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Brazilian Semi-Arid: Convergence or Divergence of Development and Income?

Semiárido Brasileiro: Convergência ou Divergência de Renda e Desenvolvimento?

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Abstract
This study analyzes whether there was convergence or divergence of income among the municipalities of the Brazilian Semi-Arid region from 2005 to 2017. A descriptive analysis of the variation averages was performed to identify whether there was a reduction of dispersion over time among the municipalities both in terms of growth and socio-economic development using the Gross Domestic Product (GDP) per capita and the Firjan Municipal Development Index as parameters. The results confirmed the existence of a convergence process among the Brazilian Semi-Arid municipalities over time both for growth and socio-economic development. This convergence was clearly induced by the tertiary sector of the economy, which presented the highest average convergence among the analyzed years.
Keywords: economic growth, inequality, regional development, economic development.

Resumo
Este estudo analisa se houve convergência ou divergência de renda entre os municípios do semiárido brasileiro nos anos 2005 e 2017. Para tanto, realizou-se uma análise descritiva das médias de variação a fim de identificar se houve, ao longo do tempo, uma redução da dispersão entre os municípios, tanto em termos de crescimento como de desenvolvimento socioeconômico, utilizando como parâmetro o Produto Interno Bruto (PIB) *per capita* e o Índice Firjan de Desenvolvimento Municipal. Os resultados confirmaram a existência de um processo de convergência entre os municípios do semiárido brasileiro ao longo do tempo, tanto para o crescimento como para o desenvolvimento socioeconômico. Tal convergência foi claramente induzida pelo setor terciário da economia, que apresentou a maior média de convergência entre os anos analisados.
Palavras-chave: crescimento econômico, desigualdade, desenvolvimento regional, desenvolvimento econômico.

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1 Introduction

The economic literature has presented in the last century a constant search to understand the causes of economic growth and the reasons why some economies grow and develop more than others. In this sense, studies on economic growth have gained notoriety due to the influence that income increases have on the population's quality of life and welfare.

These studies, in addition to evidencing a positive relationship between the Gross Domestic Product (GDP) growth and the improvement in quality of life, also give important emphasis to the convergence hypothesis whether of income or other socioeconomic variables. Convergence was originally defined by Solow (1956) as a trend to convert to a common level or the same steady state. Convergence reflects a trend towards reducing income inequalities between rich and poor regions when considering income as a parameter.

In Brazil, regional income inequalities are easily noticed, as the Southeast and South regions, the richest and most developed central-south areas in the country, historically have the best socioeconomic indicators, with a strong concentration of the most dynamic sectors of the economy. On the other hand, the North and Northeast regions, which are larger in territorial extension, still have low parameters, with high inequality and poverty indices. The central-south area represents 69% of the Brazilian Gross Domestic Product (GDP), with a concentration of 79% of resources when adding up the participation of the Midwest region of Brazil (10%), while the North and Northeast regions represent only 20% of the entire GDP (Ipeadata, 2017). According to Alves *et al.* (2018), this regional discrepancy is the result of the unification of national markets, the formation of regionalized markets, and the intensification of the industrialization process in favor of the Southeast and South of Brazil, which increased the differences between regions.

Particularly, the Northeast region had the worst indicators of poverty and development at the end of the 20th century. This region concentrated around 60% of the total number of extremely poor individuals in Brazil (approximately 50 million people), with the highest income distribution inequality index (Gini coefficient – 0.51), being higher than the national average (0.49) (Ipeadata, 2014; Oliveira, Ferrera de Lima & Barrinha, 2019).

Specifically, this inequality in the context of municipalities in the Brazilian semi-arid region was even more evident although income has increased over time. Even so, municipalities in the semi-arid region still preserve a marked inequality, in which 32% of them have a Gini index higher than 0.60, with a population heavily dependent on government transfers (Asa, 2021).

In this context, this study aims to verify whether there was income convergence between the municipalities of the Brazilian semi-arid region between 2005 and 2017 using the coefficient of variation and identify whether GDP growth was able to accentuate income discrepancies between municipalities. Moreover, the analysis of the sectoral Gross Value Added (GVA) and the Firjan Municipal Development Index (FMDI) in its three dimensions (employment and income, health, and education) were incorporated to identify the convergence in the socio-economic context and verify which economic sector contributed the most to the convergence process, thus ascertaining if the municipalities of the Brazilian semi-arid region are also converging to a common level of social welfare, in addition to economic growth.

Thus, the main contribution of this study is to identify, from the point of view of growth and economic development, whether the municipalities belonging to the Brazilian semi-arid region have been reducing the discrepancies between them and converging to a common point. Considering the marked income inequality in the region, identifying whether this inequality has

reduced over time is of paramount importance to formulate specific and more assertive public policies given the regional reality.

In addition to this introductory section, the study is divided into three more sections and final considerations, the second being a conceptual and empirical analysis of the convergence hypothesis, highlighting the most recent studies on the subject, based on a brief literature review. The third section includes the adopted methodological procedures, the study region characterization, the method description, and the analyzed variables. The fourth section consists of the results and discussions and, finally, the final considerations.

2 Income convergence: conceptual and empirical aspects

Why do some economies grow and develop faster than others? Why do regional income disparities occur? These are constant questions in the economic literature and recent empirical studies.

The economic growth of a region is defined in the pioneering studies of Kuznets (1955, 1963, 1983, 1985), Nobel laureate in economics, as the long-term growth of the capacity to provide its population with economic goods. For this to occur, the structural transformation of the economy must be high. It is defined by the author as a shift from agricultural to non-agricultural activity and, in a second historical moment, from industrial to tertiary activity. This structural transformation causes an increase in per capita product, which means a high increase rate in product per worker and, consequently, productivity.

However, Kuznets (1955, 1963, 1983, 1985) demonstrated the existence of a relationship in the form of an inverted U, in which the pattern of inequality increases with economic growth (in the short term) and decreases from an inflection point (in the long term). This trend between the level of economic growth, income distribution, and even economic development across regions became known as the Kuznets curve. In other words, differences in income and development among regional economies tend to increase in the short term, during a rapid process of economic growth. However, the pace of economic growth tends to drive regional economies towards higher convergence of income and economic development in the long term.

Thus, economic growth is reflected in the expansion of the per capita product of a place. Per capita product is the ratio between GDP and population and, consequently, the product must grow at a higher rate than the population, which also makes it an indicator of productivity. Importantly, GDP expansion depends on the availability, use of production factors, and incorporation of technologies and innovations in the production process. In this sense, economic growth is the quantitative expansion of GDP per capita and does not cover qualitative elements (Furtado, 1983; Fritsch, 1996).

