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Article

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Spatial income inequality in Brazil, 1872–2000[☆]

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Abstract

The paper provides historical perspectives on spatial economic inequalities in Brazil making use of a database on Brazilian municipalities from 1872 to 2000. A suit of maps and graphs describe the geographic factors shaping the historical development of the Brazilian economy highlighting the role of transport costs and its consequences for the spatial dynamics of income per capita and labor productivity. The remaining of the paper estimates econometric models of growth convergence for municipal income per capita and labor productivity. From 1920 onwards analyses are refined, firstly, by disaggregating the models for urban and rural activities; secondly, by assuming spatial correlation among variables of the model; and, thirdly, by enlarging the model to take account of the long run determinants of spatial growth convergence. Empirical results endorse the historical preeminence of geographic factors – in particular accessibility and transport conditions – as opposed to institutional conditions. The conclusion summarizes the results and proposes research extensions.

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JEL classification: O47; O55; R11; R12; N96

Keywords: Brazil; Transport cost; Cross-municipal growth convergence; Income per capita; Labor productivity; Spatial correlation; Geography versus institutions

Resumo

O artigo analisa as desigualdades espaciais no Brasil em perspectiva histórica baseado em dados municipais sobre produção e população economicamente ativa de 1872 a 2000. Uma série de mapas e gráficos ilustram os fatores geográficos que condicionaram o desenvolvimento secular da economia brasileira destacando o papel dos custos de transporte e suas consequências para a dinâmica espacial. O cerne da análise é a estimação de modelos econométricos de convergência municipal da produtividade do trabalho e da renda per capita no período de 1872 a 2000. Para os anos posteriores a 1920, a análise é refinada, primeiro, pela desagregação dos modelos para as atividades rurais e urbanas. Segundo, pelo tratamento da correlação espacial entre as variáveis do modelo. Terceiro, pela incorporação das variáveis estruturais que condicionaram a convergência municipal da produtividade do trabalho e renda per

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capita. Os resultados empíricos salientam a importância de fatores geográficos, em particular os custos de transporte, vis-à-vis os fatores institucionais. A conclusão sumaria os resultados e propõe extensões aprofundamentos da análise.

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Palavras-chave: Brasil; custos de transporte; convergência secular de crescimento municipal; renda per capita; produtividade do trabalho; correlação espacial; geografia versus instituições

1. Introduction

Brazil is one of the most unequal societies in contemporary world. From 1970 to 2000, the Gini coefficients of income per capita distribution remained practically constant around 0.6, one of the highest levels recorded at national level. In the last decade, inclusive growth policies made possible to bring Gini figures to something close to 0.5. For the future, the challenges are how to deepen redistribution with less dependence on income transfer policies.

In broad historical perspectives, both institutional and geographic factors played fundamental roles in the generation and reproduction of Brazilian inequality in space and time. Slavery has had and still has overwhelming implications for social equity. Concentration of income and wealth and the low levels of education prevailing today are, to a large extent, her legacies. Needless to say, this is not an excuse for the ostensible lack of social concerns of government policies during most of the 20th century.

Geographic factors were also decisive for spatial inequality. The continental size and the geographic heterogeneity of the country compounded with very high transport costs to create wide spatial disparities in the levels of productivity and income per capita. (Azzoni and Ferreira, 1997; Azzoni, 1997, 1999; Barros et al., 1995). The secular roots of regional disparities are widely discussed in Brazilian historiography (Bértola et al., 2006; Buescu, 1979; Cano, 1993, 1997; Castro, 1969; Denslow, 1977; Furtado, 1968, 1970; Leff, 1972, 1973, 1991; Marcondes, 2005). The discussion, however, lacks an adequate empirical basis. Statistical evidence when available are restricted to sparse data at state or macro-regional level. The sharp economic differences inside Brazilian states, not to mention regions, are completely neglected.

The paper provides historical perspectives on spatial economic inequalities in Brazil. For this purposes it analyzes the spatial patterns of Brazilian economic growth making use of a database on Brazilian municipalities from 1872 to 2000 organized by the Research Network on Spatial Models (<https://www.nemesis.org.br>). The first section presents a succinct discussion of the geographic forces shaping the historical development of the Brazilian economy highlighting the evolution of transport costs. The second section uses a suit of maps and graphs to describe the spatial progression of income per capita and labor productivity during the 20th century. In a more rigorous fashion, the third section, estimates econometric models of growth convergence for municipal income per capita and labor productivity in the period 1872 to 2000. The econometric analysis for the period 1919 to 2000 is refined in three ways. Firstly, by disaggregating the model for urban and rural activities; secondly, by assuming spatial correlation among variables of the model; and, thirdly, by enlarging the model to take account of the factors conditioning the patterns of spatial growth convergence in the 20th century. The final section summarizes the results and proposes research extensions. The [Appendix](#) describes the database.

2. Geography and history

The main historical driver of the geographic patterns of economic development in Brazil were the prohibitive transport costs to the hinterland imposed by the strong declivity of the coastal mountain range running parallel to the Atlantic shoreline (Ellis, 1951; Goulart and Queiroz, 2011; Silva, 1949; Summerhill, 2003). The slope of the Serra do Mar – reaching 1000 m 100 km away from the sea – combined with intense summer rainfall and the dense rainforest – slowed the development of a transportation infrastructure and therefore the economic settlement of the Brazilian hinterland (see [Fig. 1A](#)).

The settlement of the mining areas of the Center-South region during the 18th century was made viable by the negligible transport costs (high specific value) of precious minerals (Cano, 1973). But with historical hindsight, it is

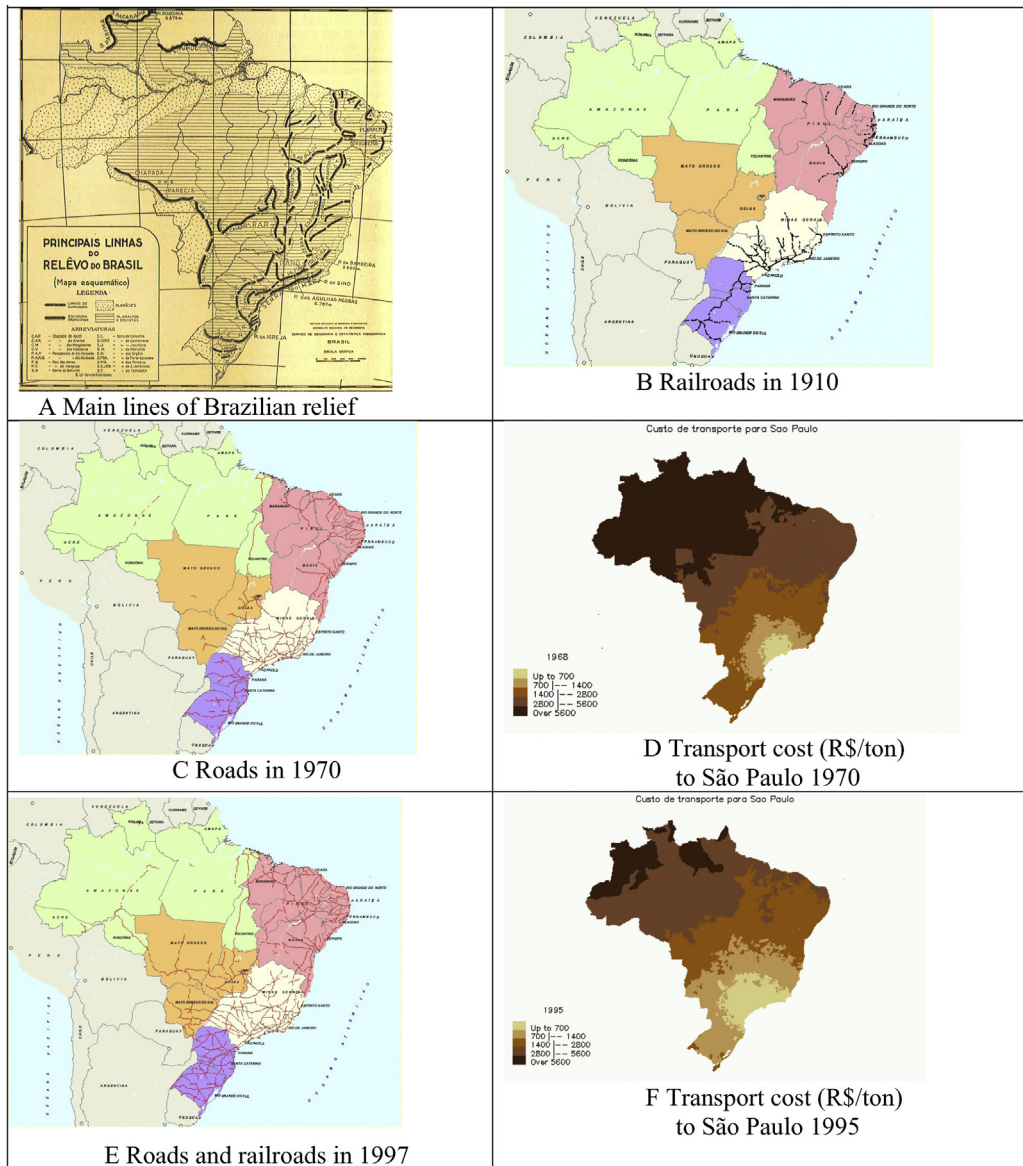


Fig. 1. (A)–(F) Brazilian relief and evolution of transportation infrastructure, 1910–1995. (A) Main lines of Brazilian relief. (B) Railroads in 1910. (C) Roads in 1970. (D) Transport cost (R\$/ton) to São Paulo 1970. (E) Roads and railroads in 1997. (F) Transport cost (R\$/ton) to São Paulo 1995. Fonte: IBGE and IPEA.

fair say that after the exhaustion of mines, high transport costs made economic development of the region unsustainable during most of the 19th century.¹

Finally, in the Amazon region where navigable rivers sanctioned low transport costs, the wild vegetation, unhealthy climate, and the poor quality of soil precluded agrarian settlement up to the last quarter of the 20th century. Rubber extraction, however, sustained a thriving economy from 1850 to 1912 when the competition of Asian plantations smashed export volumes and prices (Andersen et al., 2002; Santos, 1980).

