Social and economic convergence across Brazilian states between 1990 and 2010*

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Abstract

The present paper analyzes the convergence in economic and social terms across Brazilian states from 1990 to 2010. We argue that the focus of convergence analyses needs to ample because income convergence does not necessarily go hand in hand with social convergence and income is not the only relevant aspect of welfare. Social convergence is captured by selected welfare indicators, such as years of study, life expectancy at birth and crime. We find that GDP per capita has the largest dispersion and absolute convergence is relatively slow. Apparently, the Brazilian states posses unique steady states to which relative convergence is quite advanced. Social conditions, in contrast, have become considerably more equal and seem to converge towards a unique steady state at half-lives between 8 and 12. Crime shows a peculiar behavior and a non-linear inconclusive convergence path.

Keywords: convergence, inequality, economic growth, welfare, Brazil.
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1 Introduction

The high and persistent inequality between as well as within countries is one of the most recurring topics in economics. The present paper is devoted to the general question whether economic convergence goes hand in hand with convergence of welfare. Using GDP per capita or household income as a proxy for welfare has been justified by positive cross-country correlations between these economic indicators and life expectancy, infant survival rate, educational attainment, among many other desirable indicators (Kenny 2005). Yet looking at a broad range of indicators during four decades, Easterly (1999: 239) reaches the conclusion that "changes in quality of life as income grows are surprisingly uneven". The situation has not become clearer since Easterly's statement and the paradoxical absence of a correlation between self-reported happiness and income per capita in Easterlin (1996).[1] There is recent evidence that European, Spanish and Colombian regions experience social convergence even in the absence of economic convergence (Marchante and Ortega 2006; Rodríguez-Posé and Tselios 2015; Royuela and García 2015) and there are other examples where economic convergence is not accompanied by a reduction of social inequalities (Hobijn and Franses 2001; Todaro 1997).

The present research seeks to add to this literature by addressing convergence in GDP per capita and social convergence at the same time. In our approach, social convergence encompasses selected quality of life indicators, namely the years of study, life expectancy at birth and crime. The choice of these variables also seeks a proximity to the three optics that make up the Human Development Index (HDI), namely, education, longevity and income. Using other related variables such as literacy rate or infant mortality qualitatively yields the same results. We focus on Brazil because, to the best of our knowledge, there is no evidence on social convergence from this country thus far. Moreover, Brazil represents a highly interesting case study given its pronounced regional inequality, its vast territorial extension and its status as one of the key emerging markets.[2] We believe that our results are not only of interest in the research community but also to policy makers and scholars who wish to understand how (i) interregional welfare disparities in Brazil behaved over time, (ii) whether some of the recent major public policy programs contributed to sustainable growth and (iii) whether overall welfare gains can be attained through GDP growth or need to be targeted directly. At last, the proper current Brazilian constitution from 1988 unmistakably emphases the high importance of our topic. Article 3 declares that "reducing regional and social inequalities" is one of the Federal Republic's fundamental

[1] Easterly (1999) notes also that the current literature on economic growth did not start the analysis of the relation between living conditions and economic growth, and that the conflicting views are also not new to the literature. While early development economists were optimistic about the positive impact of growth on a range of health, education and political indicators, the second generation of economists and political scientists contested these conclusions.

[2] Brazil is also the largest economy in South America and coexists with the Southeast region representing about 55.2% of the country's GDP, while the North region participates with only 5.2%. According to recent data from the from the Atlas of Human Development (available at: `http://atlasbrasil.org.br`), the state of São Paulo has one of the highest Municipal Human Development Indexes (IDHM) in the country, reaching 0.829, while the state of Alagoas has one of the lowest indexes, of around 0.667. This scenario was even worse in 2000, when the IDHM of Alagoas was 0.471 and that of São Paulo was 0.702.

objectives.

This article applies several measures of convergence to study whether the living conditions across Brazilian states have become more equal over the period 1990 to 2010. On the one hand, our analysis follows the classical studies by Baumol (1986), Barro and Sala-i Martin (1992); Barro *et al.* (1991), considering some simple measures for the dispersion (σ-conversion) between states. β-convergence regressions are estimated in pooled OLS and using state effects to stimulate a debate over whether convergence occurs rather in absolute or relative terms in the spirit of Islam (1995). Moreover, we allow for spatial dependence as in Anselin and Rey (1991) because considering regions as open economies may be more realistic. On the other hand, we complement economic convergence with evidence on the convergence of social indicators related to education, security and health. At last, we offer a number of explanations for the observed patterns, in particular, why social convergence has occurred at a more rapid pace than economic convergence.

It is well known that convergence refers to the reduction of inequality between economic units. The concept has originally been applied to countries but a large literature exists on the convergence between different regions within continent or even a single country. According to the Solow (1956) growth model, which serves as the reference in virtually all convergence research, economies should, sooner or later, converge to a common long run equilibrium. One expects thus that economies who find themselves distant from their steady state should grow faster then richer economies. Eventually, income convergence should also lead to an improvement of well-being and living standards in the lagging regions. The prevailing view is that there is no unique steady state but rather convergence clubs formed by similar countries, such as the OECD members, see Baumol (1986), Mankiw *et al.* (1992) or Quah (1996). Regarding the overall cross-country inequality, these studies did not find a significant reduction over the postwar period. Existence of a single equilibrium seems, however, more reasonable to suppose in within-country analyses due to the absence of institutional, political or technological differences.

In sum, we find that economic and social convergence indeed go hand in hand in the Brazilian case but they occur at considerably different speed. GDP per capita shows the largest dispersion and absolute convergence is relatively slow. The data suggest that the Brazilian states posses unique steady states to which relative convergence is quite advanced. Social conditions, in contrast, have become considerably more equal and seem to converge towards a unique steady state at half-lives between 8 and 12. Crime shows a peculiar behavior and a non-linear, inconclusive convergence path.