Economic development goes beyond the simple quantitative expansion of the per capita product, as it involves living conditions, such as access to decent housing and employment, health, and education. Growth and economic development are interrelated, as development influences higher growth. However, growth does not necessarily influence development. For this purpose, it needs to be accompanied by improvements in income distribution and public policies focused on capital and human development. Fonseca (2006) calls attention to the fact that a region can develop but also fall into underdevelopment. Furtado (1983) understands that the concept of economic development involves economic growth but goes beyond it, as it involves a complex set of qualitative and quantitative variables, such as employment, income, health, quality of education, and political conditions, among others. Dubiel and Raiher (2014) point out that the variables related to education and economic dynamism have a positive effect on the development process. In this case, economic dynamism is synonymous with economic growth, and investments in education are synonymous with investments in human capital. The

regional economy, in addition to growing, must meet the needs of the population equitably over time.

In addition to the studies by Simon Kuznets, the studies by Williamson (1977) and Williamson and Fleming (1977), using the economy's per capita product and social welfare data as parameters, sought to empirically verify the perception of the Kuznets curve. Taylor and Williamson (1994) explained the effects of the income growth rate and the youth dependency rate on the formation of domestic savings. These studies referred to the idea of convergence between regional economies.

In a general sense, the convergence hypothesis corresponds to a decreasing trend over time of the socioeconomic differences between the most developed and underdeveloped economies, converging to a common level, indicating a reduction in inequality from the approximation of income and social indicators (Gomes & Esperidião, 2016).

According to Almeida and Moreira (2019), two types of convergence can be found in the literature: beta convergence, which is subdivided into absolute, conditional, and club convergence;[1] and sigma convergence, which assesses the dispersion of income levels between regions. Indications of a convergence process occur when the dispersion decreases over time. The coefficient of variation is one of the ways to verify the occurrence of convergence.

Absolute convergence assumes that all regions have the same steady state determinants. As a result, all regions would tend to converge to the same income level or the same steady state. Given the diminishing returns hypothesis, less developed regions would tend to grow at a higher rate than richer regions, eventually catching up (Gomes & Esperidião, 2016; Almeida & Moreira, 2019).

Venables (2005) pointed to increasing returns as an element to define the absolute convergence of regional economies when analyzing the relationship between the forces of agglomeration and natural advantages. According to the author, absolute convergence occurs as a function of public policies, the presence of increasing returns to scale, the profile of insertion in the trade flows of the world economy, and the geographic characteristics of the regions. Therefore, regional inequalities are due to natural advantages and the presence of forces of attraction, which are created or stimulated by government actions.

In contrast, conditional convergence considers that each regional economy has its own parameters and, consequently, its own steady-state level. Thus, income convergence between economies will not necessarily occur at a common level. On the other hand, there is club convergence; in this case, income convergence for the same steady-state level will only occur if the economies have the same structural characteristics and the same initial conditions (Gomes & Esperidião, 2016; Almeida & Moreira, 2019).

Several studies in the national literature have sought to analyze the process of income convergence both in municipalities and in regions, states, and countries with the adoption of a variety of methodologies. Among these studies, Ferrera de Lima and Bidarra (2021) analyzed the sectoral convergence of the municipalities that make up the Southern Arc of the Brazilian border strip using the methodology of variation averages from 2005 to 2015. The results indicated a higher convergence in the tertiary sector, while agriculture showed the lowest convergence.

Silva, Santos, and Amarantes (2020) used panel data modeling to identify possible changes in income disparity between municipalities in the South region of Brazil between 1999 and 2014. The results confirmed the existence of an absolute and conditional income convergence process between municipalities over the years.

Moving on to a more aggregated analysis, Almeida and Moreira (2019) analyzed the hypothesis of sigma convergence and beta convergence of per capita income among Brazilian

[1] Definition by Sala-i-Martin (1996).

states in the period 2001–2014, using the panel data methodology. The authors used the Theil index and coefficient of variation to calculate the sigma convergence. The results were favorable to this type of convergence. However, the dynamic panel data model was used for the beta-convergence test. The results of this model pointed to the existence of absolute and conditional convergence of GDP per capita in the analyzed period. Furthermore, the speed of convergence increases when analyzed by conditional convergence, going from 1.7% in the absolute version to 2.8% in the conditional version.

Batistella and Marion Filho (2018) analyzed the conditional and absolute convergence of the agriculture, industry, and service sectors in the municipalities of Rio Grande do Sul from 2000 to 2010. The methodology consisted of spatial analysis to verify whether the GDP growth of the different sectors followed a spatial pattern. The results confirmed the existence of a spatial correlation only for the agriculture and services sectors. The absolute and conditional convergence hypothesis was confirmed for the industrial sector, not identified for the other sectors.

Reis, Araújo, and Lima (2018) used a different geographical perspective and the ordinary least squares (OLS) method to analyze the absolute, conditional, and sigma convergence for municipalities in the Northeast region from 2010 to 2015, taking the GDP per capita as a variable parameter. The results showed a trend of convergence for the region as a whole. However, the conditional convergence hypothesis proved to be more satisfactory since the speed of convergence was higher than absolute convergence and, consequently, had a shorter half-life. The authors used the Firjan Municipal Development Index (FMDI) in its health and education dimensions as a parameter to analyze the conditional convergence hypothesis. This index allowed visualizing income disparities between municipalities in the Northeast region of Brazil for the two mentioned dimensions. Economic growth has contributed to reducing income discrepancies in municipalities of the Northeast region although inequalities still persist.

Marques and Fochezatto (2017) sought to verify the performance of Brazilian states in terms of economic development using the multivariate statistical technique of cluster analysis to evaluate whether or not there is development convergence between the states in four periods (1970, 1980, 1991, and 2000) from a multidimensional analysis. The results indicated the formation of two distinct clusters: one formed by states of the North and Northeast regions and the other by the states of the Southeast, South, and Midwest regions. The authors observed an increase in the distance between clusters over the four analyzed decades, and the distance within clusters has reduced, indicating a movement of convergence in several dimensions of development. Assis and Marques (2015) found similar results using the same methodology. The study showed signs of convergence within the Northeast region in five dimensions of development but the distance relative to the Southeast region did not decrease, that is, the two regions still maintain distinct patterns of very accentuated development.

Gomes and Esperidião (2016) used the dynamic panel data model to analyze the hypothesis of absolute and conditional convergence of GDP per capita in Brazilian regions in the 1995–2009 period. The results showed the existence of absolute convergence of the Brazilian regions, with a differential for the conditional convergence, which was different between the South/Southeast and Northeast regions, while the Midwest and North regions presented no conditional convergence process. The results reinforced the perception of persistent economic inequality among Brazilian regions.

