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Effects of income inequality on the economic growth of Brazilian states: an analysis using the cointegrated panel model

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EFFECTS OF INCOME INEQUALITY ON THE ECONOMIC GROWTH OF BRAZILIAN STATES: AN ANALYSIS USING THE COINTEGRATED PANEL MODEL

Abstract
This aim of this article is to investigate the effects of income inequality on the economic growth of Brazilian states in the period from 1994 to 2014. The transmission mechanism of the effects of income inequality on economic growth is derived from the model proposed by Halter et al. (2014). The empirical formulation adopted to achieve this goal is divided into two stages. The first stage is limited to short-term analysis, and panel data models with fixed effects, random effects, and instrumental variables are used. In the second stage, the discussion turns to the use of the error correction model for a cointegrated panel. The results suggest a significant negative correlation between income inequality and the economic growth of Brazilian states in both short-term and long-term analyses.

Keywords: Income inequality. Economic growth. Brazilian states.

JEL: C23, O4, O47

1 Introduction

Income inequality is a recurring theme in the Brazilian economy, principally with regard to studies of economic growth. This discussion gained ground in the economics literature of the 1990s with a series of studies investigating the role of income inequality in the process of economic growth. The following question always arises in this type of analysis: How does income inequality affect economic growth?

Two different approaches to this topic have been taken. The first, represented by Bertola (1991), Perotti (1992), Persson and Tabellini (1994), and Alesina and Perotti (1996), suggests the existence of mechanisms by which greater inequality harms economic growth; these include an endogenous fiscal policy, social and political instability, imperfect credit markets, and endogenous fertility rates.

Another branch of the economics literature emphasizes the beneficial effect of greater initial inequality in spurring economic growth through three channels: Kaldor's hypothesis, indivisible investment costs, and trade-offs between efficiency and equity. Stigliz (1969), Lazear and Rosen (1979), Li and Zou (1998), and Forbes (2000) are among the authors who emphasize this type of correlation.

Starting from this discussion, the present study investigates the effects of income inequality on the economic growth of different Brazilian states from 1994 to 2014. This study's main contribution is empirical because it presents stylized facts that aid in understanding the effects of income concentration on economic performance in different regions of Brazil.

Regional disparities in Brazil have always been a cause for concern and a subject of national debate, especially after the creation of the Superintendency for the Development of the Northeast (Superintendência do Desenvolvimento do Nordeste - SUDENE) in 1950. The notion of regional disparities is even more obvious when regional economic indicators are presented, such as those emphasized by Rands (2011). The numbers show that although the Northeast is home to 28% of the Brazilian population, it has a *per capita* gross domestic product (GDP) that is only 46.8% of the national *per capita* GDP, and only 35.3% of the *per capita* GDP found in the Southeast, which is the highest in the nation.[1] Other regions, such as the North and Center-West (excluding the federal district of Brasília) are also relatively poor, though their *per capita* GDPs are still higher than the Northeast.

Evidently, this discussion is not new for the Brazilian economy, and a number of studies have attempted to explore and test explanatory hypotheses for the differences in regional growth rates within Brazil, including Lledó (1996), Bagolin et al. (2004), Jacinto and Tejada (2004), Salvato et al. (2008), Kakwani et al. (2010), and Galeano (2014).

Most of these studies attempt to test Kuznets' hypothesis that there is an inverted U-shaped correlation between inequality and growth; examples are Lledó (1996), Bagolin et al. (2004), Jacinto and Tejada (2004), and Salvato et al. (2008). The first of these studies was not able to find evidence to confirm this hypothesis for Brazilian states in the 1970s or 1980s. By contrast, the other studies were able to validate the hypothesis by analyzing municipalities in the state of Rio Grande do Sul, the Northeast region, and the state of Minas Gerais after the 1980s.

Taking a different perspective, Kakwani et al. (2010) analyze the relationship between the growth of poverty in Brazil based on the performance of different sources of income, such as the labor market – hypothesizing that an improvement in employment rates contributes to economic growth – and social programs enacted during the 1990s, finding that these social policies were successful in reducing poverty.

Along the same line of investigation, Galeano (2014) examines the improvement in Brazil's macroeconomic environment since the mid-1990s and the theory of endogenous

[1] Data are from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística -IBGE) for 2008.

growth, using the Theil index and convergence analysis to demonstrate some economic deconcentration from 1985 to 2008. However, her study suggests few improvements in terms of regional economic inequality, indicating a process of convergence that is very slow and that does not take the desired form of strong, widespread growth but rather weak growth in the regions of Brazil.

The present study differs from the others in that it adapts the discussion proposed by Halter et al. (2014) to the analysis of Brazilian states. Halter et al. (2014) derive the transmission channel between income inequality and economic growth, showing a non-monotonic adjustment trajectory[2] of production that leads to a linear theoretical model of income inequality and economic growth that is similar to those used in this type of approach. However, this first step will only be able to measure the short-term effects of the income inequality on the economic growth of the Brazilian regions. Thus, to capture the long-term relationship between these terms will be used the method proposed by Frank et al. (2005). This is an inedited discussion of the relationship between growth and income inequality in Brazil.

It should be noted that the results obtained in this study are the same as those found by Halter et al 2014. The authors verified that the hypothesis of conditional convergence was valid, a result also verified by Galeano (2014) for the Brazilian case. In addition, Halter et al 2014 also encounter that schooling and the investment rate positively influenced economic growth, unlike the coefficients of political instability and income inequality that had a negative influence on growth. The only exception was the coefficient that captures the contemporary effect of income inequality. For the Brazilian case, both coefficients captured a negative effect of inequality on growth. Regarding the long term effects, the results showed that the long term effects are the same as those verified in the short term analysis, with income inequality and schooling presented negative and positive effects, respectively, on economic growth.

The remainder of this article is divided into five sections. The next section shows the recent behavior of income inequality in Brazil. It is followed by the proposed theoretical discussion of Halter et al. (2014) for expressing the relationship between economic growth and income inequality. Section 4 of the article presents the panel data method with cointegration, in addition to the database used and its limitations. Section 5 shows and discusses the principal results of the empirical strategy. Finally, the article concludes with final considerations.