Few other studies address the intra-regional convergence of economic and social indicators. As in the present case Royuela and García (2015) and Marchante and Ortega (2006) consider GDP per capita, life expectancy at birth, infant survival rate, literacy rate and the murder rate. Rodríguez-Posé and Tselios (2015), in contrast, focus on a single variable, Amartya Sen's welfare index, which encompasses the income level and income inequality, as measured by the Gini Index. These three papers apply the same methodology to test for convergence as we do: (i) some measure of dispersion is calculated and (ii) pooled and

fixed effects regressions with lagged variables, eventually augmented by spatial dependence terms. In none of the cases does the inclusion of spatial dependence a crucial difference. Regions in Spain, the EU and Colombia show a somewhat different behavior than the one we found for the Brazilian regions: welfare levels across regions also do converge, however, even in the complete absence of income conversion. The crime rate in Brazil, as well as in Colombia, shows a country-specific behavior and does not converge significantly. At the same time, it is not possible to reject the hypothesis that each region converges to its own steady state, however, the present paper finds clear evidence for convergence to a unique steady state in education and health conditions.

Cross-country analyses seem to favor the same results that we obtained from within Brazil: little or no absolute convergence of income but in terms of other welfare indicators. The following papers also justify our methodological approach. Hobijn and Franses (2001) look at the convergence of real per capita income and four social indicators, namely, life expectancy, infant mortality, daily calorie and protein supply using an achievement index that measures the welfare proxy relative to an absolute upper or lower bound and thus assigns a greater weight if the initial value was already close to the bound. Their conclusion is that there is a persistent gap in living standards as well as in GDP per capita. Neumayer (2003), however, contests that conclusion because it may be specific to the nutrition variables and functionality of the achievement index. Using other welfare proxies and the common $\sigma-$ and γ-convergence measures, reveals evidence for a reduction in welfare inequality without different standard or the existence of convergence clubs. Fertility differs from the other social indicators in the sense that its relation to welfare is less straightforward. One exception that focuses on fertility and convergence is Dorius (2008). He finds that fertility inequality is rising and that, less surprisingly, its behavior differs from trends in other development indicators. Becker *et al.* (2005) provide a careful assessment of the evolution of welfare inequality across countries and its relation to life expectancy. The number of years, over which income can be enjoyed, is obviously an important component of individual welfare. The authors confirm that health, in contrast to income per capita, has been converging because, in particular, the countries with the lowest incomes made significant progress in the second half of the 20^{th} century.

As we noted in the beginning, an analysis of convergence in welfare, except of income and GDP, has not yet been applied to Brazil. Our observations complement the existing results on Brazil in the following way. Azzoni *et al.* (2000) find no sign of absolute but rather of fast relative income convergence over the period 1981-1996. Once human capital, infrastructure and geographical variables are controlled for convergence speed is fairly, with implied half-life values of less than 2 years, Brazilian states seem to be close to their close to their own steady state levels of income already. Ferreira (2000) makes similar observations and adds that interstate σ-convergence occurred between 1970 and 1986 but not between 1986 and 1995. In the light of the present data, his skepticism about the further convergence process could not be confirmed. Magalhães *et al.* (2005) also cover the period 1970 to 1995 and stress that strong patterns of spatial correlation between the states require econometric models that incorporate this spatial dependence. Nevertheless,

as in the present case, the β-convergence coefficients are not very different in the spatial dependence estimations. Cravo *et al.* (2015) and Resende *et al.* (2016) previously found conditional β-convergence but at relatively slow rates. The main methodological difference is that we control for any kind of time-invariant state characteristics while the convergence in those two papers is conditional on some specific factors, such as education, population density or infrastructure. After all, the increase in convergence rates in FE estimations is in line with Islam (1995) who attributes the difference to omitted variable bias in regressions without FE. Resende *et al.* (2016) do not olny focus os the state-level but the authors also compare their results to those obtained from other less aggregated spatial units. The differences, however, are minor and suggest that the present findings hold in a general context and independent of the level of analysis. The multilevel analysis in Díaz Dapena *et al.* (2017) further reveals internal divergence in the most developed states in the Southeast, while the Northeaster states show internal convergence. Regarding the national level, their estimation confirms the previous positive relative convergence results.

2 Methodology

2.1 Theory and estimation

For the investigation of economic and social conversion, we use the neoclassic β-convergence approach from Barro (1991) and Barro and Sala-i Martin (1992) which is directly derived from well-known growth model by Solow (1956). In its original formulation, the model predicts that the growth rate between two periods t and $t+T$ depends primarily on the initial size of the economy and its distance to the steady state equilibrium. Given that all Brazilian states i have one and the same steady state, its value will be absorbed by the common intercept α in the following regression

$$\left(\frac{1}{T}\right)\ln\left(\frac{y_{i,t+T}}{y_{i,t}}\right) = \alpha - \frac{(1-e^{-\beta T})}{T}\ln(y_{i,t}) + \tau_t + \varepsilon_{i,t} \tag{1}$$

We additionally include time effects (τ_t) to distinguish the long run convergence pattern from short run macroeconomic shocks that affect all states equally. According to the seminal paper by Baumol (1986), the economies, or states in our case, converge to their steady state if the estimated value of β in the equation above is positive. In particular, β is a measure for the speed of convergence but the calculation of half-life as $\ln 2/\beta$ provides a more intuitive interpretation for the speed of convergence. The half-life is the amount of time it takes the economies to reach half the distance to their steady state (Barro and Sala-i Martin 2003). Because of the assumption that each Brazilian state has the same steady state eq. (1) evaluates whether there is absolute convergence.

If one believes that the economy's size depends on variables that differ between the units of observation, such as the saving rate or population growth, these omitted factors bias the coefficients in eq. (1) and the use of cross-section regressions may not be appropriate. Mankiw *et al.* (1992) were the first to estimate a Solow model augmented for differences

in human capital, among others. The coefficient β in such a augmented regression does not indicate absolute but relative convergence.

Identifying all variables that affect the steady state of economies is not easy task. Following Islam (1995), we exploit the panel dimension of our data and include state and time fixed effects.[3]

$$\left(\frac{1}{T}\right)\ln\left(\frac{y_{i,t+T}}{y_{i,t}}\right) = \alpha - \gamma\ln(y_{i,t}) + \mu_i + \tau_t + \varepsilon_{i,t} \tag{2}$$

For simplicity we have substituted γ for the term $-\frac{(1-e^{-\beta T})}{T}$ that appears in eq. (1). The fixed effects control for all differences between states that are time-constant, as well as for year specific shocks that may affect all regions equally. When using a fixed-effects model, it is assumed that each economy has its own steady state. The cross-section regression would only be consistent if the individual effects were not correlated with the initial size of the economy, i.e., if the speed of convergence depended only on the distance between each region's current size and the common equilibrium size. It will thus be of great importance for the present research to test whether the fixed effects are econometrically relevant or not.