Dias and Porsse (2016) and Vieira et al (2012) used the exploratory spatial data analysis model to analyze the convergence of income of municipalities in Paraná. The results converged to a process of reducing inequalities in the state of Paraná, both absolute and conditional. Still analyzing the state of Paraná, Raiher (2015) examined the absolute, conditional, and club convergence of that state from 1995 to 2009. For this purpose, the author used the panel data

model. The results found by the author corroborate those of Dias and Porsse (2016) and Vieira *et al.* (2012), indicating a trend to reduce inequalities relative to economic growth, showing that the variance of GDP per capita would be converging to a common value between the spaces under analysis.

Barbosa and Barreto (2015) analyzed the municipalities of Bahia and verified whether there was income convergence between them in the period from 1996 to 2010, using the ordinary least squares (OLS) method in a cross-section analysis. The results indicated a reduction in the disparities of GDPs per capita between the municipalities of Bahia, confirming the hypothesis of income convergence in the state of Bahia.

Raiher, Ferrera de Lima, and Klein (2014) used regional analysis indicators and the panel data model to analyze the spatial distribution of the secondary sector in the South region of Brazil and its convergence in the period from 1985 to 2009. The results indicated an increased percentage of micro-regions specialized in industry and a more homogeneous spatial distribution in the South region. Moreover, the convergence was confirmed and the variables education, population, and GDP per capita were important and relevant in determining the share of industrial GDP in the region.

Although the cited texts use GDP or GDP per capita as parameters, they are proxies for the variation of economic growth and productivity, respectively. Both do not reflect gains in terms of quality and living conditions, which characterize the economic development process. According to Sen (2000), economic development does not occur without individual freedom and the guarantee of access to improvements in their capacities. The freedom approach to assess development allows us to go beyond means, such as GDP expansion, industrialization advance, or technological progress. Therefore, valuing people and their freedoms goes beyond mercantile production, as it reflects on the institutional environment and other elements that lead to the full development of collectivities.

Considering the conceptual and empirical aspects discussed in this section, this study follows the model used by Ferrera de Lima and Bidarra (2021), proposed by Williamson and Fleming (1977), to analyze social welfare, namely: the convergence analysis by the coefficient of variation (CV), which consists of the ratio between the standard deviation and the average of the variable or parameter of analysis. Thus, convergence occurs by reducing the dispersion of the analyzed series, which implies a trend of approximation of the GDP per capita of the Brazilian semi-arid municipalities over time. This method is detailed in the next section.

3 Methodological procedures

This research performs a descriptive analysis of variation averages to identify whether there was a convergence of income and socio-economic development among the municipalities of the Brazilian semi-arid region. Therefore, a brief literature review was carried out, with a bibliographic survey of the most recent publications on the studied subject.

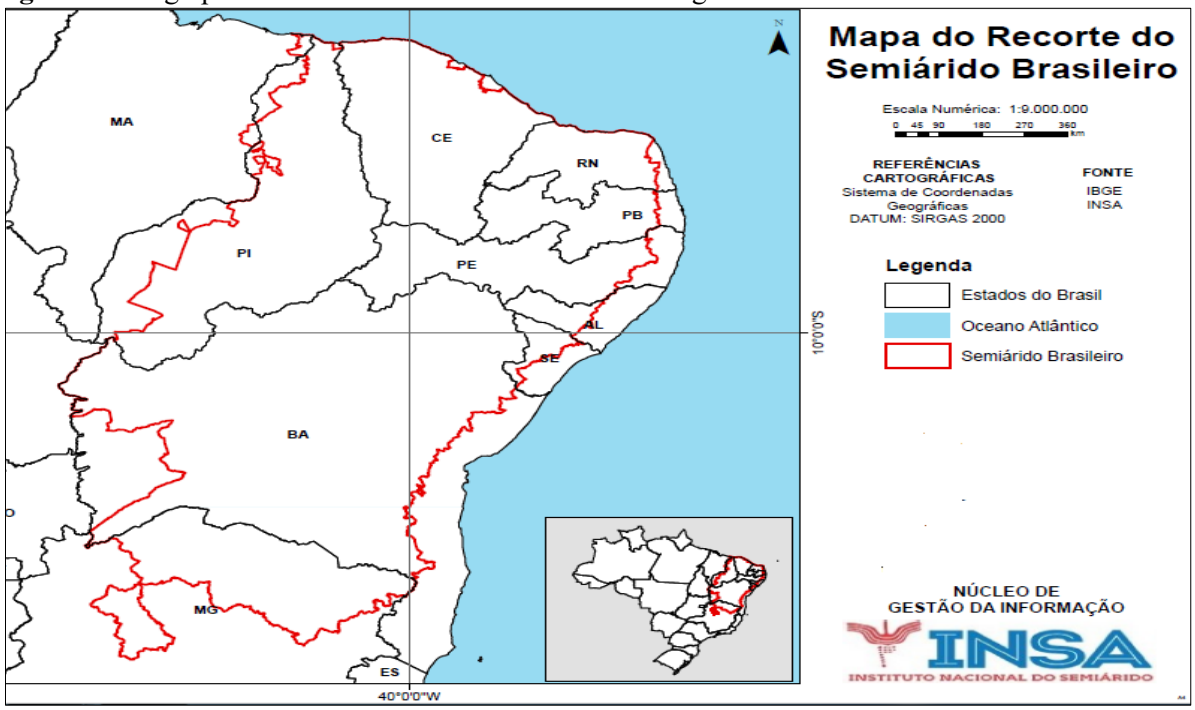
The Brazilian semi-arid region, characterized by its dry climate and low rainfall, covers an area of 1.03 million km^2, which corresponds to 12% of the country's territory and 60% of the Northeast region, comprising 1,262[2] municipalities, with a population of approximately 27.8 million inhabitants divided between urban (62%) and rural (38%) areas (MDR, 2019). Its economy is based on agriculture and particularly subsistence agriculture, with low productivity. The concentration of productive activities in the primary sector has become a risk factor due to the regional climate characteristics, as the lack of production conditions exacerbates poverty, rural exodus, and income inequality in prolonged periods of drought in the region.

[2] The current delimitation was considered. See: Resolution 115 of November 23, 2017.

The Brazilian semi-arid region extends across the nine states of the Northeast region and a portion of the northern region of the state of Minas Gerais, areas that historically have a high level of social vulnerability due to the low performance of their socio-economic indicators. The Northeast region of Brazil, which corresponds to almost all of the semi-arid region, had a Social Vulnerability Index (SVI) of 0.30 in 2019, higher than the national index (0.236) and other regions of the country (Ipeadata, 2019).

