'$ is a matrix of observations of the explanatory variables (NAV, human capital, wages, physical capital, population density and urbanization). $WX_t = (WX_{Kt}', \dots, WX_{Nt}')$ is the matrix that represents the spatial lag of the explanatory variables and $\gamma = (\gamma_1, \ldots, \gamma_K)'$ is a vector of regression externalities coefficients. $\varepsilon_t = (\varepsilon_{1t}, \ldots, \varepsilon_{Nt})'$ is the autocorrelated error term, while μ indicates a spatial specific effect.

Since spatial regression models exploit the dependence structure between units, the effect of an explanatory variable's change for a specific unit will affect the unit itself and, potentially, all other units indirectly, this implies the existence of direct, indirect and total marginal effects (Belotti *et al*., 2017). So, those elements need to be considered, that is the reason we will use a dynamic spatial panel model.

3.3 DATA DESCRIPTION

The database used in this work comes from the Demographic Censuses, collected by IBGE (Brazilian Institute of Geography and Statistics) and covers twenty-four Brazilian states plus the Federal District over 40 years, from 1970 to 2010[1]. Considering that the states of Mato Grosso do Sul and Tocantins were only split from the states of Mato Grosso and Goiás in the years 1977 and 1989, respectively, and that the data used in this work began in 1970, we chose to keep the original sample without separating them from the states of Mato Grosso and Goiás, respectively, in order to keep the panel balanced. So, when we refer in this work to the states of Mato Grosso and Goiás, it must be kept in mind that we are also considering the states of Mato Grosso do Sul and Tocantins[2]. The choice of performing the analysis by state is due to the fact that there is no GDP per capita data for smaller spatial units available in Brazil covering the entire period.

As one of the aims of this paper is to work with a larger number of sectors besides the three normally used in the literature (agriculture, manufacture and services), the sample was divided into nine sectors of the economy: agriculture; manufacturing; utilities; construction; trade services; transport services; business services; government services and personal services[3].

States' GDP per capita data were collected in IPEADATA website, they refer to states' GDP at constant prices of 2010, which were divided by the total population (Census data) to obtain GDP per capita. Subsequently, the data were transformed into a natural logarithm (ln) for better analysis.

1 All the results of this work were obtained considering this expanded sample.
2 Mossi *et al.* (2003) also regrouped these states in their sample, as a way to keep the panel balanced.
3 Appendix A1 provides the classification of sectors within each of these nine groups of sectors.

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As one of the objectives of this paper is to analyze the role of structural change in promoting GDP per capita growth, we will use two proxies for structural change here. As we saw in the literature review, economies that experience changes in productive structures toward a greater share of technology/knowledge-intensive activities will tend to observe higher economic growth (Teixeira; Queiros, 2016). Thus, the first measure of structural change (SC_1) used is the share of the manufacturing sector in relation to total employment, we understand that the use of this measure is a good approximation of the transformation of the economy in the period because it is one of the most productive sectors of the economy, despite employing little labor (10% of total employees in 2010).

The second proxy used (SC_2) is the share of high-tech/high knowledge-intensive industries in total employment and includes the manufacturing, utilities and financial services sectors. This proxy is more comprehensive than the previous one as it includes the three most productive sectors of the economy that are intensive in technology and knowledge and, despite employing little labor (approximately 15% of the total), they represented, in 2010, 72% of the total productivity of the country, being, therefore, a good proxy to verify the spatial effect of the structural change on the GDP of the states. Census data were used to calculate both proxies.

For the human capital index, the employment share of college-educated people was used considering Census data. It was calculated considering the percentage of employed graduates in relation to the total employed persons in each state and in each year. The choice of this proxy for human capital followed Blien *et al.* (2006) and Suedekum (2006). The variable population density was obtained from data provided by IBGE and refers to the total number of people in each state per square kilometer, variable also used by Resende *et al.* (2013) and Resende *et al.* (2016). This variable was also linearized. The Urbanization variable refers to the percentage of people living in urban areas in each state and was obtained via Census data. The number of observations used in this paper was 125[4].

