DISCUSSION PAPER

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ABSTRACT

This work calculates coefficients of spatial inequalities of wealth amongst Brazilian municipalities, for each year for the period from 1920 to 2016, states of the federation, from 1939 to 2017, and amongst municipalities from each of the five Brazilians' macro-regions, from 1920 to 2016. The use of non-parametric statistics reveals rough short-term paths of inequalities, and the occurrence of U-shaped relationships between spatial inequalities and the level of per capita GDP, known as the Williamson's Curve (1965). Decomposition of the changes in the Gini coefficients show intense rank turbulence and leapfrogging over richer municipalities, from 1920 to 1970. Although the coefficients confirmed a long-term convergence trend in spatial inequalities, since 1970, there have been significant differences between macro-regional spatial inequalities dynamics, and a worrying switch to divergence in the Southeast, since in 1996.

Keywords: regional inequalities; regional economic development; income convergence; non-parametric data analysis.

1 INTRODUCTION

Based on an extensive empirical analysis of a huge set of long-term data for several countries, Williamson (1965) identified the occurrence of inverted U-shaped relationships between the regional inequalities and the level of National per capita GDP, in many developed countries. To explain the causes of this phenomena, Williamson (1965) develops a thesis about the factors that initially stimulate spatial inequalities in the process of national industrialization and development, and are changed by the own process of accumulation of national wealth, and from an uncertain level of national per capita GDP, these factors inverts their effects and begin to stimulate spillovers of economic activities across the national land, and consequently to stimulate the reduction in spatial inequalities, a process commonly known as "convergency".

Recent empirical analyses have confirmed the occurrence of the Williamson's curve (1965) for many developed countries, based on long-term time series data, usually covering more than a hundred years. Kemeny and Storper (2020) have revealed, though, evidences on the returning of divergence in the USA, since the end of the 80's, after decades of spatial convergence. They develop a thesis that regional inequalities dynamics describe long-term waves of divergence and convergence, provoked by major technological shocks.

The search for long term trends in regional inequalities has motivated a great number of works in Brazil. A considerable group of works have estimated linear coefficients, with parametric regressions, to test the neoclassical prediction of per capita income convergence amongst Brazilian's regions. Non-parametric methods, such as markov chain analysis, have been applied to test ergodics clustering of regions, ranked by per capita income. The review of this literature, presented in the following section of this article, though, shows that some findings of convergency, or divergency trends, change with the methodologies, time periods and the territorial scales used by the analyses.

The diversity of these results, the occurrence of contradictions between some of them, and the absence of a long-term empirical analyses of the Brazilian's spatial inequalities into a very disaggregated territorial level, stimulated the construction of a long-term data set, from 1920 to 2016, in the Municipalities scale, to be analyzed by robust non-parametric statistical methods, in order to obtain a more comprehensive panorama of the Brazilian regional inequalities long-term trends.

This work calculates non-parametric coefficients of dispersion of per capita GDP amongst States and Municipalities in Brazil, for almost a hundred years: from 1920 to 2016. Graphs of the resulting coefficient's series offer robust descriptions on the evolution of Brazilian inequalities, that allows for abrupt changes, in the short run, and inversions of nonlinear trends, in the long term.

To calculate comparable coefficients in time, given the municipalities dismemberment process, which increased from 1304 municipalities, in the year of 1920, to 5569 municipalities in 2016, we regrouped the new municipalities with their parents into unchallengeable units in time, called Comparable Minimum Areas (CMA). Due to the continuous process of creation of municipalities in the last century, moving the base year of the analyses further to the past, gives us smaller number of CMA, with bigger territorial areas. To observe whether the results significantly depend on spatial scales, we calculate Gini's coefficients among the states of the federation, and among CMA from different time periods: from 1920 through 2016, 1970 through 2016, and 2002 through 2016. The *Gini* coefficient's series among $CMA_{1920\text{-}2016}$ is decomposed in leapfrogging and progressivity effects, between decades and big periods of time. We calculated the Gini's coefficients among $CMA_{1920\text{-}2016}$, grouped for each of the five Brazilian's macro-regions – North, Northeast, Center-west, Southeast and South –, to look for distinctions in macro-regionals spatial dynamics.

The second section of this paper presents a brief review of the literature about Brazilian regional inequalities, and describes the thesis of Williamson (1965) and Kemeny and Storper (2020). The methodology used in the work is presented in its third section. The section four describes the sources of the database and the method to regroup the new municipalities to their original municipalities, resulting in CMA for each period of time analyzed. The results are presented in the fifth section of this paper. The depiction of the coefficients series in graphs gives more intuitive and automatic readings on the dynamics of Brazilian inequalities. The sixth section of the article presents its conclusions.

2 DYNAMICS OF REGIONAL INEQUALITY

The neoclassical theory of economic growth begins fundamentally with Solow (1956) and Swan (1956). Amongst the main predictions of this model, which derives from the assumption of decreasing marginal returns of capital, is the convergence of national per capita income to a *long-term* growth rate, that is equivalent to an exogenous technological progress. This prediction implies per capita income convergence between economies, which shall be accelerated by huge capital flows from rich to poor economies, in search of higher returns.[1]

The econometric methodology developed by Barro (1991) and Barro and Sala-I-Martin (1991; 1992; 1995) to test the neoclassical hypothesis of per capita income convergence, inspired a huge

1. To correct the eventual completion of the per capita growth rate, predicted by the model, an exogenous term is incorporated that represents continuous technological progress, to which the long-term economic growth rate will converge.

group of works concerned about Brazilians' regional inequalities. Popular known as "Barro regressions", they linearly regress the economies' average growth rates on their initial income levels: a negative α coefficient, signaling a reduction in income dispersion, is interpreted as convergence.

The hypothesis of α – *convergence* amongst the per capita incomes of Brazilian's states is confirmed by Ferreira and Diniz (1995), for the period between 1970 and 1985, and by Azzoni (2001), for the period between 1939 and 1996, but is rejected by Lima, Notini and Gomes (2010), from 1947 to 2006. The rejection of the hypothesis of α – *convergence*, stimulated works to test the occurrence of β – *convergence:* the finding of a statistically significant negative "β" coefficient, in the linear regression model, implies that the poor economies are growing faster than the richer economies. A positive β reveals divergence; but the result of a β that turns to negative with the insertion of growth-conditioning variables is interpreted as a *conditioned* β – *convergence* phenomena.

The occurrence of this process, amongst Brazilian's states, was confirmed by Silveira Neto (2001), from 1985 to 1997, Silveira Neto and Azzoni (2006), from 1985 to 2001, Resende and Figueiredo (2010), from 1960 to 2000, and by Azzoni et al. (2004), from 1981 to 1996. Azzoni et al. (2004) obtained a half-life convergence shorter than one year, which reveals that the income inequalities between the states, in 1996, were already close to their long-term equilibrium pattern, and would only altern with eventual changings in the conditional variables.[2]

Quah (1993a) and Friedman (1992) discusses the weakness in Barro regressions of estimating a single linear coefficient by regressing average growth rates on initial levels for all economies, and show that a resulting negative β cannot mean convergence, but a symptom of regression towards the mean, a phenomenon known as Galton's fallacy (Islam, 2003). By using a dynamic version of Galton's fallacy, Quah (1993a) obtains coefficients with arbitrary signs, that are consistent with immutable cross-sectional distributions of income. Quah (1993b) analyzed a dataset for 118 countries, from 1962 to 1985, to show that it's unacceptable to assume permanent movements in income with mild trends in time, that are softly affected by current shocks.[3] To investigate, without parametric restrictions, the occurrence of complex and dynamic processes of convergence, or divergence,

2. See also Ferreira (2000), Chaves (2003), Santos and Carvalho (2007), Abitante (2007), Trompieri Neto, Castelar and Linhares (2008), Veloso, Villela and Giambiagi (2008), Costa (2009), Cangussu, Salvato and Nakabashi (2010). Vergolino, Nunes Neto and Barros (2004), and Cravo and Resende (2013), confirmed conditional convergence between micro-regions, and de Vreyer and Spielvogel (2005), and Kroth and Dias (2006), between municipalities.

3. The growth rate of 78% of the 118 countries analyzed by Quah (1993b), from 1962 to 1973, was higher than in the period from 1974 and 1985; but the income variability in 72% of these countries increased significantly overtime.

Quah (1993b; 1996) models the dynamics of relative distributions of economies, by their per capita income, as a Markov process, through the calculation of mobility matrices.

Applying the methodology of Quah (1993b), Magalhães and Miranda (2009) find an ergodic process of convergence, from 1970 to 2000, resulting in two clubs of municipalities, in which the rich club will be formed mainly by municipalities from the South, Midwest and Southeast of Brazil, with per capita incomes reaching two to three times the average of the poor club, formed mainly by municipalities from the North and Northeast of Brazil. Ferreira (1998) and Penna and Linhares (2013) show a polarization into two clubs of states, ranked by GDP per capita, from 1970 to 1995, and 1970 to 2008, respectively; and Mossi et al. (2003), from 1939 to 1998, with per capita income. Pôrto Júnior and Ribeiro (2000) reveal a more egalitarian process, for a shorter period, from 1985 to 1998, in which the states converge to three clubs of per capita income, and 52% of the states concentrate in the middle-income club. Magalhães et al. (2013) reveal changes in dynamics between inter-censitarian periods: while the dynamic from 1970 to 1991 forms clubs, the ergodic distribution in the following period, from 1991 to 2000, shows a displacement to intermediate classes of income. This ergodic trend is strengthened in the following decade, from 2000 to 2010.[4]

2.1 Williamson's curve: from divergence to convergence

Based on an extensive analysis of long-term data-sets from several countries, Williamson (1965) presented empirical evidences of long-term relations, shaped in the form of an inverted U curve, between the achieved level of the national per capita GDP and the country's regional inequalities, for many developed countries. These dynamics have also been confirmed by recent works, such as: Kim (1998), for U.S. data from 1840 to 1987; Tirado, Díez-Minguela and Martinez-Galarraga (2016) for Spain, from 1860 to 2010, with inequality peaking in 1930, and falling until the 80s; and Barrios and Strobl (2005), for the countries of the European Union, from 1975 to 2000.