The delimitation of the Brazilian semi-arid region was defined by the Superintendence for the Development of the Northeast (SUDENE) (Figure 1), based on climate conditions, such as aridity index of up to 0.5, rainfall with an average of less than 800 mm, and water deficit. The caatinga biome predominates in this region, with a dry and hot climate, sparse, discontinuous, and poorly distributed rains, and shallow and low-fertility soils.

Figure 1: Geographical cutout of the Brazilian semi-arid region – 2021.



Source: Instituto Nacional do Semiárido, 2021.
Brazilian semi-arid cutout map; Numerical scale; Cartographic references; Geographic coordinate system; Source; Legend; Brazilian States; Atlantic Ocean; Brazilian Semi-arid.

The variable Gross Domestic Product per capita (GDP per capita) was used as a parameter to verify whether there was a convergence of income among municipalities of the Brazilian semi-arid region. This variable was chosen because it reflects the increases in production and income of the municipalities. The GDP per capita variation is also a proxy for economic dynamics but does not reflect improvements in quality of life. However, the limitation in the use of the variable GDP per capita is related to its restriction in demonstrating the dynamics of socio-economic development. Thus, it will be possible to analyze, from the economic growth point of view, whether there was an increase or decrease in disparities between municipalities, but without inferring about living conditions. This variable was collected on the website of the Brazilian Institute of Geography and Statistics (IBGE) under the national accounts icon. The variable is already deflated at 2010 prices.

In addition to evaluating the convergence process of municipalities in the Brazilian semi-arid region in terms of GDP per capita growth, the economic sectors that contributed more or less to the process of convergence of municipalities were also verified. For this purpose, the

sectoral GDP was used as a parameter, weighted from the Gross Value Added (GVA) by the estimated population of each municipality. Moreover, we sought to verify whether this convergence process also occurred in terms of socio-economic development using FMDI as a parameter variable, that is, whether the municipalities also presented improvements in quality of life and social welfare in addition to economic gains.

The period chosen for analysis was 2005 to 2017. The option for this time frame is due to the transformations experienced by the Brazilian economy during this period, which moved from an expressive cycle of economic growth to a recessive phase, which worsened in 2014, reaching a negative growth in 2016 (−4.5%), the worst result in the last 20 years, showing signs of recovery in 2018 (IBGE, 2021). In this sense, the proposed period provides subsidies to infer whether economic growth was able to reduce income inequalities among the municipalities in the semi-arid region during the economic expansion period.

Exceptionally, data from 2005 and 2016, collected from the FIRJAN system, were used for the FMDI analysis due to the non-availability of data for the year 2017. It is a limitation of this study, which can be easily corrected in future studies when data are already available. Thus, this limitation does not prevent or compromise the robustness of results found by this research, which provides important indicators of economic and social changes in municipalities in the Brazilian semi-arid region.

The average variation methodology, initially proposed by Williamson and Fleming (1977), was used to measure the income convergence profile of the municipalities that make up the Brazilian semi-arid region. Convergence analysis by the coefficient of variation was also used by other authors, such as Ferrera de Lima and Bidarra (2021), Almeida and Moreira (2019), Gomes and Esperidião (2016), Matos Filho, Silva, and Carvalho (2012), and Ferreira and Ellery Junior (1996). Importantly, Ferreira and Ellery Júnior (1996) and Almeida and Moreira (2019) highlighted that it is a perfectly applicable and consistent technique to verify the existence of sigma convergence. Measuring only the variance of incomes may lead to the risk of obtaining an underestimated result, as income will always increase over time, which would imply an increase in variance.

The coefficient of variation (CV) was originally used by Williamson and Fleming (1977) to calculate the average convergence (AC). The coefficient of variation corresponds to the ratio between the standard deviation and the average, expressed as a percentage. Therefore, AC can be calculated based on Equation (1).

$$AC_y = [(CVt1 - CVt2/CVt1) \times 100] \div (t2 - t1) \quad (1)$$

where AC_y is the convergence average per year, CVt1 is the average variation of the initial year, CVt2 is the average variation of the final year, t1 is the initial year, and t2 is the final year.

According to Williamson and Fleming (1977, p. 243), “the greater the decrease in the coefficient of variation over time, the greater the convergence.” Thus, the coefficient of variation analysis allows disregarding the initial conditions of each municipality, focusing on the variation in the growth of the parameter variable over time.

The municipalities of Bodó (RN), Canindé de São Francisco (SE), Guamaré (RN), and Porto do Mangue (RN) were excluded from the analysis, as they presented excessively discrepant values relative to the average, which may generate distortions in the results or even overestimated results. These municipalities stand out in the electricity and gas, water, sewage, waste management and decontamination activities, tourism, and oil production, respectively. Therefore, 1,258 municipalities remained for the analysis.

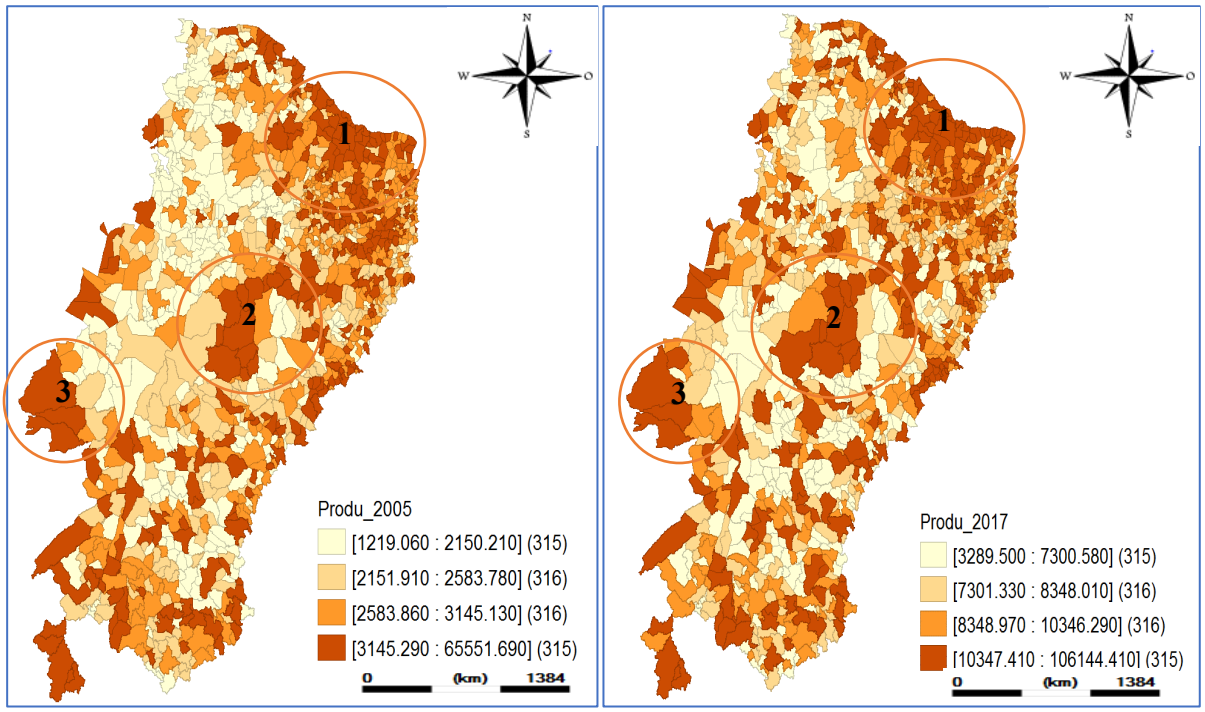
The collected data were processed in the software Excel and presented below in table format.