2 Recent behavior of income inequality in Brazil

Brazil is composed of regions that are diverse in size and shape as well as in their development and economic growth. These peculiarities lead back to the most important questions about economic growth, namely: Why does one region grow more than others? Is there income convergence among regions? What are the determinants of regional disparities? This section presents stylized facts from the literature on economic growth that can answer some of the questions posed above.

Table 1 shows growth and development statistics for the regions of Brazil in 2010. The first column contains *per capita* GDP data for 2010, showing that the Southeast held the largest share of the national GDP, making it the wealthiest region of Brazil in 2010, with a *per capita* GDP of BRL$25.99.

[2] Non-monotonic adjustment allows for certain minimum levels of investment to be required for access to productive activity. Thus, different opportunities for production are available at different points along the income distribution.

The Center-West region showed the second highest *per capita* GDP, with a value of BRL$24.95, followed by the South, with BRL$22.72. By contrast, the North and Northeast regions fell far behind, with *per capita* GDPs of BRL$12.70 and BRL$9.56, respectively.

The second column of Table 1 shows the GDP per worker in 2010. The difference between the first two columns is the denominator: the first divides the GDP by the total population, and the second divides it by the number of workers. The employment rate, shown in the third column on Table 1, is the ratio of the work force to the total population in each region.

Table 1. Growth and development statistics for 2010 (in 2010 BRL$)

Region	GDP *Per capita* (2010 BRL$)	GDP per worker (2010 BRL$)	Employed/ Total pop. (in %)	Avg. Growth, 1994-2014 (in %)	Time to double GDP
Center-West	24.95	47.00	0.53	4.16	17
North	12.70	35.75	0.36	4.59	15
Northeast	9.56	20.90	0.46	3.58	20
South	22.72	41.73	0.54	2.97	24
Southeast	25.99	48.96	0.53	2.84	25

Source: Institute for Applied Economic Research **(**Ipea) and Brazilian Institute of Geography and Statistics (IBGE).

A comparison of the *per capita* GDPs for the North and Northeast regions in 2010, for example, reveals that although they were similar in that year, the GDP/worker ratios were much different. This result is explained by the fact that workers comprise a much larger percentage of the total population in the Northeast than in the North. Finally, the last two columns in Table 1 show economic growth in Brazil's macro-regions. The fourth column reports the mean annual rate of GDP growth between 1994 and 2014, drawn from the variation in the natural logarithm of the GDP. It can be noted that the mean annual GDP growth rate of the Southeast was only 2.84% between 1994 and 2014 whereas the Center-West, Northeast, North, and South grew at a faster rate than the Southeast, with the North registering the fastest rate of growth, a remarkable 4.59%.

With regard to the time it would take each region to double its GDP, shown by column 5 in Table 1, the Southeast's GDP would double in 25 years, whereas the North's GDP would double in approximately 15 years. In other words, if these growth rates were to persist for two generations, a citizen of the North region would be approximately 20 times richer than his or her grandparents. It is important to note, however, that growth rates can lead to significant differences in individual wealth.

It is important to emphasize that all of the data presented in Table 1 can be used as measures for comparing the development levels of states or regions; however, this article uses the *per capita* GDP as a measure of well-being. This argument is the same as that made by Jones (2000), namely, that the *per capita* GDP represents the sum of the available product, per person, that can be consumed, invested, or otherwise employed and is the most general measure of well-being. By contrast, the GDP per worker is more closely related to labor productivity.

Figure 1 shows the behavior of *per capita* GDP for the regions of Brazil between 1994 and 2014. It can be observed that the richest and poorest regions at the beginning of this period maintained their relative positions over the period, with the Southeast and Northeast appearing as the richest and poorest regions, respectively, in 1994 and in 2014. Once again, this finding contradicts the hypothesis of convergence in growth rates over this period.

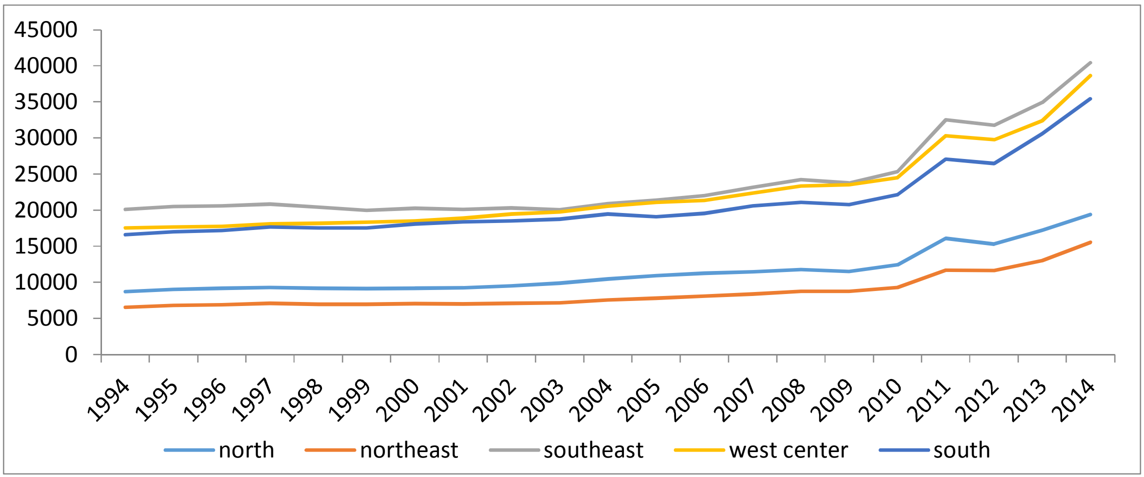

Figure 1. Behavior of *per* capita GDP in the Center-West, North, Northeast, South, and Southeast regions between 1994 and 2014.
Source: Ipea and IBGE.

Figure 2 shows the recent evolution of the gap or ratio between the richest 10% and the poorest 40% in different regions of Brazil from 1994 to 2014. During this period, the greatest reduction in the gap between the richest and the poorest was in the South, where the ratio of income between the richest 10% and the poorest 40% of the region's population declined from 18.64 in 1995 to 9.99 in 2014; this decline represents a 46.39% reduction in the gap. By contrast, the Southeast saw the smallest reduction in the rich-poor gap, at 32.88%.

