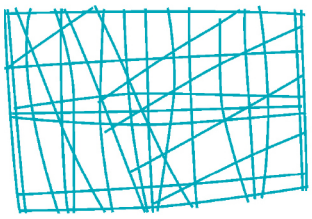

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ECONOMIC CRISES AND REGIONAL DISPARITIES IN BRAZIL IN THE XXI CENTURY

Carlos R. Azzoni
Gustavo H. L. Castro

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Economic crises and regional disparities in Brazil in the XXI Century[1]

Carlos R. Azzoni, Professor of Economics (cazzoni@usp.br)
Gustavo H. L. Castro, Ph. D. Student (gustavocastro@usp.br)
Department of Economics, University of São Paulo, Brazil

Abstract

The paper deals with the effects of two recent crises on regional disparities in Brazil. We consider the impact of The Great Recession of 2008 and a more intense national crisis starting in 2014. We calculate the yearly average latitude and longitude weighted by the regional share of the national GDP between 2002 and 2019 for agriculture, manufacturing, commerce & services, government, and the aggregate value added. We analyze the evolution of the average latitude and longitude over the period to check for changes in their trends after the national shocks. We analyze per capita income dispersion and associate it with the national economic performance. We estimate convergence equations, introducing the effect of the two crises on the convergence of per capita income and average wage. We present the effect of the Covid-19 crisis on regional wage convergence. Finally, we analyze the convergence pattern of skill intensity across regions, highlighting the impacts caused by the two shocks.

Key-words: cycles and regional inequality; economic center of gravity; labor skill intensity

1. Introduction

Brazil has a large territory and pronounced regional disparities (Azzoni & Haddad, 2018). Bucciferro & Souza (2020) analyze the Brazilian per capita GDP dispersion from 1872 through 2015, indicating that by 2015 it was at an 80-year low. They associate the ups and downs of regional per capita dispersion to commodity cycles, slavery, migration, transportation infrastructure development, trade policy, and related processes of self-reinforcing structural change. Magalhães & Alves (2021) also find an inequality peak in 1970, with subsequent decreases, with increasing polarization between the rich and poor areas. Even though inequality is lower than it was in the past, the Northeast region, hosting 28% of the population[2], is still the poorest. Its per capita income was below half of the wealthiest region, the Southeast, in the last two centuries (Barros, 2018). Benavides et al. (2022) find a similar situation in Mexico, another country with a large territory and important regional disparities. Johnson & Papageorgiou (2010) show similar results for inter-country inequality trends.

The synchronization of regional cycles has received more interest than the effects of crises on inequality. Mejía-Reyes et al. (2019) use data on Mexican states to analyze the co-movements from 2000 to 2017. Artis & Okubo (2010) identified regional business cycles for the UK, Japan, the USA, and Europe. The literature on the impact of national cycles on regional disparities is scarce. Azzoni (2001) presents the first analysis of national economic cycles' effects on Brazil's regional disparities. He finds that periods with fast national economic growth are associated with increases in regional inequality, but the effects vanish some years

[1] Paper prepared for the XLVII Meeting of Regional Studies of the Spanish Association of Regional Science (AECR), Granada, 19-21 October 2022

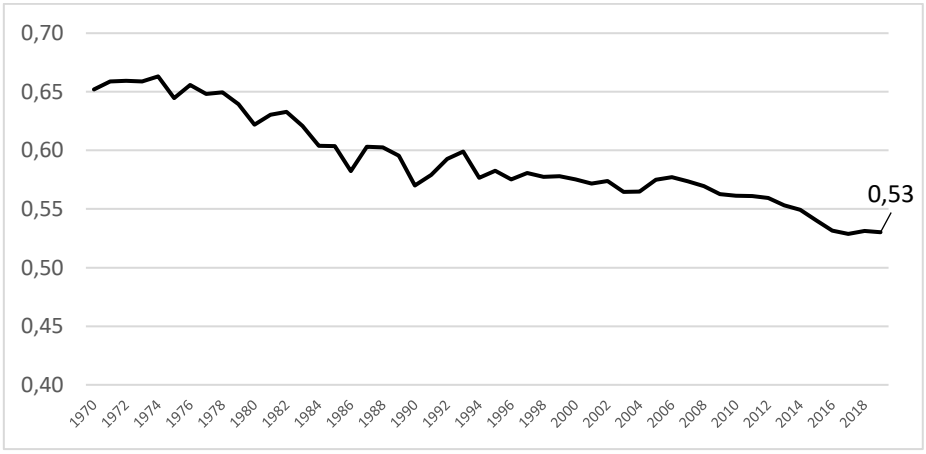
[2] 2010 Population Census

later. Benavides et al. (2022) studied regional convergence in Mexico before and after the intensification of international trade produced by the country's opening.

The relationship between macroeconomic performance and regional inequalities has interested authors for a long time. The classical works of Kuznets and Williamson indicate a possible U-shaped curve, with disparities increasing in the first phases of development, decreasing at intermediate levels, and increasing as the countries reach higher income levels (Azzoni, 2001). However, these approaches are not suitable for this investigation since the interest is in the effects of short-run movements of national production on regional disparities. The Great Recession prompted interest in the topic, with several studies on particular economies. Cuadrado-Roura et al. (2016) analyze the impact of the economic crisis on the European economy. He shows it has caused significant disparities in economic weakness between countries and regions within countries. Royuela et al. (2019) find that the Great Recession is associated with an increase in inequality across OECD regions. Gbohoui et al. (2019) analyze European countries and find that regional inequality has intensified during the financial crisis. Odoardi and Muratore (2018) conclude that the regional economic gap between Italian regions has widened during the recession.

Regional disparities can manifest through concentration and inequality. The Brazilian Southeast, which hosts the cities of São Paulo, Rio de Janeiro, and Belo Horizonte, produces over 55% of the national GDP (Figure 1). Although the regional concentration shows signs of diminution, the level is still worrying. The resource-oriented regions of the Center-West (grains) and the North (mining and a free import zone in the city of Manaus) increased their shares in population and GDP in the last decades. As a result, there is a diminishing trend in regional disparities in the country in the XXI Century. This reduction has several possible explanations, including establishing a massive regional-blind policy of cash transferences to low-income families (Silveira-Neto, 2010). As the country's economy received three successive shocks, namely the Great Recession (global), a domestic political shock, and a public health shock, it is relevant to investigate how those shocks might have influenced these trends.

