Demographic Change and Regional Economic Growth in Brazil

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Resumo. Neste trabalho, nós investigamos se a mudança demográfica desempenha um papel na dinâmica do crescimento econômico regional no Brasil. A economia brasileira teve uma transição demográfica muito rápida porque as taxas de fertilidade e mortalidade da população diminuíram significativamente nas últimas décadas. Espera-se que a mudança demográfica afete o desempenho de crescimento ao longo do tempo, uma vez que as mudanças na estrutura da população implicam mudanças nas decisões de consumo e de poupança, na oferta de trabalho e produtividade e nos investimentos públicos já que os gastos do sistema de pensões tendem a aumentar. Adicionalmente, o padrão da mudança e estrutura demográfica não é homogêneo entre as regiões brasileiras. Este artigo explora a forma como a estrutura demográfica regional tem mudado ao longo das últimas décadas em todas as regiões brasileiras e estima equações de convergência condicionadas a fatores demográficos, utilizando uma abordagem de dados em painel. A extensão dos efeitos demográficos sobre o crescimento econômico e sua sensibilidade a diferentes métodos econométricos são investigadas através do uso de OLS e System GMM para estimar equações de convergência. Além disso, uma estrutura de painel espacial também foi utilizada para estimar equações de convergência, uma vez que a dependência espacial parece estar presente na dinâmica de erro.

Palavras-chave: Estados brasileiros, mudança demográfica, convergência de renda

Abstract. In this paper we investigate whether demographic change plays a role in the dynamics of regional economic growth in Brazil. The Brazilian economy has had a very fast demographic transition because fertility and mortality rates of the population have significantly decreased over the last decades. Demographic change is expected to affect the growth performance over time since changes in the population structure imply changes in consumption and savings decisions, in labor supply and productivity and in public investments as pension system expenditures tend to increase. Additionally, the pattern of demographic change and structure is not homogenous across Brazilian regions. This paper explores how the regional demographic structure has changed over the past decades across Brazilian regions and estimates convergence equations conditioned on demographic factors using a panel data approach. The extent of demographic effects on economic growth and its sensitivity to different econometric methods are investigated through the use of OLS and System GMM for estimating convergence equations. In addition, a spatial panel structure was also used to estimate convergence equations since spatial dependence seems to be present in the error dynamics.

Key words: Brazilian states, demographic change, income convergence

JEL: J11, R11, R12

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1 Introduction

The regional structure of the Brazilian economy can be characterized by high and persistent inequality. For instance, the Northeast is the poorest region of Brazil and its per capita income accounted for 48.3% of the national per capita income in 1970. In 2010, the per capita income of the Northeast region accounted for 61.5% of the national per capita income. These data suggest the existence of dynamic convergence across Brazilian regions, which seems to be very slow. In fact, Azzoni (2001) showed that the speed of convergence for Brazilians states is 0.68% per year in the case of absolute convergence and 1.29% in the case of conditional convergence. Therefore, total equalization of per capita income across Brazilian states would be achieved only after several decades.

Many other empirical studies have been developed in order to identify the forces acting on regional growth and convergence in Brazil. Some studies show that initial conditions such as physical and human capital, industrialization and infrastructure do matter for the dynamics of regional growth (Coelho and Figueiredo 2007, Gondim, Barreto and Carvalho 2007, Barreto and Almeida 2008, Magalhães and Miranda 2009, Canêdo-Pinheiro and Barbosa Filho 2011). Geographical aspects such as location, agglomeration and spatial dependence also seem to be important for the dynamics of convergence across Brazilian regions (Silveira-Neto2001, Silveira-Neto and Azzoni2006, Resende2011).

Recently, the literature on endogenous economic growth models has sought to gain a better insight into the relationship between demographic factors and income convergence (Fukuda and Morozumi 2004, Prettner and Prskawetz 2010). Most of the literature usually assumes that population size and its growth rate are associated with economic growth and does not take into account the population age structure and its changes over time. As fertility and mortality rates have significantly decreased over the last decades but as countries have differences in their demographic transition process it seems important to take into account demographic factors as another force influencing the economic dynamics across countries. A more detailed specification of demographic factors in growth models, for instance, population age structure, is relevant because the agent`s decisions change over the life cycle. The literature assumes that the channels linking demographics with economic growth would be associated with the effect of demographic change on the consumption preferences, savings decisions, labor supply and productivity of the workforce and the need for more public expenditure to support pension systems.