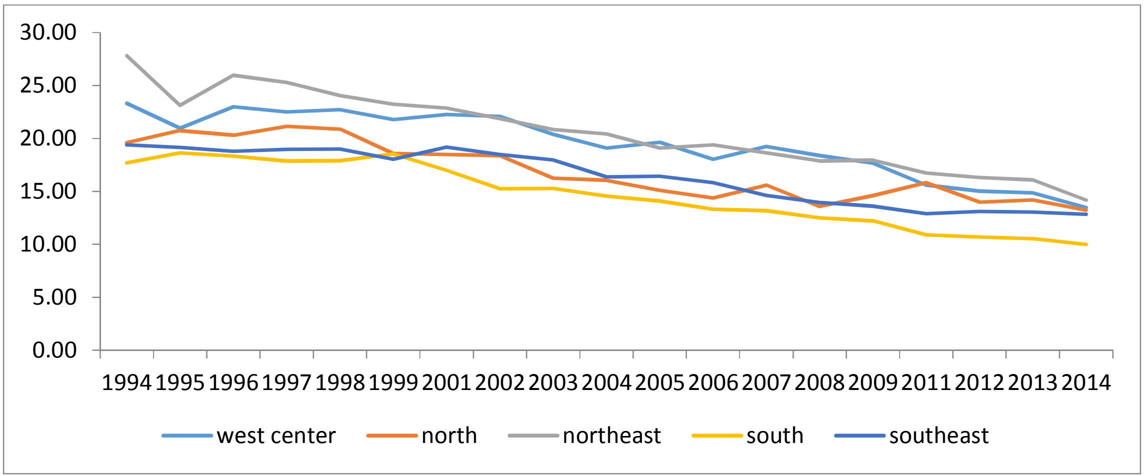

Figure 2. Ratio between the income of the richest 10% and the poorest 40% of the population
Source: Ipea and IBGE.

Table 2 also shows the behavior of income inequality on a national scale and a regional scale between 1994 and 2014, as measured by the Gini index. It is important to note that the Gini index measures the degree of income inequality among individuals, according to *per capita* household income. This index ranges from 0 to 1, with a coefficient close to 1 indicating a very unequal income distribution and a coefficient closer to 0 indicating less income concentration.

Table 2. Behavior of income inequality in the regions of Brazil from 1994 to 2014

Year-Region	Center-west	North	Northeast	South	Southeast	Brazil
1994 - 2000	0.598	0.576	0.613	0.562	0.566	0.566
2001 - 2005	0.581	0.578	0.613	0.559	0.563	0.600
2006 - 2010	0.566	0.549	0.587	0.529	0.555	0.582
2011 - 2014	0.527	0.522	0.563	0.499	0.522	0.552
Δ%(2014/1994)	-11.86%	-9.39%	-8.15%	-11.13%	-7.80%	-2.47%

Source: Ipea and IBGE.

The reduction in income inequality in Brazil shown in Figure 3 is corroborated by the analysis of the Gini index. The scenario is the same as that presented above, with a perceptible reduction in the inequality of income distribution in Brazil from 1994 to 2014 of 2.47%, which represents a reduction of 0.02 points on the Gini index. Nevertheless, with an index over 0.50 in 2014, Brazil still demonstrates a high concentration of income compared to other developing countries such as Argentina and Uruguay, where the Gini indices for 2013[3] were 0.423 and 0.419, respectively.

Following the trend of the Brazilian economy, all of the regions also showed a reduction in income inequality, though these effects were greater in the Southern region of the country. The South reduced income inequality among its population by 11% between 1994 and 2014, making it the region with the lowest concentration of income in 2014.

It is worth noting that all regions experienced a continuous downward trend in income inequality, although this trend was less pronounced in some regions than in others. Thus, after the South, the Northeast, Center-West, North, and Southeast experienced reductions in inequality of 8%, 11%, 9%, and 7%, respectively.

Nevertheless, an analysis of inequality at the end of this period, in 2014, shows that although the Southeast had the smallest decline in its income distribution gap, the Northeast, Center-West, and North are still the regions with the highest indices of income inequality in Brazil, with Gini indices of 0.563, 0.522, and 0.527, respectively.

3 Theoretical model

This section presents the discussion proposed by Halter et al. (2014) in which they seek to derive the transmission channel between income inequality and economic growth. The theoretical framework presented below permits a non-monotonic adjustment trajectory of production[4] and leads to a linear theoretical model of income inequality and economic growth that is similar to those used in this type of approach.

The model is based on an economy populated by families characterized by an infinite life horizon and aversion to risk, with this latter component represented by the discount factor $\beta < 1$. All individuals derive utility from consuming a single produced good. Thus, their preferences are represented by the following intertemporal utility function:

$$\mathcal{U}_t = \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \, c_{t+s} \right\} \tag{1}$$

where c_t denotes consumption in the period t and $\mathbb{E}_t$ is the conditional expectation operator on the information available at t. Individuals differ in their allocation of productive assets (represented, for example, by capital stock).

[3] Data are from Economic Commission for Latin America and the Caribbean (ECLAC).

[4] The idea posits minimum levels of investment required to gain access to productive activities; thus, there are different production opportunities available along the income distribution.

This economy is composed of rich and poor individuals. Poor individuals are represented by the fraction σ > ½ of the population (poor individuals are represented by P) because the majority of the population consists of wage earners and their allocation of assets takes the form $\omega^p\,(D_t) < 1$, in which 1 is the mean income in the economy.

The state variable[5] of $D_t \in \{L, H\}$ represents the degree of inequality of assets in the economy, where L signifies a low degree and H a high degree of inequality. From this segmentation arises a scenario in which the allocation of poor individuals with a low level of inequality is larger than the allocation of poor individuals with a high level of inequality, which can be described by $\omega^p(L) > \omega^p\,(H)$.