In the following regressions, the variable y will initially be GDP per capita, as in the original formulation by Solow (1956). Once we have established whether economic convergence between Brazilian states exists and if so, whether it is rather absolute or relative other variables that capture different aspects of welfare will be analyzed. We are well aware that the equations (1) and (2) are the result of a stylized but closed general equilibrium model with rigid neoclassic properties. Precisely because of the model's simplicity we feel that convergence should be applied to other variables that reflect welfare and social cohesion. After all, as is well known, GDP and GDP per capita are highly correlated with happiness, quality of life, human capital, etc. Therefore, we expect that economic convergence should come hand in hand with social progress in many other desired aspects related to the quality of life. According to the overall purpose of this paper, we will use variables related to education, health and crime, and test the convergence of their levels across states, too.

The location of a particular unit can determine the level of interaction with nearby units. In this specific case, the growth rate of a particular state may not only depend on its own distance from the steady state but on the growth rates and/or the levels of steady states in the neighboring regions. Therefore, it is pertinent to incorporate these possible spatial effects on the speed of convergence in order to avoid inconsistent results. Considering spatial dependence has another neat interpretation: as the traditional neoclassical growth model assumes that each regional economy is an independent unit, using spatial econometric techniques introduces openness to the β-convergence model (Anselin and Rey 1991). Thus the spatial models also recognize that regional convergence of welfare

[3] We did not opt for a panel data model with random effects because if the fixed effects do indeed capture variables that influence the economies' states and thus the convergence rate, they will also be correlated with the economies' initial size. The Hausman (1978) test corroborates the preference for the fixed effects model.

may not only be the result of capital accumulation and diminishing marginal products (traditional neoclassical assumption), but may be influenced by labor migration, capital mobility, technology transfer and spillovers, among other factors.

Many of the previous papers on economic convergence already recognized requirement and included robustness tests using spatial econometrics. Rey and Montouri (1999), for example, estimate the convergence assuming heterogeneity and spatial dependence among regions in the United States and find that the convergence process involves complex transition dynamics due to spatial patterns. In the present approach, the incorporation of spatial effects was adopted through the estimation of spatial error model (SEM) and spatial lag or spatial autoregressive (SAR) models following Anselin (1988) and LeSage and Pace (2009).

The SEM model is relevant when the spatial dependence structure is contained in the residuals. The specification of this model for convergence analysis is the same as the one in eq. (2) but the error term $\varepsilon_{i,t}$ is composed of two components. A random component $u_{i,t}$ which has a normal multivariate distribution with zero mean and covariance matrix $\sigma^2 I$ and a spatial component given by $\lambda W \varepsilon_{i,t}$. Therefore, the composed error is an average of the errors in the neighboring regions plus random error component. The scalar coefficient λ captures the intensity of spatial autocorrelation between the residuals and W is a matrix of spatial weights. As a result, a shock in some unit spreads to the neighboring spatial units, where the degree of spatial decay is guided by λ. A $\lambda < 1$ means that the effect decreases as it moves away from its epicenter. We chose the matrix of spatial weights *queen* of order 1, because it is widely used for the Brazilian case, see, for example, Cravo *et al.* (2015) and Resende *et al.* (2016).[4]

The idea of the SAR models is the same as in the AR (self-regressive) models in time series: An additional lag term captures the spatial dependence, i.e., the impact that neighboring regions have on the convergence rate in region i. Building on the previous fixed effects model gives the following equation

$$\left(\frac{1}{T}\right) \ln\left(\frac{y_{i,t+T}}{y_{i,t}}\right) = \alpha - \gamma \ln(y_{i,t}) + \rho W \ln\left(\frac{y_{i,t+T}}{y_{i,t}}\right) + \mu_i + \tau_t + \varepsilon_{i,t} \tag{3}$$

The autoregressive coefficient ρ represents the average effect of the neighbors on the dependent variable (y), and W is the same spatial weight matrix as in the SEM model defined above. If the coefficient ρ is statistically different from zero means that a portion of the total variation in the dependent variable Y is explained by the dependence of each observation on its neighbors. ρ's sign indicates whether that dependence is positive or negative.

[4] The queen matrix considers, in addition to the common boundaries, the common vertices (nodes), which is equivalent to the movement of the queen in chess. In this case, the matrix element assumes value 1 if the regions i and j are neighbors, and value 0, if i and j are not neighbors. The main diagonal has all elements equal to zero, by definition.

2.2 Data

In the selection of variables we sought to proxy the standards of life and well-being of the population as close and as comprehensive as possible. Our selection includes an economic variables (per capita GDP), one related to health (life expectancy at birth), one that refers to education (years of study) and one related to security (non-homicide rate). The main motivation for choosing such variables is their proximity to the human development index (HDI) and the three dimension it comprises, i.e., education, longevity and income. Note that the results are not We experienced with other variables of these categories, such as per capita household income, child survival rate and literacy rate but obtained qualitatively similar results throughout. For the sake of space, we do not report these results here, but surely provide them upon request.

The state's per capita gross domestic product is provided by the Federal Statistical Office (IBGE). This variable is deflated at 2010 prices. The education variable refers to the average years of study of people aged 25 years and over Life expectancy at birth refers to the approximate number of years a newborn child is expected to live. The education and the health variables were collected from Ipeadata, Datasus and the Atlas of Human Development in Brazil. The dataset used here included all 27 states and covers the period from 1990 to 2010. We take triennial averages of all variables, in order not to capture the short term growth and to obtain greater stability of the estimates.

Finally, the non-homicide rate is computed as the complementary measure of the homicide rate, that is, 100 minus the percentage rate of homicides per 100 inhabitants in each state. The reason for this transformation is that the since the variables represent social welfare indicators, they should to be considered positively, i.e., larger values correspond ot higher welfare. The Institute of Applied Economic Research (IPEA) published an Atlas of Violence including the number of homicides in Brazil In contrast ot the other variables, its availability is limited to the period from 1996 to 2010. Even though there are many factors linked to crime, the present paper seeks to capture social coexistence and the level of national security through the inclusion of this variable.