In this paper we investigate how demographic factors can influence the economic dynamics of Brazil from a regional perspective. The empirical literature has ignored the potential role of demographic factors in regional economic growth in Brazil. As well as in other countries, demographic transition has rapidly evolved in Brazil because fertility and mortality rates of the population have significantly decreased over the past decades. The ageing of the population is not yet the main characteristic of the Brazilian age structure, but it will certainly be in a few decades. However, important differences across Brazilian states can be observed in terms of their demographic structure, but the effects on the regional economic dynamics are not yet known. Therefore, the aim of this paper is to investigate whether demographic change plays a role in the dynamics of regional economic growth in Brazil. The sensitivity of demographic parameters is also evaluated through different specifications for the convergence equation and by use of different estimation methods.

The paper is organized into six sections including this introduction and the final remarks. Section 2 presents a brief review of the theoretical and empirical literature on economic growth models, highlighting the role of demographic factors. Section 3 explores the characteristics of the population age structure and demographic change across Brazilian regions over the past 40 years. The methodological approach is discussed in Section 4 and the results are reported and analyzed in Section 5.

2Literature Review

There are different theoretical perspectives on the issue of income convergence, but the main ones are those of the neoclassical and the endogenous growth models. The classical model proposed by Solow (1956) and Swan (1956) went on to become the landmark study of economic growth, since it served as a source of inspiration for many other models that emerged in the literature, from which new features are incorporated or simply the existing characteristics are modified.

Solow explored the role of technological change in the U.S. economy in the period 1909 to 1949, concluding that approximately 90% of its growth could be attributed to the technological factor; actually, only the production factors (capital and labor)[1] do not sustain the long-term economic growth rate, indicating that this rate is exogenous in the sense that it is not determined by the model (Jones, 2000). Thus, technology, inserted exogenously into the model, known as the Solow residual, is the responsible factor for the growth of the economy. It is important to emphasize that this result is also found in other models, the so called endogenous growth models, in which technology is treated endogenously. In this sense, the economic growth model of Robert Solow inspires many other models that emerged in the literature.

Several other studies evaluate economic growth, searching for an endogenous explanation, as the ones carried out by Lucas (1988) and Romer (1990). According to the former author, it is necessary to postulate appropriate variations in the parameters related to technology and preferences. This adjustment reflects the mobility of factors so that it is no longer possible to pay them for their marginal productivities, since the world is not competitive. This seems to be the major distinction between what the neoclassical theory predicts and the pattern of trade observed. Using a similar technique to that used in the models of Arrow (1962), Uzawa (1965) and Romer (1986), Lucas extended the neoclassical model by adding what Schultz (1963) and Becker (1964) called “human capital,” in order to address these aspects. The increase in productivity is explained by economic incentives such as higher returns for higher levels of education. Thus, an economy with more human capital grows faster, since higher levels of education have incentives in the form of higher returns, having a positive impact on the wages of individuals.

The development of endogenous models gave rise to new theories of endogenous economic growth, which differ from the original model of Solow for using increasing returns to scale (Martin and Sunley, 1998; Clemente and Higachi, 2000). These theories can be classified into two groups: the first one includes the models of Lucas, (1988), Romer (1986), and Rebelo (1991), in which technology is a public good (except for Lucas), and the second one, the neoclassical-Schumpeterian models of endogenous growth, includes the models of Romer (1990) and Aghion and Howitt (1993) in which technology is a general good subject to appropriation, introducing the idea of imperfect competition. The model of Rebelo (1991) is an example of linear models, assuming that physical capital, human capital and research are the basic sources of economic growth, adding these factors in a broad measure of capital, so that the output is a linear function of the capital measure. The neoclassical-Schumpeterian

[1]It is assumed that the output function has constant returns to scale, implying that when both production factors are increased together, the product increases proportionally.

models attribute the key role in explaining economic growth in the long run to innovation. Technological progress is explained by the pursuit of higher profits. Considering imperfect competition, investment in research and development (R&D) permit the creation of a variety of new products with higher quality, ensuring profitability.