4 RESULTS

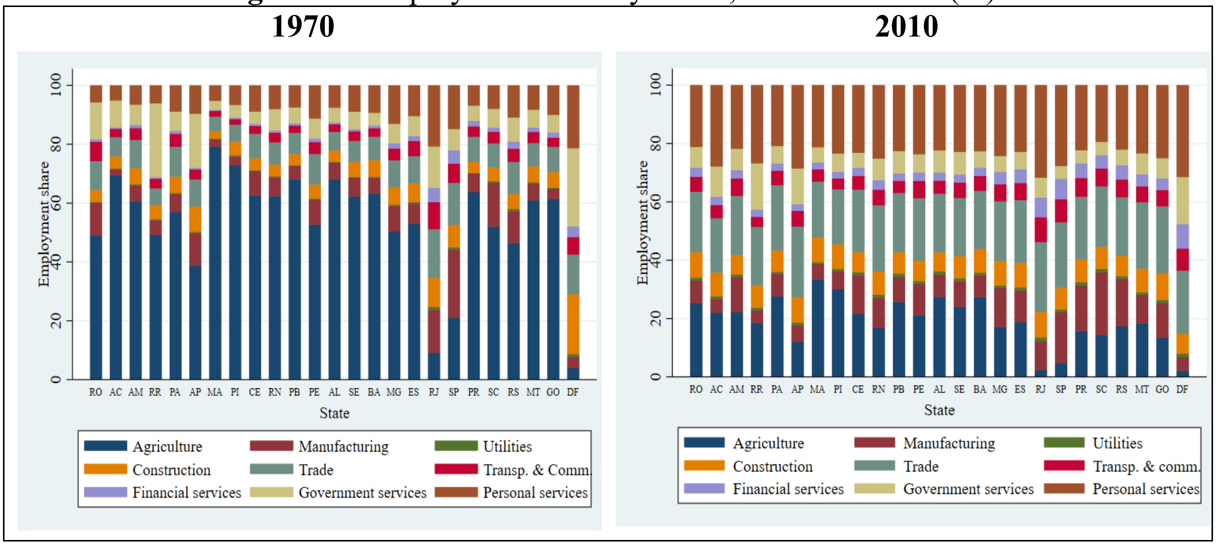
4.1 OVERVIEW OF DATA

As the current paper analyzes the effect of spatial structural change on the economic growth of Brazilian states, here we present an overview of data, starting with the change in

[4] For the manipulation of the data along with the maps, the softwares Geoda 1.14 and Qgis 3.14 were used and, for the econometric analysis, we used the software Stata 15 (command xsmle).

employment share of the nine sectors of the economy between 1970 and 2010 (Figure 1). As expected, the figure shows that the agricultural sector is the one that most lost in the employment share in the period: the biggest losses were in the states of Acre, Paraná and Goiás. In the manufacturing sector, the states of Amapá and São Paulo had the highest losses (more than 5%), while Goiás and Paraná increased their participation by 8 and 9%, respectively.

Figure 1 – Employment share by sector, Brazilian states (%)



Source: Own elaboration.

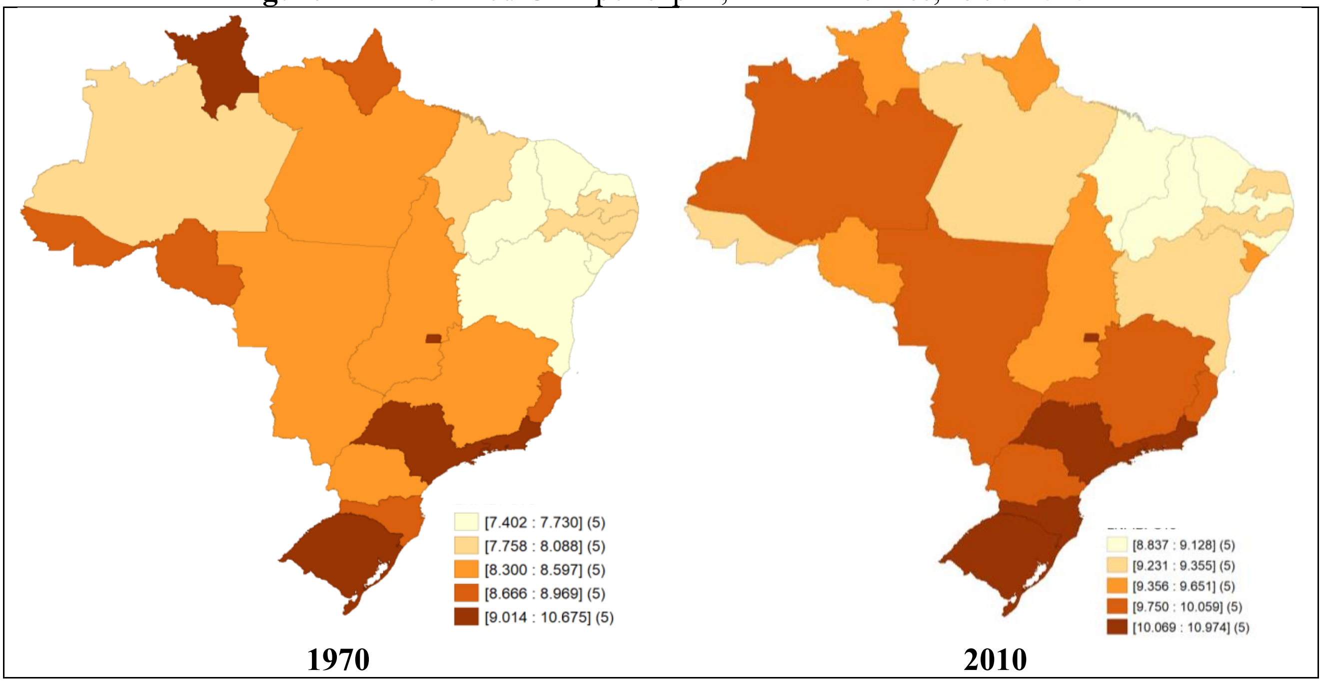
However, the services sectors significantly increased their participation, with emphasis on the trade and personal services sectors, the last one increased more than 10% in all states. The financial services sector, which is the most technologically advanced sector, also showed positive changes in all states, however, these changes were more subtle than in the other services sectors. The states of Espírito Santo, Paraná, Santa Catarina and the Federal District had the most positive percentages (more than 3% increase in employment share).