Figure 1 – Share of the Southeast region on the national GDP, 1970-2019



Source: IBGE, Contas Regionais

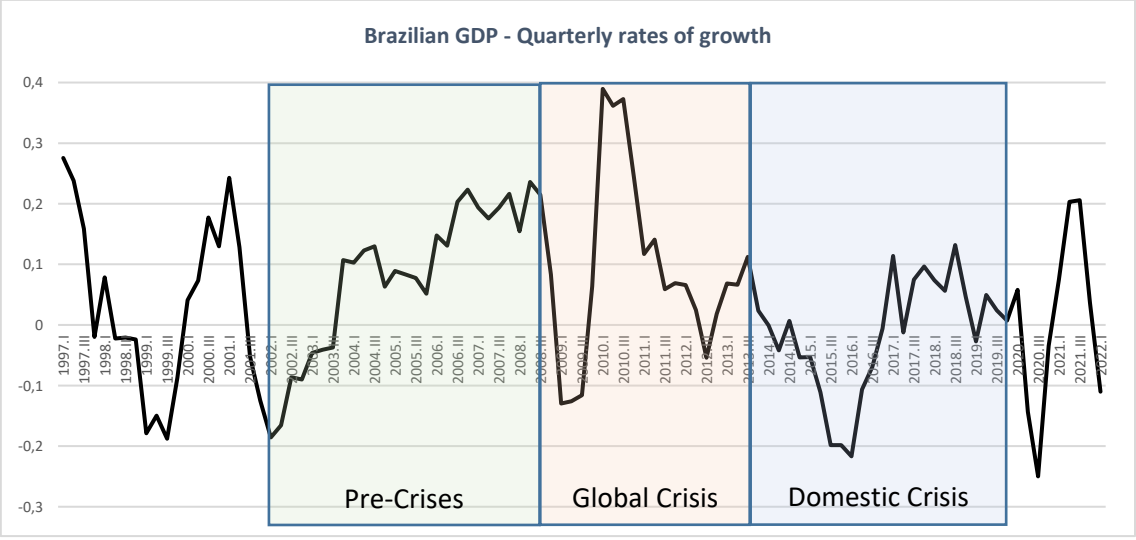
In this paper, we analyze the evolution of regional concentration and inequality across Brazilian states and regions in recent years. With state-level data, we go back in time as far as 1949; a finer geographical disaggregation allows us to refine the analysis to 510 functional regions, although, in this case, the analysis period starts in 2002. In section 3, we study the evolution of regional concentration by applying the economic geographical center of gravity concept. Section 4 concentrates on the dispersion of per capita income and estimating convergence equations for per capita income and average wage levels. In section 5,

we investigate the evolution of inequality in the complexity of occupations in manufacturing as an indicator of the future evolution of regional disparities. In all cases, we investigate the effect of the Great Recession and a deep domestic political and economic crisis. We also verify the effect of the Covid-19 pandemic on the evolution of regional wage disparities. The final section presents our conclusions.

2. Data

Given the restrictions on data availability at a fine geographical scale, our main period of study is 2002-2019, but we also use state-level data starting in 1949. Based on the quarterly rates of growth of national GDP (Figure 1), we have defined three periods for the analysis: pre-crises, 2002-2008; global crisis, 2009-2013; and domestic crisis, 2014-2019. The Covid-19 crisis involves only 2020. The Pre-Crises period presented favorable growth rates of national GDP, associated with a booming global economy demanding commodities (grains and mining products) and manufactured products (cars, planes, etc.) from Brazil. The second period is associated with the Great Recession, whose effects hit the Brazilian economy with some delay, produced an immediate rebound, but left secondary shocks that affected the economy in the following quarters. A modest recovery showed up in late 2013. However, the weakening of the global economy, associated with a local political crisis[3], caused a more profound shock, lasting for almost two years and causing the economy to suffer. The Covid-19 pandemic landed on an already weak economy and had devastating effects probably worse than in other countries. Unfortunately, there is only available information on regional wage levels to extend our analysis to capture the impacts of this third shock.

Figure 1 – National rates of GDP growth



Source: IBGE, Contas Nacionais Trimestrais, Tab_Compl_CNT_1T22_cei_fin_2021, Prices of 1995.
https://www.ibge.gov.br/estatisicas/economicas/contas-nacionais/9300-contas-nacionais-trimestrais.html?=&t=downloads

We work with yearly data on the Per Capita GDP, average wage, and labor skills of 510 functional regions, between 2002 and 2019, as displayed in Figure A1, in the Appendix. These regions were established by IBGE, the Brazilian official statistical office, based on access to consumption, job opportunities, health, education,

[3] Including the impeachment of the elected President

and public services.[4] We understand this is the proper geographical unit to analyze the problem. Although we use state-level data in some parts of the analysis, there are heterogeneities within states that cannot be captured at such a geographical level of analysis. Working with municipalities would be misleading, as conurbation and metropolisation issues would be ignored. The functional areas constitute regional labor markets and are the most adequate geographical unities to study regional disparities.

3. Regional concentration – Economic Center of Gravity

To evaluate the concentration trend from a geographical perspective, we calculated the economic Center of Gravity using data on the 27 states and the 510 geographical unities. This is simply the average of latitude and longitude, weighted by the shares of each geographical unity in the national GDP each year. Let $k_{r,t}$ be the share of region *r* on national GDP in year *t*. The average latitude and longitude are:

$$Lat_{+,t} = \sum_r \ k_{r,t} * Lat_r \qquad (1)$$

$$Long_{+,t} = \sum_r \ k_{r,t} * Long_r \qquad (2)$$

As Lat_r and $Long_r$ are constant, the average latitude and longitude are solely produced by the changes in $k_{r,t}$. Therefore, changes in $Lat_{+,t}$ reflect the combined changes in the shares of the regions in the national GDP over time. Of course, this measure for one specific year lacks any economic meaning. However, its change over time synthetizes the joint movement of the regional economies. Since the movement of the point is the resultant of the growth of all regions simultaneously, any movement to the north of the original point, for example, indicates that the set of geographical unities located to the north of that point grew faster than the unities located in other points of the territory.