The analysis of the relationship between the change in demographic structure and in economic growth is recent in the literature. Previously, the population variable was limited by the extent of its total growth and size, considering the population age structure to be constant. However, the relationship between these variables has been studied by several authors mainly from the 1990s, since the change in demographic structure is a significant variable for explaining economic growth. As to the implications of the process of demographic change for the economic sphere, Miles (1999) mentions its impact on the rate of savings, capital formation, labor supply, interest rate and real wages. Wong and Carvalho (2006) deem the impact on labor supply to be important, since the active working age population (25-64 years old) will grow at least until 2045. Nevertheless, this supply of labor can only be explored if the productivity of this population is developed, maintaining the economic, social and intergenerational balance.

Prettner and Prskawetz (2010) present an extensive review on the theoretical literature on economic growth models that deal with changes in the age structure of the population. Their review shows that the effect of demographic change on economic growth can be positive or negative depending on the framework of each study. Population ageing can have a positive impact on economic growth if savings of the working-age population increases in order to support future consumption or if R&D investments increase relative to workforce's size. But there could be a negative impact if population ageing is conditioned on declines in fertility coupled with a reduction in population growth or if pension systems are formulated in such a way that the workforce to retirees ratio decreases.

The ambiguity about the population ageing effect on economic growth also is also very clear in the overlapping generations model with capital accumulation and uncertain lifetime horizon developed by Fukuda and Morozumi (2004). Their results suggest that a large share of the output is consumed by non-productive factors when the proportion of the elderly population is large, determining a negative impact on economic growth. However, countries with a high aged dependency ratio tend to have a high life expectancy and a low rate of population growth, which contribute to increasing the savings rate of the working-age population and enhancing economic growth. Thus, the effective impact of population ageing on economic growth would not be certainly clear and depends on the relative combination of these sources. The cross-country panel analyses carried out by Fukuda and Morozumi (2004) founded evidence of a positive effect between the aged dependency ratio and economic growth.

Other empirical studies have analyzed the relationship between the components of population and economic growth per worker. According to Prskawetz, Fent and Barthel (2007) it seems that the child dependency ratio is significantly and negatively related to economic growth. Evaluating the role of demographics for Europe, Kelley and Schmidt (2005) also found that the decline in the child dependency ratio had a strong positive effect on the rate of growth of output per worker during the 1970s and 1980s. The general conclusion from these analyses is that, regardless of the method applied and the set of additional control variables considered, the relationship between the economic growth rate and demographic change seems to be robust.

In Brazil, the empirical literature on economic growth has mainly investigated the existence of convergence across regions and the importance of some factors suggested by the theoretical models such as physical and human capital as well as other structural characteristics of each region, such as agglomeration, industrialization and infrastructure (Coelho and Figueiredo 2007, Gondim, Barreto and Carvalho 2007, Barreto and Almeida 2008, Magalhães and Miranda 2009, Canêdo-Pinheiro and Barbosa Filho 2011). Other studies have explored the importance of geographical aspects such as spatial dependence on income convergence in Brazil (Azzoni et al. 2000, Silveira-Neto 2001, Silveira-Neto and Azzoni 2006, Resende 2011).

Little attention has been devoted to investigating the importance of demographic change as a potential source explaining the economic dynamics across Brazilian regions. A first study carried out by Azzoni, Menezes-Filho and Menezes (2005) using microeconomic data – household surveys - suggests that demographic structure matters for regional growth because the speed of income convergence varies considerably across birth cohorts and demographic structure tends to be different across regions. Recently, Menezes, Silveira-Neto and Azzoni (2011) have also emphasized the effects of demographic factors on regional inequality in Brazil analyzing the income convergence for age cohorts. According to this study, income convergence would only exist for the older generations. Moreover, such a convergence would be explained mainly by retirement payments, pension payments, and other government transfers and would not be observed when these transfers are controlled in the analysis.

In the present study, we investigate the role of demographic change in the economic growth of Brazilian states by estimating the of income convergence equation that explicitly addresses demographic variables. Thus, this analysis is expected to reveal the extent to which demographic change is effectively correlated with regional growth and inequality in Brazil.