These results show that, in fact, there was a structural change in Brazil with a significant loss of participation in employment share in the agriculture sector in favor of the service sectors. Additionally, the magnitude of employment share change was much greater in the five service sectors (when aggregated) than in the manufacturing, utilities and construction sectors. However, this effect represents a possible loss of dynamism in Brazil's economic growth since the relocation occurred from agriculture to low-productive and low technological intensive sectors.

In addition to the analysis of structural change, which is our main explanatory variable, it is important to analyze the behavior of GDP per capita in the period (our variable of interest). Figure 2 shows the linearized GDP per capita of the Brazilian states for 1970 and 2010. All states have increased their GDP per capita in the period, however, this increase was less than impressive. Some of the states that can be highlighted with the biggest increases are Amazonas, Rio Grande do Norte, Sergipe, Bahia, Paraná and Mato Grosso.

It is important to highlight that the states of Piauí and Ceará, despite having had a relatively high growth in the period, continue as the states with the lowest GDP per capita in the country. Furthermore, Figure 2 shows that, in the two years analyzed, the lowest GDP per capita was concentrated in the Northeast region, while the highest GDP per capita was concentrated in the Central-South states of the country and this trend has not changed in the period, which seems to be evidence that there is a spatial effect on this variable, which reinforces the importance of considering this matter in Brazilian economic growth analyzes.

Figure 2 – Linearized GDP per capita, Brazilian states, 1970-2010



Source: Own elaboration.

We can see that there is a trend toward a positive relationship between the GDP per capita of the states and the dynamism of the economy. The states that, in 2010, had the highest employment shares in the Manufacturing and Financial services sectors (more than 20% combined) were also those with the highest GDP per capita.

Matlaba *et al.* (2015) point out that the southeast-south regions would be the "core" of the country's economic growth, while the North-Northeast regions would be the "periphery", therefore, states like São Paulo and Rio de Janeiro, due to their specializations in the financial, manufacturing, services and transport and communication sectors, tend to grow more than peripheral states, which depend heavily on agriculture and low productivity services.