Table 1 provides a summary of variables and descriptive statistics for the first and the last year in the covered time span. Production, health and education clearly indicate that Brazil has made some progress over the last two decades. Average years of schooling increased by almost three years and life expectancy at birth rose by more than 6 years. Only the non-homicide rate has been decreasing, that is, security has deteriorated significantly. Except for the GDP per capita, the standard deviation indicate that the dispersion between the states has decreased. Such a decrease would be consistent with β- and σ-convergence.

Figure 1 shows the spatial distribution of the four variables for the year 2010. In general, it can be observed that the states of the North and Northeast regions have the lowest GDP per capita, whereas the states of the South and Southeast are on top of the distribution. Thus it appears that states with higher production/income are surrounded by similarly rich states and vice versa. On the one hand, this fact may be a consequence

Table 1: Summary statistics

	1990				2010			
	mean	std. dev.	min.	max.	mean	std. dev.	min.	max.
GDP per capita	11.21	8.50	4.13	46.11	16.81	10.42	6.88	58.48
schooling (years)	4.54	1.28	2.55	7.49	6.91	1.05	5.14	9.75
life expectancy	66.40	3.11	59.95	71.21	72.66	2.25	68.00	76.01
non-homicide rate	76.69	14.44	40.07	95.62	68.65	11.97	33.12	86.82

Notes: The table shows mean, standard deviation, minimum and maximum value for the main variables in the years 1990 and 2010. The number of observations is equal to 27 in each year.

of socioeconomic interaction between neighboring regions – technological spillovers, labor mobility, economies of scale, etc. On the other hand, the clustering can also result from macroeconomic policies and sociocultural characteristics.

As far as social variables are concerned, this scenario does not change much. The health and education indicators highest in the states of the South and lowest in the Northeast. It is worth noting that the non-homicide variable does not follow the same pattern. Paraná and Rio de Janeiro have a low index for the variable in 2010. However, Alagoas, Espírito Santo and Pará in the North and Mid-West lead the ranking of the lowest non-homicide rates, registering 66, 50 and 46 homicides per 100,000 inhabitants, respectively, in the year 2010.

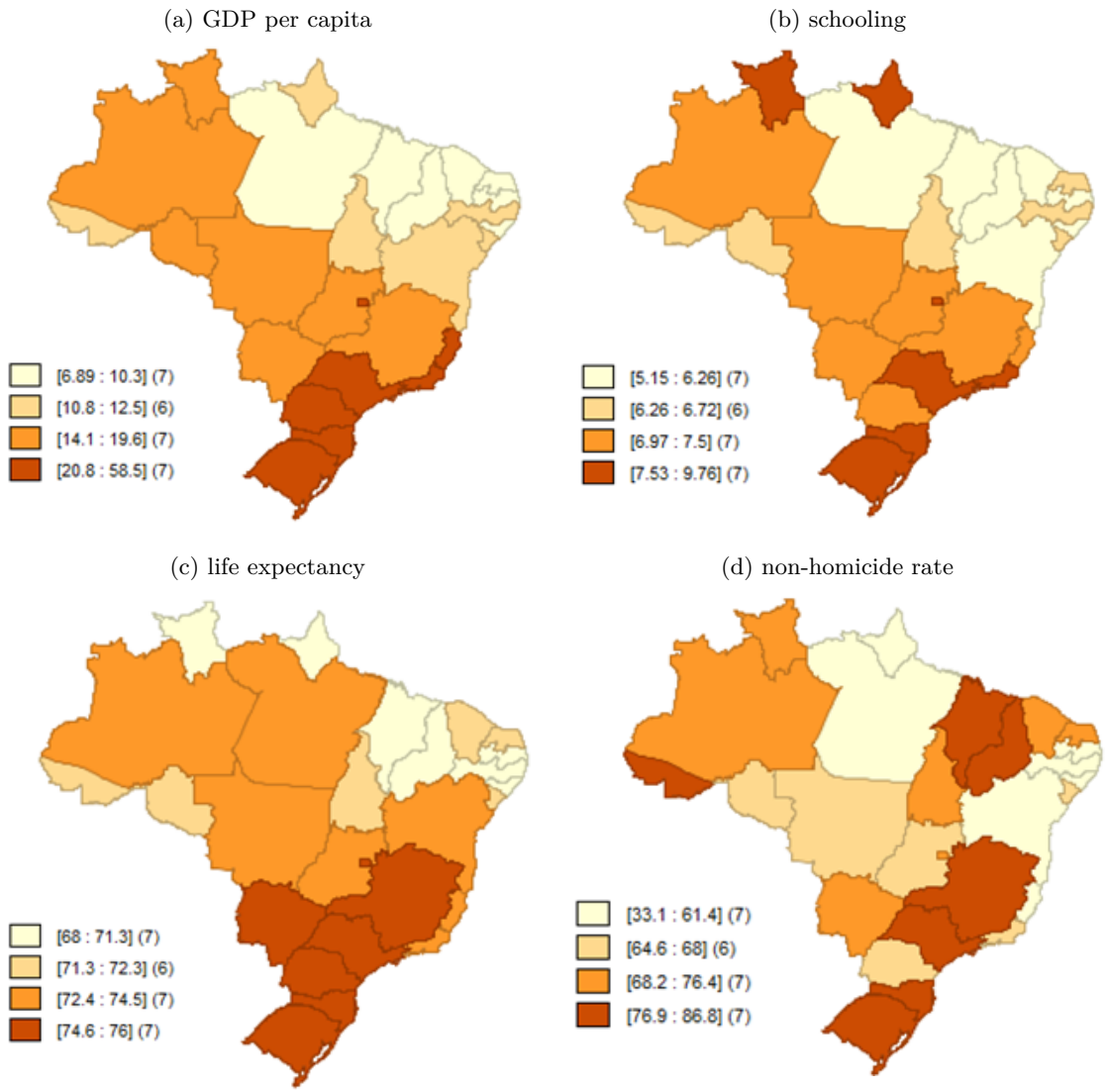
3 Results

It is well known that the convergence literature has mainly used two distinct measure for convergence: σ- and β-convergence. The latter has probably received more attention due to the seminal papers by Barro and Sala-i Martin (1992) or Mankiw *et al.* (1992). Because neither type of convergence implies convergence of the other type and because has each has its own merits and deficiencies, we agree with Young *et al.* (2008) that it is worthwhile to study and compare both of them. We begin with the evidence on σ-convergence because the methods and interpretations are more straightforward.