3 The pattern of inequality and demographic change in Brazil

In this paper, we will look at demographic change as a potential channel to explain regional economic growth in Brazil, a country characterized by strong regional inequalities. Table 1 presents the extent of regional concentration and inequality in Brazil through the share of each region in the national income and the ratio of the average per capita income of each region to the national average per capita income. In 1970, the income in the Northeast region was 14.6% of the national one, whereas that of the North reached only 2.9% of the national total. In terms of inequality, whereas the Northeast presented an average per capita income of 48.3% below the national average, and the North reached 65.6%, only the Southeast had an income that was substantially above the national average. In 2010, regional inequality changed for the North and Northeast regions while the income in the Southeast, South and Central West regions was above the national average.

In terms of demographic structure, Brazil has experienced significant changes over the last decades. The decrease in birth and mortality rates has contributed to boosting demographic transition in Brazil. Figure 1 presents the evolution of the dependency rate[2] and the child and aged components from 1940 to 2050, considering the population projections calculated by the Brazilian Institute of Geography and Statistics (IBGE). The total dependency ratio sharply decreases from 1970 and must remain so until 2020, starting to increase thereafter. The

[2]The dependency ratio calculated by IBGE considers the population under the age of 15 and over the age of 64 relative to the population over the age of 14 and under the age of 65. Consequently, the child and aged dependency ratios correspond respectively to the population participation under the age of 15 and over the age of 64.

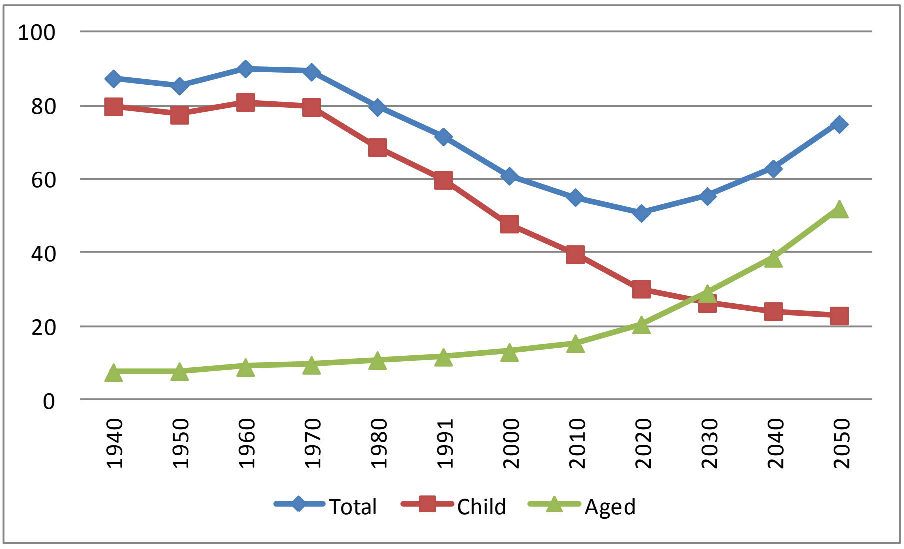
preponderance of child participation in the dependency ratio is very clear, but the ageing of the Brazilian population tends to become more prominent each year and will govern the dependency ratio after 2030.

Table 1. Income and Income per capita for Brazilian Regions

Regions	Income[a]		Population		Income per capita[b]	
	1970	2010	1970	2010	1970	2010
Brazil	100.0	100.0	100.0	100.0	100.0	100.0
North	2.9	4.7	4.4	8.3	65.6	69.2
Northeast	14.6	15.8	30.2	27.8	48.3	61.5
Southeast	62.2	52.7	42.8	42.1	145.5	119.5
South	16.1	17.9	17.7	14.4	90.8	113.1
Central West	4.2	8.9	4.9	7.4	86.1	117.0

[a] Ratio of the income of each region to the national income.
[b] Ratio of the income per capita of each region to the national income per capita.
Source: IBGE and IPEA.

Figure 1. Dependency ratio for Brazil, 1940-2050



Source: IBGE, Demographic Census 1940-2000 and Population Projections for Brazil 1980-2050, revised in 2008.