¹ The economic lethargy of mining areas in the turn of the 18th century is a much debated subject in the historiography of Minas Gerais. See, for instance, (Martins, 2004).

The railroad investments in second half of the 19th century were crucial for the viability of agrarian settlements in the hinterland. Transport costs reduced approximately 80% pushing the coffee frontier towards the southwestern regions of São Paulo (Matos, 1974; Milliet, 1982; Summerhill, 1997) and southeast regions of Minas Gerais (Cano, 1985). Furthermore, the city of São Paulo, emerged as the most important hub (the node with minimum transport cost) of the railway network, thus pulling industries to exploit economies of scale and emerging as the sustainable industrial growth pole of the country in the beginning of the 20th century (see Fig. 1B).

For other regions, however, the reduction in transport costs provided by railways had diverse consequences leading to the specialization in agriculture and to the loss of competitiveness in manufacturing and handcraft production which were previously protected by the high transport costs (Cano, 1977; Martins, 1983; Reis and Monasterio, 2010; Restitutti, 2008; Stein, 1957; Trew, 2014).

Starting in the 1890s, the concentration of industry in São Paulo was enhanced by the synergies and externalities provided by the agglomeration of technological knowledge and human capital of foreign immigrants (Cano, 1993; Reis and Monasterio, 2010; Versiani, 1993). Conversely, subsidized foreign immigration aggravated the segmentation of the Brazilian labor market reducing their effectiveness in reducing regional disparities in productivity and income. Thus, until the 1930s, internal migration to São Paulo was relatively meager despite huge regional differences in productivity and income per capita (Graham, 1972; Graham and Hollanda, 1971)²

In the second half of the 20th century, government investment in transport infrastructure concentrated on highways which gradually replaced the railroads. The initial impact of the highway option, however, was to reinforce the hegemonic position of São Paulo thus preserving regional disparities. Indeed, the dispersed highway network reduced logistics costs of the distribution of manufactured goods in the domestic market in relation to the long distance transport cost incurred to export primary products. Additionally, dispersed highways reduced costs of internal migration, thus stimulating the migration flows to large cities and ensuring unlimited supply of labor that dampened pressures for urban wage increases, particularly in Sao Paulo and Rio de Janeiro (Barat, 1978; Castro, 2003; Galvao, 1999; Graham, 1972; Graham and Hollanda, 1971; Oliveira, 1977).

During the sixties, the federal capital moves to Brasília and the federal government starts to implement regional development policies, combining investments in infrastructure, fiscal and credit incentives. The priority given to highways in detriment of railways was inadequate for the transportation requirements of the agricultural exports from flatlands of the *Cerrado* areas in the Center-West and North regions of the country. As consequence, the growth of agricultural productivity and output in these areas were retarded (Castro, 2002; Gasques, 1985; Reis and Blanco, 2000; Reis and Margullis, 1990; Silveira, 1957; Weinhold and Reis, 2008).

Fig. 1 C–F illustrate the expansion of the road infrastructure and its spatial effects on the transportation costs in Brazil during the last quarter of the 20th century. They show that the costs of moving one unit of cargo to São Paulo (a proxy for the domestic market) was reduced in more than 40% from 1968 to 1995. Despite that, high transportation costs still remain one of the most critical obstacle to Brazilian competitiveness and development.

For the *Cerrado* areas in the Center-West and North regions, in addition to the reduction in transport costs, the profitability of economic activities was enhanced by the possibilities of agricultural mechanization in the flatlands. Last but not least, an important factor was Embrapa's agricultural research which adapted new cultivars – in particular soybeans, rice, and cotton – to the ecological conditions prevailing in the in these areas (Arantes and Souza, 1993; Helfand and Rezende, 1998). Both mechanization and innovation, however, were induced by the reduction of factors and to that extent are endogenous factors.

3. Spatial patterns of growth, 1872–2000

This section uses a suit of maps to illustrate the spatial patterns of Brazilian development during the 20th century. The number of Brazilian *municípios* increased from 642 in 1872 to 5507 in 2000. Therefore, to allow consistent inter-temporal analysis, *municípios* are combined in 432 Mínima Comparable Geographic Areas (MCA 1872–2000). Thus, the term municipality refers to MCA 1872–2000 which are mapped in Fig. A1 of the Appendix. Note that in the North

² The state of Rio Grande do Sul in the temperate zones of the extreme south of the country is a double exception. The flatlands of the Pampas were highly productive and had low transport costs. European immigration to this region was significant since the mid-19th century.

and Center-West regions, where settlement and creation of municipalities took place in recent times, the MCA are too few and too big, thus introducing visual and statistical distortions.³

Figs. 2A to 3E map the spatial distribution of income per capita and labor productivity in 1872, 1919, 1949, 1980 and 2000. Though the time benchmarks are primarily determined by the Census data, they are useful to provide a fairly broad characterization of the main phases of Brazilian development. It is reasonable to assume that patterns of spatial convergence of income per capita and labor productivity were significantly different between the various development phases during the 20th century (Reis et al., 2004).

Up to 1872, the incursion of economic activity into the Brazilian highlands was practically restricted to the mining areas of the Center-South region which were settled during the 18th century. Figs. 2A and 3A show the wide spatial disparities of income per capita and labor productivity in 1872. The Northeast, in particular the semi-arid areas of the hinterland, was already the poorest region of the country. The richest areas were located around Rio de Janeiro, which was then the capital and the largest port of the country, and the cities of Rio Grande and Porto Alegre in the extreme south of the country which were then the main ports for the fertile areas of the Pampas. The high income per capita levels in the Amazon region were explained by the rubber boom.

From 1872 to 1920, growth was mainly driven by the export of primary commodities, in particular coffee in the Center-South region and rubber in the North region. During most of the 20th century the economic frontier moves in the southwest direction pushed by coffee and industry. Figs. 2B and 3B show that, in 1920, São Paulo, together with Rio Grande do Sul, display the highest levels of income per capita and labor productivity, both areas combining a very productive agriculture with an emerging manufacturing activities. By then, the rubber economy in the Amazon had busted.

From 1920 to 1950, the country completed the first stage of an import substitution industrialization process based mainly upon non-durable consumer goods industry. During this period the city of São Paulo and her surroundings consolidate their place as the dominant industrial pole of the country. Figs. 2C and 3C show that the concentration of income per capita in São Paulo is intensified by the mid-century when urbanization and the import substitution industrialization processes reached their peaks. Supplementing the industrial boom of São Paulo, coffee and soybean cultivation explains the spread of high income per capita towards the southwest areas of São Paulo and Paraná.

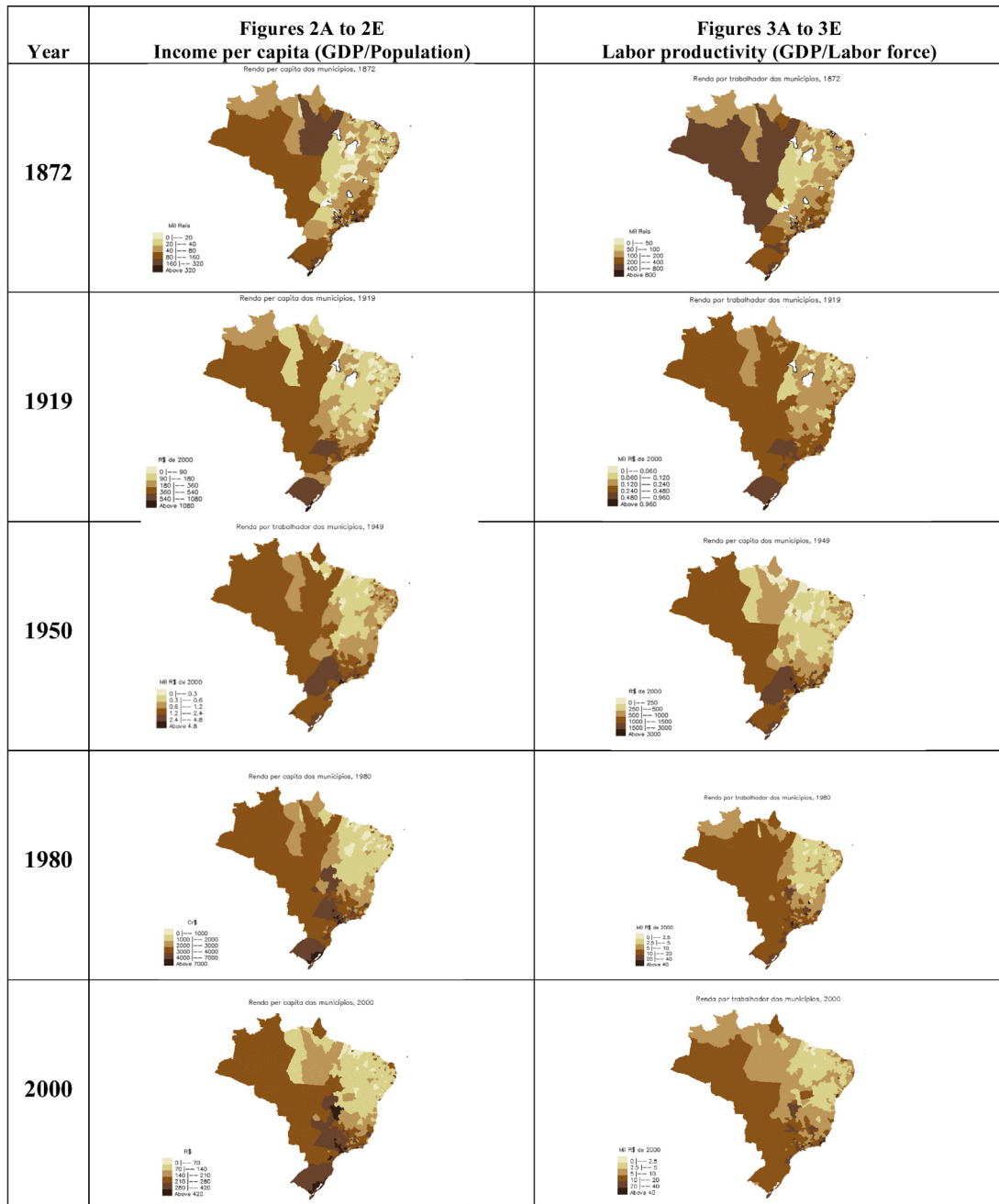
From 1950 to 1980, coupled to a strong urbanization process, high trade protection, and strong state intervention, the import substitution industrialization deepened going into durable consumer, basic raw material and capital goods industries. By the end of this period, Brazil was perhaps the most autarkic economy of contemporary world with an import coefficient close to 5% of GDP, out of which non-oil imports responded for less than 3% of GDP. Figs. 2D and 3D show that during this period, economic activity definitely turned towards the northwest direction led both by the change in the location of the federal capital to Brasília and the expansion of the agricultural frontier led by cattle, rice, corn and soybean.