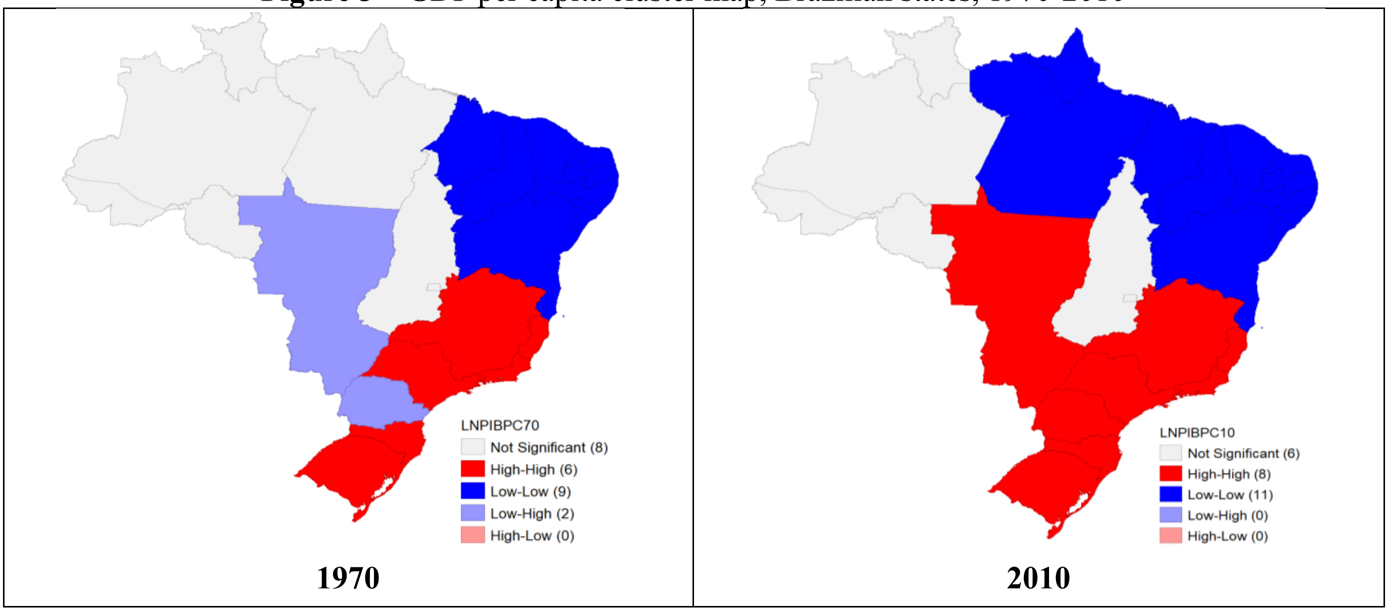
4.2 EXPLORATORY SPATIAL DATA ANALYSIS

As the aim of this paper is to analyze the spatial effect of structural change on the economic growth of Brazilian states, an exploratory spatial data analysis should be conducted to verify the existence of autocorrelation in the sample and the first step to perform spatial analysis is to create the matrix of spatial weights. There are several matrix possibilities, so that, Appendix A2 presents the coefficient of global Moran's I for linearized GDP per capita for the matrices of 1 nearest neighbor (K1), 5 neighbors (K5), 10 neighbors (K10) and 15 neighbors (K15), in addition to the Tower and Queen for all years of study.

All weight matrices showed positive and statistically significant values, indicating the existence of positive spatial autocorrelation, however, the greatest coefficients of the global Moran's I were for the matrix of 5 closest neighbors (in 4 of the 5 periods). Thus, the K5 matrix was chosen to perform the spatial regressions.

Figure 3 presents the clusters map of state's GDP per capita for 1970 and 2010. It is possible to verify that, especially in 2010, the states located further south of the country tend to present a high-high pattern, that is, those states present high values of their GDP per capita and are surrounded by other states that present this value also high, while the states of the Northeast presented a pattern of the low-low type, that is, they are states with low values of GDP per capita surrounded by others with low values. Additionally, this trend seems to have intensified in the period, given that there are more states in each of these groups in 2010.

Figure 3 – GDP per capita cluster map, Brazilian states, 1970-2010



Source: Own elaboration.

4.3 EMPIRICAL RESULTS AND DISCUSSION

With exploratory spatial data analysis, we found evidence that there is a positive spatial autocorrelation in the model, however, this must be confirmed with some tests. To perform these tests, we started the analysis with three static panel regression models: Pooled OLS (POLS), which ignores the specific characteristics of each group, random effects, where the idiosyncratic characteristics are random and fixed effects, which admits the idiosyncratic characteristics of each state (Table 1).

Table 1 – Results of the static panel models

Variables	POLS (1)	Fixed effects (2)	Random effects (3)	POLS (4)	Fixed effects (5)	Random effects (6)
Human Capital	0.0137	0.0300***	0.0108	0.0197*	0.0382***	0.0165*
	[1.26]	[2.88]	[1.24]	[1.90]	[3.64]	[1.92]
SC_1	0.0390***	0.0346***	0.0342***			
	[4.48]	[3.74]	[3.84]			
SC_2				0.0450***	0.0371***	0.0378***
				[6.08]	[4.68]	[4.96]
Physical Capital	-0.0529***	0.0787***	-0.00067	-0.0626***	0.0670***	-0.0111
	[-3.05]	[3.15]	[-0.03]	[-3.82]	[2.73]	[-0.55]
Population density	0.00191***	-0.00220	0.00152**	0.00129**	-0.00342**	0.000765
	[3.31]	[-1.62]	[1.98]	[2.36]	[-2.52]	[1.00]
Urbanization	2.227***	0.534	1.686***	1.740***	0.167	1.346***
	[5.94]	[1.38]	[5.29]	[4.64]	[0.42]	[4.15]
Constant	7.749***	7.305***	7.512***	7.926***	7.520***	7.669***
	[33.50]	[30.38]	[33.21]	[35.49]	[31.32]	[34.31]
Moran's I test	Pr = 0.0000					
Pesaran's CD test	Pr = 0.0000					
Hausman Test	Pr = 0.0000					
N	125	125	125	125	125	125
R^2	0.684	0.708	0.694	0.718	0.728	0.714
$\hat{\rho}$		0.836	0.494		0.849	0.498

Notes: *t* statistics in brackets, $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$.
Source: Own elaboration.

The first three models show the results of these three regressions for the first structural change proxy, while models 4, 5 and 6 for the second proxy. Overall, the results showed that, regardless of the structural change proxy used, the results hold. Both proxies showed significance and positive effect on GDP per capita.

The results of the three models show little significance in the results, only the variables representative of wages and urbanization were significant in all models and physical capital was significant in the POLS and random effects models. Thus, we have a first evidence that the structural change and the other explanatory variables have an effect on the growth of GDP per capita of the states. As this paper aims to consider the spatial effect of economic growth, after performing these regressions, we tested to assess the presence or not of spatial dependence. To do so, we performed two tests: the Moran's I test and the Pesaran's CD test, in both we considered the matrix of the 5 closest neighbors. The null hypothesis of no spatial dependence between the states was rejected in both tests and for both specifications, which allow us to conclude that there are spatial effects in the model, therefore, they must be considered.

Besides, to decide which estimator is the most suitable to follow the analysis, we used the Hausman test. It showed that the random effects model is inconsistent, therefore, it implies the choice of the fixed effects (EF) model in both specifications. Thus, new estimates were made considering the spatial effect and fixed effects models.