3.1 σ-convergence

Brazil underwent moments of economic growth, others of crisis and several severe structural changes between 1990 and 2010. Of particular importance are the trade liberalization and the implementation of the Real Plan in order to contain inflation and uncontrolled devaluation of the currency. Over the 1990s, economic indicators performed worse than in the 1980s. GDP grew by an average of about 1.7% a.a. between 1990 and 1999 (2.9% per year between 1980 and 1989), the average annual inflation was 278% (272%), the average investment rate was at 15.9% of GDP (18.2%) and exports advanced by an average of 4.5% per year (in comparison to 8.5% annual average over the 1980s). The first decade of the new millennium can again be characterized as more prosperous relative to the country's performance in the 1990s.

Figure 1: Spatial distribution of economic and social indicators in 2010



Notes: The maps display the spatial distribution of the variable indicated above each graph across the 27 Brazilian federal states. The numbers in square brackets indicate the range of values each color captures. The numbers in round brackets show the number of observations in each category.

In the analysis of σ-convergence it will be possible to verify whether the dispersion trajectory of the social and economic variables mirror the positive political and economic transformation process. A favorable result for this form of convergence indicates that the states are becoming closer in social and/or economic terms. Based on the summary statistics in table 1, we previously noted that the standard deviation of schooling and life expectancy increased between 1990 and 2010, while GDP per capita and the non-homicide rate indicate in increase in dispersion over time.

The standard deviation, however, is not a suitable measure to compare variables that are measured at different scales or even when the scale of a single variable changes significantly over time. The coefficient of variation (CV), which is defined as the standard deviation relative to a variable's mean, is independent of the variable's absolute magnitude and is thus a more appropriate measure for testing σ-convergence. Table 2 also provides the

weighted coefficient of variation, proposed by Williamson (1965), which uses the population in each state relative to the population of the country as weights in the calculation.

Table 2: Coefficients of variation

	GDP per capita		schooling		life expectancy		non-homicide rate	
	CV	CV-W	CV	CV-W	CV	CV-W	CV	CV-W
1990	0.759	0.549	0.285	0.232	0.054	0.060	-	-
1995	0.687	0.504	0.219	0.205	0.043	0.041	-	-
2000	0.677	0.483	0.192	0.178	0.038	0.035	0.186	0.219
2005	0.643	0.458	0.183	0.167	0.035	0.032	0.147	0.146
2010	0.620	0.462	0.152	0.143	0.031	0.028	0.174	0.166

Notes: The table shows the coefficient of variation (CV) and the population weighted coefficient of variation according to Williamson (1965) (CV-W) for the main variables between 1990 and 2010. The number of observations is equal to 27 in each year.

In contrast to the standard deviation, both versions of the coefficient of variation also indicate clearly that the dispersion of per capita production has become more equal over time. Nevertheless, table 2 shows that the relative dispersion of GDP per capita is by far the highest among the four variables. Note also that the divergence between the CVs and the standard deviation is caused by the general increase in the GDP per capita. That is the higher dispersion, as measured by the standard deviation, is not due to higher inequality between states but entirely due to the higher values of GDP per capita. The fact that the population weighted CV is smaller than the unweighted CV indicates that states with a higher population tend to closer to the mean than less populated states. For example, the poorest states in the Northeast (Piauí, Paraíba and Alagoas) as well as the richest state (the Federal District) account for less than 2% of the population in 2010.

Turning to the analysis of social variables, it can be observed that the variables referring to education and health also present a downward trajectory for both the standard CV and the weighted CV throughout the analysis period. Despite the small magnitude of the coefficients of variation, a reduction of about 50% over time is apparent. In case of life expectancy at birth, the CV and CV-W are closest to zero, indicating that there are almost no differences between the states in 2010. The non-homicide rate, which refers to social coexistence and the level of national security, shows a drop in dispersion between 2000 and 2005 followed by an increase in dispersion between 2005 and 2010 close to its original value. In fact, the average number of homicides increased during the period of analysis in the entire country. Faced with this behavior, it is not possible to confirm a positive σ-convergence trajectory in this case.

Another indicator that is frequently used to infer the evolution of dispersion is the max-min ratio, obviously defined as the the maximum value divided by the lowest value of all observation units. Again, table 1 already indicates in which direction this indicator has evolved. For all but the non-homicide rate the dispersion became more narrow over time, in line with the results from the coefficient of variation. Life expectancy at birth, years of schooling and GDP per capita show an almost monotone decreasing trend over time. The spread of GDP per capita has decreased from a factor of 11.5 to 8.5 while the relation for schooling dropped from over 3 to below 2. Similar to the dispersion as

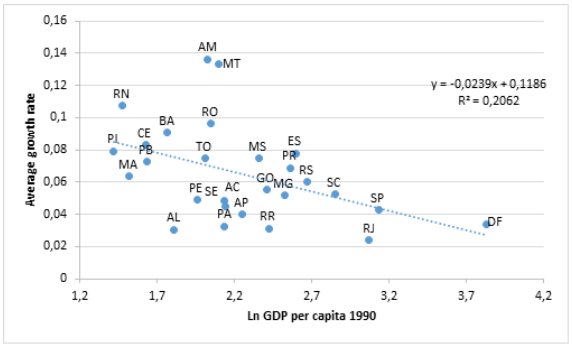
measured by the CV, the difference between the maximum and minimum value of life expectancy is almost zero. In sum, the conclusions from either the traditional CV, the weighted CV or the max-min ratio show that the Brazilian states are becoming closer in terms of production/income, health and education but not in terms of personal security and crime.