4 Results and discussion

Figure 2 shows the GDP per capita evolution in the Brazilian semi-arid region between 2005 and 2017. The spatial distribution showed a large income discrepancy between inland municipalities and those located close to the coast of Rio Grande do Norte (1), Petrolina/PE, Juazeiro/BA, and nearby regions (2), and Barreiras/BA and Formosa do Rio Preto/BA region (3), mainly in 2005. These regions present the highest GDP per capita among the municipalities.

Progress was noticed in 2017, especially in inland municipalities, which began to have higher homogenization and integrate the middle and upper GDP classes. This homogenization became even more noticeable when it is analyzed in terms of percentage variation, showing a higher dynamism from 2005 to 2017. Only nine out of the 1,262 municipalities in the semi-arid region showed a percentage variation above 1,000%; 14 municipalities presented variation between 500% and 1,000%;[3] 1,200 showed variation between 500% and 100%; 32 showed a variation of less than 100%; and only seven showed a negative variation. These percentages suggest a substantial improvement in the income of the semi-arid municipalities as a whole. The average GDP per capita of the municipalities increased three times during this period (Table 1).

Figure 2: Spatial distribution of GDP per capita of municipalities in the Brazilian semi-arid region, 2005 and 2017.



Note: Cluster 1: coast of Rio Grande do Norte; Cluster 2: Juazeiro/BA, Petrolina/PE, Campo Formoso/BA, and nearby regions; Cluster 3: Barreiras/BA, Riachão das Neves/BA, and Formosa do Rio Preto/BA region.
Source: Research results with original data from IBGE (2021).

Municipalities located on the coast of Rio Grande do Norte had the highest GDPs per capita for the two analyzed years, as this region received strong investments in the extraction of oil and sea salt. According to Aquino and Nunes (2019), Rio Grande do Norte has been consolidating its oil production, taking the lead in national production. It generated important

[3] Curral Novo do Piauí/PI (3,299%), Parazinho/RN (2,818%), Bodó/RN (2,696%), Pedra Grande/RN (1,903%), São Gonçalo do Amarante/CE (1,776%), Simões/PI (1,700%), São Miguel do Gostoso/RN (1,387%), Ribeira do Piauí/PI (1,207%), São Bento do Norte/RN (1,002%).

transformations in the state's economy from supplementary revenues with the payment of royalties to the state government and city halls. At the same time, the salt industry showed growth, another sector that the state leads in national production. All this consolidates the regional growth and the prominent position compared to other municipalities in the semi-arid region.

Importantly, in general, the results shown in Figure 2 agree with Cavalcanti Junior and Lima (2019) and Buainain and Garcia (2013), who have already shown a significant improvement in the income of semi-arid municipalities, with growth above the national average. Cavalcanti Junior and Lima (2019) identified growth rates above 200% for the average values of GDP and GVA of the industry of semi-arid municipalities, calculated from the averages of the years 1999–2001 and 2011–2013, standing out Parazinho/RN (1170%), Toritama/PE (397%), Sebastião Leal/PI (342%), Currais/PI (342%), and Baraúna/RN (334%). Buainain and Garcia (2013) also identified percentage variations higher than 100%[4] during the period from 2000 to 2008.

According to Buainain and Garcia (2013), this growth in the semi-arid region was the result of important transformations driven by a wide range of factors such as population densification; economic democratization process; higher political and economic decentralization; public investments in irrigation complexes, which enabled other private investments, and higher integration with the national economy. All this led to changes in the regional economic structure. However, inequality still remained high, with the continuity of poor areas, to the detriment of the formation of higher growth complexes, forming a corridor (Clusters 1, 2, and 3 in Figure 2), showing signs of a process that Cavalcanti Junior and Lima (2019) called "concentrated deconcentration." In this sense, the authors inferred that the growth rates observed for the semi-arid region are related to more dynamic regions and a concentration process in the most attractive regions.

The descriptive statistics shown in Table 1 confirmed the economic growth of municipalities in the Brazilian semi-arid region between 2005 and 2017. The coefficient of variation, which was reduced by 11%, shows a decrease in the GDP per capita dispersion of the municipalities, that is, there is a convergence between them over time.

Table 1: Descriptive statistics regarding GDP per capita of municipalities in the Brazilian semi-arid region – 2005, 2017.

Statistics	2005	2017
Mean	R$ 2,984.50	R$ 9,726.31
Median	R$ 2,581.86	R$ 8,346.04
Standard deviation	R$ 1,923.55	R$ 5,558.41
CV	64%	57%
Minimum	R$ 1,219.06	R$ 3,289.5
Maximum	R$ 27,470.74	R$ 80,480.27

Note: Values for the 1258 municipalities considered in the analysis.
Source: Research results from data by IBGE (2021).

The GDP per capita convergence process denoted the reduction of disparities between municipalities in the Brazilian semi-arid region. The coefficient of variation showed that the deviations reached 64% of their value relative to the average in 2005. The variation was smaller in 2017 and the deviations reached 57% of their value relative to the average. In this period, the convergence hypothesis, i.e., the reduction of disparities between semi-arid municipalities, was confirmed, as the coefficient of variation reduced by 11% and the average annual convergence

[4] See Buainain and Garcia (2013).

trend was 0.94. Similarly, Reis, Araújo, and Lima (2018) identified a convergence of income between the municipalities in the Northeast, while Matos Filho, Silva, and Carvalho (2012) identified a reduction in the per capita income dispersion among the Northeast states, especially from 2001.