The results are in Table 2, two models of static spatial panel models (SDM) were run considering the spatial matrix of the five closest neighbors, model (1) refers to the first structural change proxy and model (2) to the second.[5]. A first point to highlight is that the spatial dependency coefficients ($\hat{\rho}$ and $\hat{\lambda}$) are significant, demonstrating that the models with spatial control have a strong explanatory capacity. Again, we can see the positive and significant effect of the structural change variables to explain the regional GDP per capita, however, when considering the effects over space (Wx), both are no longer significant. However, these models are not the focus of this work because they do not consider the short and long-term effects of the explanatory variables. In order to consider such effects, we did an analysis of dynamic spatial panel models, which include time lagged dependent variable and space-time lagged dependent variable.

Appendix A4 presents the results of these regressions, models (1), (2) and (3) refer to the model with "SC_1" variable as proxy for structural change and models (2), (3) and (4) to the "SC_2" proxy. Additionally, models (1) and (4) have only the time-lagged dependent variable included, models (2) and (5) only space-time lagged, and models (3) and (6) include both.

5 It is important to highlight that the model used in this paper is the Spatial Durbin Model (SDM) with short and ong-term effects of the explanatory variables, so that the results presented refer to this model.

Table 2 – Results of the static spatial panel models – Five neighbors matrix

	Variables	(1)	(2)
Main	**Human Capital**	-0.0245*	-0.0228
		[-1.76]	[-1.64]
	SC_1	0.0237***	
		[4.18]	
	SC_2		0.0237***
			[4.34]
	Physical Capital	-0.00783	-0.0129
		[-0.41]	[-0.67]
	Population density	-0.00272***	-0.00324***
		[-3.11]	[-3.61]
	Urbanization	-0.733**	-0.884**
		[-2.14]	[-2.52]
Wx	**Human Capital**	0.0349*	0.0443**
		[1.92]	[2.25]
	SC_1	-0.0141	
		[-1.13]	
	SC_2		-0.00705
			[-0.63]
	Physical Capital	0.0654*	0.0648*
		[1.79]	[1.77]
	Population density	0.00285*	0.00169
		[1.68]	[0.83]
	Urbanization	0.516	0.363
		[1.07]	[0.71]
Spatial	$\hat{\rho}$	0.680***	0.661***
Variance	σ^2	0.0219***	0.0219***
Statistics	**N**	125	125
	R^2	0.111	0.104
	AIC	-85.30	-86.67

Notes: *t* statistics in brackets, $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$.
Source: Own elaboration.

Again, the spatial dependency coefficient ($\hat{\rho}$) for all models is significant, demonstrating that the models with spatial control have a strong explanatory capacity. The analysis of the Akaike information criteria (AIC) was performed to define the most appropriate model. Thus, the model that showed the best results was the Spatial Durbin Model (SDM) with both time lagged dependent variable and space-time lagged dependent variable included in the models

(models 3 and 6).

However, as highlighted by Lima and Silveira-Neto (2015), in the presence of spatial dependence throughout the dependent variable, the estimated coefficients of the variables do not represent the marginal short and long-term effects of the explanatory variables on the dependent variable. When it is analyzed the short and long-term spatial effects, the results show the feedback process among spatially correlated units, which leads to the distinction between direct, indirect and total marginal effects (Belotti *et al*., 2017). Thus, direct, indirect and total effects must be calculated for both short and long-term. Tables 3 and 4 presents these results.

Table 3 presents the short- and long-term effects for model (3), whose structural change proxy considers the share of people employed in the manufacturing sector. All results were significant. We can note that the short-term effects for all variables are greater than the long-term ones, showing that such effects tend to dissipate over time. The structural change accompanied by human capital and urbanization had positive effects on the per capita GDP of the states. The results show that the 1% increase in the share of employees in the manufacturing sector in state i generates a direct growth of 0.152% of the GDP per capita in that state.

Table 3 – Direct and indirect short- and long-term effects of the variables on states' GDP per capita – First structural change proxy

Variables	Short-term			Long-term		
	Direct	Indirect	Total	Direct	Indirect	Total
Human Capital	0.093^{***}	0.114^{***}	0.208^{***}	0.034^{***}	-0.001^{***}	0.032^{***}
SC_1	0.152^{***}	0.092^{***}	0.245^{***}	0.022^{***}	0.016^{***}	0.038^{***}
Physical Capital	-0.867^{***}	-0.408^{***}	-1.275^{***}	-0.082^{***}	-0.118^{***}	-0.201^{***}
Population density	-0.013^{***}	-0.008^{***}	-0.021^{***}	-0.002^{***}	-0.001^{***}	-0.003^{***}
Urbanization	8.946^{***}	9.819^{***}	18.76^{***}	2.868^{***}	0.092^{***}	2.961^{***}

Notes: *t* statistics in brackets, $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$.
Source: Own elaboration.