All individuals have access to a simple technology that uses the productive physical capital asset as an input factor. In formal terms, the technology is characterized by the following production function:

$$q\,(\omega, G_t) = \begin{cases} a^l\,\omega X(G_t):\ \omega < \omega^c \\ a^h \omega X(G_t):\ \omega \geq \omega^c \end{cases},\ a^l < a^h \tag{2}$$

where q is the product; $X(G_t)$ represents the level of public good provided by the government; and a^h and a^l represent high and low levels of productivity, respectively.

The supply of the public good is represented by the state variable of $G_t \in \{0,1\}$. For low levels of inequality, if the government invests in the public good, then G_t = 1; otherwise, $G_t = 0$. As a result, we have $X(1) - X(0) \equiv \Delta X > 0$.

The aggregate production of the private sector is represented as follows:

$$\mathbb{Y}\,(D_t, G_t) = (a^h - \sigma\,(a^h - a^l)\,\omega^P\,(D_t))\,X(G_t) \tag{3}$$

Note that the aggregate production is lower than its first best level, which is equal to $a^h\,X\,(G_t)$. This occurs because a positive fraction of the total stock of productive assets is used by companies with low average productivity.

To linearize the model, we impose $\omega^P\,(D_t) = 1 - D_t$, with $D_t \in \{L, H\}$ being the difference between the mean allocation and a poor individual's allocation. Next, the logarithms of both sides of equation (3) should be taken. Then, rearranging the terms, we obtain the following:

$$y_t \equiv \ln \mathbb{Y}_t = \ln\left(1 - \frac{\sigma\,(a^h - a^l)\omega^P\,(D_t)}{a^h}\right) + \ln\left(\frac{X(G_t)}{X(0)}\right) + \ln a^h + \ln X(0) \tag{4}$$

It is important to emphasize that G_t is a variable of choice that takes the value of 1 if $D_{t-1} = L$ and 0 if $D_{t-1} = H$. Thus, $X(G_t)$ can be written as $\frac{X(0) + \Delta X\,(H - D_{t-1})}{(H - L)}$. Using the expression for $X(G_t)$ and given that $\omega^P\,(D_t) = (1 - D_t)$ in equation (4), it is possible to obtain the following:

$$y_t = \ln\left(1 - \frac{\sigma\,(a^h - a^l)\omega^P(D_t)}{a^h}\right) + \ln\left(1 + \frac{\Delta X}{X(0)}\frac{H - D_{t-1}}{H - L}\right) + \ln a^h + \ln X(0) \tag{5}$$

[5] This is the smallest group of variables that determines the state of a dynamic system. If at least "n" variables $(X_1(t), X_2(t), \ldots, X_n(t))$ are necessary to completely describe the behavior of a dynamic system, then these "n" variables are a group of state variables. They describe the future response of a system, given the current state, the input stimuli, and the equations that describe the dynamic.

where $\mathcal{Y}_t$ is a non-linear function of the indicators of asset inequality D_t and D_{t-1}. Provided that the ratios $\frac{(a^h - a^l)}{a^h}$ and $\frac{\Delta X}{X(0)}$ are not very large, $\mathcal{Y}_t$ can be closely approximated by a linear function, specifically:

$$\mathcal{Y}_t \cong \theta_1 D_t + \theta_2 D_{t-1} + \mu, \tag{6}$$

where $\theta_1 \equiv \frac{\sigma\,(a^h - a^l)}{a^h}$, $\theta_2 \equiv \frac{-\Delta X}{(X(0)(H-L))}$ and μ includes all of the constant terms.[6] Note that $\theta_1 > 0$ captures inequality's short-term positive effect, whereas $\theta_2 < 0$ shows its negative lagged effect.

The theoretical discussion presented includes two channels by which asset inequality affects economic performance. However, empirical models of inequality and growth such as those by Alesina and Rodrik (1991) and Alesina and Perotti (1996), including the model estimated in section 5, generally rely on measures of income inequality, mainly due to the availability of data. In our case, the two concepts are closely related. Consider the following measure of income inequality:

$$D_t^{\mathcal{Y}} = \frac{\mathbb{Y}(D_t, G_t) - a^l\,\omega^P(D_t)\,X(G_t)}{\mathbb{Y}(D_t, G_t)} \tag{7}$$

which gives the relative difference between mean income and the poor individual's income and is therefore equivalent to the measure of asset inequality D_t. Using the functional form of $\mathbb{Y}$ given in equation (3) and given that $\omega^P\,(D_t) = 1 - D_t$, this measure of income inequality can be approximated by the following linear function such that D_t:

$$D_t^{\mathcal{Y}} = \frac{a^h - a^l}{a^h} + \frac{a^l}{a^h} D_t \tag{8}$$

The structure of equation (8) reflects the fact that income inequality is propelled by two different factors: rich individuals become richer, that is, $D_t > 0$, and rich individuals also obtain a better return on their wealth, which is shown by the constant on the right-hand side of (8). The approximation obtained in equation (8) is possible considering the fact that $\frac{a^h - a^l}{a^h}$, σ and ω^P are close to 0.

Expression (8) allows us to relate the logarithm of the current level of production, $\mathcal{Y}_t$, to the current and past levels of income inequality. Isolating D_t from equation (8) and substituting it into equation (6), we obtain the following:

$$\mathcal{Y}_t \cong \delta_1 D_t^{\mathcal{Y}} + \delta_2 D_{t-1}^{\mathcal{Y}} + v \tag{9}$$

where $\delta_1 \equiv \theta_1 \left(\frac{a^h}{a^l}\right) > 0$, $\delta_2 \equiv \theta_2 \left(\frac{a^h}{a^l}\right) < 0$, and v includes all of the constants. It is valid to note that a simple linear relationship between $D_t^{\mathcal{Y}}$ and the Gini coefficient for income distribution exists: $GINI_t^{\mathcal{Y}} \cong \sigma D_t^{\mathcal{Y}}$.