Table 2: Brazil: GDP per capita average convergence of semi-arid municipalities, 2005 and 2017.

GDP *per capita*	**2005**	**2017**
Average	R$ 2,984.50	R$ 9,726.31
Standard deviation	R$ 1,922.78	R$ 5,556.20
Coefficient of variation	64%	57%
AC = 0.94		

Source: Research results from data by IBGE (2021).

The confirmation of the income convergence hypothesis raises questions about the role that economic sectors played in the dynamism of the semi-arid economy and led to this convergence process. The average convergence was more expressive for the tertiary sector, which had the highest average (6.05) between 2005 and 2017 (Table 3). The standard deviation was higher than the average in 2005, showing a large income disparity in the semi-arid region. The coefficient of variation showed that the deviations reached 102% of their value relative to the mean. The industry average increased three times in 2017 over the previous period, while the standard deviation was reduced by 14%. This amount indicated the reduction of dispersion among municipalities, that is, they were leveled in terms of the gross added value of the tertiary sector. The coefficient of variation in 2017 showed that the deviations reached 28% of their value relative to the average – a reduction of 72.5% in the coefficient of variation.

Table 3: Brazil: sectoral average convergence of semi-arid municipalities, 2005 and 2017.

Primary sector	**2005**	**2017**
Average	R$ 559.00	R$ 1,116.69
Standard deviation	R$ 1,106.62	R$ 1,842.07
Coefficient of variation	198%	165%
AC = 1.39		

Secondary sector	**2005**	**2017**
Average	R$ 376.51	R$ 1,054.71
Standard deviation	R$ 1,327.60	R$ 3,211.37
Coefficient of variation	353%	304%
AC = 1.16		

Tertiary sector	**2005**	**2017**
Average	R$ 2,230.30	R$ 6,972.56
Standard deviation	R$ 2,282.86	R$ 1,960.26
Coefficient of variation	102%	28%
AC = 6.05		

Source: Research results from data by IBGE (2021).

The primary sector had the second highest average convergence (1.39). A particularity of this sector was that the standard deviation was almost double the average, showing the great heterogeneity of municipalities in terms of primary production. Deviations from the coefficient of variation reached 198% of their value relative to the average in 2005. The standard deviation was also higher than the average in 2017, but with a smaller difference than in 2005. Regarding the coefficient of variation, the deviations reached 165% of their value relative to the average.

It means a reduction of 16.6% between 2005 and 2017. In other words, the disparities between the municipalities in the semi-arid have been reduced over time.

In contrast, the secondary sector presented an annual average convergence of 1.16. This sector had the lowest average compared to the other sectors and the highest dispersion relative to the average, with three times the average value for the two analyzed years. The average increased by 180%, but there is still a high dispersion among municipalities. Deviations from the coefficient of variation reached 353% of their value relative to the average in 2005. The coefficient of variation in 2017 was 304%, which means a reduction of 14%. A decrease in disparities was observed over time between the municipalities of the Northeast semi-arid.

The growth of the secondary sector in the semi-arid region is attributed to the expansion process of some industries, such as the non-metallic mineral extractive industry, textile and footwear industry, chemical industry, and civil construction. According to Cavalcanti Junior and Lima (2019), these industries stood out in the region and are important for the local dynamics due to the role of their supply chaining in the region, in addition to the ability of some of them to be labor intensive. Supply chaining was defined by Rippel (2016) as the chain effects that some production activities generate, stimulating the economy both in the production of raw materials and the aggregation of value.

In summary, convergence was observed between municipalities of the Northeast semi-arid region both in terms of GDP per capita and sectoral product. This convergence was induced by the participation of the tertiary sector, especially the public administration. It represented 44% of all gross value added to the tertiary sector, making clear the importance of the public sector for the region. In terms of socioeconomic development, the improvement in quality of life and social welfare showed higher convergence of municipalities, with an average higher than the average GDP per capita.

Thus, the convergence process in the Northeast semi-arid region demonstrates the need for policies focused on local development to strengthen the industrialization of municipalities. In this context, specific actions for rural agro-industry, support for micro and small industrial companies, and the formation of specific incentives for the region can be instruments to expand the production structure and increase sectoral convergence more harmoniously.

The average FMDI-general for the municipalities increased by 39% from 2005 to 2016. The coefficient of variation presented a reduction of 38.8%, which means an average trend of convergence of 3.19 over time. The analysis of the FMDI composition showed that the FMDI-education dimension had the highest average annual convergence (4.44). The average FMDI-education increased by 59%, while the coefficient of variation decreased by 50%. The dispersion relative to the average decreased over time and the municipalities became more homogeneous compared to the education dimension, reducing illiteracy and school dropout.

Table 4: Brazil: FMDI average convergence of semi-arid municipalities, 2005 and 2016.

FMDI – General	**2005**	**2016**
Mean	0.43	0.60
Standard deviation	0.0755	0.0689
Coefficient of variation	18%	11%
AC = 3.19		
FMDI – Employment & Income	**2005**	**2016**
Mean	0.45	0.40
Standard deviation	0.0935	0.0883
Coefficient of variation	21%	22%
AC = −0.53		
FMDI – Education	**2005**	**2016**

Mean	0.44	0.70
Standard deviation	0.1044	0.0848
Coefficient of variation	24%	12%
AC = 4.44		

FMDI – Health	**2005**	**2016**
Mean	0.40	0.71
Standard deviation	0.1259	0.1345
Coefficient of variation	32%	19%
AC = 3.63		

Source: Research results from data by the FIRJAN (2021) system.

The FMDI-health dimension presented the second highest annual average convergence (3.63), a reflection of the performance of the Unified Health System (SUS), child vaccination programs, and basic health care for the most vulnerable agents such as the elderly, children, and pregnant women. These investments resulted in significant improvements in health care quality and, consequently, the population's quality of life, reduction of deaths, and hospitalizations (Buainain & Garcia, 2013). The average FMDI-health dimension increased by 77.5% between 2005 and 2016. On the other hand, the coefficient of variation was reduced by 40.6%, that is, a reduction in discrepancies was found over time between municipalities regarding the health dimension, presenting a convergence trend between them.

These results reaffirm the transformations and improvements in income and quality of life that are underway in the Northeast semi-arid region. Reis, Araújo, and Lima (2018) had already pointed out these improvements for municipalities in the Northeast region. The authors identified that the health and education dimensions contributed significantly to minimizing income disparities between municipalities. It indicates that the economic growth contributed to reducing income discrepancies of the Northeast municipalities. Struminski and Raiher (2017) also corroborated this finding when analyzing poverty and its determinants in Brazilian municipalities, inferring that higher investments in health have positive repercussions on development indices both in those that have income as a dependent variable and in those that use multidimensional variables. In addition to these studies, Marques and Fochezatto (2017) and Assis and Marques (2015) identified a process of economic development convergence within the Northeast region, indicating that distances have been reduced intra-regionally.