Demographic transition at the regional level has been similar to the national tendency, but the demographic structure and its dynamics are not totally homogenous across Brazilian regions as shown by the data presented in Table 2. The child dependency ratio represents most of the total dependency for each region, but it is more important for the North and Northeast. The child dependency ratio for these regions has remained systematically above the national ratio while the opposite occurs for the Southeast. In the case of the South and Central West, the child dependency ratio is initially above the national ratio in 1970 but ends up below the national ratio in 2010. It is worth noting that the current pattern of the regional child dependency ratio somehow replicates in some way the North/Northeast versus South/Southeast polarization also observed in the per capita income inequality, suggesting a negative correlation.

In the case of the aged dependency ratio, only that of the Northeast and of the Southeast was above the national ratio in 1970. But in 2010, only the aged dependency ratio of the Southest remained above the national ratio it includes also the South. As to the Northeast region, the aged dependency ratio seems to converge towards the national ratio. Although not well defined as in the case of the child dependency ratio, the North/Northeast versus South/Southeast polarization observed in per capita income inequality also has been replicated for the case of the aged dependency ratio. The difference in this case lies in the position of the regions since the correlation between aged dependency ratio and per capita income inequality seems to be positive.

These results imply that the demographic transition process tends to occur more quickly for the South and Southeast. As mentioned before, the demographic change can affect the growth dynamics by way of several channels and demographic change could be another source to explain the dynamics of regional inequality in Brazil. Thus, the relevance of this source is empirically investigated through the estimation of convergence equation models for the Brazilian states as discussed in the next section.

Table 2. Dependency ratio of population for Brazilian regions, 1970-2010

Regions	1970	1980	1991	2000	2010
Dependency ratio					
Brazil	82.4	73.1	65.4	55.0	45.9
North	96.4	95.4	83.7	69.3	55.7
Northeast	93.7	91.5	80.1	63.5	50.9
Southeast	72.8	62.1	57.1	49.4	42.5
South	83.9	66.9	58.5	50.9	42.7
Central West	88.8	77.4	62.7	51.9	43.5
Child dependency ratio					
Brazil	76.6	66.1	57.5	45.9	35.1
North	92.0	90.0	78.1	63.1	48.6
Northeast	87.5	83.1	71.0	54.0	40.1
Southeast	66.8	55.3	49.0	39.9	30.9
South	78.6	60.5	50.6	41.5	31.2
Central West	85.2	72.7	57.4	45.5	35.1
Aged dependency ratio					
Brazil	5.8	7.0	8.0	9.1	10.8
North	4.4	5.4	5.5	6.2	7.1
Northeast	6.2	8.4	9.1	9.5	10.8
Southeast	6.0	6.8	8.1	9.5	11.5
South	5.4	6.4	7.9	9.4	11.6
Central West	3.7	4.7	5.3	6.5	8.4

Source: IBGE, Demographic Census 1970-2010.

4 Methodological procedures

The methodological approach designed in this study to investigate whether demographic change plays a role in the economic dynamics of Brazilian states follows the usual specification of the convergence equation as a panel data regression presented in Durlauf et al. (2005). In the conditional form, β-convergence is evaluated through a regression where the growth rates of per capita income are the dependent variable and the initial values of the income per capita level and other variables representing the structural characteristics of each region are the independent variables. The general dynamic panel data specification for the convergence equation used in this study is represented as follows[3]:

$$g_{i,t}=\beta y_{i,t}+\delta X_{i,t}+\mu_i+\varepsilon_{i,t} \quad (1)$$

where $g_{i,t}$ represents a vector with observations for average per capita income growth rates for each state i in each decade t (i = 1, …, 27; t = 70's, 80's, 90's)[4]. Moreover, $y_{i,t}$ is the initial income per capita, $X_{i,t}$ is a vector of explanatory variables containing those determinants suggested by the growth literature, μ_i are the individual-specific effects and $\varepsilon_{i,t}$ is the vector of error terms. The individual-specific fixed effect model has the advantage of dealing with the problem of omitted variables associated with fixed effects related to heterogeneity across regions and that are constant over time. As noted by Islam (1995), the fixed effect panel model would be superior to the pooled panel model because it allows for differences in the aggregated production function across regions.