Williamson (1965) develops a thesis of the factors that stimulates the industrialization and acceleration of national economic growth in a territorially heterogeneous way. At the initial levels of development, high migration costs, in relation to per capita income, stimulate an adverse selection process, in which the majority of migrants are young, entrepreneurial, more qualified and skilled, and move from the stagnant regions to the most dynamic region of the country. This flow of human capital increases the productivity differential between the regions, which follows the theoretical

4. See also Gondim, Barreto and Carvalho (2007), Laurini, Andrade and Pereira (2003).

hypotheses of the cumulative causation effects of Myrdal (1957) and Hirschman's polarization (1958), was confirmed by several empirical works, such as Eckaus (1961) and Dziewonski (1962).

The existence of few interregional transport links also delays technological, social and income multipliers for backward regions.[5] The region in which the industrialization process begins absorbs capital from the stagnant regions, which seek the benefits generated by the agglomeration of projects. High risk premiums, resulting from an immature capital market, discourage capital flows to regions with low capital stocks, even if we assume decreasing marginal capital productivity returns.[6] Federal national development policies also tend to focus on the regions with higher industrial growths, responding to urgent demands for capital-intensive public investments, and implementing tariff policies to protect the national industry. Das and Barua (1996) show that regional inequality increased in India between 1970 and 1992, and that national, industrial and trade growth policies were implemented without concerns about adverse regional impacts. Tafenau and Paas (2010) show that while spatial inequalities and economic growth were negatively correlated in the already developed countries of Western Europe, in the least developed countries of Eastern Europe, spatial inequalities were generally higher in periods and countries with highest economic growths. These dynamics can fit the Williamson (1965) thesis if we admit that India, and the least developed countries of Eastern Europe, were, during the periods of these analyzes, beginning their industrial development processes.

Williamson (1965) argues that the factors that stimulated regional divergence change with national economic development, and from an uncertain level of GDP per capita, they start to stimulate regional convergence. The development and capillarization of the transport system enables the migration of less skilled workers, who had not been able to migrate previously, and offer opportunities to skilled workers in starting projects in delayed regions.[7] In addition to the neoclassical prediction of convergence in wages in the absence of high migratory costs, theories of spatial balance, which allow different types of capital, work, preferences and amenities of cities, such as in Roback (1982), generate a tendency to the convergence of real wages and total utility, which includes the amenities offered by cities.

5. Hirschman (1958) and Friedman (1959) show that the larger, and more productive the agricultural area in the dynamic region is, the more isolated will stay the delayed regions.

6. Lasuén (1962) shows how the immature development of financial institutions generated perverse flows of capital in Spain. Evidence of perverse interregional flows of private capital was also observed in several underdeveloped nations in Europe at that time, and in countries such as Pakistan and Indonesia.

7. See Lebergott (1964) and Goreux (1956).

Advances in national infrastructure, and in the telecommunications, also stimulate regional trade and production factors flows, and technological overflows across the country. The development and capillarization of the capital market reduces risk premiums and facilitates investments in the poorest regions. The beginning of industrialization in delayed regions, even at slow rates, marginally reduces agglomeration's externalities of the projects in the rich region, which overlapped the higher marginal productivity of capital in regions with lower capital stocks.

Long-term economic growth stimulates socio-political development. High levels of regional inequality also pose a political problem. With democratic development, strong pressures arise for central policies to be geographically egalitarian, and concerned about national disintegration. Pressures for the establishment of more progressive tax systems and transfers to low-income populations induce income's transfers to poorer regions.

2.2 The return to divergence

Since the end of the 1980s, the downward trend in spatial inequalities has begun to cease, or reverse, in some developed nations. Petrakos, Rodriguez-Pose and Rovolis (2005), with data from the regions of France, Great Britain, Italy, Portugal, Spain, Belgium, Greece and the Netherlands, from 1981 to 1997, find increases in spatial inequalities in the regions with highest per capita GDP growth rates. Janikas and Rey (2005) find a positive relationship between spatial inequality in the U.S. and income level, from 1969 to 2000. Kemeny and Storper (2020) analyzed U.S. data, from 1860 to 2017, and confirm the end of a long period convergence in per capita income and in the quality of life in the U.S., and a return to divergence in the end of the 1980s.

For Kemeny and Storper (2020) this inflexion point, from convergence to divergence, results from the beginning of the third industrial revolution with regionally concentrated development of technologies. They show increases in real income differentials between U.S. regions due to large increases in real wages received by highly skilled workers, coupled with migrations of these workers to the most technologically developed cities and regions in the country. Several studies had already identified processes of concentration of skilled workers in large urban centers. Glaeser, Scheinkman and Shleifer (1995) reveal that the growth rate of income and population in the American cities are positively related to the initial level of education of their inhabitants. Kemeny and Storper (2020) argue that major technological shocks initially regionally concentrate wealth to deconcentrate it in the long run, drawing a dynamic wave of regional inequality.

3 METHODOLOGY

Regional inequalities can be measured by a variety of exploratory analytical instruments.[8] This work calculates four nonparametric indices of inequality, *Gini*, *Theil*, *variation*, and *variation of the average log*, amongst per capita GDP in Brazilians municipalities, for each year between 1920 through 2016, and amongst per capita GDP in the 26 Brazilians' states and the Federal District, between 1937 through 2017. The resulting time series of coefficients are presented graphically. This method can describe possible inflexions in long-term trends, from divergence to convergence, or vice versa, and nonlinear dynamics of spatial inequality.

Calculus for different territorial scales show if the results are robust to changings in scales. We also group the municipalities under their macro-regions, to search for differences in the dynamics of spatial inequalities amongst the five Brazilians macro-regions: North, Northeast, Center-west, Southeast and South.

The standard deviation of regional per capita GDP *(y)* is defined as:

$$\sigma = \sqrt{\frac{1}{T-1}\sum_{i}(y_i - \mu)^2}, \tag{1}$$

where T is the number of spatial units; y_i is the per capita GDP of the region *i;* and μ is the arithmetic average of regional per capita GDP. This index is calculated after the transformation of the data to a logarithmic scale to reveal proportional variations, which would be slightly perceived on a natural scale. Therefore, this makes it efficient to show information of variations, both from the tail and from the middle of the curves. This transformation is discussed by Barro and Sala-I-Martin (1995). Ceteris paribus, the lower the standard deviation, the more egalitarian the distribution of wealth will be.

As pointed out by Shankar and Shah (2003), the *coefficient of variation (CV)* is one of the most used measures of regional inequality in the literature, being a measure of dispersion around the average. The *CV* of regional per capita GDP *(y)* is obtained by the ratio between its standard deviation and its arithmetic mean *(μ):*

$$CV = \frac{\sqrt{\frac{1}{T-1}\sum_i(y_i - \mu)^2}}{\mu}, \tag{2}$$

8. Yamamoto (2008) describes several instruments of testing dispersions, for Data from the United States.

where *T* is the number of space units analyzed. Ceteris paribus, the lower the coefficient of variation, the more egalitarian the distribution of wealth will be.

The *Theil index* (1967), is calculated as follows:

$$T = \sum_i x_i \log\left(\frac{x_i}{q_i}\right), \quad (3)$$

where x_i is the share in GDP of the region *i* and q_i is the portion of the population of the region *i.* If the distribution is perfectly egalitarian, the Theil index will be equal to 0 – in this case, there is an equality between all regionals GDP, that is, the regional GDP is proportional to its respective population. At the opposite end, the natural logarithm of the number of observations represents absolute concentration. The main disadvantage of the Theil index is that its values are not always comparable between different units, for example, between nations. If the number and size of the groups are different, then the index limits will also be different. On the other hand, the index places few demands on the data and can add a lot of information about inequality when approaching different scales of aggregation of the data.

Commonly used to calculate inequalities in income distributions, the Gini index can be used for any distribution of data and, according to Kakwani (1980), is calculated as follows:

$$G = \left(\frac{1}{2\mu}\right)\frac{1}{n(n-1)}\sum_i^n \sum_j^n |y_i - y_j|, \quad (4)$$

where y_i and y_j are the per capita GDP of regions *i* and *j,* respectively, and μ *is* the arithmetic mean per capita GDP regions. *G* varies between perfect equity (= 0) and perfect inequality (= 1), and is thus an arithmetic mean of n(n - 1) differences amongst per capita GDP regions, taken as absolute values, divided by the maximum possible value of this average 2μ (Shankar and Shah, 2003). The Gini coefficient is a complete information measure. It looks at all parts of the distribution and performs direct comparisons between two populations, regardless of their sizes. In the case of this work, we can directly compare the results between different geographical scales of data.

Jenkins and van Kern (2006) created a methodology that, we use in this article, which decomposes Gini coefficient changing in its time series into effects of progressivity and leapfrogging. Changings in the Gini coefficient describe processes of absolute convergence, known as "α convergence", or divergence. The progressivity effect, also known as β convergence, describes a reduction in the Gini coefficient resulting from faster growths in poorer municipalities. The leapfrogging effect describes an increase in the Gini coefficient due to a much faster growth in one, or several, poorer municipalities to the point of overtaking wealthiest municipalities in such a striking way that increases the old gap between them.[9]

4 DATABASE

The work used national gross domestic product (GDP) – data series from 1920 to 2016, and state GDP, from 1939 to 2017, elaborated by the Brazilian Institute of Geography and Statistics (IBGE) – by the concept of market prices. These data were deflated, by the "implicit deflator of GDP", to millions of reais – R$ – of the year 2010. The work used all the municipal GDP data available for the years between 1920 through 2016. These data were elaborated by IBGE for the census years of 1920, 1940, 1950, and 1960; by the Institute for Applied Economic Research (Ipea) for the years 1970, 1975, 1980, 1985, 1996; and since 1999 they were annually elaborated by IBGE. The data from 1920 through 1996 was elaborated by the concept of cost of factors, and since 1999 they were elaborated by the concept of market prices. Since the change in concept affects the municipalities per capita GDP equally, it does not affect the Gini coefficient between them.