In contrast, the FMDI-employment and income dimension had a negative average convergence (−0.53), and unlike a convergence process, the municipalities are diverging from each other, that is, the distances between them have increased over time. This fact can be verified by the growth in the coefficient of variation. The comparison of this result with the previous ones shows that the secondary sector is the most concentrated in the region, showing the role that industrialization has in the creation of employment and income.

In 2005, 281 municipalities were classified as having a low[5] stage of development for the employment and income dimension and only 12 municipalities had a high[6] stage of development. This scenario worsened in 2017 and the number of municipalities with a low stage of development increased to 521, whereas the number of municipalities with a high stage of development reduced to only four. This worsening of the scenario is attributed to the aggravation of the economic and political crisis experienced by Brazil in recent years. The employment and income dimension measures the generation of formal employment, labor market formalization rate, income generation, wage bill, and the Gini index, variables that are negatively affected by economic cycles, with a direct and immediate reflection in the indicators.

[5] Low stage of development – FMDI between 0.0 and 0.4.
[6] High stage of development – FMDI between 0.8 and 1.0.

In this scenario, the ongoing changes in the Brazilian semi-arid economy, although positive and significant, have not been consolidated in an increase in employment and income for the population evenly in space. Oliveira and Ferrera de Lima (2021) noticed this trend when analyzing the Northeast region of Seridó, whose portion is part of the semi-arid region. The authors pointed out that improvements in the health and education dimensions did not stimulate repercussions in employment and entrepreneurship. According to Silva *et al.* (2016), the trend is to maintain low levels of income and capacity to generate employment, as the economy is focused on activities of the tertiary and primary sector, which has low remuneration and high risk due to the constant and severe droughts that lead to production losses, increasing hunger, unemployment, and rural exodus.

5 Final Considerations

This study aimed to verify, from the coefficient of variation, whether there was a convergence of income and socioeconomic development between municipalities of the Brazilian semi-arid region between 2005 and 2017.

The results indicated a reduction in the GDP per capita dispersion among municipalities in the Brazilian semi-arid region. It confirmed the income convergence process between them in the analyzed period. This convergence was also verified by sectors, standing out the tertiary sector (6.05), which presented the highest average convergence, followed by the primary (1.39) and secondary sectors (1.16).

In terms of socioeconomic development, a reduction in dispersion among municipalities was also observed over time, with an average convergence above the average GDP per capita. The education and health dimensions presented the highest average convergences among the semi-arid municipalities. It indicates that the improvements in GDP found in the region contributed to increasing municipal revenues, generating more investments in education and health, and reducing discrepancies between municipalities, providing improvements in the quality of life and social welfare.

On the other hand, the employment and income dimension showed a divergence between municipalities, which was already expected due to the economic and political crisis experienced by the Brazilian economy in the last decade, eroding the sources of employment and income for families. The Brazilian semi-arid region feels the effects of economic crises more expressively due to its socioeconomic and climate characteristics and strong dependence on government transfers, which may have corroborated this non-convergence. In other words, improvements in GDP per capita growth and health and education dimensions did not affect the creation of formal jobs.

Although the income improvements in the Brazilian semi-arid region are notorious, confirming the hypothesis of income convergence, inequality is still a factor that persists in the region and lacks the attention of public policymakers. Therefore, new actions can be implemented to maintain and expand the income convergence process to remedy inequalities and improve conditions for job creation.

The research results showed an improvement in the socioeconomic development profile of municipalities in the region under analysis, but substantial differences still persist in terms of economic dynamism despite the GDP per capita convergence. Employment and income conditions continue to be disparate, reinforcing the centrality of regional hubs. Municipalities need to obtain budgetary resources from the local production structure to maintain investments in health and education. For this purpose, the construction of local development policies, focused and based on territorialities, becomes the keynote for a more inclusive development model.

Finally, the main contribution of this research was to present and align the conclusions with other studies, confirming a process of convergence between the municipalities of the Brazilian semi-arid region in terms of economic growth and development based on quantitative evidence. Due to the limited data available, we suggest that future studies incorporate more recent and multidimensional data, in addition to other verification methodologies that include absolute and conditional convergence measures, thus allowing going beyond this analysis to verify the speed and half-life that semi-arid municipalities took to reduce the dispersion between them.

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References

Almeida, R. D. C.; Moreira, T. B. S. (2019). Convergência de renda entre os estados brasileiros: uma análise em painel dinâmico. Planejamento e Políticas Públicas, 52, 325-354.

Alves, D. F.; Júnior, F. D. O.; Siqueira, R. M. de; Filho, P. J. R. (2018). Estrutura produtiva nas mesorregiões do Nordeste brasileiro: uma análise fatorial. Informe Gepec, 22(1), 81-98.

Aquino, J. R. de; Nunes, E. M. (2019). Desempenho recente e perspectivas da economia do Rio Grande do Norte no século XXI. BNB Conjuntura Econômica, 289-306.

Asa. (2021). Articulação do Semiárido Brasileiro. Recuperado de https://www.asabrasil.org.br/semiarido

Assis, R. S. de; Marques, A. M. (2015). Convergência ou divergência no desenvolvimento? Um estudo com clusters para o Sudeste e o Nordeste do Brasil, 1990-2010. Revista Econômica do Nordeste, 46(1), 169-189.

Barbosa, A. O.; Barreto, R. C. S. (2015). Uma análise sobre o crescimento econômico dos municípios do estado da Bahia: um teste da hipótese de convergência de renda. Economia & Região, 3(1), 57-80.

Batistella, P. B.; Filho, P. J. M. (2018). Crescimento econômico e convergência de renda nos municípios do Rio Grande do Sul: uma análise dos três grandes setores (2000-2010). Estudo & Debate, 25(2), 284-309.

Buainain, A. M.; Garcia, J. R. (2013). Desenvolvimento rural do semiárido brasileiro: transformações recentes, desafios e perspectivas. Revista Franco-Brasilera de Geografia, 19.

Cavalcanti Junior, C. A. A.; Lima, J. P. R. (2019). O semiárido nordestino: evolução recente da economia e do setor industrial. Revista Econômica do Nordeste, 50(13), 69-88.

Dias, F.; Porsse, A. (2016). Convergência de renda nos municípios paranaenses, no período 2000-10: uma abordagem de econometria espacial. Ensaios FEE, 37(2), 581-602.