After 1980, all the bad things came together: the debt crisis, hyperinflation, and stagnation. In the ensuing decades the unavoidable policies were stabilization, fiscal adjustment and liberalization which are still lurking. Trade liberalization policies eliminated a large part of the bias against exports of primary commodities. During this period, agricultural and mineral exports were the main sources of growth. Demographically, the country faced the end of the urbanization process and the beginning of the population ageing process. With the end of the urbanization and import substitution processes, the high levels of income per capita start spreading towards the agricultural frontier in the Center-West and North regions. São Paulo and Rio Grande do Sul kept their leading positions while the Northeast region lagged far behind the rest of the country. By 2000, both in terms of income per capita and labor productivity there is a clear divide of the country in the northwest-southeast direction.⁴

Finally, Fig. 4 presents Lorenz curves for the municipal income per capita distribution for the same Censuses years as before. In per capita terms, the highest levels of spatial concentration takes place in 1872 which practically dominates the curves for all the other years. Conversely, the lowest levels of spatial concentration takes place in 2000 which is practically dominated by the curves for all the other years. The spatial dispersion of income per capita was far from

³ Note also that the State of Acre is excluded from map of Brazil because in 1872 it was still part of the Bolivian territory. It was only in 1905 that it was incorporated to the Brazilian territory.

⁴ It is curious to observe that his division line resembles the southern boundaries of the Inter-Tropical Convergence Zone (ITCZ) observed in the Brazilian territory around January–April.



Figs. 2 and 3. Brasil: Geographic distribution (AMC 1872–2000) of income per capita (GDP/Population) and of labor productivity (GDP/Labor force) in 1872, 1919, 1949, 1980 and 2000 (units and scale variable). **Fig. 2(A–E)** Income per capita (GDP/Population); **Fig. 3(A–E)** Labor productivity (GDP/Labor force)
 Source: IBGE and author estimates.

monotonic, however. The curves display a strong dispersion of the spatial distribution of income per capita in the periods 1872–1919, when the economy was driven by coffee and rubber exports, and in 1970–2000, with the emergence of the agricultural frontier in the *Cerrado* areas of the Center-West region. In contrast, there is a strong concentration process from 1919 to 1970, during the heydays of the urbanization and import substitution industrialization process. It should be kept mind, however, that growth rates of the economy were significantly higher during this later period.

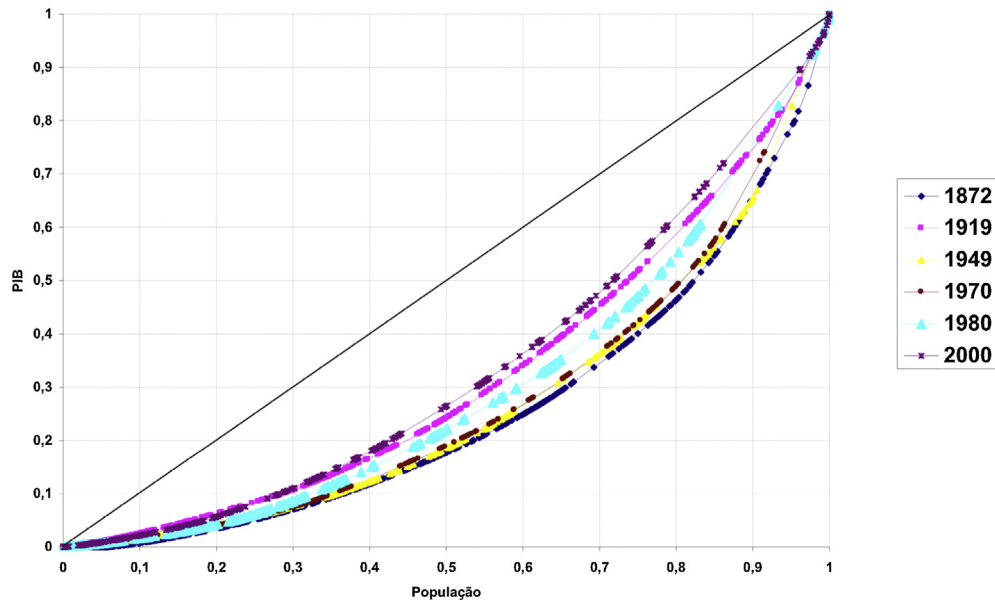


Fig. 4. Lorenz Curves for the Municipal Distributions of GDP according to Municipal Population, 1872–2000.

4. Secular patterns of convergence of labor productivity and income per capita in Brazil, 1872–2000

This section analyzes the patterns of spatial convergence of municipal income per capita and labor productivity from 1872 to 2000. For this purpose it estimates very simple convergence models where growth rates of income per capita or of labor productivity in a period of time are specified as a functions of the respective variable – income per capita or labor productivity – in the initial year of the period in case.

The basic specification of the convergence model is thus:

$$\log \left(\frac{y_{i,t}}{y_{i,t-n}} \right)^{1/n} = \alpha + \beta \cdot \log (y_{i,t-n})$$

where, $y_{i,t} = (Y_{i,t}/Pop_i)$ is GDP per capita (or GDP per labor force) in municipality i , Census year t ; $Y_{i,t}$ is GDP per capita in municipality i , Census year t ; $Pop_{i,t}$ is population (or labor force) in municipality i , Census year t ; β is a estimated coefficient that measures the speed of convergence of income per capita (or labor productivity) of municipalities.

Estimations for 1872 to 2000 were made for the main regions, as well for the sub-periods 1872–1919, 1919–1949, 1949–1980 e 1980–2000 for Brazil as whole. The results of OLS (Ordinary Least Square) estimations are available in (Reis, 2014).

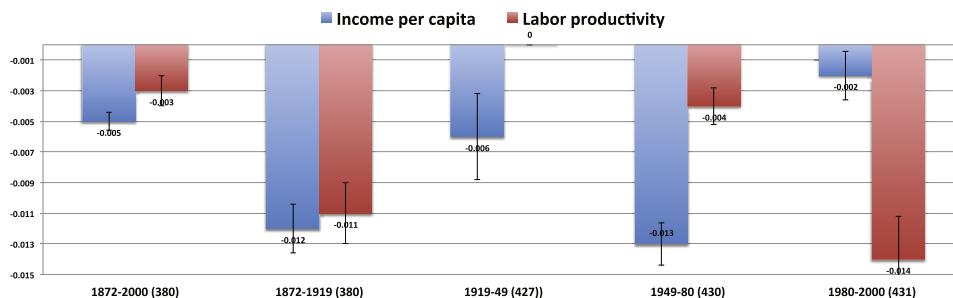


Fig. 5. Beta-convergence of the municipal distribution (AMC 1872–2000) of income per capita (GDP/Pop) and labor productivity (GDP/Labor force) for Brazil, 1872–2000 and selected sub-periods.

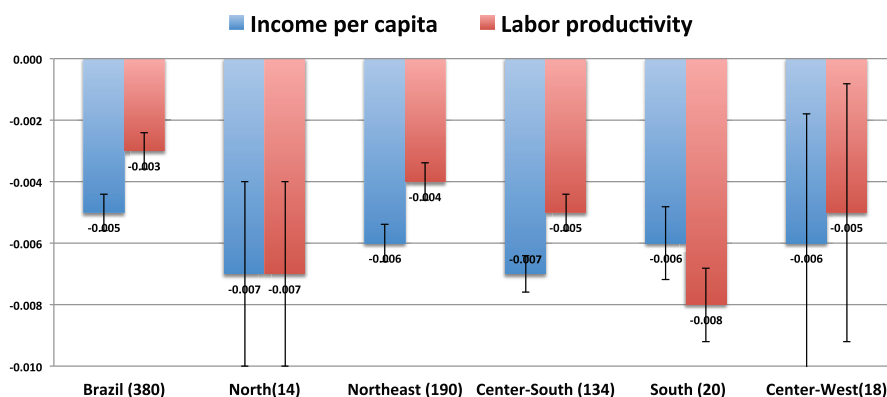


Fig. 6. Beta-convergence of the municipal distribution (AMC 1872–2000) of income per capita (GDP/Pop) and labor productivity (GDP/Labor force) for Brazil and main regions, 1872–2000.