Equation (8) expresses the level of the production logarithm $\mathcal{Y}_t$ as a function of inequality. To find the standard specification used in the empirical literature, we must add a multiplicative parameter A_t into the production function that does not depend on the use of

[6] If the condition (C2) is violated, the level of the public good will never change. As a result, θ_2 will be equal to 0 (while θ_1 remains unchanged).

productive assets, represented by $A_t = (\mathbb{Y}_{t-1})^{\varphi}$, with $\varphi \in [0,1)$. Thus, the relationship between product growth and inequality is given as follows:

$$\mathcal{Y}_t - \mathcal{Y}_{t-1} \cong \gamma \mathcal{Y}_{t-1} + \delta_1 D_t^{\mathcal{Y}} + \delta_2 D_{t-1}^{\mathcal{Y}} + \eta \quad (10)$$

where $\gamma \equiv \varphi - 1 < 0$. The equation above is the basis for the empirical model that is estimated in the following section, and it is similar to the empirical models commonly used in the literature on inequality and growth. Thus, the implication is that both current and past inequality can affect growth.

4 Methodological procedures

4.1 Empirical strategy

The short- and long-term effects of inequality on growth are estimated by transforming equation (10) into a panel data model, which can be represented as follows:

$$y_{it} - y_{it-1} = \gamma y_{it-1} + d_{it} + d_{it-1} + \delta' x_{it-1} + \zeta_t + (\eta_i + \nu_{it}) \quad (11)$$

where $i = 1, \ldots, N$ denotes one of the 27 states Brazilian that comprise the data sample and $t = 1, \ldots, T$ is time.

On the left-hand side, y_{it} represents the log of real *per capita* GDP and shows an approximate rate of growth. On the right-hand side, in addition to the lagged *per capita* GDP are the terms that represent the current and lagged value of income inequality, represented by d_{it} and d_{it-1}, respectively. Additionally, there is the vector x_{it-1}, which is composed of variables that characterize each state, such as education level, gross fixed capital formation, and market distortions, as proposed by Halter et al. (2014); a period-specific effect ζ_t used to capture productivity changes common to all the countries; a country-specific effect η_i that captures non-observed and time-invariant characteristics of a country; and an idiosyncratic error term ν_{it}.

It is important to emphasize that the studies applied to this topic and directed to the Brazilian economy, are mostly limited to short term analysis and use the ordinary least squares method for panel models with fixed and random effects. However, this method can generate biased and inconsistent estimates in the presence of endogeneity. With the purpose of circumventing this possible limitation, alternative specifications are adopted, incorporating instrumental variables at the moment of expression estimation (11). In them we introduced the series of degree of commercial opening of the states and regional dummies as instruments. Before proceeding with the estimation of equation (11), the unit root tests proposed by Hadri (2000) and Levin et al. (2002) are applied.

For the case where the series present the same order of integration, the next step is to verify the possibility of cointegration between economic growth and the other variables. If the series are cointegrated, then the discussion turns to the analysis proposed by Frank et al. (2005). This analysis seeks to present the mean group (MG) estimator and the pooled mean group (PMG) proposed by Pesaran et al. (1999), which combines both the poolings and the means of the data and the dynamic fixed effect (DFE) estimator. Now, the strategy is to study the magnitude of the long-term relationship between the inequality-growth binomial, differentiating this study from the strategy adopted by Halter et al. (2014).

It is important to highlight that the analysis proposed by Frank et al. (2005) was directed to examine the empirical relationship between income inequality and economic growth using U.S. state-level data during the post-war period. The authors construct a sample of 48 U.S. states with annual observations over the period 1945 to 2001. Findings indicate that the long-run relationship between inequality and growth is negative in nature, though this negative relationship appears to be larger for low-income states.

4.2 Description and source of the data

This section presents the variables used in the empirical model, in addition to the sources from which they were drawn and the expected signs, as shown in Table (3). The dataset used in this analysis is composed of annual figures for real *per capita* GDP, the Gini index, investment or gross fixed capital formation, and political instability over the period from 1994 to 2014.

Table 3. Description of the variables

Variables	Symbol	Expected sign	Source
Economic growth rate	$[y_t - y_{(t-1)}] * 100$		IPEA
Gini coefficient	$d_{i,t}$	(-)	IPEA
Per capita GDP	$y_{(t-1)}$	(-)	IPEA/IBGE
Education level	$edu_{(t-1)}$	(+)	IPEA and PNAD
Investment	$inv_{(t-1)}$	(+)	Ministry of Finance
Political instability	$PI_{(t-1)}$	(-)	IPEA
Corruption	$Corrup_{(t-1)}$	(-)	Boll (2010)
Energy	$Energ_{(t-1)}$	(+)	IPEA

Source: Authors.

It is important to highlight some observations about the data: 1) The choice of variables is based on the work of Halter et al. (2014); 2) the choice of this time period was made due to the availability of data; 3) the capital spending of states was used as a proxy for investment; 4) homicide rates were used as a proxy for political stability; 5) the education level was calculated as the mean number of years of schooling among people 25 years of age and older.

In addition, the capital spending series and the number of homicides were substituted by industrial energy consumption (in *kWh*) and corruption indices, as proposed by Boll (2010), with the intention of verifying the robustness of the results. Series of regional dummies and the degree of trade openness were also used as control variables; the inclusion of these terms is discussed in more detail in section 5.

Finally, all of the series were treated as natural logarithms and calculated as means of the previous three years. In this regard, this study differs from Halter et al. (2014), who treated these variables as means of the previous five years. The use of three-year means rather than five-year means is related to data availability, and the purpose of using means for the variables is to capture the past effects of the lagged explanatory variables on economic growth.

The discussion of the relationship between economic growth and its determinants starts with the analysis of the mean behavior of the studied series during the period from 1994 to 2014. Table 4 shows the mean value of the series of *per capita* GDP, investment, the Gini index, political instability, and education level for each of the Brazilian states and the Federal District.

As Table 4 shows, the Brazilian states are a heterogeneous group. The Federal District, for example, has a *per capita* GDP of R$ 50.87 and mean educational level of 8.76 years of schooling. By contrast, Piauí has a *per capita* GDP of R$ 5.58 (only 11% of that of the

Federal District) and a mean educational level of 4.30 years of schooling. These regional differences are also evident in the other variables.