Dubiel, S. A.; Raiher, A. P. (2014). Desenvolvimento econômico dos municípios do Paraná: evolução e seus determinantes. Informe Gepec, 17(2), 6–22.

Ferreira, P. C.; Ellery Júnior, R. (1996). Convergência entre a renda per capita dos estados brasileiros. Revista de Econometria, 30(4), 2129-2132.

Ferrera de Lima, J.; Bidarra, B. S. (2021). Convergência setorial na fronteira Sul do Brasil. Revista Brasileira de Desenvolvimento Regional, 9(2), 211-226.

Fonseca, M. A. R. da. (2006). Planejamento e desenvolvimento econômico. São Paulo: Thomson Learning.

Fritsch, W. (1996). A riqueza das nações: Investigação sobre sua natureza e suas causas. São Paulo: Nova Cultural Ltda.

Furtado, C. (1983). Teoria e política do desenvolvimento econômico. 8ª ed. São Paulo: Ed. Nacional.

Gomes, R. R.; Esperidião, F. (2016). Convergência de renda: uma análise em painel para as regiões brasileiras no período 1995-2009. Ensaios FEE, 37(1), 115-144.

IBGE. (2021). Instituto Brasileiro de Geografia e Estatística. Recuperado de https://www.ibge.gov.br/

IFDM. (2021). Índice Firjan de Desenvolvimento Municipal. Recuperado de https://www.firjan.com.br/ifdm/

INSA. (2021). Instituto Nacional do Semiárido. Recuperado de https://www.gov.br/mcti/pt-br/composicao/rede-mcti/instituto-nacional-do-semiarido

IPEADATA. (2014). Instituto de Pesquisa em Economia Aplicada. Recuperado de http://www.ipeadata.gov.br/Default.aspx

IPEADATA. (2017). Instituto de Pesquisa em Economia Aplicada. Recuperado de http://www.ipeadata.gov.br/Default.aspx

IPEADATA. (2019). Instituto de Pesquisa em Economia Aplicada. Recuperado de http://www.ipeadata.gov.br/Default.aspx

Kuznets, S. (1983). Crescimento económico e desigualdade de rendimento. In: Silva, M. (Org.). Desenvolvimento Económico e Repartição do Rendimento. Lisboa: Editorial Estampa. Cap. 1, 21-50.

Kuznets, S. (1985). Crescimento econômico moderno: descobertas e reflexões. Revista Brasileira de Economia, 39(02), 225-239.

Kuznets, S. (1955). Economic growth and income inequality. American Economic Review, 45, 1-28.

Kuznets, S. (1963). Quantitative aspects of the economic growth of nations. Economic Development and Culture Change, 11, 1-80.

Marques, A. M.; Fochezatto, A. (2017). Uma análise multidimensional do processo de convergência entre os estados brasileiros — 1970-2000. Ensaios FEE, 38(3), 467-498.

Matos Filho, J. C.; Silva, A. B. da; Carvalho, T. N. (2012). A convergência da renda nas microrregiões da Região Nordeste do Brasil. Economia e Desenvolvimento, 11(2), 67-85.

MDR. (2019). Ministério de Desenvolvimento Regional. Recuperado de https://www.gov.br/mdr/pt-br

Oliveira, N. S. M. N., Ferrera de Lima, J., & Barrinha, R. N. (2019). Desenvolvimento humano municipal no estado da Bahia. Revista Brasileira de Desenvolvimento Regional, 7(1), 137-164.

Oliveira, O. F., Ferrera de Lima, J. (2021). Desenvolvimento regional diferenciado no Seridó brasileiro. Revista de Economia Regional, Urbana e do Trabalho, 10(1), 129-150. DOI: 10.21680/2316-5235.2021v10n1ID23796.

Raiher, A. P. (2015). Crescimento econômico e sua convergência no estado do Paraná. Gestão & Regionalidade, 31(92), 136-150.

Raiher, A. P., Ferrera de Lima, J., & Klein, C. F. (2014). A distribuição espacial da indústria no Sul do Brasil e sua convergência. Análise Econômica, 32(61), 81-104.

Reis, L. D. R., Araújo, R. C. P., & Lima, J. R. F. (2018). Convergência da renda per capita no Nordeste. In: Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural, XIII., 2018, Juazeiro. Anais [...]. Juazeiro: XIII SOBER-Nordeste.

Rippel, R. (2016). Encadeamentos produtivos e a polarização na economia regional. In: Piacenti, C., Ferrera de Lima, J., & Eberhardt, P. Economia & Desenvolvimento Regional. Foz do Iguaçu: Parque Itaipu, 80-88.

Sen, A. (2000). What Is Development About? In: Meier, G. M., & Stiglitz, J. E. Frontiers of Development Economics. Washington (DC): World Bank, 506-513.

Silva, F. P. da, Araújo, J. A., Costa, E. M. V. F., & Ribeiro, J. E. (2016). Eficiência técnica das regiões semiárida e não semiárida do Nordeste brasileiro: mensurando a função de meta-fronteira de produção. In: Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural, 54., 2016, Maceió. Anais [...]. Maceió: SOBER.

Silva, F. da, Santos, L. G. dos, & Amarantes, A. de. (2020). Análise de convergência de renda per capita nos municípios da Região Sul do Brasil entre 1999 e 2014. Revista Brasileira de Gestão e Desenvolvimento Regional, 16(2), 354-366.

Struminski, C., & Raiher, A. P. (2017). Pobreza e seus determinantes nos municípios brasileiros: abordagem monetária, de privações e multidimensional. Revista de Desenvolvimento Econômico, 2(37), 186-211.

Taylor, A. M., & Williamson, J. (1994). Capital flows to the new world as na intergenerational transfer. Journal of Political Economy, 102(2), 348–371. Disponível em: link

Venables, A. J. (2005). Spatial disparities in developing countries: cities, regions, and international trade. Journal of Economic Geography, 05(01), 03-21.

Vieira, F. L., Staduto, J. A. R., Parré, J. L., Bechlin, A. R., & Letti, A. G. (2012). Convergência de renda e desenvolvimento regional no Paraná (1999-2006). Informe GEPEC, 16(1), 213–235.

Williamson, J. B., & Fleming, J. (1977). Convergence theory and the social welfare sector. International Journal of Comparative Sociology, 18(3-4), 242-253. Disponível em: link

Williamson, J. (1977). Desigualdade regional e o processo de desenvolvimento nacional: descrição e padrões. In: Schwartzman, J. Economia regional: textos escolhidos. Belo Horizonte: Editora UFMG, 53-116.

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