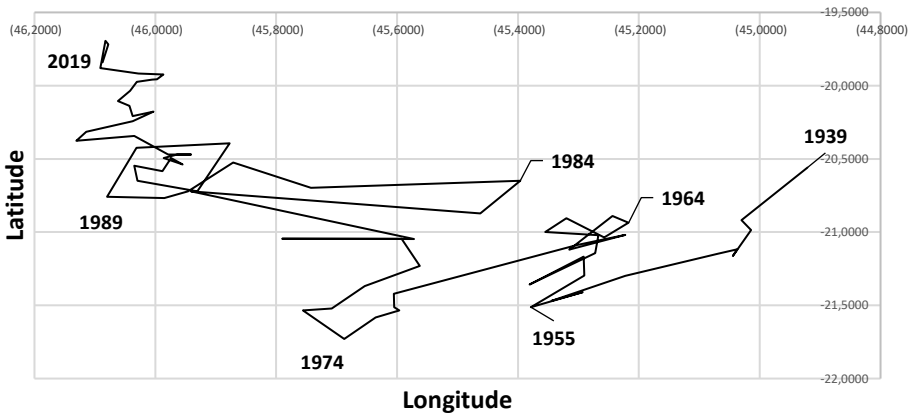
Figure 2 provides a long-term view of the movement of the center of gravity of the Brazilian economy. In this case, the geographical unities are the 20 states[5] since no information is available at a finer spatial disaggregation for such a long period. The movement of the center of gravity reflects the spatial dynamics of the sectors that compose the national production. The transition westbound is a result of the explosive growth of agricultural activities in the center-west region, which is now a breadbasket of grains to feed the world, and by mining activities in the northern region. The establishment of a tax-free import zone in Manaus, in the middle of the North region, in the early 1960s, also had an important effect. These two regions increased their share of population and GDP impressively in the last seven decades or so. At the same time, Brazil is facing strong deindustrialization, negatively affecting the Southeast's traditional manufacturing centers. Finally, as with any other economy in the world, there is a tertiarization process in place, as commerce and services become the predominant activity in the country, reaching 72.7% in 2021[6]. This third aspect tends to favor the advanced economies in the southeast. In summary, over these 80 years, there was a "march towards the west," with a slight northbound component.

[4] IBGE (2021) Divisão Urbano-Regional do Brasil, 2nd Edition, *https://biblioteca.ibge.gov.br/visualizacao/livros/liv101862.pdf*

[5] Until 1970 there were only 20 states. We kept this configuration for the whole period.

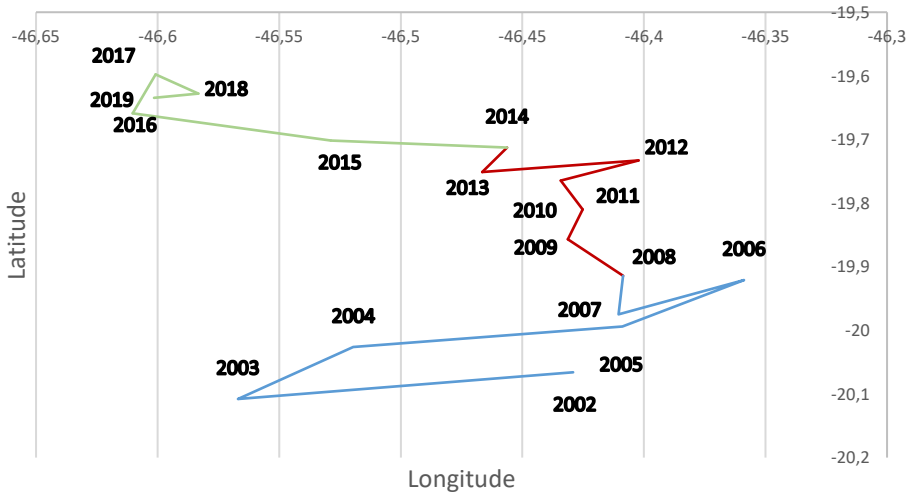
[6] https://sidra.ibge.gov.br/home/cnt

Figure 2 – Economic Center of Gravity, Value Added, 1939-2019 (state-level information)



We repeated the exercise with data for 510 functional regions to have a finer view of more recent trends. Figure 3 shows the estimated centers of gravity of the national economy between 2002 and 2019. Figure A2 in the Appendix gives the geographical location of the resulting points, although, as mentioned before, it is important to monitor the movement of the point, not its location. Their points' position in the Southeast region, in the state of Minas Gerais, is a consequence of the concentration already mentioned. It is evident that the movement observed in this period is limited geographically. It has a clear northwest orientation, but with nuances in different periods. From 2002 through 2005, it oscillated east west, followed by a northbound movement up to 2014. From this point on, it clearly moved west, with a slight change northwards.

Figure 3 – Economic center of gravity –Value Added, 510 regions



To check if the crises affected the observed trends in the center of gravity, we perform a simple econometric exercise, estimating the following equations:

$$Lat_t = \alpha + \beta Time + \gamma Long_t + \delta C + \theta(Time * C) \quad (3)$$

$$Long_t = \alpha + \beta Time + \gamma Lat_t + \delta C + \theta(Time * C) \quad (4)$$

The coefficients β indicate the trend in the movement of latitude (longitude). The dummy variable indicating the periods are $C = 0$ for the period before the crises, and $C = 1$ during the crises. Therefore, coefficient δ indicates the effect of the crisis on the average latitude (longitude), and coefficient θ measures the effect of the crisis on the trends of these variables. In the latitude (longitude) equation, the longitude (latitude) is included. The idea is to capture the movement of one of the variables, given the level of the other.

Tables 1 and 2 exhibit the results. As the information in the figures presented above indicates, the latitude trend for the aggregate value added (Table 1) is positive and significant, meaning that the center of mass is moving north. The same conclusion holds for agriculture, and commerce & services. Manufacturing and public administration show no significant trend. For the aggregate value added, the crises had no significant impact either on the center of gravity level (δ) or on its trend (θ). Agriculture, ranching, and mining had the level affected with a negative sign, showing that the crises contributed to moving it south, although they affected the trend otherwise. The opposite happened for industry and commerce & services, and the public administration was not affected. As for the longitude, the trend for the aggregate value added is negative, showing a westbound movement, replicated for commerce & services and agriculture (in this case, only at the 10% significance level). The crises had no effect on levels and trend at the aggregate value-added level, but some sectors presented significant impacts, especially agriculture.