Figs. 5 and 6 present the estimates of β , the speed of municipal convergence for income per capita (GDP/Population) and labor productivity (GDP/Labor force) in Brazil for the whole period, 1872–2000, and selected sub-periods. The capped lines show the two standard deviation confidence interval of the estimates of β , and the figures in parenthesis in the horizontal axis show the number of observation for each estimation period.

For the 1872–2000 period, corrected R^2 in the equations for income per capita and labor productivity were equal to 0.43 and 0.15, respectively. Thus, 43% of the variance of the growth of income per capita in Brazilian municipalities from 1872 to 2000 is explained solely by the level of income per capita in 1872, a quite good adjustment. Labor productivity growth has a much larger share of unexplained variance.

The estimated speeds of convergence, β , is -0.005 for income per capita, and -0.003 for labor productivity, both highly significant. In the former, the value of estimates say that municipalities with 1% more in the level of income per capita in 1872 had 0.005 less in their annual average growth rates in the period 1872–2000. The smallest speed of convergence for productivity growth indicates that the growth of income per capita was to some extent reinforced by changes in the dependency ratios – the ratio population/labor force – during the same period. Thus, one may speculate that the poorest municipalities had higher dependency ratios in the initial period and had larger relative decreases in the dependency ratio during the period of analysis.

Compared to other countries, the convergence of municipal income per capita in Brazil was quite slow. Indeed, estimates of β are close to -0.02 , both in the case of personal income in the US states in the period 1950–80 and of income per capita of Japanese municipalities in the period 1955–87 (Barro and Sala-i-Martin, 1995). Equivalent estimates for income per capita of Italian municipalities are -0.025 for the period 1951–70, and -0.003 for the period 1970–2000 (Arbba et al. (Felice, 2013)). The magnitude of those estimates are significantly higher than those estimate for Brazil in the periods 1950–80 or 1980–2000.

Looking at results across sub-periods, note first that the absolute values of β in all sub-periods are larger than those for the entire 1872–2000 period. Thus, the processes of convergence of income per capita and labor productivity in the different sub-periods were not reinforcing but reversing themselves.

It is difficult to pinpoint the forces shaping this historical pattern of convergence. The expansion of the coffee and rubber frontiers were probably responsible for the faster convergence from 1872 to 1919 while from 1949 to 1980 regional government policies coupled with the natural resources content of raw materials and commodities were responsible for the faster growth dispersion in both industry and agriculture. Changes in the dependency ratio associated with migration and urbanization trends probably played differential roles across sub-periods.

Looking at labor productivity, the speed of convergence was significantly faster in the periods 1872–1919 and 1980–2000. A suggested interpretation is that import substitution phases were associated with urban concentration, economies of scale and agglomeration, thus implying relatively slow decrease in the spatial inequality of labor productivity. On the other hand, export led growth phases were characterized by intense use of land and other natural resources leading to the spatial dispersion of economic activities and a much faster convergence of labor productivity. It should be kept in mind, however, that average growth rates were much higher in the import substitution phases.

For income per capita the speed of convergence was much faster in the periods 1872–1919 and 1949–80. Demographic factors are a suggested explanation for the much higher convergence in those periods. This is particularly plausible in 1949–80 period when rural–urban migration and urbanization were particularly strong.

It is interesting and somewhat puzzling to compare the β -convergence estimates of income per capita with the Lorenz curves presented in Fig. 6 which showed that the municipal concentration of income per capita reduced significantly from 1872 to 1919, increased from 1919 to 1949, was practically unchanged from 1949 to 1970 and decreased significantly from 1970 to 2000.

For the whole period 1872–2000, estimations were also disaggregated by main regions – North, Northeast, Center-South, South and Center-West – to get a more detailed picture of geographic patterns of convergence of income per capita and labor productivity. Fig. 6 shows that β estimates are negative and significant for all regions though the samples are relatively small for the North, South and Center-West.

In all regions the speed of convergence was a bit faster (absolute values of β were larger) than in Brazil as a whole. That suggests a secular process of regional divergence which was counteracted by a slow process of spatial convergence inside each region. The concentration of import substitution industrialization in the Center-South region of the country and the marked regional contrasts in soil aptitude and agricultural development were, undoubtedly, major factors in process of spatial divergence. Inside the regions, the speed of convergence was faster in the South and in the North Region, but slow in the Northeast. For all regions, however, β estimates are exceedingly low in international perspective.

5. Urban and rural GDP growth convergence, 1919–2000

In what follows the analysis of growth convergence for 1919–2000 will be detailed in two ways. First by the disaggregation of the analysis for urban and rural activities. And, second, by assuming spatial correlation among the variables of the model, as well as among equations of describing the processes of urban and rural growth.

For the period 1919–2000, the economic censuses allow the estimation of separate convergence equations for labor productivity in rural (agriculture) and urban (non-agricultural) activities. The sectorial disaggregation is not made for income per capita simply because the Census of 1920 did not collect data on rural and urban population despite collecting data on labor force according to major economic activities.

Before coming to the regression results it is interesting to observe that, in the period 1919–2000, average municipal growth rates were higher for income per capita (3.3% p.a.) than for labor productivity (3.0% p.a.) thus, indicating that, on average, labor force grew faster than population, that is, the average dependency ratio decreased during this period.

Another interesting finding is that average growth of labor productivity was higher in agriculture (2.6% p.a.) than in urban activities (2.4% p.a.). To a large extent the explanation lies in the weight of the service sector and all kinds of low productivity informal activities in the growth of urban output and employment.

OLS results for convergence equation are presented in the first line of Table 1. Adjusted correlation coefficients are small compared to the estimates obtained for 1872–2000. The speed of convergence were negative and significant as attested by the t statistics. Convergence faster for labor productivity than for income per capita, both however extremely low when compared to other countries. The faster convergence of labor productivity is difficult to interpret without further analysis of demographic patterns of growth – dependency ratio, in particular – during this period.

Convergence equation for the growth of labor productivity in rural and urban activities in the 1920–2000 period show that the speed of convergence was faster for urban activities, though both still very low compared to international standards. This result sounds reasonable given the relatively footloose characteristics of urban activities, while agriculture depends on the availability of adequate soils and climate which are concentrated in specific areas – particularly in the South and Center-West regions – of the country.

Finally, it is interesting to observe that both rural and urban activities show higher speed of convergence than aggregate labor productivity in the economy, thus suggesting that there were synergies and cross-correlations between the processes of growth in labor productivity in both sectors. Rural and labor productivity grew faster or slower in the same areas, thus characterizing patterns of growth high–high or low–low in both sectors.

6. Spatial auto-correlation of convergence

To further investigate the processes of convergence of labor productivity in rural and urban activities, estimations were made assuming spatial auto-correlation in both the dependent (SACD) and residual (SACR) variables of the

Table 1

Brazil: Estimates of β -convergence for GDP per capita and labor productivity, 1919–2000 and sub-periods. OLS and ML models with spatial autocorrelation in the dependent variable (SACD), in the residuals (SACR), and SURE with spatial autocorrelation in the residuals (SURE + SACR).

Period and model specification	Growth of GDP per capita		Growth of labor productivity					
	Beta (t-st.)	SAC (ERC)	All activities		Agriculture		Non-agricultural activities	
			Beta (t-st.)	SAC (ERC)	Beta (t-st.)	SAC (ERC)	Beta (t-st.)	SAC (ERC)
Period 1919–2000								
OLS	−0.0031 (−6.04)		−0.0044 (−9.08)		−0.0051 (−9.84)		−0.0079 (−16.7)	
SACD	−0.0032 (−4.82)	0.6	−0.0039 (−5.37)	0.50	−0.0047 (−5.73)	0.50	−0.0075 (−2.10)	0.30
SACR	−0.009 (−19.7)	0.8	−0.0092 (−20.4)	0.75	−0.012 (−26.5)	0.85	−0.0113 (−20.9)	0.70
SURE + SACR					−0.0109 (−17.2)	0.99 (0.61)	−0.0114 (−22.9)	0.92 (0.61)
Period 1919–49								
OLS	−0.0058 (−4.22)		−0.0070 (−5.12)		−0.0209 (−20.8)		−0.0007 (−0.36)	
SACD	−0.006 (−3.68)	0.5	−0.0068 (−4.07)	0.50	−0.0182 (−7.32)		−0.0032 (−1.31)	0.65
SACR	−0.013 (−9.08)	0.6	−0.0147 (−10.5)		−0.0291 (−29.1)		−0.0061 (−2.60)	0.65
SURE + SACR					−0.0301 (−24.6)	0.92 (0.28)	−0.0047 (−2.13)	0.78 (0.28)
Period 1949–1980								
OLS	−0.013 (−18.6)		−0.111 (−10.4)		−0.010 (−7.64)		−0.024 (−29.3)	
SACD	−0.007 (−5.35)	0.45	−0.0094 (−5.92)	0.45	−0.0096 (−5.20)	0.55	Negative sq. root	
SACR	−0.016 (−15.8)	0.7	−0.0175 (−16.2)	0.65	−0.0221 (−16.9)	0.75	Negative sq. root	
SURE + SACR					−0.0231 (−16.1)	0.95 (0.06)	−0.0276 (−29.8)	0.72 (0.06)
Period 1980–2000								
OLS	−0.002 (−2.50)		−0.0139 (−9.76)		−0.0027 (−1.27)		−0.0226 (12.7)	
SACD	−0.009 (−5.49)	0.5	−0.0068 (−4.07)	0.50	−0.0065 (−2.66)	0.60	−0.0211 (−7.20)	0.45
SACR	−0.021 (−17.1)	0.7	−0.0147 (−10.5)	0.65	−0.0248 (−11.7)	0.75	−0.0305 (−14.7)	0.65
SURE + SACR					−0.0253 (−8.45)	0.97 (0.22)	−0.0319 (−7.62)	0.92 (0.22)

Authors estimation (modelace01pib_pearu, regrace01pibpea_urbano, regrace01pibpea-rural).

equations. In addition, estimations were made assuming both correlation among the residual of the growth convergence equations for rural and urban activities in a seemingly unrelated specification (SURE) and spatial auto-correlation of the residuals of each equation (SACR).