The first-difference formulation derived from equation (1) can also be adopted to handle the issue of omitted variables since the term μ_i is eliminated. In this specification, equation (1) is reformulated as follows:

$$\Delta g_{i,t}=\beta\Delta y_{i,t}+\delta\Delta X_{i,t}+\varepsilon_{i,t}-\varepsilon_{i,t-1} \quad (2)$$

Although the problem of omitted variables is not presented, this specification shows the endogeneity problem because the lagged term in the first component is correlated with the lagged error term of equation (2). The first-differenced GMM method developed by Arellano and Bond (1991) would be another alternative, but Bond et al. (2001) showed that the lagged first-difference of the explanatory variables used as instruments can be weak instruments for the explanatory variables in equation (2). As a consequence of weak instruments, the coefficient variance increases asymptotically and the coefficients can be biased in small samples. In order to reduce these problems, Blundell and Bond (1998) developed the system GMM (SYS-GMM) estimator where the instruments for the regression in differences (in levels) are the lagged levels (differences) of the explanatory variables.

It is worth noting that there are other potential sources of endogeneity in the context of growth models related to variables such as human capital and demographic factors. The growth dynamic can be influenced by human capital and human capital accumulation can be influenced by the income dynamics. Additionally, as the demographic change component can indirectly cause economic growth when there is a prevalence of working-age people, economic growth can also affect the demographic change in the sense that the working-age population can be attracted to the regions with faster growth dynamics. These aspects enhance the need for using the SYS-GMM approach to estimate the convergence equation.

We are particularly interested in evaluating the signal and significance of the demographic variables and their sensitivity to different estimation methods and to different specifications for the convergence equation. Thus, the panel model for the convergence equation was estimated using the OLS fixed-effect procedure and the SYS-GMM method. Also, in order to avoid the potential problem of instrument proliferation in GMM estimations observed by

[3] As can be observed, the dynamic structure comes from the following equivalent formulation of equation (1): $y_{i,t+1} = (1+ \beta)\, y_{i,t} + \delta X_{i,t} + \mu_i+\varepsilon_{i,t}$.

[4] The average per capita income growth rates were calculated using a formula equivalent to ($ln\ y_{i,t+1}$ - $ln\ y_{i,t}$)/10. The per capita income data comes from the demographic census for the 1970-2000 period, for which there are data available only for 1991 but not for 1990. Thus, the denominator of that formula is 10 only for 1970-1980, 11 for the 1980-1991 and 9 for 1991-2000.

Roodman (2009a, 2009b), the SYS-GMM approach used in this paper follows the empirical strategy proposed by Roodman (2009b) for collapsing the instruments[5].

The OLS and SYS-GMM methods were applied to estimate three different specifications for the convergence equation. The first one (model 1) is equivalent to the augmented Solow's growth model where the set of explanatory variables $X_{i,t}$ is composed only of population growth, average education as a proxy for human capital and population density to account for scale effects. The second one (model 2) has a set of explanatory variables containing the same one mentioned before and two additional demographic variables, the child dependency ratio and the aged dependency ratio. We considered these two components of the dependence ratio separately into the convergence equation due to their heterogeneous distribution across Brazilian regions and also because the empirical literature has suggested that each one can affect the growth dynamic in specific terms. The third model (model 3) consists of the spatial panel structure of model 2, where a spatial lag of the dependent variable is included in the set of explanatory variables. Models 1 and 2 were estimated using both OLS and SYS-GMM methods and model 3 was estimated using only the SYS-GMM method. The explanatory variables (excluding the spatial lag of the dependent variable) are considered in terms of their initial values in each decade and are summarized in Table 3.

The estimation of the spatial panel version of model 2 is relevant if spatial dependence is presented in the error term, but ignoring it would still yield a biased coefficient variance. A convergence study carried out by Silveira-Neto and Azzoni (2006) about the GDP per capita dynamics across Brazilians states showed that spatial dependence is more relevant for the unconditional than for the conditional convergence equation. Another study, conducted by Resende (2011), showed that the more fragmented the spatial unit in the regression models the more important the spatial dependence. Even though the spatial dependence problem seems to be less relevant if the variables associated with the spatial linkage across regions are computed into the vector of explanatory variables, this issue needs to be assessed when regression models are specified for territorial units.