Table 4. Mean value of the *per capita* GDP, investment, Gini index, political instability, and education level series

State	*Per capita* GDP (in thousands of reais)	Investment (in millions of reais)	Political instability (in units)	Gini Index	Education level (in years of schooling)
AC	9.49	371	123	0.59	6.01
AL	6.76	271	1209	0.59	4.42
AM	14.07	778	629	0.54	6.72
AP	10.76	145	176	0.53	6.87
BA	8.89	127	2871	0.58	4.83
CE	7.62	111	1529	0.58	4.84
DF	50.87	692	804	0.61	8.76
ES	18.52	133	1646	0.55	6.31
GO	13.42	535	1254	0.54	6.10
MA	5.66	491	780	0.57	4.43
MG	15.07	246	2964	0.54	6.01
MS	14.64	407	671	0.55	6.22
MT	15.49	493	864	0.54	6.01
PA	9.03	698	1673	0.54	5.76
PB	6.78	269	749	0.59	4.88
PE	8.88	879	4046	0.58	5.31
PI	5.58	309	295	0.59	4.30
PR	17.12	128	2555	0.54	6.47
RJ	22.64	177	6671	0.56	7.57
RN	8.83	373	442	0.58	5.28
RO	11.23	269	491	0.53	5.92
RR	12.13	169	108	0.52	6.59
RS	20.05	874	1892	0.53	6.73
SC	21.84	669	585	0.48	6.79
SE	9.72	286	468	0.58	5.43
SP	25.45	731	10.471	0.53	7.34
TO	9.51	597	199	0.56	5.26

Source: Authors.

In addition, this initial analysis does not clarify the influence of income inequality on economic growth. It can be observed that the highest mean concentration of income and the lowest mean *per capita* GDPs are found in the states of Piauí, Maranhão, Alagoas, and Paraíba. However, the Federal District shows the highest mean Gini index and the highest mean *per capita* GDP. Thus, this initial analysis does not make explicit the possible sign or effect of inequality on growth. This effect is only captured in the empirical analysis.

5 Discussion and analysis of the results

The initial analysis presented in Table 4 does not make explicit whether inequality has a positive or negative effect on growth, nor does it clarify the size of the effect, which is only captured in the empirical analysis. Before proceeding, the estimates from the panel data models are subjected to the unit root tests proposed by Hadri (2000) and Levin et al. (2002). The idea is to compare the results obtained from tests that have different null hypotheses. In the case at hand, the test proposed by Hadri (2000) takes the absence of a unit root as the null hypothesis, whereas the test of Levin et al. (2002) takes the presence of a unit root as the null hypothesis. The results of these tests reject the hypothesis of a unit root for the series, concluding that they are integrated on the same order I(0), as shown in Table 5.

Table 5. Panel unit root test

Variable	Levin, Li and Chu	Hadri	Conclusion
GDP	-4.82	-4.78	*I (0)*
p-value	(0.00)	(0.99)	
Gini	-5.99	-4.42	*I (0)*
p-value	(0.00)	(0.99)	
Investment	-23.45	-4.79	*I (0)*
p-value	(0.00)	(0.99)	
Education level	-26.16	-4.68	*I (0)*
p-value	(0.87)	(0.99)	
Political instability	-9.14	-4.93	*I (0)*
p-value	(0.00)	(0.99)	

Source: Authors.

Table 6 shows four distinct methods of estimating the relationship between economic growth and the determinants proposed in this article (educational level, income inequality, investment, and political instability). The estimates obtained from the panel models with fixed and random effects are shown in the second and third columns, respectively. The Hausman test indicates that the random effects model is preferable to the fixed effects model (at a 5% level of significance).

The following columns show the estimates obtained by estimating with instrumental variables, with Model B incorporating the state's trade openness and Model C including both the state's trade openness and regional dummies.

The results of Table 6 show that political instability is the only non-significant variable. The estimates of models B and C reinforce the consistency of the random effects model. It is notable that the lagged *per capita* GDP negatively affects the mean growth rate. In contrast to the observations made in section 2, this result suggests a process of absolute income convergence among the states. The coefficients that measure the effect of inequality suggest that, as expected, current inequality (d_t) has a negative effect on growth but the coefficient of past inequality (d_{t-1}) has a positive effect on growth.

With regard to the coefficient of past inequality, two observations may be made. First, the positive effect on growth may be understood as a consequence of income inequality's creation of an incentive for effort. According to Mirrless (1971), the possibility of obtaining a relatively higher income as a reward for greater effort acts as an incentive for individuals with different skill levels to achieve greater productivity. The second observation is related to the fact that Halter et al. (2014) address the effect of past inequality to show the long-term effects of inequality on economic growth, using the methodology proposed by Frank et al. (2005) and Herzer and Vollmer (2012) to capture this effect.

Table 6. Panel models with fixed and random effects and instrumental variables

	Model A		Model B	Model C
	Fixed effect	Random effect		
Constant	-	-37.98	-26.98	-21.72
p-value	-	(0.00)	(0.11)	(0.02)
$y_{(t-1)}$	-15.92	-8.78	-8.46	-5.29
p-value	(0.01)	(0.00)	(0.00)	(0.02)
d_t	-0.32	-0.28	-0.52	-0.78
p-value	(0.04)	(0.05)	(0.05)	(0.00)
$d_{(t-1)}$	0.09	0.17	0.49	0.78
p-value	(0.68)	(0.32)	(0.08)	(0.00)
$inv_{(t-1)}$	0.03	0.01	0.01	0.01
p-value	(0.01)	(0.00)	(0.30)	(0.09)
$edu_{(t-1)}$	0.19	0.19	0.20	0.13
p-value	(0.02)	(0.00)	(0.00)	(0.00)
$PI_{(t-1)}$	0.03	0.001	-0.004	-0.007
p-value	(0.12)	(0.94)	(0.54)	(0.18)
Hausman test	-	11.17	-	-
Significance level	-	0.08	-	-
No. observations	138	138	138	138
No. of groups	27	27	27	27
Chow F-test	3.7	-	-	-
Significance level	0	-	-	-
R^2 (within)	0.53	-	-	-

Source: Authors.