The first model (SACD) says that there is spatial inertia in the growth of labor productivity. Thus, without specifying the underlying causes, the model assumes that labor productivity growth is transmitted to contiguous municipalities in a contagious process. Emulation, migration of people and technology are possible explanations for the contagious process in labor productivity.

Statistics for the spatial auto-correlation of the dependent variables (SACD- ρ) are presented together with the estimates of β -convergence presented in Table 1. Though the spatial auto-correlation is significant, in particular for rural activities, estimations of β are for the whole period, 1919–2000, are practically unaffected by their inclusion in the model. The same is true for rural activities in the sub-periods considered, except for 1980–2000. For urban activities, the evidence is blurred by very fact that the lack of convergence in the estimation for the period 1919–1949 introduces problems in the estimation.

The second model (SACR) assumes that the residuals of the growth of labor productivity in rural and urban activities are subject to spatial auto-correlation. That is, the determinants of these respective growth processes, though unknown, are supposed to be subject to spatial inertia as in the case of most geographic variables; or else to be subject of spatial contagion through markets, culture, or any other kind of institutional mechanisms. This assumption is confirmed by the pretty high values of the respective SAC- ρ presented in the table.

Estimates of β in the table show that this assumption modifies the results in a significant way. For the whole 1920–2000 period, values of the speed of convergence, β , are now close to 1.1 both in rural and urban activities. Once again, in the international context, this is still a relatively slow speed of convergence.

Looking at the selected sub-periods, the speed of convergence are now much higher, with estimates in the range 2.5–3.0, in absolute values. The increase in the speed of convergence is particularly strong in the urban activities which leads the process of convergence in all sub-periods, except 1919–1949.

Note, however, that the speed of convergence of labor productivity is now being measured among groups of contiguous municipalities that have some common unspecified determinants of the growth of productivity. In this way, it is a conditional convergence measure.

Finally, the last model combines the assumption of correlation of residuals of the growth convergence equations for labor productivity in urban and rural activities with the assumption of spatial auto-correlation in the residuals of each of the equations (SURE + SACR). It is possible to see that the results are pretty similar to the ones obtained with the SACR model. Thus, what matters most for the process of convergence of labor productivity in rural and urban activities is the spatial auto-correlation observed for each of these activities and not the correlation between the growth of productivity in rural and urban activities. Thus, residual factors in the growth convergence equations of labor productivity in the rural and urban activities the growth of labor productivity in rural and urban activities in the Brazilian economy during the 20th c. were quite independent processes with each of them subject to spatial inertia processes.

7. Factors conditioning convergence patterns, 1920–2000

To analyze the determinants of the growth pattern of the Brazilian economy in the period 1920–2000, the specifications of the growth convergence equations are enlarged to incorporate the determinants of steady state growth rates of Brazilian municipalities. This is made by the specification of a conditional model which uses variables like infrastructure, geographical attributes, institutions, and human capital, among other, to explain the growth of municipalities from 1920 to 2000.⁵

In the case of the growth of GDP per capita the model to be estimated becomes:

$$\log \left(\frac{y_{i,t}}{y_{i,t-n}} \right)^{1/n} = \alpha + \beta \cdot \log(y_{i,t-n}) + \gamma \cdot X_{i,t-n}$$

⁵ It was not possible to extend the analysis to 1872 because to estimate income per capita for this year it was necessary to use all the conditional variables available, thus unavoidably introducing problems of endogenous variables bias.

where, $y_{i,t} = Y_{i,t}/\text{Pop}_i$ (or $Y_{i,t}/\text{Labor}_i$) is the aggregate, urban, or rural labor productivity (GDP/labor force) or GDP per capita of município i in year t , $Y_{i,t}$ is aggregate, urban, or rural GDP of município i in year t , $\text{Pop}_{i,t}$ is total, urban or rural population of município i in year t . $\text{Labor}_{i,t}$ is aggregate, urban or rural labor force of the município i in year t . $X_{i,t-n}$ = matrix of explanatory variables including all the arguments that condition the steady-state rate of growth of Brazilian municipalities from 1920 to 2000

The conditioning or explanatory factors are listed in the first column of [Table 1](#). They include major characteristics of the municipalities in terms of geography (area, latitude, longitude, altitude, temperature, precipitation, soil types, etc.), demography (population, foreign population, labor force), economy (GDP by sectors, landownership concentration, electricity generation, area of farms, share of coffee in cropped area), accessibility and transport (existence and age of railway station, distance to sea, and distance to capital, potential market index), human capital and education (literacy, enrollment and number of primary schools) and a few institutional dimensions like the number of slaves in 1872 and the number of voters in 1910. Most of the variables refer to 1920. The exceptions are schools, and voters which were not available for 1920 and, for obvious reasons, slavery and geographic conditions. A detailed description of their definition and measurement is presented in the database appendix.

Estimation results presented in [Table 2](#) shows that initial socio-economic conditions in 1920 explain more than 50% of the variance of the growth rates of Brazilian municipalities in the period 1920–2000. Note that the simple growth convergence equation explained around 15%.

The speed of convergence is approximately equal to 1 for both income per capita and labor productivity. Thus, municipalities which were 1% richer in 1920 show, on average, a rate of growth 0.01% smaller in the period 1920–2000. For urban and agriculture activities the estimates for GDP per worker are 1.2, approximately. These values are relatively small given that we are talking about conditional growth. That is, municipalities which had the same initial conditions. Thus, even in this case the speed of convergence is slow compared to other countries.

To identify the most important growth conditioning factor we use the threshold of 5% significance level for the t -statistics. In [Table 2](#) the variables which pass the threshold criteria and therefore are considered important growth factors are marked with one asterisk. Two asterisks denote the threshold of 1% significance.

A careful look shows that population in 1920 is not significant in all the equations (marginally in the case of the growth labor productivity) but is kept as a normalizing variable for all the other variables demographic variables. Some variables with a high incidence of null observations, however, were specified in per capita terms.

The most important variable is the dummy for the existence of a railway station in 1920. *Ceteris paribus*, that would imply an increase of 14% p.a. in average growth rates from 1920 to 2000. This is a huge impact, hardly believable, but results were double checked. One possible explanation would be that railroad stations are capturing the effects of omitted variables related to transportation costs, accessibility, and other previous locational advantages. Note, however, that the huge effect is restricted to urban activities; growth rates of agricultural productivity were not significantly affected by the existence of a railroad in 1920.

The age of the railway station also has a small but significant positive effect on the average growth rate. Early comers in the railway access have had a lasting growth advantage.

To be a state capital was also an important factor for the secular growth rate of both income per capita and labor productivity. The increase in average growth rates in the period 1920–2000 are 0.5% for GDP per capita and 0.4% for GDP per worker. Surprisingly, when we disaggregate the analysis for labor productivity, the effect is only marginally significant in the growth for urban activities, and as expected, not significant for the growth of agricultural productivity.

The distance to a state capital, however, had a positive effect on the growth rate of labor productivity in agriculture but none on the other dependent variables. It looks like as the consequence of home markets effects or some form of access to technology since capital are both more rich and populated and also sources of knowledge and human capital.

Other infrastructure variables with significant effects have to do with electricity generation. Both the number of companies of electricity generation installed in a municipality in 1920 and their capacity of generation (in Kw) in that same year had a significant positive effect on the secular growth rate of GDP per capita and per worker. Each additional company brings 0.1% of increase in the annual average secular growth of the municipality. The effect is wholly due to industry. Growth rates of GDP per worker in agriculture are not affected by electricity infrastructure, as we should expect given the fact the distribution of electricity in rural areas was practically absent in Brazilian municipalities in 1920.

Apart from infrastructure, the other important factor is the potential market of the municipality in 1920 measured by the average GDP of Brazilian municipalities weighted by the inverse of their geographic distances to the municipality

Table 2

Brazil: OLS estimation of conditional growth convergence of GDP per capita and Labor Productivity in Urban and Rural activities, 1919–2000.