3.2 β-convergence

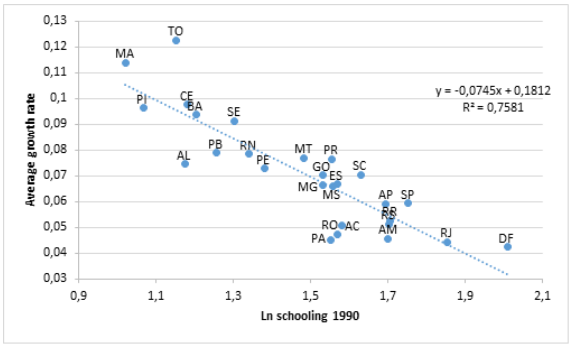
Before analyzing the empirical results obtained for convergence, figure 2 presents four graphs, according to the representation in Barro *et al.* (1991), that are intended to facilitate the investigation of the convergence process. These graphs show the relationship between the variable of interest's initial value and its triennial average growth rate between 1990 and 2010. To improve the visualization of this relationship, a trend line is drawn and the associated linear regression result is also displayed. The decreasing relation in all four graphs shows that those state with higher the initial values experience lower growth rates in that variable. This behavior is typical for a convergence process, which can thus be perceived in both economic and in social variables.

Figure 2: Relation between initial level and average growth grate

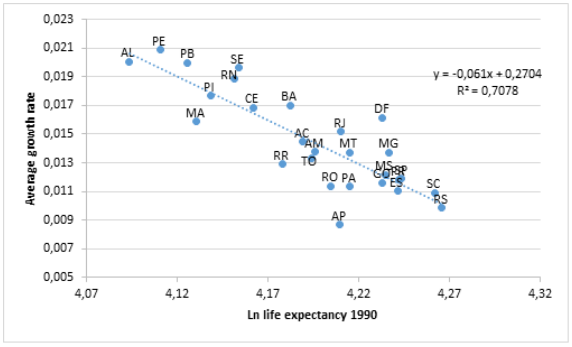
(a) GDP per capita



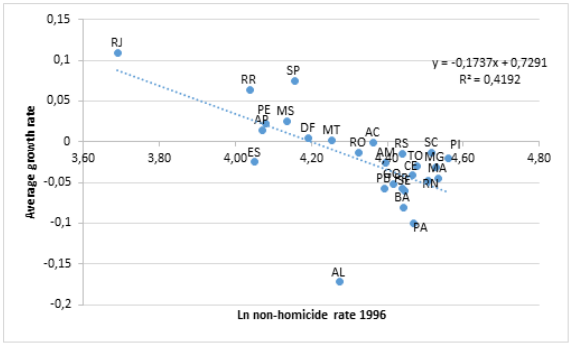
(b) schooling



(c) life expectancy



(d) non-homicide rate



Notes: The graphs display the initial value, i.e., the value in the first period of observation in our sample, for all of the 27 Brazilian states and the triennial average growth for each of the four variables under consideration. The two capital letters above the observations correspond to the official state abbreviations. Each graph includes the results of a simple linear regression between the two variables under consideration and displays the predicted regression line.

The states with the greatest economic lag and with above average growth rates of over 6% per year are: Piauí, Rio Grande do Norte, Maranhão, Paraíba, Ceará and Bahia - all members of the Northeast region. Among the characteristics that may have influenced the process of convergence in that region, the following stand out: (i) income redistribution policies – principally through the direct aid program *Bolsa Família* for the poorest families exists since 2009 and its transfers to the Notheastern states represent more than 52% in both benefits and values of the national total and among the main beneficiary states of this program are Bahia (25.4%), Pernambuco (16.2%), Ceará (15.5%) and Maranhão (14.4%); (ii) the expansion of the agricultural frontier in the Cerrado Arc – particularly in the soybean complex, irrigated fruit farming and export diversification. The result was an increase in the share of manufactured and semi-manufactured products (automotive, textile, petrochemical and footwear); (iii) credit expansion with emphasis on housing credit through the program *Minha Casa Minha Vida* – in 2006 credit loans represented 26% of the region's GDP, and in 2010 this number increased to 49%; (iv) economic stability through the implementation of the *Real Plan* – stability is known to be a key factor for sustainable economic growth and, in addition, low inflation increases the purchasing power of the low-income population and contributes to reduction of social inequality.

Regarding the social indicators in graphs (2b) and (2c), one observes that the states with the greatest convergence, i.e., low initial values and high growth rates, are also from the Northeast and some from the North. Hence it seems that the factors that influence social convergence are most likely linked to the factors that have contributed to economic convergence. It is also outstanding that the convergence process in the social conditions seems to be much more predictable and in line with expectations as the R^2 in those regressions is much higher than in case of GDP per capita. Another reason for optimism is that the average growth rates in schooling, life expectation as well as production per head are all positive throughout the period 1990 to 2010. Some of the reasons for the continuous increase in average years of schooling are (i) the expansion of subsidized student loans to low income families Rocha *et al.* (2016) (ii) a general increase in the supply and demand for superior education in private universities (Corbucci *et al.* 2016), (iii) the obligatory school attendance of children in families that receive benefits from the *Bolsa Família* program;

As before, the non-homicide rate shows a different behavior. About half of the states, including the poorest with the greatest convergence rates in the Northeast, experience negative growth rates, which corresponds to an increase in the murder rate. The largest exception of this development is the state of Rio de Janeiro which had an index of 40 non-homicides in 1996 and increased that value to 64 in 2010. It is also striking that the wealthiest states, Rio de Janeiro, São Paulo and the Federal District could contain or even reduce the homicide rate while Alagoas, Pará, Bahia and Rio Grande do Norte experienced an increase in the non-homicide rate from 71, 84, 87 and 90 in 1996 to 33, 58, 53 and 74 in 2010, respectively.

According to the empirical and theoretical considerations in 2.1, we test for β-convergence using four related approaches: a Pooled Ordinary Least Square (POLS) estimation, a fixed effects (FE) model and two extensions that allow for spatial dependencies between

the states. The main problem of the pooled analysis is that by stacking the data and disregarding specific characteristics of the regions, their unobserved heterogeneity may lead to biased coefficient estimates. Recall also that the pooled estimation provides evidence for or against absolute β-convergence, whereas the fixed effects model tests for conditional β-convergence. To have some econometric guidance in the choice between the pooled and the FE estimation, we perform a Chow test, under the null hypothesis of stability of the estimated coefficients in both estimations.