The coefficients of the investment and education level variables yield the expected results. However, the effect of public investment on growth is small, which may be due to the states' limited capacity for investment. During the period studied, the states' mean investment is only 3% of the state GDP.[7] The magnitude of the education level coefficient reflects the importance of human capital. The results ratify the idea that educating the workforce has a direct relationship with gains in productivity and, consequently, with economic growth. This result was obtained in other studies applied to the Brazilian economy, among which: Barbosa et al. (2015).

It should be noted that in addition to the exercises displayed in Table 6, corruption and energy consumption are also employed as proxy variables to represent political instability and investment, respectively, with the same results achieved.

5.1 Cointegrated panel and its long-term relationship

In addition to the discussion presented above, it is important to test the hypothesis of cointegration between the terms studied, which is the most common method of expressing the long-term relationship between the variables proposed in the study. This stage of the research limits itself to analyzing the long-term effects of income inequality and education level on growth because these variables have the greatest explanatory influence on growth in Brazilian states. First, cointegration tests for panel data based on Pedroni (2004) are applied to

[7] Data from the National Treasury Secretariat (Secretaria Nacional do Tesouro – STN) and IBGE

determine whether there is a long-term relationship between the variables described in the preceding paragraph.

Table 7. Pedroni's test (2004) for cointegration in panels

Test *within*	Test statistics	Critical value
Statistic - v	-0.67	2.19
Statistic - ρ	4.98	2.19
Statistic - PP	-5.99	2.19
Statistic - ADF	5.71	2.19
Test *between*		
Statistic - ρ	6.98	2.19
Statistic - PP	-8.89	2.19
Statistic - ADF	17.68	2.19

Source: Authors.

The test results suggest a relationship of cointegration between economic growth, income inequality, and education level, given that the null hypothesis of no cointegration is rejected by all of the tests. Thus, the cointegration tests indicate long-term equilibrium between these terms. With this done, the next stage is limited to capturing the long-term effect of inequality and educational level on economic growth.

Assume an autoregressive distributed lag (ARDL) dynamic panel $(p, q_1, \dots, q_k)$ that takes the following form:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (12)$$

where the number of groups i = 1, 2, ..., N; the number of periods is t = 1, 2, ..., T; X_{it} is a vector $k\ x\ 1$ of explanatory variables; δ_{it} are the coefficients of the vectors $k\ x\ 1$; λ_{ij} are the scalars; and μ_i is a group-specific effect.

Imposing a lag on all of the terms of the autoregressive distributed lag equation (1,1,1) yields the following:

$$y_{it} = \gamma_i + \delta_{10i} esc_{it} + \delta_{11i} esc_{i,t-1} + \delta_{20i} d_{it} + \delta_{21i} d_{i,t-1} + \lambda_i y_{i,t-1} + \varepsilon_{it} \qquad (13)$$

where y_{it} represents the logarithm of real *per capita* income, edu_{it} represents the logarithm of educational level, and d_{it} represents the level of income inequality.

The following equation results from the error correction model:

$$\Delta y_{it} = \phi_i \left[y_{i,t-1} - \theta_{0i} - \theta_{1i} edu_{i,t-1} - \theta_{2i} d_{i,t-1} \right] + \delta_{11i} \Delta edu_{i,t-1} + \delta_{21i} \Delta d_{i,t-1} + \varepsilon_{it}$$
(14)

where $\theta_{0i} = \frac{\gamma_i}{1-\lambda_i}$, $\theta_{1i} = \frac{\delta_{10i} + \delta_{11i}}{1-\lambda_i}$, $\theta_{2i} = \frac{\delta_{20i} + \delta_{21i}}{1-\lambda_i}$, and $\phi_i = -(1 - \lambda_i)$.

The terms θ_{1i} and θ_{2i} capture the long-term effects and represent the effects of educational level and income inequality, respectively. The parameter ϕ_i represents the error-corrected speed of adjustment. If the variables show a return to long-term equilibrium, then this parameter will be significantly negative because as the error correction term measures deviations from long-term equilibrium between the variables. If the term $(1 - \lambda_i)$ is positive, then a negative correction should occur in the following period, ensuring that the system returns to equilibrium. If $\phi_i \geq 0$, then there would be no evidence for a long-term relationship.

Table 8 shows the three estimates that attempt to measure these effects, namely: a) MG estimates that impose no restrictions; b) PMG estimates that impose common long-term effects; and c) DFE estimates that require that all slope coefficients and all error variances be the same.[8]

Table 8. Alternative Pooled Estimates

ARDL (1,1,1)	MG	PMG	DFE
Education level effect (esc_{it})	0.02059	0.00918	0.03191
Standard deviation	(0.0197)	(0.00712)	(0.01353)
Inequality effect (d_{it})	-0.00157	-0.0020	-0.19038
Standard deviation	(0.00009)	(0.0004)	(0.09445)
Speed of adjustment (ϕ_{it})	-0.62399	-0.53979	-1.68892
Standard deviation	(0.07557)	(0.06482)	(0.12355)
Log likelihood	-133.98	-160.72	-69.45
No. of parameters estimated	77	57	17

Source: Authors.

Table 8 shows that the effects of income inequality and education level do not change in the long-term analysis, which reinforces the idea that an increase in inequality negatively affects growth and, conversely, higher education levels positively affect growth. This result is robust, considering that all of the cointegrating coefficients tied to long-term effects are shown to be significant.

With regard to the parameter that represents the speed of adjustment of the error correction, it can be observed that the estimates obtained from the MG and PMG estimators (ϕ_{MG} = -0.62 and ϕ_{PMG} = -0.54) indicate short-term dynamics that are different, significant, and smaller than those obtained by pooling estimates. These estimators suggest, for example, that the speed of convergence to the equilibrium is approximately 62% per year for the MG estimator, 54% for the PMG estimator, and 169% for the DFE estimator.

6 Conclusion

The discussion about the transmission channel for the effects of income inequality on economic growth is not new, and over the years, it has drawn the attention of researchers who attempt to explain the importance of this relationship. This study, for example, uses the theoretical model proposed by Halter et al. (2014), in which a theoretical model with a non-monotonic adjustment trajectory leads to a linear model that represents the inequality-growth relationship.