Table 3. Explanatory variables in the convergence equation

Code	Description
WTCRPC	Spatial lag of the dependent variable
INC	Logarithm of initial per capita income
AEST	Logarithm of average years of schooling
DENS	Logarithm of population density
POG	Logarithm of population growth
CDPR	Child dependency ratio
ADPR	Aged dependency ratio

Notes: All variables are assessed at the beginning of each decade, that is, 1970, 1980, 1991. The data were collected from IPEADATA (Institute of Applied Economic Research) and from the Demographic Census conducted by IBGE. The population growth variable was calculated based on the demographic data and adjusted for depreciation and technological growth, meaning that it is equivalent to $n_{i,t}$+d+g in accordance with the Solow's model.

[5] We used the collapse suboption for the xtabond2 command in Stata, which combines instruments by adding smaller sets without dropping any lags. As observed by Vieira and Haddad (2011), this procedure implies the creation of one instrument for each variable and lag distance, rather than one for each time period, variable, and lags distance. The final outcome is obtained by dividing the GMM-style moment conditions into groups and summing up the conditions in each group to form a smaller set of conditions. In the end, we have a set of collapsed instruments, one for each lag distance, with zero indicating any missing values.

The spatial dependence problem is evaluated by using the global spatial autocorrelation measure known as Moran's I statistics (Anselin 1988). This statistics is calculated for the cross-sectional errors generated for each time span in the panel, providing information on the spatial autocorrelation effects across the three decades (1970s, 1980s and 1990s). Moran's I statistics is represented as follows:

$$I = \frac{\sum_i \sum_j w_{ij}(\varepsilon_i - \bar{\varepsilon})(\varepsilon_j - \bar{\varepsilon})}{\sum_i (\varepsilon_i - \bar{\varepsilon})^2} \tag{3}$$

where ε_i and ε_j are the values of the cross-sectional errors, $\bar{\varepsilon}$ is the mean of the errors and w_{ij} are elements of the spatial weighting matrix that is row-standardized, that is, the elements w_{ij} in each row total 1. To perform this test, we used the Queen and K-nearest neighbors to calculate w_{ij}. The weighting matrix calculated by the Queen form implies a first-order contiguity matrix that considers all the states bordering one specific state while the weighting matrix calculated by the K-nearest form assumes a number of neighborhoods specified *a priori*. The statistics were computed for 1 to 5 neighborhoods and allow evaluating the sensitivity of the spatial dependence to different neighboring levels. The matrix with higher significant values is chosen.

5 Results

As previously discussed, three different convergence equations were estimated through OLS fixed-effect and SYS-GMM methods in order to assess how important demographic change is to Brazilian regional growth. As the spatial panel model was estimated only for the SYS-GMM method, five convergence equations were estimated, whose results are presented in Table 4. The speed of convergence is negative and significant for all models and varies between 15.53% per year (model 1 in the OLS fixed-effect estimation) and 28.11% per year (model 2 in the SYS-GMM estimation). The bias towards the speed of convergence estimated by the OLS procedure is very high compared with the SYS-GMM estimation. All the errors obtained from models 1 and 2 in both estimation methods present spatial dependence, as shown by the Moran's I test, at least in one sub-period. However, the potential bias and inefficiency caused by spatial dependence seem to be very low for all coefficients. The following analysis is based on the SYS-GMM estimation, which is more appropriate.

The effect of education – a proxy for human capital – on regional economic growth is positive as predicted by to the theoretical literature, but it seems overestimated when demographic factors such as child and aged dependency ratios are not considered into the set of explanatory variables. The population growth effect is negative for all estimated models, while the population density effect is significantly negative only for model 1. It is worth noting that the effect of population growth on economic growth is very controversial in the empirical literature, but the results obtained for the SYS-GMM estimations seem to be robust.

The relevance of child and aged demographic change to regional growth can be evaluated through the estimation of models 2 and 3. Based on the results, these two demographic change variables present statistically significant and negative coefficients for the SYS-GMM estimation[6]. For the regional dynamics in Brazil, these results suggest that the higher the child(aged) dependency ratio the lower the economic growth. In addition, the coefficient of

[6] For the coefficients estimated by the OLS method, note that there is an expressive bias on the value obtained for the aged dependency coefficient whose signal was positive. This result suggests that the estimation of the convergence equation including demographic change variables without correcting for endogeneity could provide misleading information about the importance of these variables to the economic growth dynamics.