The Brazilian territory has been politically disaggregating from 1304 municipalities, in the year of 1920, to 5569 municipalities in 2016. In order to analyze data from areas that don't change during the period of analysis, we regroup the emancipated municipalities to their municipalities' origins, or "parents". This method was created by Reis (2011), who followed and tabulated the emancipation process of all Brazilian municipalities to construct comparable minimum areas (CMA) codes for each period of analysis. CMA are the most disaggregated geographic areas, or invariable territorial units, which can be compared between two points in time. These areas can be interpreted as municipalities with constant borders throughout the studied period. They are formed by the meeting of municipalities that together were involved in some kind of territorial modification (annexation, dismemberment or both) throughout the studied period.[10]

Since some municipalities were created by dismemberments of two or more municipalities, this regrouping delivers a smaller number of CMA than the number of municipalities that existed in the base year of the period. The further the analysis goes into the past, the smaller is the resulting

9. Available at: <https://bit.ly/3N9y0pj>.

10. The publication *Comparable minimum areas for the inter-census periods of 1872 to 2000*, by Eustaquio J. Reis (2011), describes the methodology of construction of AMC.

number of CMA, and consequently the bigger is the territorial scale.[11] So if we want to study the period from 1920 through 2016, we obtain 932 CMA, from 1,304 existing municipalities in 1920; 3,659 CMA to the period from 1970 through 2016, amongst 3,952 existing municipalities in 1970; and 5,556 CMA, to the period from 2002 through 2016, among 5,560 municipalities in 2002. Calculations of Gini coefficients among the states and among these three territorial scales, $CMA_{1920\text{-}2016}$, 3,659 $CMA_{1970\text{-}2016}$, 5,556 $CMA_{2002\text{-}2016}$, showed how variations in scales affected the dynamics in spatial inequalities.

5 RESULTS

In order to obtain time comparable municipalities per capita GDP, this work regrouped the new municipalities to their original parents, for each period of analysis. The resulting data series, called CMA, allowed the time comparable calculations of dispersions amongst municipal per capita GDP, through four statistical coefficients: Gini, Theil, variation, and variation of the average log. The coefficients are calculated for each year of available data, for three sets of time: from 1920 through 2016, from 1970 through 2016, and from 2002 through 2016.

Figure 1 presents the calculated time series of spatial inequality's coefficients, for the period from 1920 through 2016.[12] Although the four methods presented similar results, the coefficients of Gini and of the variation on the average log offered better descriptions of the inequalities' path. This, and the fact that the Gini coefficient can be decomposed into progressivity and leapfrogging effects, were the reasons we chose Gini to calculate the spatial inequalities for the other territorial scales, that will be presented in the following subsections.[13]

11. An analysis of this process can be obtained in the chapter *Political and administrative emancipation of municipalities in Brazil*, by João C R. Magalhães, (2007).

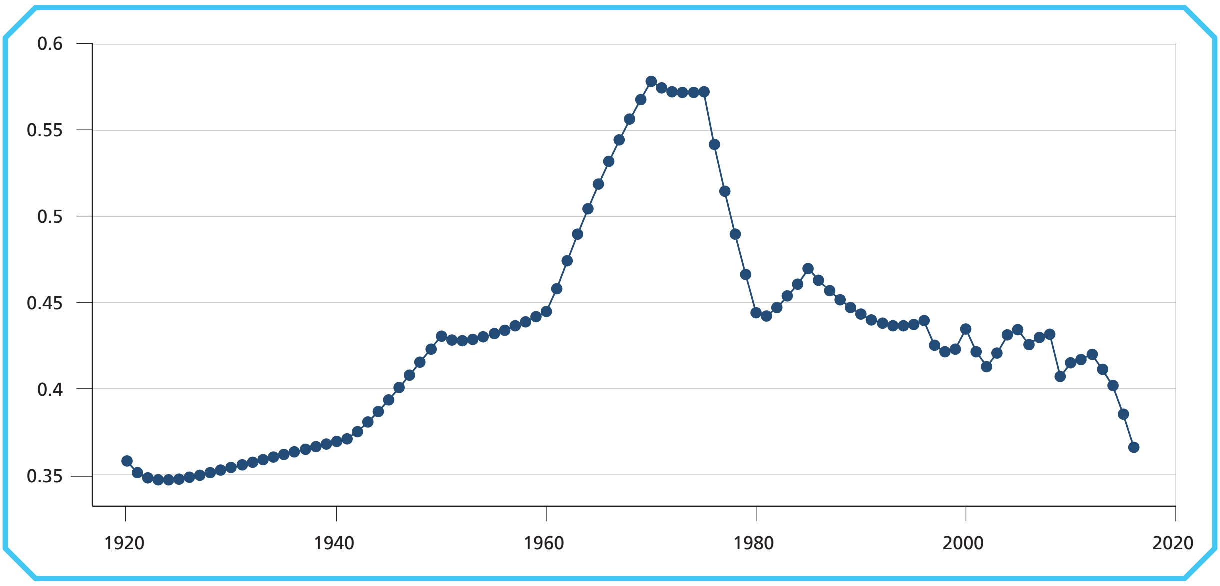
12. The coefficients for the years with missing data were estimated by exponential interpolation, to facilitate the viewing on the trends of inequality. There municipality data is available for 1920, 1940, 1950, 1960, 1970, 1975, 1980, 1985, 1996, 1999, and annualy since 1999.

13. Magalhães and Resende (2013) defend the need to calculate regional inequality at different scales, revealing that the pattern and evolution of inequality of per capita GDP, from 1970 through 2008, between municipalities, meso-regions, micro-regions and the federal states depend on the chosen territorial area.

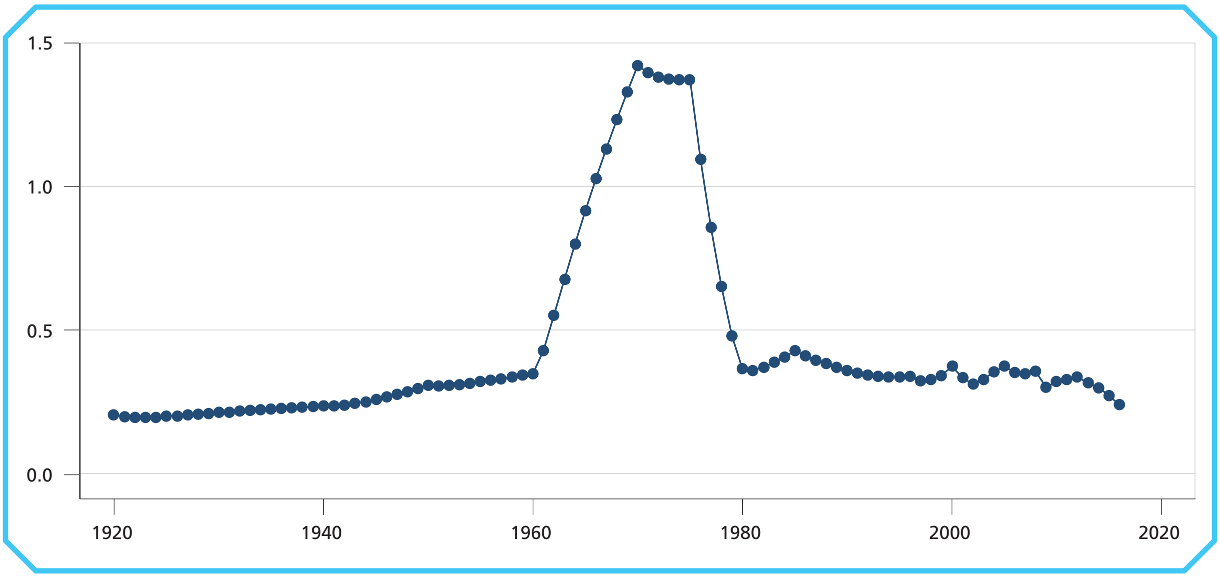
FIGURE 1

Inter-municipality per capita GDP dispersion coefficients (1920-2016)