#		Growth of GDP per capita 1919–2000	Growth of aggreg. labor productivity 1919–2000	Growth of rural labor productivity 1919–2000	Growth of urban labor productivity 1919–2000
1	N.Obs.	397	397	395	397
2	F-value	7.193	6.898	8.600	6.632
3	R-Square	0.552	0.541	0.597	0.532
4	Adj R-Sq	0.475	0.463	0.527	0.451
5	Dependent Mean	0.034	0.030	0.026	0.024
6	Root MSE	0.006	0.005	0.008	0.006
7	Coeff. Var.	16.567	18.419	32.072	22.852
8	Variable				
9	Intercept	-0.188**	-0.155*	-0.065	-0.098
10	Log (GDP per capita1919)	-0.010**			
11	Log (Labor productivity 1919)		-0.010**		
12	Log (Labor productivity rural 1919)			-0.012**	
13	Log (Labor productivity urban 1919)				-0.012**
14	Log(Population in 1920)	-0.004	-0.005	-0.005	-0.003
15	Log (Labor force 1920)	0.000	0.002	-0.014*	0.003
16	Log (Labor force in agriculture 1920)	0.002	0.002	0.012**	0.000
17	Log (Labor force in manufacture1920)	0.000	0.000	-0.001	0.000
18	Log (Foreigners in 1920)	0.001**	0.001*	0.002**	0.001
19	Log (Literates in 1920)	0.001	0.000	0.004	-0.002
20	Students public primary school 1920/Population 1920	-0.128	-0.108	0.018	-0.077
21	Students private primary school 1920/Population 1920	0.084	0.082	0.158	0.106
22	Number of state primary schools in 1920/Population in 1920	2.300	1.978	0.487	0.755
23	Number of private primary schools in 1920/Population in 1920	3.313	2.582	-0.684	-0.899
24	Dummy for railway station in 1920	0.148*	0.141*	-0.066	0.153**
25	Inaugural year of railway in the municipality	0.000*	0.000*	0.000	0.000**
26	Dummy for electricity generation station in 1920	0.277	0.298	0.254	0.340
27	Inaugural year of electricity in the municipality	0.000	0.000	0.000	0.000
28	Number of electrical motors in municipality 1920	-0.001	-0.001	0.000	-0.001
29	Power of electrical motors in municipality 1920 (Kwh)	0.000*	0.000*	0.000	0.000*
30	Number of enterprises generating hydroelectricity 1920	0.001*	0.001*	0.000	0.001*
31	Number of registered voters in 1914/Population in 1920	-0.011	-0.005	-0.070*	0.002
32	Share of slaves in total population 1872	0.007	0.006	0.000	0.006
33	Log (Area of agricultural establishments in 1920)	0.001	0.001	0.002**	0.001
34	Crop area of coffee 1920/Area of farms 1920	-0.005	-0.006	0.008	-0.001

Table 2 (Continued)

#		Growth of GDP per capita 1919–2000	Growth of aggreg. labor productivity 1919–2000	Growth of rural labor productivity 1919–2000	Growth of urban labor productivity 1919–2000
35	Theil index of landownership inequality in 1920	0.000	0.000	0.000	0.000
36	Log (GDP potential market in 1919)	0.007**	0.007**	−0.002	0.006**
37	Log (Geographic area of AMC)	0.000	0.000	−0.001	0.000
38	Latitude of seat of municipality	−0.0003	−0.0002	−0.0015**	0.0000
39	Longitude of municipality seat	0.0001	0.0001	0.0002	0.0000
40	Dummy for state capital	0.0050**	0.0038*	0.0004	0.0032
41	Geodesic distance to the state capital (in km)	0.0000	0.0000	0.0000**	0.0000
42	Geodesic distance to the sea (in km)	0.0000*	0.0000*	0.0000	0.0000
43	Share of area w/altitude 0 a 99 m	0.007**	0.007**	0.006	0.009**
44	Share of area w/altitude 200 a 499 m	−0.002	−0.003	0.002	−0.001
45	Share of area w/altitude 500 a 799 m	0.001	0.000	0.008*	0.002
46	Share of area w/altitude 800 a 1199 m	0.002	0.000	0.000	0.001
47	Share of area w/altitude 1200 a 1799 m	−0.007	−0.005	0.006	−0.002
48	Share of area w/altitude 1800 a 3000 m	−0.131	−0.127	0.105	−0.125
49	Share of area 7.5–15% declivity-moderate erosion	−0.006	−0.005	−0.006	−0.003
50	Share of area 30–45% declivity-strong erosion	−0.005	−0.004	−0.006	−0.004
51	Share of municipal soil in class 1	0.158*	0.144*	0.062	0.093
52	Share of municipal soil in class 2	0.160*	0.145*	0.058	0.095
53	Share of municipal soil in class 3	0.144*	0.128*	0.054	0.080
54	Share of municipal soil in class 4	0.150*	0.136*	0.057	0.087
55	Share of municipal soil in class 5	0.149*	0.135*	0.048	0.091
56	Share of municipal soil in class 6	0.156*	0.141*	0.061	0.092
57	Share of municipal soil in class 7	0.160*	0.145*	0.059	0.096
58	Share of municipal soil in class 8	0.158*	0.143*	0.058	0.094
59	Share of municipal soil in class 9	0.161*	0.148*	0.083	0.084
60	Share of municipal soil in class 10	0.156*	0.141*	0.058	0.092
61	Share of municipal soil in class 11	0.146*	0.131*	0.055	0.083
62	Share of municipal soil in class 12	−0.049	−0.068	0.309	−0.159
63	Average precipitation Dec–Feb 1961–90	−0.00005*	−0.00003	0.00003	−0.00004
64	Average precipitation Jun–Aug 1961–90	−0.00004*	−0.00002	0.00009**	−0.00002
65	Average precipitation Mar–May 1961–90	0.00004	0.00003	0.00000	0.00000
66	Average precipitation Sep–Nov 1961–90	0.00002	0.00000	−0.00007	0.00003
67	Average temperature Dec–Feb 1961–90	−0.00210	−0.00138	−0.00613**	0.00039
68	Average temperature Jun–Aug 1961–90	−0.00129	−0.00040	−0.00507**	0.00092
69	Average temperature Mar–May 1961–90	0.00189	0.00115	0.00549*	−0.00136
70	Average temperature Sep–Nov 1961–90	0.00100	0.00009	0.00743**	−0.00060

Source: Author's estimates (pib14si.xls).

Obs.:

* Significant at 5% level.

** Significant at 1% level.

in case. Each percent implied 0.001% more of average growth rates in 1920–2000. Thus, municipalities that were close to rich municipalities in 1920 grew more in the 1920–2000 period. Thus, market agglomeration effects were important and demand as well as historical accidents probably played an important role in the development process.

Foreign born population was also an important factor of productivity and income per capita growth. Interestingly, however, the effect was mainly felt in the growth of agricultural productivity. For the growth of urban productivity it was not significant. Suggested explanations for her importance in agricultures are capital, technology, human capital as well as cultural and institutional innovations introduced by the immigrants.⁶ It could as well be that migrants anticipated the agricultural prospects of the areas for where they migrated. Note, however, that coffee as percent of agricultural establishments is not significant. Thus, if their prospection methods were not an obvious one, in particular if we consider that they were relatively ignorant about the country.

Agricultural activities tend to show some inertial or cumulative features in that the growth of agricultural productivity was higher in the municipalities with larger labor force in agriculture and area of a larger share of agricultural establishments in 1920. Note, however, that the size of total labor force pushes tends to decrease the growth of agricultural productivity.

Geographic variables have some expected effects and other quite surprising. Temperature and precipitation on income per capita and, moreover, soils significance in per capita growth perhaps taking the effects of state dummy that should be introduced. See the joint significance tests below.

Finally, the model tests the importance of some institutional conditions of the municipalities. As proxies of institutional conditions were included the share of slaves in total population in 1872; Theil index for landownership concentration in 1920; a group of variables related to education including the literacy rate of population in 1920, and four other variables describing the availability of schools as well as the attendance of schools in 1907; and, finally, political participation in 1914 as measured by the share of registered voters in total population.⁷

Surprisingly, however, considered in isolation or jointly, all the institutional proxies selected were not statistically significant (at the 5% level) for the growth of Brazilian municipalities in the 20th century. The only significant proxy of institutional factors is, therefore, the share of foreign born population in 1920.

To test the institutional hypothesis, variables were aggregated in three groups of variables composed as follows:

- (A) Slavery in 1872 + Registered voters in 1910 + landownership concentration in 1920
- (B) Education condition described by literacy rate in 1920 + students enrolled in public and private schools in 1910 + the number of public and private primary schools in 1910.
- (C) The share of foreign born population in 1920.

As shown in [Table 3](#), *F*-tests for the joint significance of A, B, A + B and A + B + C were conducted with the result that, at 5% confidence level, A, B, A + B are not significant in all cases. Only A + B + C is significant which is not surprising given that the share of foreign born population was already significant when singly considered. But in the case of the growth of labor productivity in urban activities even A + B + C is not significant. Thus, climate conditions were binding factors for Brazilian agricultural growth but soil conditions and altitude were circumvented.

Finally, [Table 3](#) presents also test of joint significance for the main geographic factors. Figures show that, jointly considered, temperature and precipitation were significant explanatory factors for the growth of rural labor productivity. Surprisingly, however, altitude and geo-morphology of soils were significant explanatory factors for the growth of growth of income per capita and of labor productivity in the economy, as well as of the growth of labor productivity in urban areas, but and in the urban activities in particular but, surprisingly, not for the growth of rural labor productivity.

8. The persistence of conditional effects through time

An interesting question to be posed is how persistent were the effects of railroads stations and foreign born population in 1920 on the growth of Brazilian municipalities. To analyze this question we estimate the same conditional growth convergence model for each of the sub-periods 1919–1950, 1950–1980, and 1980–2000, that is, using the same

⁶ For a learned discussion of the interactions of culture and institutions in the development process, see ([Alesina and Paola, 2013](#)).

⁷ International comparative analysis can be found in ([Lagerloef, 2004, 2005](#)).

Table 3

F-tests of joint significance for the conditional growth equations of GDP per capita and labor productivity, 1919–2000.