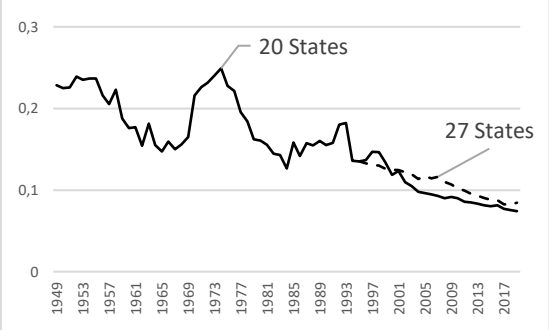
4. Regional inequality

The analysis of the center of gravity deals with the regional concentration of economic activity. Another aspect of regional disparities is inequality in per capita income or wages. In this section, we deal with the dispersion of per capita income across the 27 states (sigma convergence) and across the 510 regions.

4.1. Per capita income dispersion: Sigma convergence

To provide a longer view of the dispersion of per capita income, we work at the state level. Since 1985, there are 27 states (including the Federal District, Brasília) but some of them were part of an existing state. We have reconstructed the existing conformation of states as of 1980, resulting in a 20-state time-constant configuration. Figure 4 shows Theil's inequality index[7] from 1949 through 2019. There is a decreasing trend over the whole period, with some situations of dispersion increases. The emblematic case is the period 1967-76, known as the "Brazilian miracle", with high rates of national GDP growth. That period of prosperity was followed by "the lost decade", with low GDP growth at the national level and decreasing inequality.

Figure 4 – Theil's state-level per capita income dispersion, 1949-2019



[7] Theil's Inequality Index is given by the formula: $J = \sum_{i=1}^{n} (^{P_i}/_{P}) ln[(^{P_i}/_{P})/(^{Y_i}/_{Y})]$, in which P_i and Y_i are the population and GDP of region *i*, respectively, and *P* and *Y* are the same variables for the country as a whole.

Table 1 – Latitude trends

	All Sectors		Agriculture		Industry		Com & Services		Public Adm	
Longitude	0,2870	***	0,1570651	***	0,17001		0,264614	***	0,01982	***
	0,0001		*0,037*		*0,023*		*0,036*		*0,015*	
Trend	0,000192	***	0,000397	***	0,00012		0,000154	**	-0,000050	
	0,0001		*0,0001*		*0,0002*		*0,00005*		*0,00009*	
Trend x Global Crisis	-0,001120		0,001292	*	-0,00200	***	-0,000928		-0,001780	
	0,0008		*0,001*		*0,0014*		*0,0005*		*0,0004*	
Trend x Domestic Crisis	-0,000642		0,002890	***	-0,000237		-0,001413	***	0,000099	
	0,0004		*0,0009*		*0,002*		*0,0004*		*0,0005*	
Global Crisis	0,002639		-0,002780	*	0,004355	***	0,002096		0,004026	
	0,0019		*0,002*		*0,003*		*0,001*		*0,001*	
Domestic Crisis	0,001672		-0,007664	***	-0.000008		0,003551	***	-0,000796	
	0,0012		*0,0026*		*0,0061*		*0,001*		*0,0015*	
Constant	-0,003901		-0,020535	**	-0,013994	***	-0,005018	***	-0,02257	***
	0,003		*0,004*		*0,001*		*0,002*		*0,0011*	
FE ind.	Yes		Yes		Yes		Yes		Yes	
# Obsv	9056		9056		9056		9056		9056	
R2	0,7433		0,7022		0,8868		0,7359		0,6644	
LogLik	38282,39		32588,32		29703,16		42452,52		39208,91	
AIC	-76552,79		-65164,64		-59394,33		-84893,04		-78405,83	
BIC	-76510,12		-65121,89		-59351,66		-84850,38		-78363,12	

Table 2 – Longitude trends

	All Sectors		Agriculture		Industry		Com & Services		Public Adm	
Latitude	2,69713	***	3,74406	***	4,07393	***	2,87691	***	4,58395	***
	0,103		*0,505*		*0,409*		*0,208*		*1,066*	
Trend	-0,0007	***	-0,00127	*	-0,00068		-0,00070	***	-0,00016	
	0,0002		*0,0006*		*0,0009*		*0,0002*		*0,0005*	
Trend x Global Crisis	0,00219		-0,00938	***	0,00926		0,00064		-0,01563	
	0,002		*0,003*		*0,005*		*0,001*		*0,0158*	
Trend x Domestic Crisis	0,00129		-0,0165	**	0,00523		0,00344	**	0,0018153	
	0,0016		*0,007*		*0,012*		*0,0016*		*0,00525*	
Global Crisis	-0,00508		0,02093	**	-0,02043		-0,00121		0,03677	
	0,005		*0,008*		*0,0148*		*0,003*		*0,037*	
Domestic Crisis	-0,00326		0,04321	**	-0,01271		-0,00881	**	-0,00640	
	0,004		*0,0216*		*0,0344*		*0,003*		*0,015*	
Constant	-0,0039		0,03235	*	0,03360	***	0,00140		0,03422	
	0,002		*0,019*		*0,011*		*0,004*		*0,025*	
FE ind.	Yes		Yes		Yes		Yes		Yes	
# Obsv	9056		9056		9056		9056		9056	
R2	0,7433		0,7022		0,8868		0,7359		0,6643	
LogLik	28137,91		18032,21		15324,79		31650,18		14385,75	
AIC	-56263,8		-36052,42		-30637,57		-63288,37		-28759,49	

Observing these results induces to arguing about the relationship between national economic growth and regional inequality. The objective is to check if the national GDP growth in the previous period influences the level of regional inequality at the end of it. To check for that idea, we estimate Equation (5)

$$J_t = \alpha + \beta \Delta GDP_{t-k,t} \qquad (5)$$

Another exercise involves arguing about the length of the influence of national cycles on regional inequality. As shown in Azzoni (2001), the effect might be short-lived, and the stimulus of the national boom (crisis) would not reach the following k-year period. To check for that we add another variable to Equation (5), the national growth rate in the previous k-year period.

$$J_t = \alpha + \beta \Delta GDP_{t-k,t} + \gamma \Delta GDP_{t-2k,t-k} \qquad (6)$$

The results on Table 3, involving the series of 20 states starting in 1949, does confirm the idea of the association of the national performance with the dispersion of per capita income levels across regions. To check if this association is influenced by the length of the period, we vary the lagged GDP growth by 1, 3, and 5 years. Comparing the single lag equations (first columns for each *k*), we see that the national GDP growth coefficient increases as the number of years growth. This conclusion is corroborated by the consideration of the second period lag. Although with smaller coefficients and lower significance levels, we still have positive coefficients. It seems, thus, that booms and crises tend to affect regional inequality, and that the effect does not vanish in the short term. At least, not for subsequent periods of at least five years.