Indirect effects, however, show the spatial spillover effects. The results show that such spatial spillovers are positive for the variables of structural change and urbanization, both in the short and in the long term and are positive for human capital in the short term. This means, for example, that an increase of 1% of the structural change of all neighboring regions is associated with an increase of 0.0929 percentage points in the GPD per capita income of a region i in the short-term and an increase of 0.0615% in the long-term. Physical capital and population density showed negative signs, which means that they contribute negatively to the GDP of the state itself as well as that of neighboring states. The total effects show that, in fact, urbanization, structural change and human capital contribute to the GDP per capita of Brazilian states.

Table 4 presents the same effects (direct, indirect and total) referring to model (6) in Appendix A4, whose structural change proxy is the share of high-tech/high knowledge-intensive sectors in total employment (SC_2). All signs remained in relation to those in Table 3, however, fewer results were significant. The short-term indirect effects show that the spatial spillovers of human capital, structural change and urbanization are positive, that is, the increase in these indicators in neighboring states leads to an increase in the GDP of state i. For the same long-term effect, only structural change continues to show spatial spillovers. However, in the long term we can see that the direct effects of human capital and urbanization are positive and significant, which shows that, for this model, these variables together with structural change have a large impact on the state's own GDP as well as on the total GDP per capita.

Table 4 – Direct and indirect short- and long-term effects of the variables on states' GDP per capita – Second structural change proxy

Variables	Short-term			Long-term		
	Direct	Indirect	Total	Direct	Indirect	Total
Human Capital	-0.002	0.331***	0.328***	0.056***	-0.009	0.047***
SC_2	-0.017	0.322***	0.305***	0.032***	0.011**	0.043***
Physical Capital	0.044	-1.041***	-0.996***	-0.122***	-0.020	-0.142***
Population density	0.001	-0.034***	-0.033***	-0.005***	0.0005	-0.005***
Urbanization	-0.381	14.74***	14.36***	2.124***	-0.069	2.055***

Notes: *t* statistics in brackets, $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$.
Source: Own elaboration.

4.4 DISCUSSION OF THE RESULTS

As the aim of this paper is to analyze the spatial effect of structural change on the economic growth of Brazilian states, an initial exploratory spatial data analysis was conducted to verify the existence of spatial autocorrelation, the K5 matrix was chosen to perform the spatial regressions. The cluster map analysis suggests the existence of two clusters in the country: one located in the southern region with a high-high pattern and another um in the Northeast region with a pattern of the low-low type. Other authors in the literature have found similar results for Brazil (e.g., Magalhães *et al*., 2005; Cravo, 2012; Resende *et al*., 2013; Mossi *et al*., 2003 and Resende *et al*., 2016).

The results also indicated the importance of considering spatial dependence in the

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analysis of economic growth in Brazilian states. We found that the spatial dependency coefficient ($\hat{\rho}$) for all models was significant, demonstrating that the models with spatial control have a strong explanatory capacity. All authors who used spatial models to analyze Brazilian economic growth also pointed to the need to include space in the analysis (e.g., Cravo 2012; Resende *et al*., 2013; Mossi *et al*., 2003; Cravo *et al*., 2015; Lima and Silveira Neto, 2015 and Resende *et al*., 2016).

Overall, the regression results showed significant impacts of the explanatory variables on GDP per capita. However, direct and indirect effects (spatial spillovers) are the main results of this work. In both models, we verify that there are short and long-term direct and indirect effects on GDP per capita. The variables human capital and urbanization showed a positive direct impact, which means that states that invest more in human capital can achieve higher growth rates. Furthermore, the short-term indirect impact was also positive, showing that investment in human capital from neighboring states can spill over into state i. These results follow other works in the literature that found similar results (e.g., Tian *et al*., 2010; Özyurt and Daumal, 2013; Lima and Silveira Neto, 2015).

For the physical capital and population density, however, the short-term spatial spillovers were negative for both models. This means that the investment in physical capital as well as the increase in population density in neighboring states may be contributing, in the short term, to the reduction in the GDP per capita of a certain state i. In the long term, however, the results were not significant. Authors such as Tian *et al*. (2010) and Lesage and Fischer (2008) found similar results for China and Europe.

Regarding the structural change variables (both proxies), the results proved highly promising. The direct effects were positive, showing that the increase in the employment share of knowledge- and technology-intensive sectors has a positive effect on the GDP per capita of the state itself. As for spatial spillovers, the results also point to a positive short- and long-term effect, showing that the increase in people employed in high-productivity sectors in nearby states increases the GDP of a given state i.

It is important to emphasize that the direct and indirect effects results from both models are close and kept the signals, showing consistency and that both proxies have explanatory power over the dependent variable. This shows us that, both in the short and long-term, the effect of structural change on GDP per capita is positive both when influencing the growth of this variable in the state itself and when the other states spillover to it, which leads to the growth of the country as a whole. So that the results can indicate a positive impact of structural change on GDP per capita as well as confirm the need to address spatial dependency in the model.

Structural change proved to play an important role in explaining the economic growth of Brazilian states, however, as highlighted by Firpo and Pieri (2016) although the agriculture sector still employs a large share of the labor force, it is no longer a net supplier of workers, therefore, the most effective policies oriented at increasing economic growth in an emerging economy like Brazil seem to be policies oriented at increasing within-sector productivity for all economic sectors.