Table 3 presents the estimates with data in triennial averages. The results are favorable to the both absolute and relative β-convergence, however, the data seem to favor the second type of convergence and the associated existence of several steady states and distinct regional production functions. The Chow test statistics reject the null of coefficient stability and thus indicate preference for the FE model, except for the analysis of years of schooling. In the other three cases the Chow test confirms that the inclusion of state fixed effects alters the speed of the β convergence significantly. According to the AIC values, the FE estimation is preferred for all four variables. Finally, the R^2 of both types of estimations also point to a relatively good adjustment.[5] It is interesting to note that years of study and non-homicides present better adjustment for the pooled model, confirming the direction of the Chow test.

Table 3: β-convergence analysis

	GDP per capita		schooling		life expectancy		non-homicide rate	
	POLS	FE	POLS	FE	POLS	FE	POLS	FE
$\ln(Y)_{i,t-1}$	-0.021***	-0.434***	-0.093***	-0.206***	-0.065***	-0.207***	-0.125**	-0.014
	(0.007)	(0.074)	(0.012)	(0.059)	(0.005)	(0.037)	(0.048)	(0.012)
constant	0.264***	4.056***	0.217***	0.384***	0.290***	0.883***	0.528**	0.049
	(0.069)	(0.683)	(0.020)	(0.090)	(0.023)	(0.157)	(0.211)	(0.528)
time effects	✓	✓	✓	✓	✓	✓	✓	✓
implied β	2.03	27.79	8.20	16.03	5.93	16.10	10.61	-
half-life	34.03	2.49	8.45	4.32	11.67	4.30	6.52	
Chow test		8.95		0.98		9.24		2.09
		[0.00]		[0.50]		[0.00]		[0.01]
AIC	-510	-679	-636	-667	-1,397	-1,569	-240	-300
R^2	0.30	0.66	0.29	0.16	0.50	0.58	0.13	0.08
obs.	162	162	162	162	162	162	108	108

Notes: The table shows the results from the pooled OLS (POLS) regression in eq. (1) and its extension with fixed effects (FE) in eq. (2). Both models include time effects. The lower part of the table shows the implied half-life and β coefficient, as well as some test statistics related to the goodness of fit of these models. Standard errors are in parentheses and P-values in squared brackets. (*) denotes significance at 10%, (**) at 5% and (***) at 1%.

Turning to the analysis of the estimated coefficients in table 3, the one of initial per capita GDP is negative and significant in both models, POLS and EF, which is consistent with the existence of a convergence process in absolute and relative terms. Assuming that all Brazilian states will eventually reach the same equilibrium, the estimates imply that this state of equality is still far in the future. Reducing the actual gap by half takes an average of 34 years for the lagging states. When specific effects of the states are controlled for,

[5] Since the variation of interest in the FE model is within states, we report the within-R^2 in these cases.

the speed of convergence increases, showing that these effects may be important. In this case, the convergence velocity is equal to 27.7% and half-life is 2.5 years, which suggests that the Brazilian states are already close to their own steady states. Although the period of analysis and the method are not exactly the same, our results are similar to those of Azzoni *et al.* (2000) who also find expressive values for the economic convergence rate.

Years of schooling and life expectancy also present negative and highly significant lagged coefficients. The differences between the coefficients in the POLS and FE models are not as pronounced as for GDP per capita but, nevertheless, relative convergence should occur at least about twice as fast. In conclusion, both relative and absolute convergence in education and life expectancy are well underway since the beginning of the 1990s and one can expect, everything else equal, that the convergence process may be completed in relatively short period of time.

This result intuitively makes sense, because the health and education system are much easier to organize and influence than the economic system. Production primarily depends on the individual decisions of entrepreneurs and managers and the government has relatively few effective tools to gear these decisions, Policy, in contrast, can much more effective in promoting equal school and health provision throughout the country. Islam (1995) also points out that evidence of faster β-convergence in the panel approach requires an effective development policy, as improvements in each individual region possesses its own steady state. Attending the states' unique requirements to come closer to their steady state will lead to higher rates of transition growth, i.e., a greater speed of convergence.

The non-homicide rate presents, once again, results that are distinct from the other social and economic indicators. At first, the POLS estimation implies absolute convergence at a relatively high pace (10.6%). Once state effects are included, the lagged coefficient loses its significance, hence no β-convergence and implied half-life time can be computed. This finding either indicates that there is no relative convergence process regarding crime or that the states already have reached their proper equilibria, and therefore no further convergence is necessary. Although the econometric test statistics point out that each state has its distinct steady state, a situation of absolute convergence seems to be closer than in any of the other variables we analyzed.

Nevertheless, the absolute crime numbers do not point to an improvement over time, as previously noted, see figures 1 and 2. Quite the contrary, because the nationwide average number of homicides per 100,000 inhabitants increased from 23 to 31.3 between 1996 and 2010. The Southeast, and mainly Rio of January, has shown a inflection in its homicide rates for consecutive years, making the Northeast the most violent region of the country as of 2006. In the Southeast, the homicide rate decreased from 34 in 1996 to 23 in 2010. In the Northeast region, the rate increased from 18 to 41. Thus, this scenario is not favorable to the extent to which the convergence process occurs at the expense of increased violence in certain regions.

Crime in Brazil has a number of explanations, though there is not sufficient or decisive evidence on all of them. Among these factors, the most important seems to be the ineffi-

ciency of the control system, namely, obsolete laws, poor security systems and prevailing impunity. According to Cerqueira and Lobão (2003), factors such as highly complex urban spaces, a large contingent of young people without supervision and orientation, widespread and uncontrolled access to elements such as weapons and drugs, dictated by the failure of the justice system, can be considered structural constraints that allowed the growth of crime. Loureiro *et al.* (2017) and Loureiro *et al.* (forthcoming) add that the proper party of the government in power and the partisan disruption had an important effect on the development of the homicide rate.

In the scenario established with selected social and economic variables, the empirical evidence shows that economic convergence is accompanied by social convergence, except for the scope of national security, since we observed an increasing number of homicides. The poorest regions are growing faster than the richest regions, both in terms of per capita income and in terms of living conditions and well-being, as witnessed in the areas health and education.