Table 3 – National growth and dispersion of regional per capita income, 1949-2019

Dependent Variable: J_t

	k = 1				k = 3				k = 5			
Constant	0.1473	***	0.1390	***	0.1353	***	0.1232	***	0.1153	***	0.0962	***
	0.0065		0.0069		0.0067		0.0067		0.0067		0.0068	
$\Delta GDP_{t-k,t}$	0.1491	*	0.1648	**	0.1805	***	0.1437	***	0.1928	***	0.1707	***
	0.0609		0.0584		0.0435		0.0400		0.0272		0.0225	
$\Delta GDP_{t-2k,t}$			0.1369	*			0.1384	**			0.0949	***
			0.0583				0.0401				0.0228	
Resid St Error	0.0492	67 df	0.0469	65 df	0.0446	65 df	0.0397	62 df	0.0370	64 df	0.0301	58 df
Mult R-sq	0.0821		0.1637		0.2096		0.3456		0.4397		0.5875	
Adj r-sq	0.0684		0.138		0.1974		0.3245		0.4309		0.5733	
F-statistic	5.995		6.361		17.23		16.37		50.22		41.3	
# Observ	69		68		67		66		65		64	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Continuing on this line of reasoning, we calculate the sigma speed of convergence, from the formulas

$$CV_t = CV_0 * \exp(-st) \qquad (7)$$

$$-s = [ln\left(\frac{CV_t}{CV_0}\right)]/t \qquad (8)$$

Positive values of *s* indicate inequality reduction; negative values indicate increasing inequality. Growing values indicate that inequality is reducing at a fast rate, and declining values indicate otherwise. Figure … displays the results the same series used for the previous exercise. To check if the merging of states who split from previous geographical unities affects the results, we also calculate the speed of convergence indicator from 1995 on with 27 geographical unities. As the lines in Figure 5 suggest, the use of 20 states instead of 27 does not change the overall result. Therefore, in the econometric exercise that follows, we will work with the longer series of 20 states. We estimate the following regression:

$$\Delta S_{t-3,t} = \alpha + \beta \Delta GDP_{t-3,t} \qquad (9)$$

As the result in Table 4 indicates, periods of high national economic growth are associated with decreasing speed of convergence, and periods of sluggish national performance, with high speeds of convergence. The national growth coefficients increase as the period become longer.

Figure 5 - Sigma speed of convergence, 1949-2019, 3-year periods

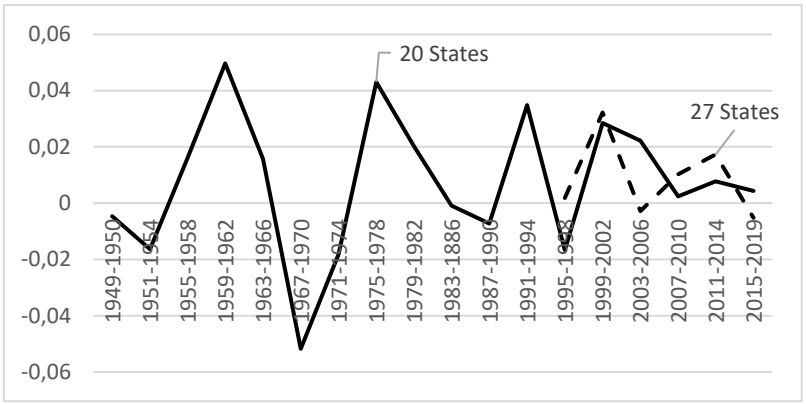


Table 4 – National growth and Sigma speed of convergence, 1947-2019

Dependent variable: $-s_t$

	k=1		k=3		k=5	
Constant	0,9837	***	0,9647	***	0,9221	***
	0,0058		0,0085		0,0145	
$\Delta GDP_{t-k,t}$	0,2002	***	0,2263	***	0,2647	***
	0,0552		0,0554		0,0587	
Resid St Error	0,0441	68 df	0,0569	67 df	0,0799	65 df
Mult R-sq	0,01655		0,1994		0,2385	
Adj r-sq	0,1532		0,1875		0,2268	
F-statistic	13,48		16,69		20,36	
# Observ	69		67		65	

4.2. Beta convergence of per capita income and wages

Beta convergence analyses the relationship between the initial level of per capita income in a region and its growth over a period. If regions with lower levels exhibit higher rates of growth, the inequality level among regions tend to diminish. We have estimated equations to verify the occurrence of convergence and if the regional convergence pattern has suffered any alterations after the crises.

In panel form, we estimate equations as

$$log\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = \alpha_i - \beta log(y_{i,t-1}) + \mu_i + \varphi_i + u_{i,t} \quad (10)$$

In which $y_{i,t}$ is the per capita GDP of region *i* in year *t*; α_i is the constant term; μ_i indicates the time-invariant unobserved regional characteristics; φ_i is the time fixed-effect, capturing year-specific shocks affecting all regions simultaneously; $u_{i,t}$ is the independently and identically distributed error term for *i* and *t*, with zero mean and constant variance. Typically, the error term is assumed to have zero mean and constant variance for all observations ($E(uu') = \sigma^2 I$). However, the existence of spatial spillovers among regions tends to violate this assumption. Considering that we work with a

large number of small regions, it is probable that spatial spillovers will be present. Therefore, we must deal with this problem to avoid an omitted variable bias (Arbia, 2006).