As human capital also had positive direct impacts, policies should focus on increasing the country's human capital level while stimulating the growth of the most technology- and knowledge-intensive sectors, as a way to boost the country's growth. Teixeira and Queirós (2016) suggest that the promotion of economic growth should not only include investment in human capital through (formal) education, but also investment in technology/knowledge intensive activities, which generate high added value to the economies. The authors argue that human capital promotion policies must take into account the areas of knowledge and skills required by the industries that accelerate economic growth rates.

Nassif *et al.* (2020b) propose similar actions. According to the authors, Brazilian growth recovery should focus on re-industrialization and macroeconomic policies should focus on stimulating productive investment to enhance productive growth. In the same line of thought, Silva and Teixeira (2011) argue that the implementation of industrial policies aimed at changing the pattern of specialization toward the promotion of leading technology sectors may be worthwhile.

As for the spatial dimension, our results show that the policies implemented by neighboring states play an important role in determining the growth of states. Furthermore, Resende *et al.* (2016) highlight that it would be desirable for economic growth policy to be coordinated with a broader regional focus in order to explore possible income and technology externalities. The coordinated action of the regions aiming to attract new high-tech industries and services could be an alternative to promote the development of the states while would allow the creation of a chain of other industries and services in neighboring states, promoting the growth of the entire region.

5 CONCLUSIONS

This paper made an analysis of the spatial effect of structural change on the economic growth of the Brazilian states in the period from 1970 to 2010. In the literature, there are

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countless papers that have analyzed and rectified the role of structural change in driving economic growth; however, few studies have analyzed the spatial effect that this structural transformation can have. Additionally, there is no study in Brazilian literature that has proposed to verify these connections by analyzing spatial spillovers, so our paper sought to fill this gap.

To measure the structural change of the period, we used two proxies: the share of the manufacturing sector in relation to total employment (SC_1) and the share of high-tech/high knowledge-intensive industries in total employment, which includes the manufacturing, utilities and financial services sectors (SC_2). Overall, the results of structural transformation showed that this change in the country was due to the transition of labor from agriculture to the services sectors, mainly that of personal services, which require low qualification and provides low remuneration. In addition, spatial analysis have shown that states with high GDP per capita tend to be surrounded by other states with high GDP value, while those with low GDP per capita are also concentrated close to states with low GDP, which qualifies the need to consider the spatial issue in the model. Besides, the tests showed that there is a positive spatial autocorrelation in the model.

From these considerations, for the empirical model, a dynamic spatial panel model was used, which considered the spatial effects of the variables, as well as their short and long-term effects. Several models were tested, and the best fit was the Spatial Durbin Model (SDM) with lag in the dependent and explanatory variables, considering a spatial matrix of five closest neighbors. It is important to highlight that the spatial dependency coefficients for all models were significant, demonstrating that the models with spatial control have a strong explanatory capacity.

The results corroborate the initial conclusions that high GDP per capita in the neighboring states positively influences high GDP per capita in the state. Besides, the lag of the dependent variable was significant, which showed that the model adapts well to capture the effects of other variables that impact GDP growth. When we analyzed the short and long-term spatial effects, we verified that the variables human capital and urbanization showed a positive direct impact and a positive short-term indirect impact. For physical capital and population density, however, the short-term spatial spillovers were negative for both models. Thus, we can conclude that policies aimed at promoting urbanization and the development of human capital have positive effects on regional economic growth in Brazil.

Regarding the structural change variables (both proxies), the results proved highly promising. The direct effects were positive, showing that the increase in the employment share of knowledge- and technology-intensive sectors has a positive effect on the GDP per capita of the state itself. As for spatial spillovers, the results also point to a positive short- and long-term effect, showing that the increase in people employed in high-productivity sectors in nearby states increases the GDP of a given state i.

Therefore, the results showed that, in the long-term, the effect of structural change on GDP per capita is positive both when influencing the growth in the state itself and when the other states spillovers to it, which leads to the growth of the country as a whole. Which means that Brazil has the prospect of boosting its growth even more if it continues to promote structural change, especially if this change occurs toward more technological and knowledge intensive sectors and with greater potential to add value to the Brazilian GDP.

Thus, the general conclusion of this study is that it is necessary to address spatial dependency in the model, so that not using a spatial model can compromise the results and, consequently, the researcher analysis. Also, there is a positive impact of structural change on GDP per capita of the states, but there is a need for regional coordination that seeks to attract industries and services and high technology to the states in that region in order to leverage its growth. However, it is also important to create policies to promote the human capital necessary to allow the development of these industries as well as seeking to maintain a stable institutional and economic environment.

As a suggestion for future work, we propose the inclusion of other variables that can spatially affect GDP per capita, which were not the focus of this work, such as the impact of institutions as well as it would be important to add (if data are available) a variable that captures the added value of the sectors, as a way to directly analyze the impact of labor productivity on economic growth.