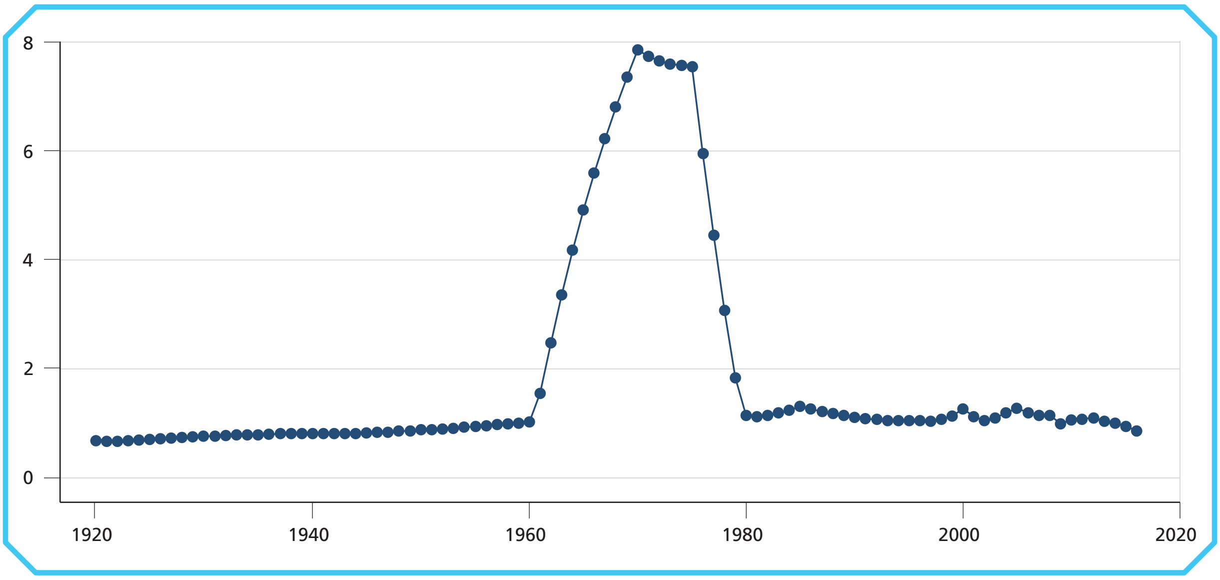
1A – Gini



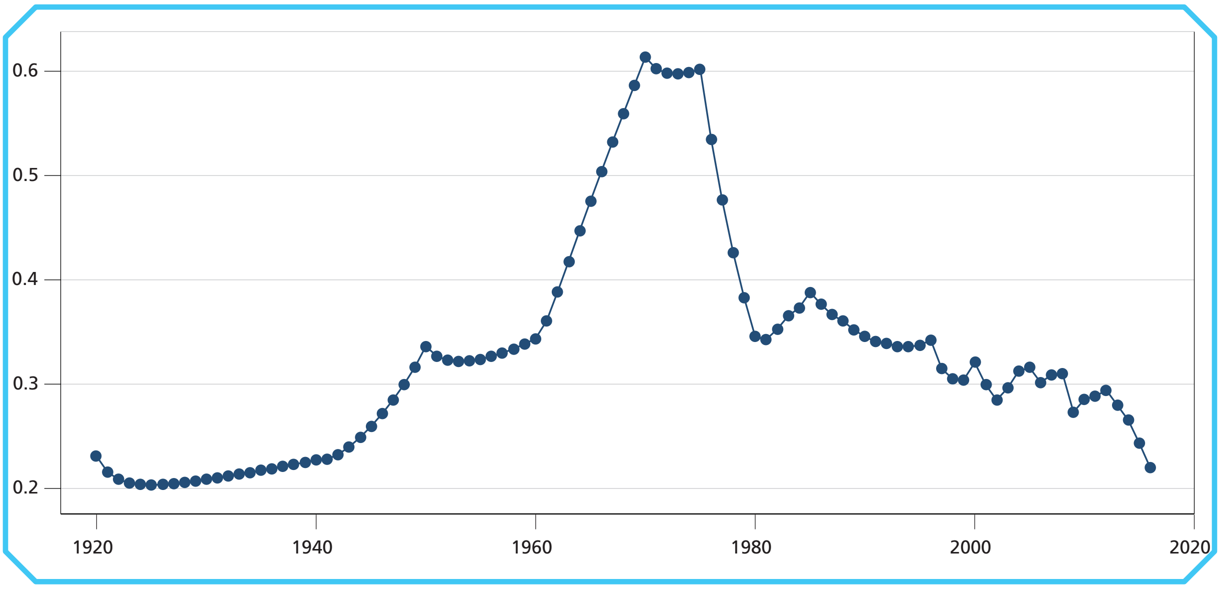
1B – Theil



1C – Coefficient of variation



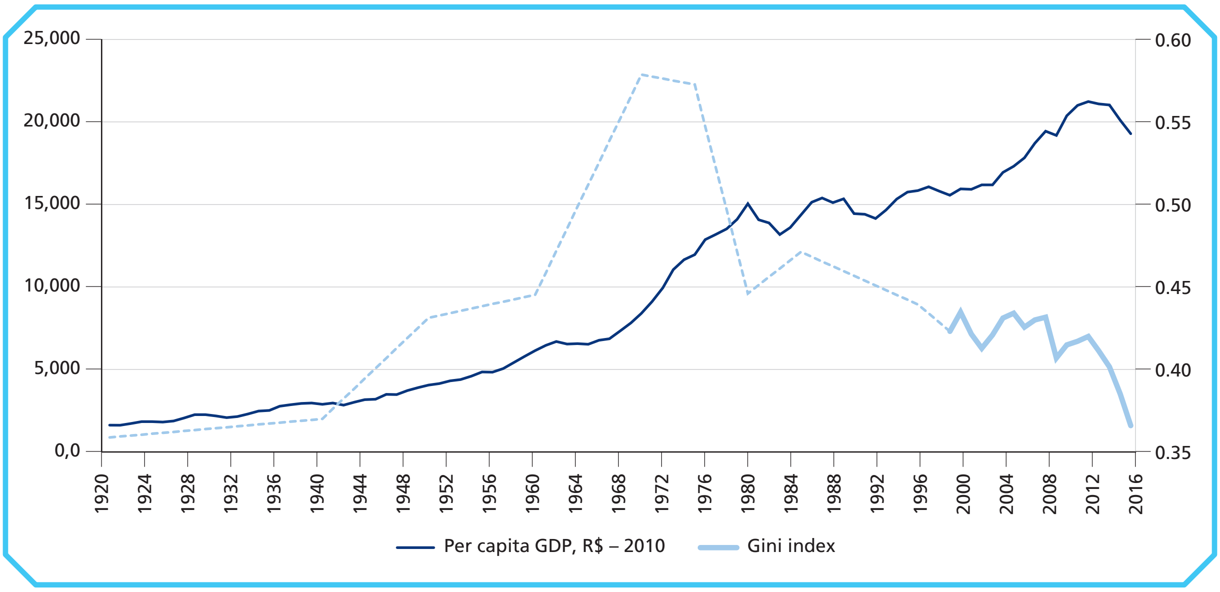
1D – Mean log deviation



Authors' elaboration.

Figure 2 graphs the $CMA_{1920\text{-}2016}$ and the level of the Brazilian per capita GDP, on reais – R$ – of December, 2010. The dashed lines in the following graphs show the periods with missing annual data. These graph shows the great increase in Brazilian regional inequality from 1920 to 1970, with huge leaps in the 40's and 60s. The spatial inequalities peak in 1970, the year when the divergence trend switches to convergence. There's a striking convergence between 1975 to 1980, a period of great economic growth, that we can see in figure 2, and in table A.1, from the appendix. With the annually availability of data since 1999, we can see how abrupt was the path of spatial inequality in Brazil. Coincidentally, the spatial inequalities level in 2016 almost returned to the level of 1920, a century before.

FIGURE 2
National per capita GDP and Gini index – $CMA_{1920-2016}$

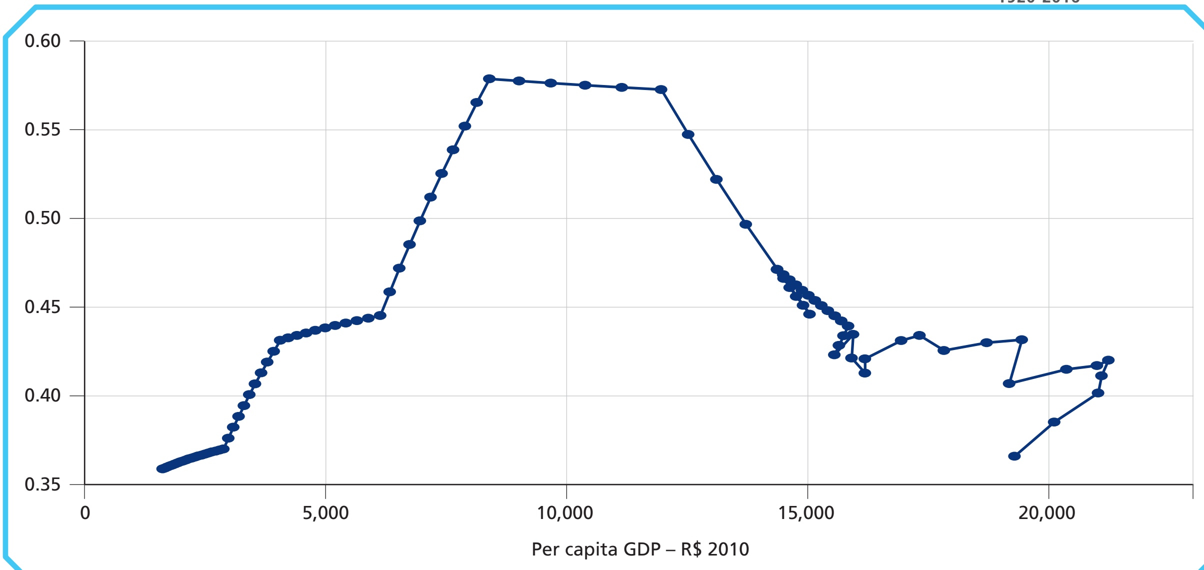


Authors' elaboration.

5.1 Williamson's curve

Figure 3 presents the relation between the national per capita GDP and the Gini index among $CMA_{1920-2016}$. This relation describes a pattern that approximates to an inverted U curve, a la Williamson (1965). This pattern changes in the last four years of the period, in which the Gini index and the national per capita GPD simultaneously fell. This was a period of a strong economic crises. The Brazilian national industrial production fell 3.2% in 2014, 8.3% in 2015, and 6.4% in 2016. This fall probably reduced more aggressively the wealth of the richest and most industrialized municipalities.

FIGURE 3
Relation between national per capita GDP and Gini coefficient – CMA$_{1920-2016}$



Authors' elaboration.

The Brazilian experience confirmed Williamson's predictions. The beginning of the national industrialization process was concentrated in one region of the national territory, the Southeast, which had the biggest population of the country, and consequently, the biggest consumption and production markets. The whole national production of coffee was done in the southeast. Brazil has been the first world producer of coffee since 1840, and it's exports accounted for almost 70% of the total Brazilian's exports, in the end of the nineteenth century and beginning the twentieth century.