To choose the best specification (LeSage and Pace, 2009; Elhorst, 2010), we start with

$$log\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = \beta_i\, log\left(y_{i,t-1}\right) \times c|_1^k + \rho \sum_{i=1}^{n} w_{ij} log\left(\frac{y_{i,t}}{y_{i,t-1}}\right) + \theta_i \sum_{i=1}^{n} w_{ij}\, log\left(y_{i,t-1}\right) \times c|_1^k + \mu_i + \varphi_t + u_{i,t} \quad (11)$$

With $u_{i,t} = \lambda \sum_{i=1}^{n} w_{ij} u_{i,t} + \varepsilon_{i,t}$ and $\varepsilon_{i,t} \sim i.i.d.(0, \sigma_\varepsilon^2)$

In which ρ is a parameter capturing the sensitiveness of the endogenous variable to the spatially lagged variable (neighbors' per capita GDP growth); θ captures the effect of the spatially lagged exogenous variables (per capita GDP level of neighbors); λ is the spatial error parameter, indicating the intensity of the spatial autocorrelation among the residuals. The remaining parameters are the same as before. If $\lambda = 0$, we have the Spatial Durbin Model (SDM). If $\lambda = 0$ and $\theta = 0$, we have the Spatial Autoregressive Model (SAR), which captures the effect of the interactions of changes in the per capita income of neighbors, measured by the weighted average of all neighbors. If $\rho = 0$ and $\theta = 0$, we have the Spatial Error Model (SEM), which measures the average effect of the neighbors' errors. We use the Method of Maximum Verisimilitude to estimate the models. We use the restriction tests of the parameters λ, θ, and ρ to choose the most adequate model for each situation. The effect of the crises in the convergence process is captured by the dummy variable $c|_1^k$, which assumes the value of one in a crisis situation and zero otherwise. We estimated models with $3 \leq k \leq 30$ neighbors and choose the model with the least AIC value (Stakhovych and Bijchoose, 2009; Zhang and Yu, 2018).

Table 5 presents the results. The initial income coefficient is negative and significant, indicating the existence of conditional regional per capita convergence across Brazilian regions in the period. In all columns, both the Global and Domestic crises accelerated the process of regional convergence. The SDM model indicated by the tests allows for the calculation of the effects of the neighborhood on the regions' convergence. As Table 6 shows, these indirect effects are negative and significant for the pre-crises period and are positive, although not significant, for both crises. The total effect, which incorporates the direct and indirect effects follow the previous pattern of results in terms of initial income coefficients: -0.27 before the crises, -0.285 (sum of -0.27 and -0.014) during the Global crisis, and -0.309 during the Domestic crisis.

Another form of studying regional inequality is by observing the average wage levels. As wage levels are proxies for productivity, it is theoretically more suitable than per capita GDP. Another advantage in our case is that we can incorporate a third crisis into the study, the Covid-19 pandemic, since we have data available for 2003-2020. A caveat is that the data on the wage per worker refers only to workers with a labor contract under the laws that regulate employment relationships. Formal jobs accounted for 58.6%[8] of all occupations in Brazil in 2019. The ratio of formal/informal jobs in the private sector in 2022 is 73% for the country as a whole, with variations across states: a minimum of 46% and a maximum of 87%, with larger shares of

[8] IBGE, PNAD, Tabela 1.1. Indicadores estruturais do mercado de trabalho
https://www.ibge.gov.br/estatisticas/sociais/trabalho/9221-sintese-de-indicadores-sociais.html?=&t=resultados

Table 5 – GDP per capita and average wage convergence

	Per Capita GDP				Average Wage			
	OLS	**SDM**	SAR	SEM	OLS	**SDM**	SAR	SEM
B	-0.250***	-0.235***	-0.227***	-0.241***	-0.358***	-0.334***	-0.152***	-0.247***
	(0.003)	(0.017)	(0.015)	(0.017)	(0.021)	(0.018)	(0.010)	(0.013)
B Global crisis	-0.014***	-0.021***	-0.014***	-0.017***	-0.051**	-0.079***	-0.032***	-0.053***
	(0.003)	(0.007)	(0.003)	(0.005)	(0.021)	(0.018)	(0.002)	(0.004)
B Domestic crisis	-0.040***	-0.055***	-0.036***	-0.045***	-0.101***	-0.150***	-0.0753***	-0.122***
	(0.005)	(0.009)	(0.004)	(0.006)	(0.034)	(0.036)	(0.005)	(0.008)
B Covid crisis					-0.049***	-0.084***	-0.181***	-0.280***
					(0.018)	(0.029)	(0.009)	(0.010)
Wx		0.051***				0.242***		
		(0.014)				(0.018)		
WX Global crisis		0.012*				0.061***		
		(0.007)				(0.018)		
WX Domestic crisis		0.029***				0.107***		
		(0.009)				(0.035)		
WX Covid crisis						-0.044		
						(0.029)		
rho		0.324***	0.305***			0.419***	0.335***	
		(0.020)	(0.019)			(0.018)	(0.022)	
lambda				0.329***				0.422***
				(0.006)				(0.017)
FE ind and time	yes	yes	yes	yes	yes	yes	yes	yes
Obs.	8670	8670	8670	8670	8670	8670	8670	8670
R2	0.0541	0.0198	0.0124	0.0212	0.195	0.1178	0.1349	0.1192
LogLike	9905.14	10373.3	10356.92	10365.74	13466.85	12347.19	11867.45	12106.01
AIC	-19772.38	-20730.61	-20683.83	-20721.48	-26893.7	-24674.39	-23722.91	-24200.01
BIC	-19637.99	-20674.06	-20648.49	-20686.15	-26752.35	-24603.71	-23680.5	-24157.61
LMl	1524.1***				103.26***			
RLMl	12.16***				38.92***			
LMe	1594.1***				190.79***			
RLMe	82.15***				126.45***			
Restriction	Prob>Chi2				Prob>Chi2			
Wx =0 e rho !=0	0,000		SDM != SAR		0.000		SDM != SAR	
Wx = -lambda*B	0.0438		SDM != SEM		0.000		SDM != SEM	

Table 6 - Direct and Indirect effects – SDM Model

	Per Capita GDP				Average Wage			
Direct Effects	Coef	SD	Z	P(z)	Coef	SD	Z	P(z)
B	-.2379929	.0176215	-13.51	0.000	-.3152747	.0177022	-17.81	0.000
B Global crisis	-.0211448	.0068481	-3.09	0.002	-.075409	.016127	-4.68	0.000
B Domestic crisis	-.0529561	.0085375	-6.20	0.000	-.1417072	.0314382	-4.51	0.000
B Covid crisis					-.099648	.0252901	-3.94	0.000
Indirect Effects								
B	-.0342029	.0161604	-2.12	0.034	.1572067	.0173505	9.06	0.000
B Global crisis	.0078069	.0065603	1.19	0.234	.0446022	.0156992	2.84	0.004
B Domestic crisis	.0155576	.0087404	1.78	0.075	.0680481	.0304668	2.23	0.026
B Covid crisis					-.1229903	.0240942	-5.10	0.000
Total Effects								
B	-.2721957	.024233	-11.23	0.000	-.158068	.0080418	-19.66	0.000
B Global crisis	-.013338	.0050484	-2.64	0.008	-.0308067	.0023866	-12.91	0.000
B Domestic crisis	-.0373986	.0068693	-5.44	0.000	-.0736591	.0041583	-17.71	0.000
B Covid crisis					-.2226383	.0058141	-38.29	0.000

informal workers in poorer states. Another bias refers to the lower bound of the wage distribution, as any formal job must earn at least the national minimum wage, which makes the bottom of the wage pyramid more homogeneous across states than the upper levels.