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APPENDIX

Appendix A1 – Classification of the nine major sectors

Major sectors	Minor sectors	ISIC Ver.3
Agriculture	Agriculture, hunting, forestry and fishing	01, 02, 05
Manufacturing	Manufacturing, Mining and quarrying	10-35
Utilities	Electricity, gas and water supply	40-41
Construction	Construction	45
Trade	Wholesale and retail trade, hotels and restaurants	50-52, 55
Transport and Communication	Transport, storage, and communication	60-64
Financial services	Finance, insurance, real estate and business services	63-67, 70-74
Government services	Government services	75, 80, 85
Personal Services	Community, social and personal services	90-93, 95, 99

Source: Own elaboration.

Appendix A2 – Coefficient of Global Moran's I for linearized GDP per capita, 1970-2010

Year	K1	K5	K10	K15	Tower	Queen
1970	0.331*	0.473***	0.295***	0.048**	0.349***	0.338***
1980	0.576***	0.622***	0.377***	0.081***	0.476***	0.453***
1991	0.633***	0.609***	0.366***	0.099***	0.492***	0.476***
2000	0.622***	0.644***	0.393***	0.119***	0.503***	0.475***
2010	0.654***	0.666***	0.413***	0.133***	0.508***	0.487***

Source: Own elaboration.

Appendix A3 – AIC criteria for selecting models

Matrix	Static models		Dynamic models	
	SC_1	SC_2	SC_1	SC_2
K1	-59.46	-63.38	-88.86	-88.54
K5	-85.30	-86.67	-113.9	-117.0
K10	-91.84	-92.74	-108.6	-109.2
K15	-106.6	-107.0	-112.6	-116.5

Note: K1 refers to the matrix of 1 nearest neighbor, K10 refers to the matrix of 10 nearest neighbors and K15 refers to the matrix of 15 nearest neighbors.
Source: Own elaboration.

Appendix A4 – Results of the dynamic spatial panel models

	Variables	(1)	(2)	(3)	(4)	(5)	(6)
Main	**L.GDPpc**	0.733^{***}		1.425^{***}	0.708^{***}		1.926^{***}
		[1.023]		[2.000]	[1.000]		[2.719]
	L.WGDPpc		0.203	4.746^{***}		0.321^{*}	4.148^{***}
			[1.24]	[3.473]		[1.89]	[2.916]
	Human Capital	0.009	-0.012	-4.780^{***}	0.009	-0.014	-0.035^{***}
		[0.94]	[-1.01]	[-4.591]	[0.88]	[-1.12]	[-3.45]
	SC_1	-0.009^{**}	0.005	-3.806^{***}			
		[-2.05]	[1.08]	[-8.497]			
	SC_2				-0.013^{***}	0.004	-0.049^{***}
					[-2.90]	[0.78]	[-1.089]
	Physical Capital	0.029	0.025	1.650^{***}	0.033	0.027	0.147^{***}
		[1.31]	[0.93]	[7.284]	[1.48]	[0.99]	[0.652]
	Population density	0.0001	-0.003^{***}	0.333^{***}	0.0006	-0.002^{***}	0.004^{***}
		[0.19]	[-3.18]	[3.930]	[0.79]	[-2.99]	[4.77]
	Urbanization	0.426	-0.476	-4.095^{***}	0.813^{**}	-0.452	-1.860^{***}
		[1.27]	[-1.09]	[-1.139]	[2.35]	[-1.03]	[-5.16]
Wx	**Human Capital**	-0.061^{***}	0.023	-1.922^{***}	-0.083^{***}	0.011	-0.297^{***}
		[-4.31]	[1.41]	[-1363.55]	[-5.41]	[0.61]	[-19.12]
	SC_1	-0.036^{***}	-0.019	-2.454^{***}			
		[-3.90]	[-1.48]	[-2.245]			
	SC_2				-0.058^{***}	-0.032^{**}	-0.260^{***}
					[-5.96]	[-2.22]	[-2.165]
	Physical Capital	0.062	0.021	1.309^{***}	0.005	0.022	0.864^{***}
		[1.27]	[0.33]	[2.356]	[0.11]	[0.37]	[1.653]
	Population density	0.005^{***}	0.001	2.165^{***}	0.007^{***}	0.002	0.030^{***}
		[3.46]	[0.83]	[1.342]	[4.53]	[1.38]	[1.731]

Continue

Continuation

	Urbanization	-1.608***	-0.311	-1.760***	-0.635	-0.203	-1.274***
		[-3.23]	[-0.49]	[-3065.35]	[-1.29]	[-0.34]	[-2.383]
Spatial	$\hat{\rho}$	1.080***	0.644***	1.166***	0.945***	0.609***	2.023***
Variance	σ^2	0.009***	0.016***	-0.425***	0.009***	0.016***	0.006***
	N	100	100	100	100	100	100
Statistics	R^2	0.503	0.0007	0.043	0.713	0.011	0.198
	AIC	-113.1	-75.24	-113.9	-115.8	-76.40	-117.0

Notes: The matrix used for these estimations was the 5 nearest neighbors, *t* statistics in brackets, $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$.
Source: Own elaboration.