The production of coffee stimulated the development and industrialization of the southeast. Its intensive labor nature stimulated the textile industry and ancillary agricultural production to the consumption of their workers; demanded skilled labors from other regions of the country; and distributed income, since the coffee was produced in small and medium farms, differently from the nowadays plantation methods of soy. The coffee production also stimulated the industrialization process with the demand for basic steel equipment's and machineries for the processing of the beans, and the financial markets, with the monetization of the commercial production process: many merchants became the bankers. Merchants would finance the farmers by buying the coffee on the sheet, to collect them on future. This financing would facilitate the farmers to buy machinery and to invest in other activities, between the cycles of the coffee's production activity, and as Williamson (1965) predicted, also absorbed capital from the stagnant regions of Brazil.[14]

14. See Magalhães (1968) and Merrick and Graham (1979).

The concentration of national production in the southeast was strengthened by federal development policies. Capital-intensive federal investments were bigger in the southeast, responding to demands from its industrialization, and strong import barriers and tariff policies to protect the national industry, a policy known as "import substitution", were implemented.

The reach of huge regional disparities levels, in the 60's, became political unsustainable, leading the federal government to create the Superintendence for the Development of the Northeast – Sudene –, in 1959, and the Superintendence for the Development of the Amazon – Sudam –, in 1966, to develop regional policies. Together with federal public policies, the development of the national transport and telecommunication infrastructures, that reduced migration costs across the country, the capillarization of the capital market, and the changing of the Federal Capital to the center-west of the country, contributed to the development of new economic activities across the national territory and to the inflection point in 1970, marking the beginning of the regional convergence path.

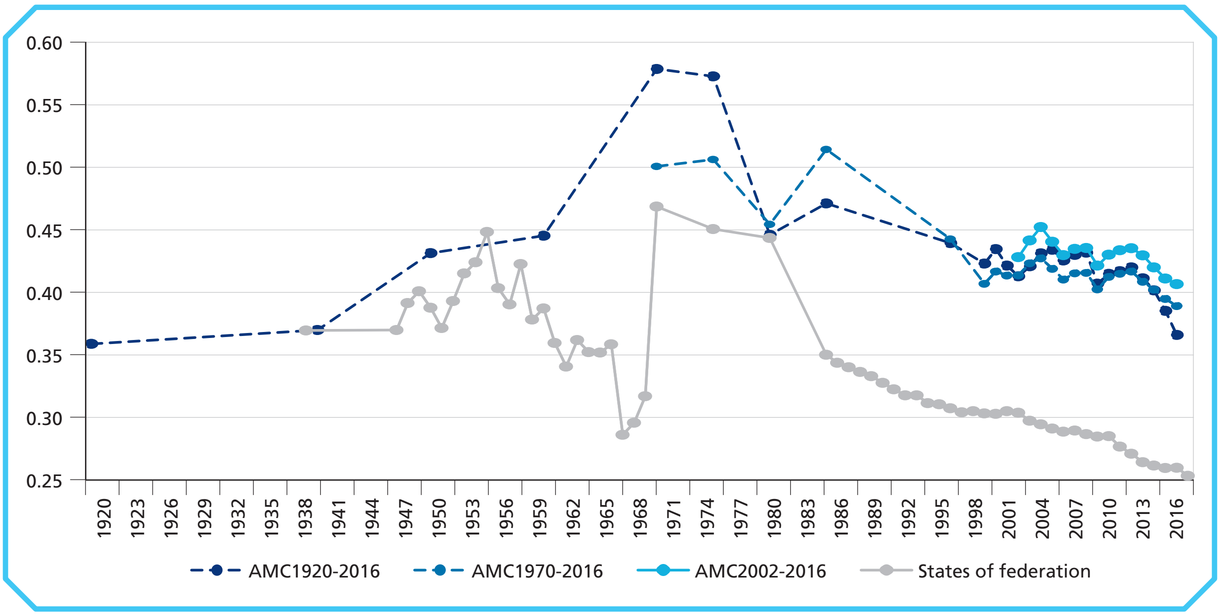
There were many economic fluctuations and political crises and policies, in Brazilian history, that affected the regional inequalities trajectory, such as the creation of Constitutional Funds for Financing the Center-west, North and Northeast, in 1989; the military regimen, from 1964 to 1984; the end of the hyperinflation in 1994, with the Real Plan; the implementation of income transfer programs, since the 90's; and the development of the agrobusiness in the Center-west of Brazil, stimulated by the availability of land, water, researches and the huge rise of the commodities international prices in Brazilian Reais. This citation of factors that affected the regional inequalities dynamics in Brazil, doesn't intend to be exhaustive or to rank the importance of these factors, and is not the focus of this article, which just aims to describe, by the calculus of robust non-parametric coefficients, the Brazilian regional inequalities dynamics in the last century.

5.2 Dependence of the spatial dynamics on territorial scales

Due to the intense and continuous dismemberment of the Brazilian municipalities, the matching of the municipalities into CMA for each time series results into time-specifics cuts of the national territory: 952 $CMA_{1920\text{-}2016}$, 3659 $CMA_{1970\text{-}2016}$, and 5556 $CMA_{2002\text{-}2016}$. Figure 4 presents the Gini index series for those three territorial scales, and for the 26 Brazilian federation states and the Federal District. This graph reveals that changes in scales affects, but not significantly, the spatial inequalities dynamics. One of the major changings occurs in the inequalities' peak year: 1970 for the states and $CMA_{1920\text{-}2016}$ series, and 1985 for the $CMA_{1970\text{-}2016}$. The availability of annual data for the states revealed unsettled dynamics between 1970 through 1995, that can't be seen in the $CMA_{1920\text{-}2016}$ series. All the series patterns approximate to an inverted U curve, a la Williamson (1965).

It is noteworthy that the value of the Gini coefficient of the end of the state data series, in 2016, is much lower than that of the beginning of the series in 1939, while the Gini coefficients among the CMAs, which also capture the dynamics of inequality within the states of the federation, are similar in 1940 and 2016. This difference can be explained by the occurrence of processes of economic growth territorially more concentrated in the poorest states of the federation, an assumption that deserves deeper analysis for each state of the Brazilian federation. Resende (2011) reveals the occurrence of a nonparametric ergodic process of formation of two income clubs from 1991 to 2000, in which the dispersion *of per capita income* falls in the club of the rich regions, but increases in the club of the poor regions, in all spatial scales evaluated.

FIGURE 4
Gini index (1920-2016)



Authors' elaboration.

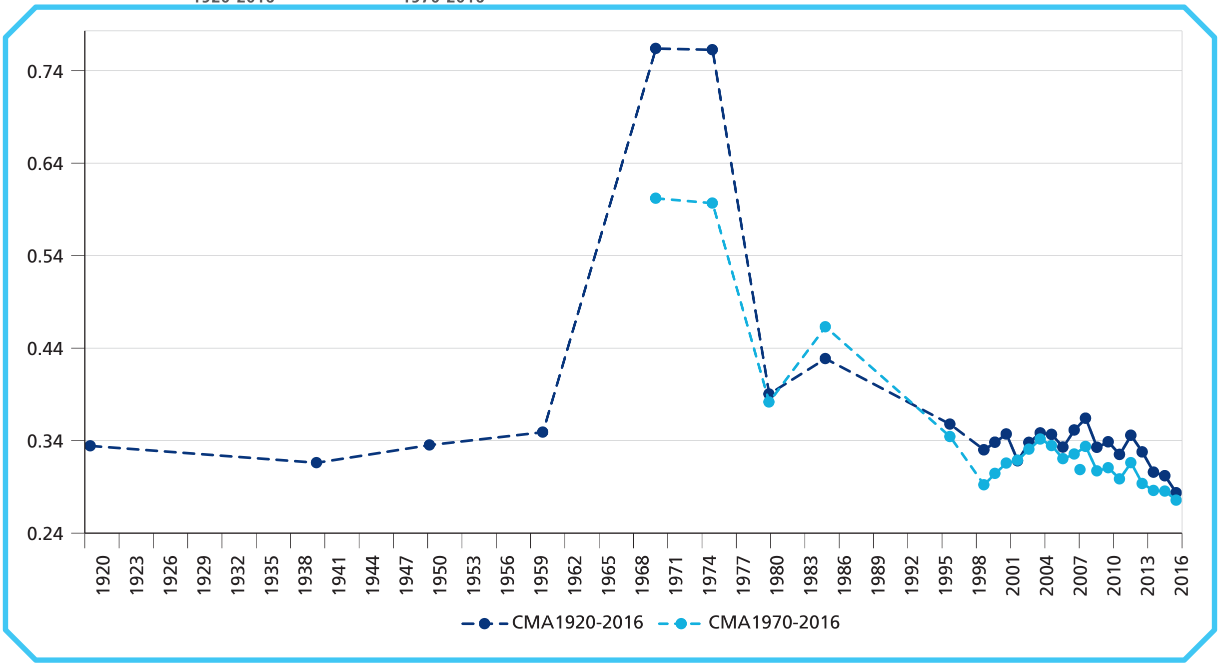
5.3 Spatial inequalities in Brazilians' macro-regions

The Brazilian territory is divided by the following five macro-regions: North, Northeast, Center-west, Southeast and South. The majority of the Brazilians' $CMA_{1920-2016}$, 83%, are located in the Southeast and Northeast of Brazil.

Figures 5 and 6 show that the Northeast, 41% of the $CMA_{1920-2016}$, had the greatest influence on the Brazilian path of spatial inequalities, descripted in figures 1 and 2. This influence was also caused by the radical northeastern' dynamic of the spatial inequalities, which reached a *Gini* of 0.764 in 1970, and 0.762 in 1975.