Groups of variables	Growth of GDP per capita		Growth of labor productivity					
	<i>F</i> Value	Pr > <i>F</i>	Aggregate		Rural		Urban	
			<i>F</i> -value	Pr > <i>F</i>	<i>F</i> -value	Pr > <i>F</i>	<i>F</i> -value	Pr > <i>F</i>
A) Slave + Politic + Farm Theil	1.02	0.38	0.34	0.42	1.37	0.25	0.87	0.46
B) Education	1.78	0.11	1.37	0.24	1.24	0.29	1.27	0.28
C) A + B	1.51	0.15	1.23	0.28	0.96	0.47	1.13	0.34
D) A + B + foreign	2.67	0.01	2.08	0.03	3.21	0.00	1.34	0.22
E) Temperature	0.56	0.69	0.44	0.78	6.84	0.00	0.71	0.59
F) Precipitation	1.77	0.14	1.07	0.37	7.33	0.00	1.35	0.25
G) Declivity	1.15	0.32	1.09	0.34	0.53	0.59	0.43	0.65
H) Altitude classes	3.93	0.00	4.38	0.00	1.60	0.15	4.61	0.00
I) Soil geo-morphol.	2.30	0.01	2.31	0.01	0.67	0.78	1.73	0.06

Source: Author's estimates.

Obs.: Significant *F*- values are highlighted by bold font.

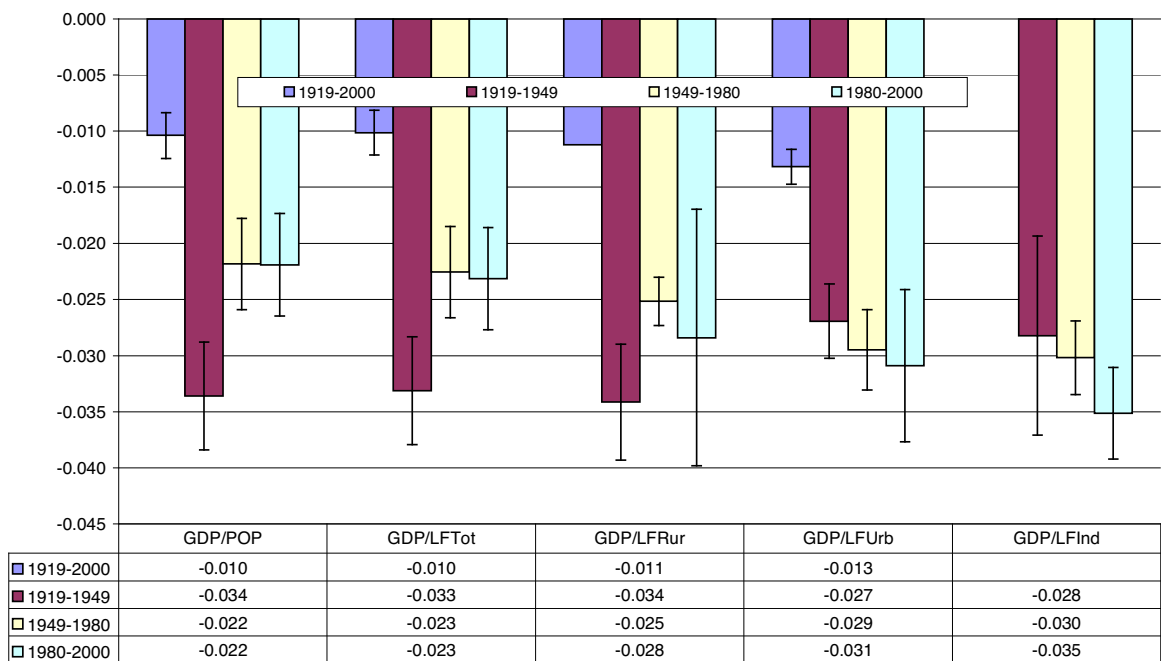


Fig. 7. Estimates of Beta-convergence for income per capita (GDP/POP) and labor productivity (GDP/LF) in selected activities and periods (changing only the year of lagged dependent variable for each period: lines show 1 std-error).

specification except by the year of the lagged dependent variable. Figs. 7–9 summarize the values (and standard deviation) of the coefficients estimated for B-convergence, the station railroad dummy, and the foreign bron population in 1920 for each activity and sub-period.⁸

Fig. 7 shows that the speed of conditional growth convergence for income per capita was significantly slower in the whole 1919–2000 period, than in each one of the sub-periods. This is a puzzling result. Intuitively, one should expect that conditional convergence would be faster in the long run. It was significantly faster in the 1919–1950 period than in the 1950–1980 and 1980–2000 periods when they are approximately equal.

This pattern of conditional growth convergence practically the same for labor productivity in the whole economy, and to a lesser extent in the rural activities where convergence was a bit faster since 1950. For industrial and urban

⁸ Though not reproduced in this paper, the remaining regression results are available on request.

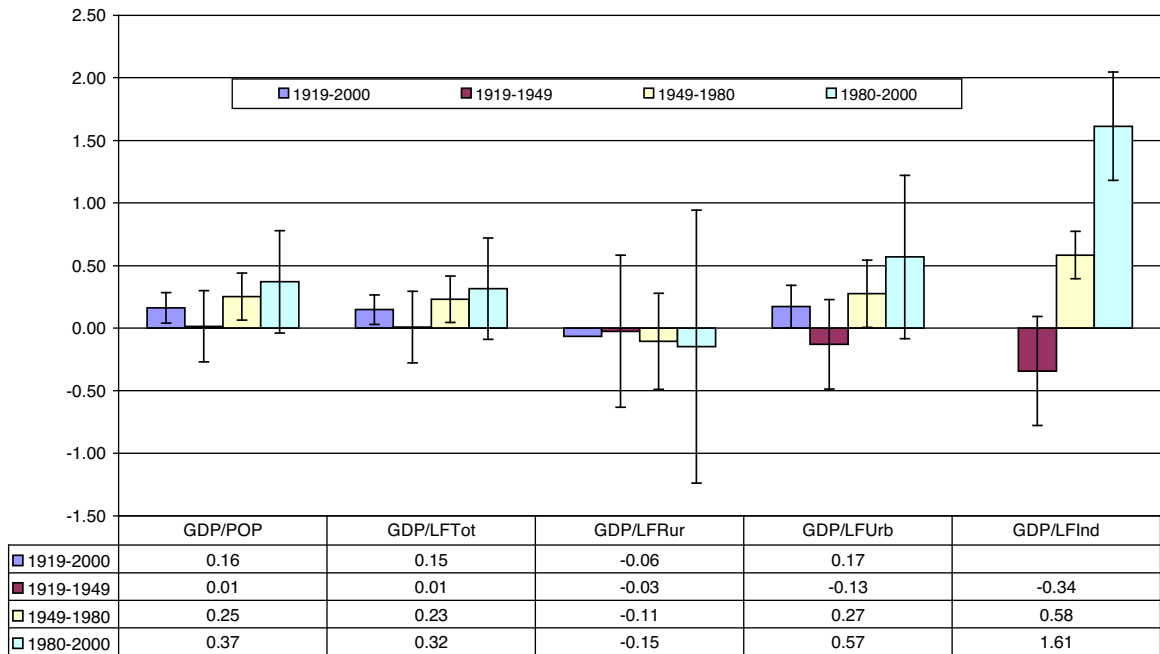


Fig. 8. Impact of railroad stations in 1920 in the growth of income per capita (GDP/POP) and labor productivity (GDP/LF) in selected activities and periods (changing only the year of lagged dependent variable for each period; lines show 1 std-error).

activities, however, the speed of conditional growth convergence shows a significant acceleration in the more recent sub-periods. That is, the growth of labor productivity in the urban activities was increasingly dispersed as time goes on. The catching up of the least productive municipalities at the beginning of each sub-period was increasingly faster.

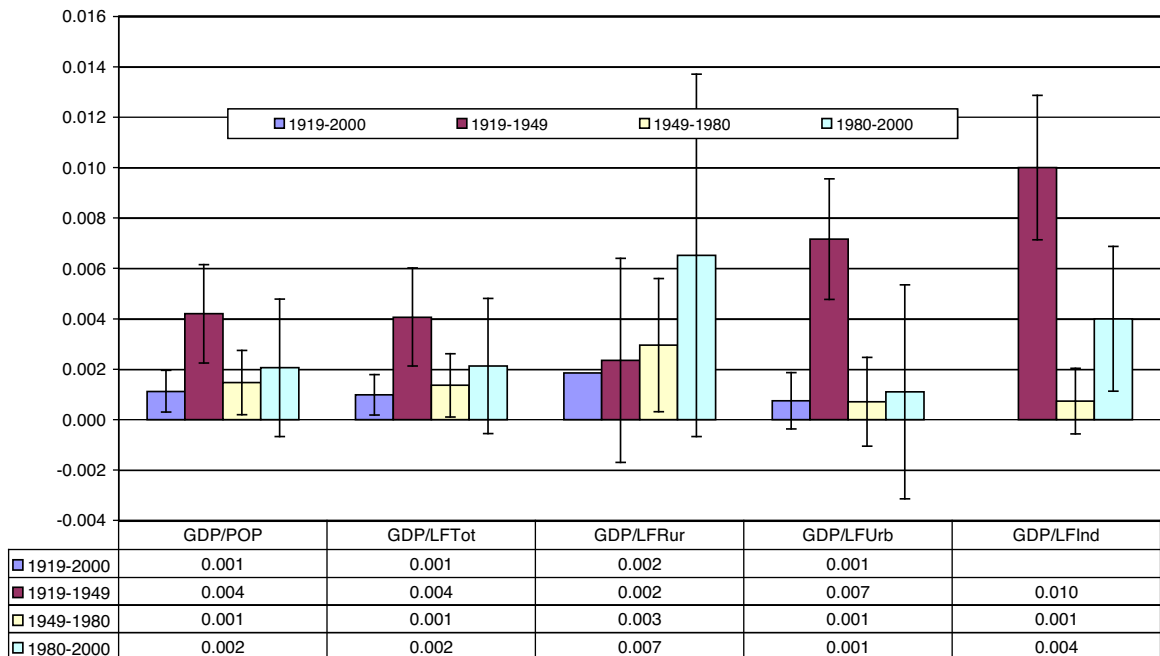


Fig. 9. Elasticity of foreign born population in 1920 in the growth of income per capita (GDP/POP) and labor productivity (GDP/LF) in selected activities and periods (changing only the year of lagged dependent variable for each period; lines show 1 std-error).