The empirical results suggest that, among all of the factors studied, only the effects of education level and income inequality are analyzed in both the short term and the long term. The main conclusion drawn from these analyses is that regardless of which method is adopted (panel model with fixed effects, random effects, instrumental variables and cointegration

[8] Baltagi (2008) notes that the DFE standard-errors are corrected by the heteroscedasticity of the error variances among countries; the non-corrected values are substantially smaller. The robust heteroscedasticity of the standard errors are calculated by means of a general covariance matrix of the disturbances ε_{it} among the individuals *i*.

analysis), education level and income inequality affect economic growth positively and negatively, respectively, and that these factors are able to explain some of the differences in growth rates among different regions of Brazil.

The results suggest that the dynamics of economic growth in the Brazilian states must respond positively to social policies to reduce income inequality and to encourage schooling. In recent years, Brazil has implemented a social program called "Bolsa Família", which has as main characteristics the transfer of income linked to the maintenance of children in school. This policy, according to the results found, must have a significant impact on the economic growth of the states in the long run.

However, in addition to social programs, policies should be adopted that increase the efficiency of public investments in education. The strong educational inequalities between states (see table 4) are determinant for understanding the economic discrepancies between Brazilian regions. Thus, the success of economic growth policy is strongly associated with the educational performance of the states.

A future discussion will address the effects of statistical predictability on economic growth and income inequality using the Granger test of causality. The importance of this analysis is that causality suggests that changes in economic growth are able to predict changes in inequality, and vice versa, an element that has been little explored in the literature. In addition, the Brazilian states will be divided into two groups (those with higher and lower indices of inequality) for the purpose of verifying whether the effect of inequality on growth remains valid or whether other factors become more relevant in explaining the economic growth of these states.

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References

Alesina, Alberto e Roberto Perotti (1996). Income distribution, political instability, and investment. *European economic review*, 40, 1203–1228.

Alesina, Alberto e Dani Rodrik (1991). Distributive politics and economic growth. Technical report, National bureau of economic research.

Bagolin, Izete Pengo, João Gabe, e Eduardo Pontual Ribeiro (2004), Crescimento e desigualdade no rio grande do sul: uma revisão da curva de kuznets para os municípios gaúchos (1970-1991). *Encontro de Economia Gaúcha*, 2.

Baltagi, Badi (2008), *Econometric analysis of panel data*. John Wiley & Sons.

Barbosa, Marcelo Ponte; Petterini, Francis Carlo; Ferreira, Roberto Tatiwa. Composição do capital humano, crescimento econômico e produtividade total dos fatores nos municípios brasileiros. In: XX Encontro Regional de Economia, 2015, Fortaleza. Anais do XX Encontro Regional de Economia, 2015.

Bertola, Giuseppe (1991), Factor shares and savings in endogenous growth. Technical report, National Bureau of Economic Research.

Boll, José Luis Serafini (2010), A corrupção governamental no brasil: construção de indicadores e análise da sua incidência relativa nos estados brasileiros.

Forbes, Kristin J (2000), A reassessment of the relationship between inequality and growth. *American economic review*, 869–887.

Frank, Mark W et al. (2005), Income inequality and economic growth in the us: A panel cointegration approach. *Sam Houston State University Working Paper*, 05–03.

Galeano, Edileuza Aparecida Vital (2014), Evidências de desigualdades econômicas e convergência do pib per capita entre os estados brasileiros no período de 1985 a 2008. *Revista Econômica do Nordeste*.

Hadri, Kaddour (2000), Testing for stationarity in heterogeneous panel data. *The Econometrics Journal*, 3, 148–161.

Halter, Daniel, Manuel Oechslin, e Josef Zweimüller (2014), Inequality and growth: the neglected time dimension. *Journal of Economic Growth*, 19, 81–104.

Herzer, Dierk e Sebastian Vollmer (2012), Inequality and growth: evidence from panel cointegration. The Journal of Economic Inequality, 10, 489–503.

Jacinto, Paulo de Andrade e César Augusto Oviedo Tejada (2004), Desigualdade de renda e crescimento econômico nos municípios da região nordeste do brasil: O que os dados têm a dizer. *Encontro de Economia da Anpec*, 32.

Jones, Charles Irving (2000), *Introdução à teoria do crescimento econômico*. Campus.

Kakwani, Nanak, Marcelo Côrtes Neri, e Hyun H Son (2010), Linkages between propor growth, social programs and labor market: the recent brazilian experience. *World Development*, 38, 881–894.

Lazear, Edward P e Sherwin Rosen (1979), Rank-order tournaments as optimum labor contracts.

Levin, Andrew, Chien-Fu Lin, e Chia-Shang James Chu (2002), Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of econometrics*, 108, 1–24.

Li, Hongyi e Heng-fu Zou (1998), Income inequality is not harmful for growth: theory and evidence. *Review of development economics*, 2, 318–334.

Mirrlees, James A. An exploration in the theory of optimum income taxation. The review of economic studies, v. 38, n. 2, p. 175-208, 1971.

Pedroni, Peter (2004), Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the ppp hypothesis. *Econometric theory*, 20, 597–625.

Perotti, Roberto (1993), Political equilibrium, income distribution, and growth. *The Review of Economic Studies*, 60, 755–776.

Persson, Torsten e Guido Tabellini (1994), Is inequality harmful for growth? *The American Economic Review*, 600–621.

Pesaran, M Hashem, Yongcheol Shin, e Ron P Smith (1999), Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, 94, 621–634.

Rands, Alexandre (2011), *Desigualdades regionais no Brasil*. Elsevier Brasil.

Salvato, Márcio Antônio, Patrícia Silva Alvarenga, Cristina Soares França, e Ari Francisco de Araujo Junior (2008), Crescimento e desigualdade: evidências da curva de Kuznets para os municípios de minas gerais–1991/2000. *Revista Economia & Gestão*, 6.

Stiglitz, Joseph E (1969), Distribution of income and wealth among individuals. *Econometrica: Journal of the Econometric Society*, 382–397.