FIGURE 5

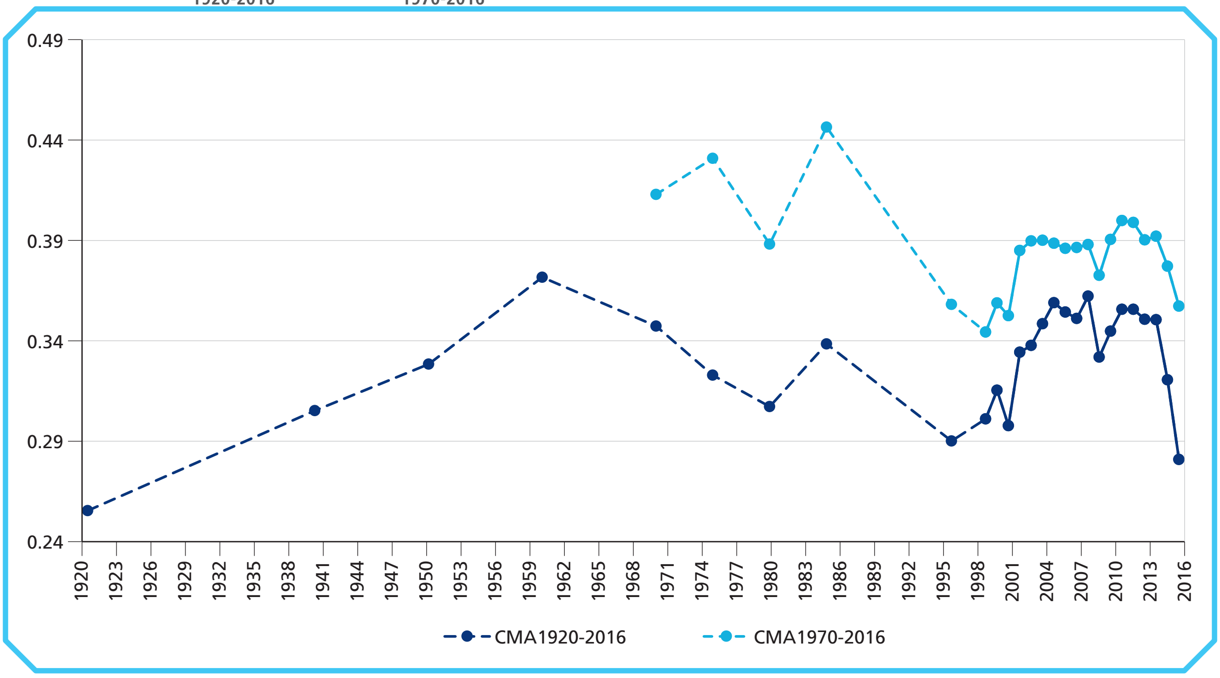
Gini $CMA_{1920-2016}$ and $CMA_{1970-2016}$ – Northeast



Authors' elaboration.

FIGURE 6

Gini $CMA_{1920-2016}$ and $CMA_{1970-2016}$ – Southeast



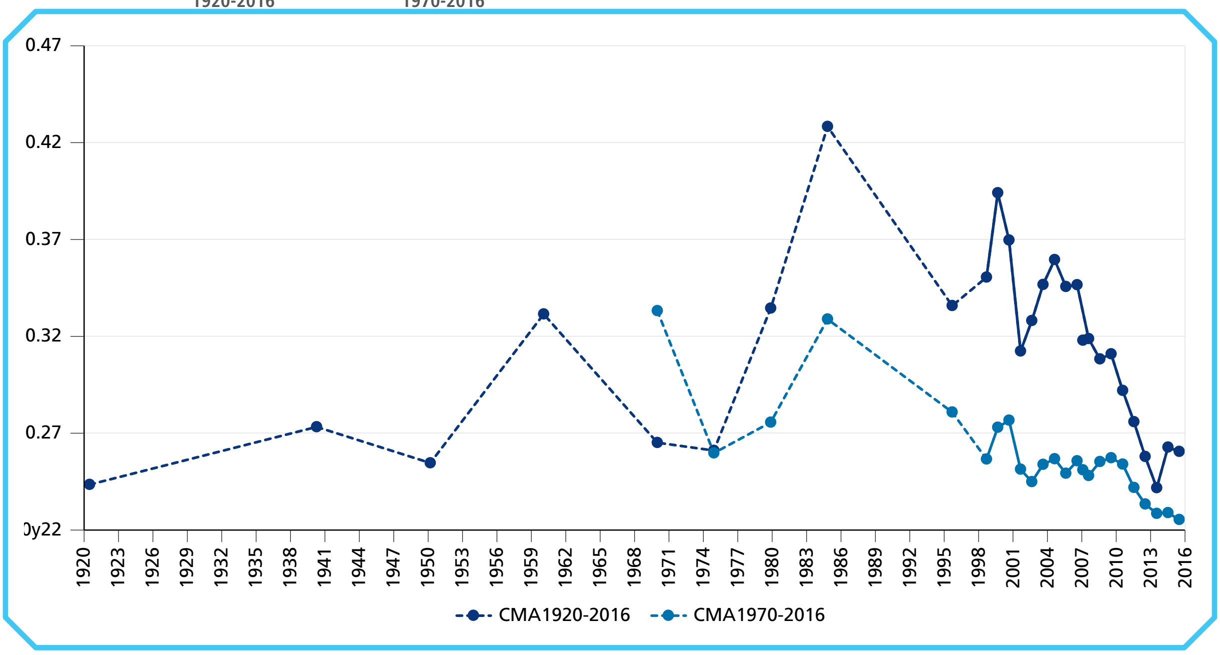
Authors' elaboration.

The spatial inequality dynamics in the southeast was quite different: it increased from 1920 to 1960, fell between 1960 through 1996, and grew again from 1996. This inequality peaked in 2008, and only returned to fall since 2014, with the occurrence of a great economic depression, from 2012 to 2016.

The switch to spatial divergence in the southeast since 1996 is worrisome and deserves future researches. This growth may result from the beginning of the process appointed by Kemeny and Storper (2020) as the “third industrial revolution”, which significantly increased the salaries of highly skilled workers in the U.S., and stimulated strong migrations of this profile of workers to the most developed urban centers in the country. Similar processes of spatial divergence have also been occurring in other highly developed countries.

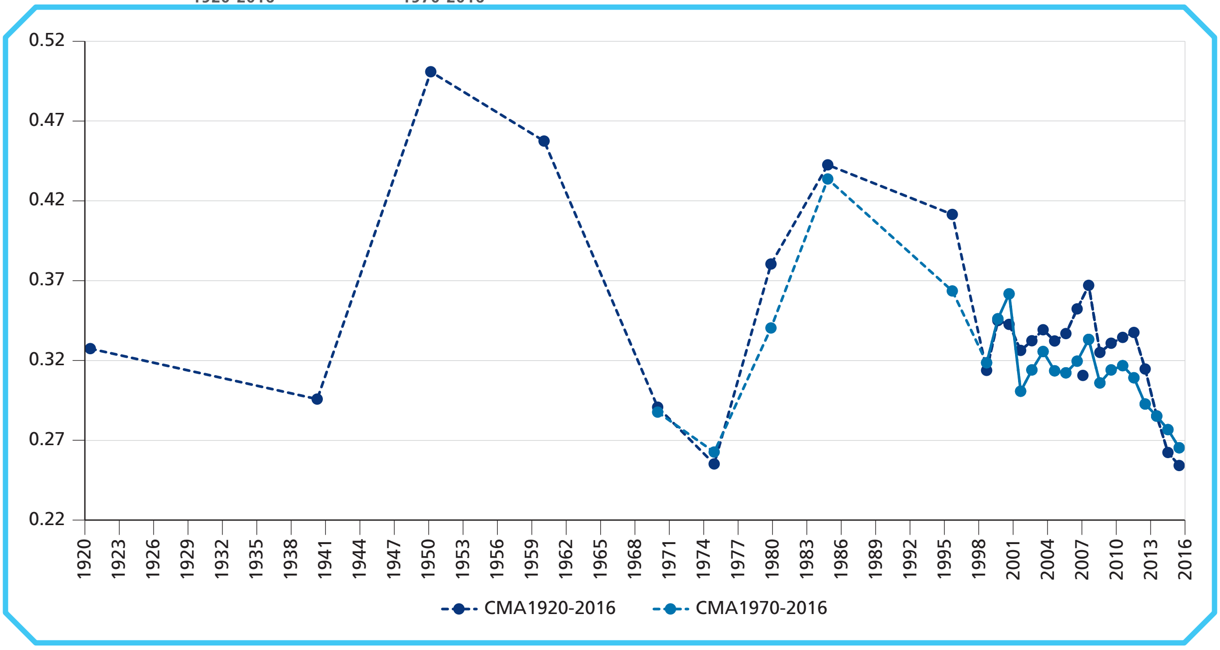
FIGURE 7

Gini CMA$_{1920-2016}$ and CMA$_{1970-2016}$ – South



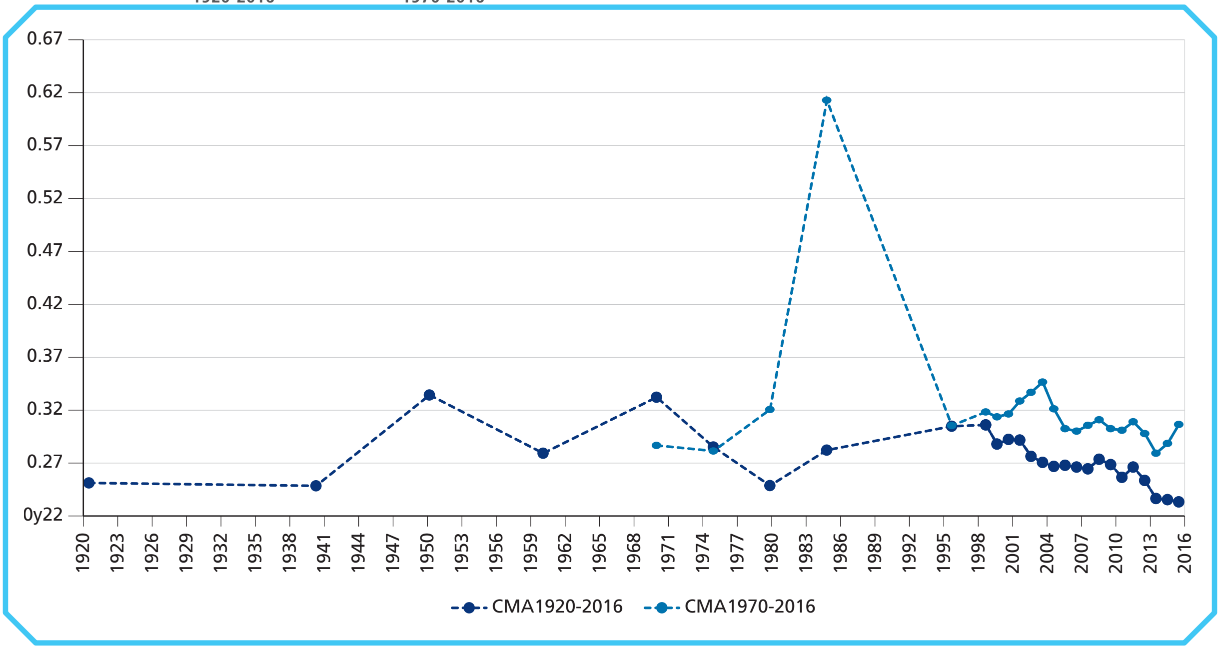
Authors’ elaboration.