Fig. 8 below shows that the effects of 1920 railroads stations dummies on growth of municipalities were significant and persistent in the case of labor productivity in industrial and, to a lesser extent, in urban activities. They were practically non significant for income per capita and total productivity and productivity in urban activities.

Foreign born population had significant effects in 1919–49 but the lasting effects were on rural activities.

9. Conclusions and extensions

The basic hypothesis of this paper is the overwhelming role played by the geographic factors, especially transport costs, in the historical generation and reproduction of spatial inequalities in Brazil. Empirical evidence are given by the analysis of the spatial patterns of growth of labor productivity and income per capita of the Brazilian municipalities from 1872 to 2000.

The main result of the analysis is that spatial inequalities in the density of economic activity, income per capita and labor productivity remained practically unchanged – with negligible reductions – from 1872 to 2000. The maps show clearly the secular persistent northwest-southeast divide of the country.

Estimation of econometric models of growth convergence provide a more rigorous test of the hypotheses. Estimation reported show, first of all, that the speed of convergence of both income per capita and labor productivity was very slow compared to other countries. Disaggregation of the analysis by sub-periods, regions and sectors show, respectively, that phases of export led growth were more dispersive than the import substitution phases; convergence was faster inside each region and thus regional disparities reinforced spatial inequalities in the country as a whole; and convergence of labor productivity was faster in urban activities than in rural activities.

More notably, estimated parameters show that conditions of access to infrastructure in 1920 – as proxied by the existence of railway station in the municipality – was by far the most important factor conditioning the growth of Brazilian municipalities during the 20th century. Other variables related to accessibility like the distance to the state capitals, and the market potential of the municipality also played roles in the long run growth of municipalities. This strong result corroborates the perception that Brazilian development strategies during the second half of 20th century had misguidedly disregarded investment in railway infrastructure which therefore remains as a crucial obstacle of steady growth.

In contrast, institutional factors – as proxied by slavery (in 1872), education and human capital, political participation, and landownership concentration – did not play a significant in long run growth of income per capita or labor productivity of Brazilian municipalities. Even jointly tested, their coefficients remain insignificant. The only exception role is perhaps the institutional innovations brought with the Europeans immigrants since the share of foreign born population in 1920 had a significant positive effect on the secular rates of growth both labor productivity and income per capita, specially in the agricultural activities.

Needless to say, the results are still preliminary and further extensions and scrutiny are required. Obvious extensions of the analyses are to disaggregate them for the all the 10 inter-censuses periods as well as economic activities available to estimate in more rigorous way the interplay between factors conditioning growth of Brazilian municipalities. A priority in this way is to update the analyses for the 2000–2010 to disentangle the role played by spatial inequalities in the recent redistributive process (Rodrigues-Silveira, 2012)

In this way the tasks ahead are to complete the historical database on the conditioning factors – in particular on demographic aspects related to migration and dependency ratio; urban and transportation infrastructures; education and human capital; political participation, etc. – for the periods from 1920 and 1960 when data are still in printed format.

Another line of scrutiny would be a more rigorous econometric treatment of problems like spatial correlation, seemingly unrelated equations, and endogenous variables in the model.

A couple of examples illustrate the relevance of these issues. The existence of railroad station is a poor proxy for transportation infrastructure to the extent that they tend to be located in places which had previous advantages in terms of access and natural resources and thus that were likely to grow faster in the long run. Thus, railroad stations are endogenous and to that extent their importance and significance are biased. A solution proposed is to use as instrumental variables on transport accessibility previous to railways. An example is the distance to main seaports by mule troops in 1870 which is now being compiled.

Analogously, slavery in 1872 gives a biased picture of the secular and persistent effects of the institution because concentration of the slave population in the booming coffee areas slaves in took place in the short period of a few

decades during the mid 19th c.⁹ To that extent the share of slaves in 1872 are to some extent endogenous to the development prospects of this region. Suggestion to circumvent this problem are to use as instrumental variables the data on black population in 1872 and in 1890. The rationale is that a large share of blacks (pardos e pretos livres in 1872) is a better proxy for the historical prevalence of slavery in the municipality and thus to capture the long run effects of slavery.

Appendix – Database.

Brazilian *município* is the basic geographic unit of observation of the data. The number of Brazilian *municípios* in Brazilian censuses increased from 642 in 1872 to 1304 in 1920, 3951 in 1970 and 5507 in 2000. The changes in number and geographic boundaries of *municípios* preclude consistent intertemporal analysis unless *municípios* are combined in Minima Comparable Geographic Areas (MCA). The number of MCA changes depending of the inter-censuses period in case. For the inter-censuses period 1872–2000 there are 432 AMC (Reis et al., 2011).



Fig. A1. Brazil: Minimum Comparable Areas for Census years 1872 and 2000.

Source: Reis et al. (2007). Obs.: The MCA for the period 1872–2000 does not include the State of Acre because it was part of the territory of Bolivia in 1872.

Estimates of municipal GDP for 1872 are based upon econometric models which combine data on wages of civil servants in 1876 with the 1872 Census demographic data (E. Reis, 2008). For Census years from 1920 to 1996, GDP estimates are based on Census data for major sectors of economic activity (Industry, Trade, Services, and Agriculture). For each sector and year, the estimation procedure was to calculate proxies of valued added at municipal level which

⁹ The time elapsed from 1872 to the abolition in 1888 is not a major problem for the analysis because from 1872 to 1888 several institutional changes like the enacted legislations on freedom of slave womb and sexagenarians; the creation of emancipation funds; voluntary manumission and the abolitionist movement have contributed to distort the spatial picture on the importance of the economic and social legacies of slavery.

were then normalized by the respective Brazilian GDP figures in the National Accounts (E. Reis et al., 2005). From 1999 on, IBGE started publishing yearly estimates of municipal GDP for the major sectors of economic activity.

The labor force or economic active population (PEA) is not consistently measured across different censuses. In the 1920 Census, the economic active population includes all persons with a declared profession. Out of the labor force population includes persons without profession or with undeclared profession representing 47% of the population; and persons with a ill-defined profession representing 2% of the population. These categories, in its turn, probably includes retired persons, rentiers, students, jailed persons, as well as those doing domestic services in their own households since declared domestic servants represent only 4% of women older than 15 years of age. From 1940 to 1960, the Census definition of economic active population excludes both voluntary and involuntary unemployment. The labor force is then equal to employed population and thus can be disaggregated according to major sector of activities (agriculture, industry, trade and others services). Non economic active population includes persons doing domestic services in their own homes, retired persons, rentiers, students without jobs, and jailed persons. Since 1970, the definition provided by the Demographic censuses include all the persons that were employed as well as those involuntarily unemployed defined as the persons older than 10 years of age which have searched for employment in the two months preceding the Census date of reference. The population out of the labor force (NPEA or non economic active population as IBGE names it) includes voluntarily unemployed; occupied with unpaid domestic services in their own homes, retired persons, rentiers, students without jobs, and persons in jail. The PEA and NPEA are measured in both rural and urban households.

In the 1872 Census, there is no explicit definition of labor force though population was surveyed according to professions. The criteria adopted in this survey, however, seems quite different from the other censuses since counting every person with a declared profession, the labor force adds up to six million people, approximately, or 60% of total population. This figure is extremely high when compared to the other censuses. Thus, the share of the population in the labor force remains between 30% and 33% in the censuses from 1920 to 1970, and thanks to increased labor force participation, jumps to 36%, 40%, and 46%, respectively, in the censuses of 1980, 1991, and 2000. To circumvent this problem the definition of labor force adopted in the analyses is the sum of free male population between 16 and 60 years old with male and female slave population between 11 and 60 years old. For the whole country, this hypothesis implies a labor force equivalent of 34% of total population. The differences between the two definitions are thus quite significant and the last definition is preferred because it sounds more reasonable when compared to other Censuses years. The age classes adopted in the definition of the labor force as well as the exclusion of free women are quite arbitrary assumptions.

Proxies of human capital are given by literacy ratio of the labor force (16–60 years of age) available in the Demographic Censuses since 1872.

The geographic variables include latitude (LAT_GMS), longitude (LONG_GMS), altitude (ALT_M) and the distance to the sea (DSHOR) of the seat of municipalities. For the Censuses of 1991 and 2000 it became possible to superimpose geographical attributes on the maps of municipal networks and, thus, by the aggregation of municipalities in minimum comparable areas (MCA) it is possible to obtain other geographic variables for all for different intercensus periods. Up to the Census of 1991, geo-referenced information at municipal level for Brazil were scarcely available.

Other geographic were obtained from IBGE/EMBRAPA including the geographic area in square kilometer; the proportion of the area in 7 classes of altitude in meter (PALT_x); soil susceptibility to erosion or declivity (in degrees) in 3 classes of (PERO_x); 4 classes of soil agricultural aptitude (PPTNC_x); 13 classes of soil geo-morphological conditions (PSOLO_x). Georeferenced climate data obtained from the Climatic Research Unit of the University of East Anglia (CRU/EA) include averages for the period 1961–90 of average precipitation (PRE30) and temperature (TMP30) of municipalities in the different seasons of the year, namely, summer (December to February), autumn (March to May), winter (June to August), and spring (September to November (Reis et al., 2007). Since the figures are average values for a thirty years period, for most of the analysis it is fair to assume that they are time invariant as other geographic variables.

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