Considering the direct and indirect effects, there is an interesting pattern. The direct effect is stronger for wages than for GDP per capita, but the indirect effects are positive and significant, indicating that the neighborhood effect has contributed to halting the convergence process. As a result, the total effect, considering both the local and neighborhood effects, is lower than for per capita GDP. The crises' effects repeat the previous pattern: all crises contributed to increasing the convergence process, with increasing effect: the domestic crisis effect more than doubles the influence of the global crisis, and the Covid-19 crisis triples the effect of the previous crisis.

5. Future disparities: labor skill intensity in manufacturing

The previous analyses provide a good description of the events in recent years but are of less interest in providing insights into future movements. To provide an idea of future trends, we analyze the intensity of labor skills involved in production. Skill intensity is an indicator of competitiveness. Therefore, by analyzing the trend in this, variable one grasps insights into the future of inequality. The analysis is restricted to manufacturing. Although this sector is not quantitatively relevant, its role in regional development is still crucial (Attiah, 2019; Moyo and Jeke, 2019).

The future depends on how competitive the region has been and, most importantly, how it will evolve. Complex production processes involve hiring personnel for occupations requiring greater workers' skills. A given region may have an extensive set of people with a high level of education. Still, the companies located there might demand low-skilled workers, not taking advantage of existing resources. A relevant aspect of the region's future competitiveness, therefore, is the complexity of the activities it hosts, as revealed by the skills requirements of its workers. The basic assumption is that the more complex the occupations of their workers, the more competitive firms tend to be. Extending the idea to the regional level, the more complex the activities developed by the workers employed there, the greater the regional competitiveness.

The basic source of information is RAIS - Annual Social Information Report of the Ministry of Labor, which indicates the occupation of each employed worker, following the International Classification of Occupations. Maciente (2013) defined the complexity of each 2,708 occupations, adapting a study developed by the American Department of Labor (ONet) to the Brazilian reality. We have the list of skills and the intensity with which these skills are required in each occupation. Neves (2018) classified a subset of the 263 skills available into three groups: cognitive, social, and motor. Cognitive skills indicate logical reasoning, learning capacity, and oral and verbal mastery of the language; social skills focus on interpersonal relationships in the workplace; Motor skills reflect manual dexterity and various skills linked to strength and ability to perform strenuous work. The skill intensity of an occupation is an indicator of its complexity. Although competitiveness is more clearly related to cognitive and, to a lesser extent, social skills, motor skills are also relevant. Both the work of a floor cleaner and of an aircraft mechanic, for example, require motor skills, but the second requires a lot more motor skills than the first. Therefore, the latter receives a grade closer to one, and the former, a grade closer to zero in the motor skills indicator.

As described in Neves et al. (2021), each occupation receives a value in the 0 – 1 numeric interval. Therefore, each occupied employee receives three scores, one for each type of skill. We average the numeric values of all regional workers to produce an indicator of the regional average skill level. Therefore, each region has three indicators per year (for cognitive, social, and motor skills). The analysis of the levels and the evolution of these indicators composes a comparative picture of the complexity of the activities developed and how

Table 7 – Skill Convergence

	Cognitive				Social				Motor			
	OLS	SDM	SAR	**SEM**	OLS	SDM	SAR	**SEM**	OLS	**SDM**	SAR	SEM
B	-0.471***	-0.486***	-0.466***	**-0.4808*** **	-0.439***	-0.441***	-0.438***	**-0.441*** **	-0.435***	**-0.421*** **	-0.427***	-0.430***
	(0.043)	(0.054)	(0.044)	**(0.047)**	(0.038)	(0.038)	(0.038)	**(0.038)**	(0.037)	**(0.039)**	(0.037)	(0.038)
B Global C	-0.140*	-0.119	-0.116	**-0,1351**	-0.003	0.005	-0.001	**0.002**	-0.053	**-0.144**	-0.062	-0.096
	(0.077)	(0.129)	(0.076)	**(0.093)**	(0.056)	(0.056)	(0.056)	**(0.056)**	(0.095)	**(0.109)**	(0.095)	(0.102)
B Domestic C	-0.092	-0.081	-0.085	**-0,089**	0.011	0.011	0.013	**0.014**	-0.027	**-0.190***	-0.034	-0.092
	(0.083)	(0.134)	(0.083)	**(0,025)**	(0.088)	(0.091)	(0.087)	**(0.089)**	(0.086)	**(0.098)**	(0.085)	(0.090)
Wx		0.151***				0.068**				**0.051**		
		(0.038)				(0.029)				**(0.033)**		
WX Global C		-0.023				-0.157*				**0.231** **		
		(0.120)				(0.090)				**(0.103)**		
WX Domestic C		-0.004				-0.052				**0.0349*** **		
		(0.127)				(0.101)				**(0.105)**		
rho		0.196***				0.049**	0.033*			**0.175*** **	0.137***	
		(0.026)				(0.020)	(0.019)			**(0.017)**	(0.016)	
lambda				**0.198*** **				**0.049** **				0.178***
				(0.025)				**(0.020)**				(0.017)
FE ind and time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	6565	6566	6567	6568	6569	6570	6571	6572	6573	6574	6575	6576
R2	0.0749	0.0254	0.0305	0.033	0.0762	0.076	0.0687	0.0708	0.0820	0.0438	0.0523	0.0529
LogLike	15826.17	15923.03	15886.43	15917.89	20181.56	20191.54	20184.41	20186.71	13236.44	13322.93	13285.29	13307.19
AIC	-31622.33	-31830.06	-31762.86	-31825.77	-40333.11	-40367.09	-40.358.82	-40363.41	-26442.89	-26629.86	-26560.58	-26604.38
BIC	-31520.49	-31775.74	-31728.92	-31791.82	-40231.27	-40312.77	-40324.87	-40329.47	-26341.05	-26575.55	-26526.63	-26570.43
LMl	246.89***				5.97**				169.13***			
RLMl	3.33*				2.12				6.98***			
LMe	345.24***				10.66***				247.25***			
RLMe	101.68***				6.81***				85.11***			