FIGURE 8
Gini $CMA_{1920\text{-}2016}$ and $CMA_{1970\text{-}2016}$ – North



Authors' elaboration.

FIGURE 9
Gini $CMA_{1920\text{-}2016}$ and $CMA_{1970\text{-}2016}$ – Centerwest



Authors' elaboration.

Although distinct, the dynamics in the South, North and Center-West had small impact on the national spatial inequalities' dynamics, since their $CMA_{1920-2016}$ represent only 8%, 5.2%, and 3.7%, respectively, of the Brazilians' $CMA_{1920-2016}$.

The southern spatial inequality's dynamics approaches an inverted U-shape, with a peak in 1985. The convergence dynamics in the South region is confirmed by the more disagregated territorial scale, $CMA_{1970-2016}$, with a softer path, figure 7. Spatial inequality in North begins and ends the period with low levels, but describes a distinct path to the rest of Brazil: it's low in 1970 and 1975, and its peaks occurs in years where the Brazilian spatial inequalities weren't the highest. The worrying switch to divergence, that happened in the Southeast from 1996 through 2008, is also seen in the North, from 1999 through 2008, but is less evident in the $CMA_{1970-2016}$ spatial scale. The Center-west dynamics is closer to the National dynamics, with two peaks of spatial inequality: in 1950 and 1970. In a more disagregated territorial scale, $CMA_{1970-2016}$, we can see a huge inequality peak in 1985, followed by convergence until 1996. Coincidentally, the Center-West also passed through a divergence path, from 1996 to 2004, resemblying the path of the Southeast, already mencioned.

5.4 Decomposition of the Gini coefficient in leapfrogging and progressivity effects

Jenkins and Van Kerm (2006) developed a method of decomposing the Gini coefficient, into progressivity and leapfrogging effects, that was used in this work and is presented in this section. Faster growths on poorer municipalities per capita GDP that don't surpass the richer ones, and consequently reduces the Gini coefficient, are called *progressivity* effects, a process also recognized as β-convergence. The *leapfrogging* effects increase the Gini, which imply increased dispersion, α-divergence, with mobilities in the relative positions of municipalities, due to accelerated per capita GDP growths of poorer municipalities that surpasses the per capita GDP of richer municipalities. This convergence estimator has the advantage of being non-parametric and not relying on regression's estimates or on a linear growth process, as demonstrated by O'Neill and van Kerm (2008). The inference of estimates is based on resampling techniques using *jackknife*.

The Gini decomposition, presented in table 1, reveals that the 22 points increase in Gini, from 1920 to 1970, resulted from intense leapfrogging movements, that would increase Gini by 61.10 points, with hadn't also occurred intense progressivity's movements, that reduced *Gini* by 39.10. This shows how intense was the movement in the relative positions of wealth among Brazilian municipalities.

TABLE 1

Gini CMA$_{1920\text{-}2016}$ per capita GDP, decomposition in leapfrogging and progressivity effects

Periods	Initial Gini	Final Gini	Difference α	Leapfrogging effect	Progressivity effect – β
Big periods					
1920-2016	35,90	36,60	0,72	17,00***	-16,30***
1920-1970	35,90	57,90	22,00	61,10	-39,10
1970-2016	57,90	36,60	-21,30	9,84***	-31,10*
1970-2013	57,90	41,10	-16,70	14,90***	-31,60*
1980-2016	44,60	36,60	-8,01***	7,72***	-15,70***
1920-1980	35,90	44,60	8,73***	17,60***	-8,84***
Between decades					
1920-1940	35,90	37,00	1,12	8,99***	-7,87***
1940-1950	37,00	43,10	6,13***	6,45***	-0,32
1950-1960	43,10	44,50	1,39	4,94***	-3,55***
1960-1970	44,50	57,90	13,30	55,50	-42,10
1970-1980	57,90	44,60	-13,30	5,25***	-18,50
1980-1996	44,60	43,90	-0,67	5,67***	-6,34***
1996-2000	43,90	43,50	-0,47	4,52***	-4,99***
2000-2010	43,50	41,50	-1,98	3,08***	-5,06***
2010-2016	41,50	36,60	-4,89**	2,03**	-6,93***
2013-2016	41,10	36,60	-4,53***	1,50***	-6,03***

Authors' elaboration.

Obs.: 1. N = 951. *** probability less than 1% ** probability less than 5% * probability less than 10%.

2. The values in the table are percentage changes of the Gini coefficients of the initial period. The Gini coefficients are weighted in convention of the poorest CMA, i.e., estimated with v = 2. The values are calculated using the Stata DSGINIDECO program (Jenkins and van Kerm, 2009). The actual Gini coefficients are made using jackknife.

The second half of the analyzed period, from 1970 to 2016, presented a great reduction on the leapfrogging effect to 9.84 points, that explained the inflection point in 1970, switching spatial divergence to convergence, since the progressivity effects maintained high impacts of the Gini coefficient: 31.10 points. In the estimates between decades, the weak progressivity between 1940 and 1950, and the big mobility movements in the 60s stand out.

6 CONCLUSIONS

This work calculated coefficients of inequality, by four statistical methods, *Theil*, *Gini, variation* and *variation of the average log*, amongst municipalities per capita GDP, from 1920 through 2016, and amongst states of the federation per capita GDP, from 1939 through 2016, for each year of these periods.

One of the main contributions of this paper, the estimation of spatial inequalities for long-term series, with highly disaggregated territorial scales, was made possible by the regrouping of municipalities that were dismembered, into time comparable minimum ar. Since municipalities there were created by the dismemberment of two or more municipalities have to be all grouped together into a single CMA, this process reduces from 1304 existing municipalities in 1920, to 952 $CMA_{1920\text{-}2016}$; from 3,952 existing municipalities, in 1970, to 3,659 $CMA_{1970\text{-}2016;}$ and from 5,560 municipalities in 2002 to 5,556 $CMA_{2002\text{-}2016}$.

All the methods revealed rough and non-linear paths of spatial inequalities in Brazil. The inequalities have grown significantly since the beginning of the period, in 1920, until 1970, year when it peaks and switches to a rough convergence trend. The spatial inequalities coincidently reach a level in the last year of the series, 2016, close to the initial levels of 1920, in municipality data, and 1939, in the state of federation data.

The graphing of the relation between the spatial inequalities and the level of national per capita GDP reveled inverted U-shaped curves, confirming Williamson (1965) predictions, with the peaks of inequality occurs in 1970 for the $CMA_{1920\text{-}2016}$ and states of the federation series, and in 1985 for the $CMA_{1970\text{-}2016}$ series. Williamson (1965) shows that, although we cannot determine which is the achieved level of per capita GDP that changes the factors, from stimulating spatial divergence to begin to stimulate convergence, synergies between these factors will anticipate their switches, by the time the first factor switches, and a long-term convergence trend will set in. Williamson (1965) analyses gives an optimistic prediction that a deepening on the Brazilian economic development will accelerate its long-term convergence trend, that begun in 1970.

The decomposition of the *Gini* coefficient revealed that the huge increase in inequality, from 1920 to 1970, resulted from immense *leapfrogging* effects, meaning increases in municipalities mobilities, that overcame high *progressivity* effects, also known as "β - convergence". The spatial convergence since the 70's resulted from the decrease in the mobilities of the municipalities' position of wealth, and on the maintenance of the progressivity's effects.

Significant macro-regionals spatial inequalities were shown by *Gini* coefficients calculations. Gini among northeastern $CMA_{1920\text{-}2016}$ showed that the Northeast spatial inequalities' dynamics had the greatest impact on the Brazilian's inequality dynamics. This region had a very radical dynamic, reaching a *Gini* of 0.764 points, in 1970, and 0.762, in 1975. The paths of spatial inequality in the South and Center-west also describe, less clearly, inverted U shapes, with peaks of inequality in 1985, in the South, and in 1950 and 1970, in the Center-west. The Northern inequality is significantly distinct from the other regions, with a low level in 1970 and 1975, and high level in 1950 and 1986.

The Southern Gini path describes an inverted U curve, from 1920 to 1996, with a peak in 1960, but reveals a worrisome return of divergence since 1996. This return, which only ceases between a period of huge economic depression, from 2014 to 2016. Spatial divergence long-term trends have been returning in several developed nations, since the 80s and 90s. Kemeny and Storper (2020) show that the return of regional divergence in the U.S. resulted from the sharp increase in the salaries of highly skilled workers of high-tech sectors, who moved to the country's most developed major urban centers. This process, called by Kemeny and Storper (2020) as one of the results of the beginning of the "third industrial revolution", stimulates further analyses of Brazilian data, since it can preview the problematic return of regional divergence in Brazil.