Finally, we apply two models with spatial interaction as explained in section 2.1: the spatial lag model (SAR) and a model with spatial autoregressive error (SEM). Both were estimated with state and time fixed effects, since the prior test statistics pointed to greater relevance of this model. Table 4 shows that the spatial parameter ρ in the SEM model is significant in all four estimations. Therefore, the error structure seems to be dependent across states and idiosyncratic shocks will affect neighboring regions. However, the specific values of the variables GDP per capita and years of schooling apparently do not influence the development in other regions. The non-homicide rate is even associated with a significantly negative autocorrelation between states. Only for life expectancy do we find a positive interaction between states. These observations are in line with Cravo *et al.* (2015) who note that spatial dependence turns out to be significant in income growth regressions, but the positive spillover are only related to the economic size of the regions.

In all cases, except for the non-homicide rate, the relative convergence is proceeding at a expressively fast rate. Consequently, the overall tendency remains the same, whether or not spatial dependence is considered or not. The Brazilian states thus seem to be close to their own steady states. Looking at the direct parameter estimates γ in more details even reals that the results do not undergo significant changes in convergence when compared to the traditional fixed effect model. We can thus confirm the persistence of convergence in economic and social conditions across the Brazilian states, with the exception of the homicide rate.

A comparison between the AIC values in table 4 and the FE estimates in table 3 confirm that there is not much of an improvement after including the spatial dependence terms. The same applies to the values and significance levels obtained for Moran's I, an index of spatial autocorrelation, proposed by Moran (1948).[6] Only for schooling does Moran's I show a value of 0.29 which is significant below the 5% level. For the other three economic

[6] Moran's I can vary between -1 and +1 and indicate the degree spatial autocorrelation similar to the usual Spearman correlation coefficient. Moran's I is obtained through regression using the growth rate of the variable and a value of the initial variable, both taken in mean values.

Table 4: β-convergence analysis with spatial dependence

	GDP per capita		schooling		life expectancy		non-homicide rate	
	SAR	SEM	SAR	SEM	SAR	SEM	SAR	SEM
$\ln(Y)_{i,t-1}$	-0,433***	-0,457***	-0,204***	-0,232***	-0,179***	-0,255***	-0.046	-0.02
	-0.039	-0.037	-0.053	-0.053	-0.025	-0.026	-0.174	-0.085
ρ	-0.047		0.238		0,357***		-0,435*	
	[0,657]		[0,108]		[0,007]		[0,090]	
λ		0,048*		0,067**		0,119***		0,082**
		[0,097]		[0,015]		[0,000]		[0,026]
time effects	✓	✓	✓	✓	✓	✓	✓	✓
implied β	27.74	28.77	15.91	17.6	14.32	18.93	-	-
half-life	2.49	2.4	4.35	3.93	4.83	3.66		
AIC	-676	-678	-666	-669	-1574	-1583	-207	-301
R^2	0.66	0.66	0.17	0.15	602.00	0.55	0.09	0.08
obs.	162	162	162	162	162	162	108	108

Notes: The table shows the results from the spatial error model (SEM) and the spatial autoregressive (SAR) model in eq. (3). Both models include state and time effects. The lower part of the table shows the implied half-life and β coefficient, as well as some test statistics related to the goodness of fit of these models. Standard errors are in parentheses and P-values in squared brackets. (*) denotes significance at 10%, (**) at 5% and (***) at 1%.

and social variables, the index suggests that there is no relevant spatial interaction with neighboring states. The possible limitation for the spatial interaction tests may be at the aggregation level. Spillover perception is obviously more difficult between states than between smaller geographical units.

4 Conclusion

This paper analyzed the convergence process among Brazilian states, considering not only economic variables, but also social indicators of education, health and crime. The variables were selected in order to approximate the three perspectives of the Human Development Index, namely access to knowledge, a long, healthy, secure life and a decent standard of living. We examined the process of σ-convergence through inequality indicators, as well as the process of β-convergence using econometric models. Analyzing social and economic convergence in Brazil is novel to the literature.

In general, the results show a consonance between the economic and social convergence for the period 1990 to 2010, with the exception of the variable related to crime. In the analysis of σ-convergence, the variables show a decreasing trajectory in their dispersion, indicating that Brazilian states have become, on average, more equal in education levels, health issues and economic terms. In particular, life expectancy (as well as infant survival and literacy rates) have very low coefficients of variation at the end of the observed period and hence the situation in these aspects is almost equal between states. The largest divergence remains in the production per capita. Our β-convergence analysis confirms that an approximation in these regards exists but the convergence of GDP per capita is much slower than in terms of schooling and life expectancy, for example.

A more difficult question is to decide whether the states converge to the same steady

state or if, by virtue of the existence of distinct equilibria, convergence is rather relative than absolute. Our reading of the data is that given the high absolute β-convergence rates, equal conditions in schooling and health indicators are likely to exist in the near future. However, due to the slow absolute convergence speed and the high significance of the state effects in our estimations, it is rather unlikely that Brazilian states tend to the same steady state in per capita production. Consequentially, without further regional development initiatives, regional wage inequalities are likely to persist.

Graphical analysis reveals that the states with the highest convergence rates are part of the Northeast region. Among the main explanations for improved social conditions are the large government-imposed income transfers through social programs, macroeconomic stability due to the implementation of the *Real Plan*, the expansion of the agricultural frontier and an increase in (public) credit supply.

The non-homicide rate shows decreasing dispersion until 2005 but again increased at the end of the period. In fact, the homicide rate has been increasing in states with initially low rates, particularly in the Northeast, while it has been decreased in states with high violence, such as Rio de Janeiro. Consequentially, the data points to the existence of absolute β-convergence but at the expense of an overall increase in violence. Since crime rates move in opposite directions across states, there is no evidence of relative β-convergence here.

Finally, this analysis seeks to contribute to the literature insofar as it provides robust empirical evidence on convergence, particularly bringing the social context to the scope of economic growth. Identifying convergence only considering income variables does not necessarily guarantee the simultaneous convergence of social welfare. In this sense, we expected our results to be useful for the discussions of public policies. The existence of convergence or divergence but the issue is also directly related to the role of government and its actions whether those already developed or yet to be developed. The role of convergence analysis itself in policy consulting is, however, a modest one. Our evidence of convergence is purely descriptive and the projection of past approximation rates into the future is a purely ceteris paribus exercise. Any significant shocks, either at the local or the national level, or permanent policy changes will obviously have an impact on future convergence rates. Nevertheless, we tried to identify, which we believe to be, the most influential policy interventions and how they are supposed to affect the economic and social cohesion in Brazil.

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