Robust Standard Error * p<0.05, **p<0.01, *** p<0.001

Restriction	Prob>Chi2		Prob>Chi2		Prob>Chi2	
Wx =0 e rho !=0	0.0000	SDM != SAR	0.0452	SDM != SAR	0.0000	SDM != SAR
Wx = -lambda*B	0.2970	SDM = SEM	0.1662	SDM = SEM	0.0019	SDM != SEM

Table 8 - Direct and indirect effects – Motor Skills

Direct Effects	Coef	SD	Z	P(z)	[95% Conf. Interval]	
B	-.4204149	.0401358	-10.47	0.000	-.4990797	-.3417501
B Global crisis	-.1396367	.1082651	-1.29	0.197	-.3518324	.0725589
B Domestic crisis	-.1736139	.0966976	-1.80	0.073	-.3631378	.0159099
Indirect Effects						
B	-.0271324	.0346582	-0.78	0.434	-.0950612	.0407963
B Global crisis	.2443181	.1058105	2.31	0.021	.0369333	.4517029
B Domestic crisis	.3708004	.1122934	3.30	0.001	.1507095	.5908914
Total Effects						
B	-.4475473	.0487091	-9.19	0.000	-.5430155	-.3520792
B Global crisis	.1046814	.1080229	0.97	0.333	-.1070397	.3164024
B Domestic crisis	.1971865	.111692	1.77	0.077	-.0217259	.4160989

this complexity varies over time. Regions with higher levels of complexity are, by assumption, in a better competitive position. Regions with positive (negative) evolution of the complexity of occupations increase (decrease) this competitiveness compared to the other regions.

We have estimated convergence equations similar to the ones estimated with per capita GDP with the average skill-intensity indicators of the 510 regions. Table 7 displays the results. The tests indicated the SEM Model for cognitive and social skills and the SDM Model for motor skills. As the negative coefficients of the initial level of complexity indicate, there was conditional convergence of skill levels across regions in the period. The values of the coefficients are only slightly different: -0.48 for cognitive skills, -0.44 for social skills, and -.45 for motor skills (from Table 8, direct and indirect). The crises did not present a significant effect on the skill intensity convergence. Thus, the regional equalization process of regional competitiveness, represented by the equalization of the skill intensity, seems to follow its path independently of the intense shocks received by the national economy.

6. Conclusions

In this paper, we analyzed the effects of the Great Recession and a national crisis on the regional income concentration and inequality in Brazil in the first two decades of the XXI Century. We also checked the effect of the Covid-19 shock in one particular case.

We analyzed the evolution of the geographical center of mass of the national GDP and verified that the crises had no significant impact neither on the level of the geographical center of mass nor on its trend for the aggregate value added. Agriculture, ranching, and mining had the level affected with a negative sign, showing that the crises contributed to moving it south, although they affected the trend otherwise. The opposite happened for industry, and commerce & services, and the public administration was not affected. As for the longitude, the crises had no effect on levels and trends at the aggregate value-added level, but some sectors presented significant impacts, especially agriculture. Thus, from this point of view, the crises produced minor effects.

The analysis of regional inequality involved Sigma and Beta convergence. We have presented indications that, although there is a decreasing trend in regional per capita income dispersion, periods of favorable national economic performance tend to be accompanied by increases in regional dispersion, and periods of sluggish macroeconomic growth tend to act otherwise. Therefore, the analysis of the crises considered in this study should be interpreted in this context. As the Brazilian economy faced hard times since 2008, one would expect regional disparities to diminish, following the previous historical pattern. We estimated Beta convergence equations for the per capita GDP, wages, and labor skill intensity. In the case of per capita GDP,

the results indicate that both crises increased (in module) the convergence coefficient, with a stronger effect for the domestic crisis. As for skill intensity, we verified that the crises did not present noticeable effects, indicating that the equalization process of regional competitiveness seems to be independent, at least over the period, of the intense shocks received by the national economy.

In summary, our results indicate that the convergence process that was in march in Brazil has accelerated with the crises. Looking at the future, words of concern are called for. Each crisis had its impact estimated individually, regardless of the other. Unfortunately, data limitations caused the incorporation of the Covid-19 pandemic shock only in the analysis of wage levels. The conclusion that the domestic crises that succeeded in time the Great Recession had larger impacts, in general, might be caused by the residual effect of the former. As the Covid-19 shock resulted in a third successive massive blow on an already feeble economy, the combined effects might be much stronger. Disentangling the individual effect of each crisis from the possible residual cumulative effect of previous shocks is a topic to explore in further research.

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Appendix

Figure A1 - Regions considered in the study

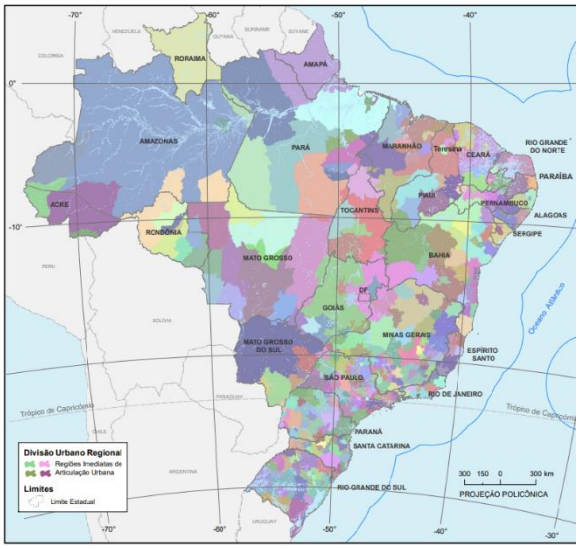

Figure A2 – The location of the centers of gravity