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APPENDIX A

TABLE A.1

Gini index amongst CMA, and Brazilian per capita GDP

(In R$ 2010)

Year	Gini index									GDP
	CMA								States	Per capita (R$ 2010)
	1920-2016						1970-2016	2002-2016		
	Brazil	North	Northeast	Southeast	South	Center-West				
1920	0.359	0.327	0.334	0.255	0.243	0.251				1,624.32
...										...
1939									0.370	2,966.13
1940	0.370	0.296	0.316	0.305	0.273	0.249				2,884.38
...										...
1947									0.370	3,483.49
1948									0.392	3,725.16
1949									0.401	3,907.29
1950	0.431	0.501	0.335	0.328	0.255	0.334			0.388	4,060.34
1951									0.371	4,140.70
1952									0.393	4,316.10
1953									0.415	4,387.39
1954									0.424	4,589.91
1955									0.448	4,844.84
1956									0.403	4,835.70
1957									0.390	5,051.31
1958									0.423	5,428.48
1959									0.378	5,781.72
1960	0.445	0.457	0.349	0.372	0.331	0.279			0.387	6,136.57
1961									0.360	6,467.10
1962									0.341	6,691.78
1963									0.362	6,536.57
1964									0.352	6,564.93
1965									0.352	6,532.06
1966									0.359	6,774.93
1967									0.286	6,865.02
1968									0.296	7,333.29
1969									0.317	7,815.55
1970	0.579	0.291	0.764	0.347	0.265	0.332	0.501		0.469	8,401.79
...										...
1975	0.573	0.255	0.763	0.323	0.261	0.285	0.506		0.451	11,958.88
...										...

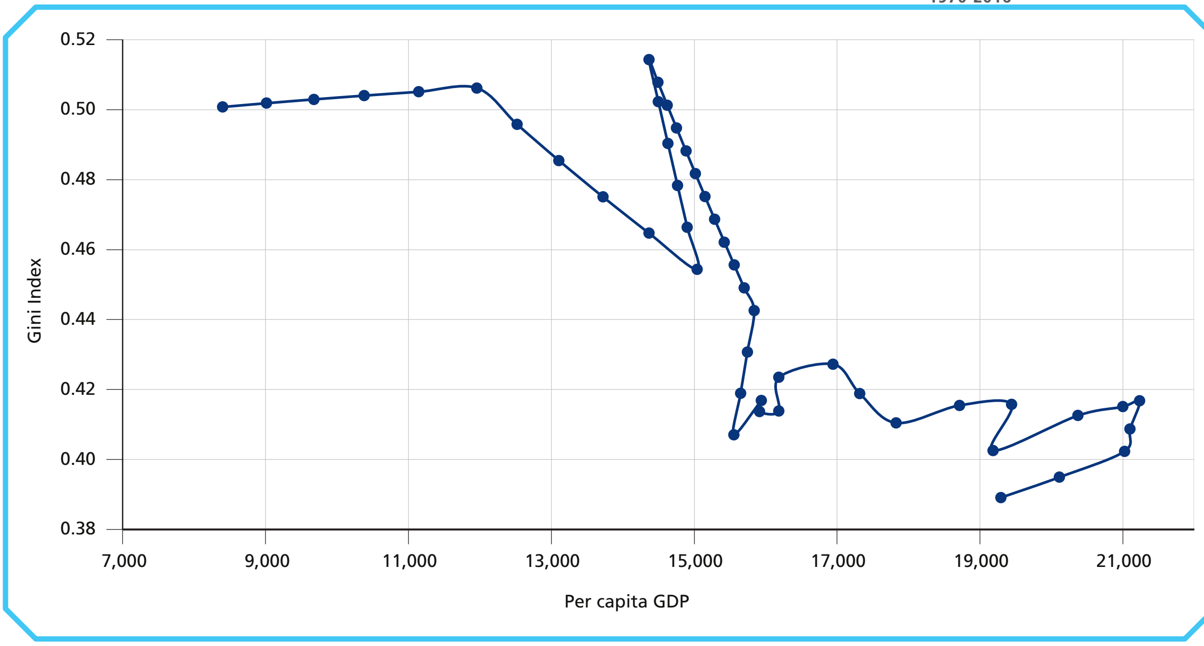
(Continues)

(Continued)

Year	Gini index									GDP
	CMA								States	Per capita (R$ 2010)
	1920-2016						1970-2016	2002-2016		
	Brazil	North	Northeast	Southeast	South	Center-West				
1980	0.446	0.380	0.390	0.307	0.334	0.249	0.454		0.443	15,040.78
...										...
1985	0.471	0.442	0.428	0.338	0.428	0.282	0.514		0.350	14,366.26
1986									0.344	15,142.36
1987									0.340	15,387.74
1988									0.336	15,111.37
1989									0.333	15,336.22
1990									0.328	14,449.67
1991									0.322	14,399.93
1992									0.318	14,144.17
1993									0.318	14,663.14
1994									0.312	15,327.40
1995									0.311	15,752.27
1996	0.439	0.412	0.358	0.290	0.336	0.305	0.443		0.307	15,839.25
1997									0.304	16,068.31
1998									0.305	15,797.15
1999	0.423	0.314	0.330	0.301	0.350	0.306	0.407		0.303	15,554.72
2000	0.435	0.345	0.338	0.315	0.394	0.288	0.417		0.303	15,941.72
2001	0.421	0.343	0.347	0.298	0.370	0.292	0.414		0.305	15,913.88
2002	0.413	0.326	0.318	0.334	0.312	0.292	0.414	0.428	0.304	16,186.17
2003	0.421	0.332	0.338	0.338	0.328	0.276	0.423	0.442	0.297	16,186.01
2004	0.431	0.339	0.348	0.349	0.347	0.271	0.427	0.452	0.295	16,943.98
2005	0.434	0.332	0.346	0.359	0.359	0.267	0.419	0.441	0.291	17,317.21
2006	0.426	0.337	0.333	0.354	0.346	0.268	0.410	0.430	0.289	17,827.55
2007	0.430	0.352	0.351	0.351	0.347	0.266	0.415	0.435	0.290	18,713.00
2008	0.432	0,367	0,364	0,362	0,319	0,265	0,416	0,436	0.287	19,441.96
2009	0.407	0.325	0.333	0.332	0.308	0.274	0.403	0.421	0.285	19,182.21
2010	0.415	0.331	0.339	0.345	0.311	0.269	0.413	0.430	0.285	20,370.79
2011	0.417	0.334	0.325	0.356	0.292	0.256	0.415	0.434	0.277	21,001.67
2012	0.420	0.338	0.346	0.356	0.276	0.266	0.417	0.435	0.271	21,236.84
2013	0.411	0.315	0.328	0.351	0.258	0.254	0.409	0.430	0.264	21,099.27
2014	0.402	0.285	0.306	0.351	0.242	0.237	0.402	0.420	0.262	21,024.07
2015	0.385	0.262	0.302	0.321	0.263	0.236	0.395	0.411	0.260	20,111.82
2016	0.366	0.254	0.283	0.281	0.260	0.233	0.389	0.407	0.260	19,293.09
2017									0.253	

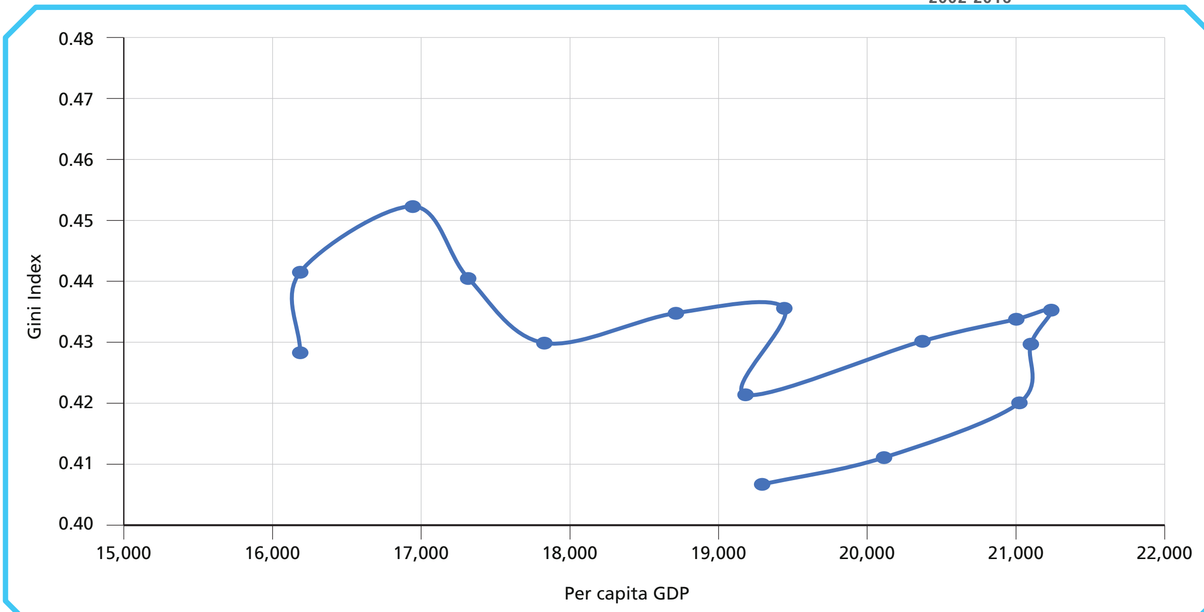
Authors' elaboration.

FIGURE A.1
Relation between national per capita GDP and Gini index – $CMA_{1970-2016}$



Authors' elaboration.

FIGURE A.2
Relation between national per capita GDP and Gini index – $CMA_{2002-2016}$



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