Table 4. Panel Data Results for the convergence equations

Explanatory Variables	OLS - Fixed Effects		SYS-GMM		
	Model 1	Model 2	Model 1	Model 2	Model 3
WTCRPC – Spatial lag					0.0056 (0.0028)***
INC – Initial income per capita	-0.1553 (0.0081)*	-0.1685 (0.0060)*	-0.2531 (0.0354)*	-0.2811 (0.0315)*	-0.2806 (0.0319)*
POG – Population growth	-0.0210 (0.0121)***	-0.0014 (0.0115)	-0.1610 (0.0597)**	-0.1090 (0.0596)***	-0.1054 (0.0468)**
AEST – Education	0.1131 (0.0072)*	0.0765 (0.0086)*	0.2744 (0.0231)*	0.1939 (0.0598)*	0.1892 (0.0537)*
DENS – Population density	0.0100 (0.0068)	0.0013 (0.0074)	-0.0181 (0.0078)**	-0.0151 (0.0127)	-0.0153 (0.0090)
CDPR – Child Dependency ratio		-0.1597 (0.0249)*		-0.1822 (0.0553)*	-0.1826 (0.0551)*
ADPR – Aged Dependency ratio		0.4769 (0.1652)*		-0.8794 (0.2921)*	-0.8932 (0.2635)*
Constant	0.5670 (0.0773)*	0.8324 (0.0780)*	0.2627 (0.1226)**	0.6109 (0.1335)*	0.6188 (0.1264)*
R-squared	0.9917	0.9897			
Adjusted R-squared	0.9867	0.9828			
Hansen			0.221	0.064***	0.123
Hansen-Diff			0.800	0.046**	0.115
Number of Groups			27	27	27
Number of Instruments			21	19	23
Collapsing the number of instruments			no	yes	yes
Testing for spatial autocorrelation:					
Moran's I for 70's	0.3542	-0.0952	0.7154*	0.4178***	0.1886
Moran's I for 80's	0.5870*	0.7387*	0.0514	0.0205	-0.0844
Moran's I for 90's	0.7026*	0.3787***	0.3389	0.1665	0.0527

Note: * significant at 1%, ** significant at 5%, *** significant at 10%. For the fixed-effect OLS estimation, correction of the cross-sectional weights was used for the standard errors. For the SYS-GMM estimation, all explanatory variables were considered to be potentially endogenous. For the spatial model (model 3), we used a first-order k-nearest matrix, as it was the one with higher significant values.

the aged dependency ratio is much higher than the one estimated for the child dependency ratio. These differences imply that demographic change could contribute to reducing regional inequality in Brazil given the spatial pattern of child and aged dependency across Brazilian regions. As the child (aged) dependency ratio is higher for the poorest (richest) regions and is rapidly declining (increasing) over the decades, the continuation of such a process could effectively contribute to reducing regional inequality in Brazil.

For the whole country, in the context of a more prominent ageing process, these results would imply less economic growth in the future than in the present. However, as suggested by the growth literature and also according to our results, one important strategy to mitigate or postpone the potential negative impact of demographic change would be to increase investments, thus improving the human capital stock and enhancing productivity and growth.

6 Final remarks

Economic growth can be influenced by demographic change as people's economic behavior changes over their life cycle. In this paper, we addressed the importance of demographic change to the dynamics of regional economic growth in Brazil, a country characterized by high and persistent regional inequality. Most of the empirical literature on regional growth in Brazil usually investigates the existence of convergence and the role of some factors postulated by the endogenous growth models such as physical and human capital. Some studies explore other factors such as agglomeration, spatial effects and urbanization, but little attention has been devoted to gaining a better insight into the demographic sources of regional inequality in Brazil.

Following the recent developments in the theoretical and empirical literature on economic growth in which demographic change is explicitly modeled, we estimate convergence equations to evaluate how demographic change is related to the dynamics of economic growth across Brazilian states. These convergence equations were estimated by using the OLS and system GMM techniques and accounting for spatial dependence in the error term. Two basic formulations for the set of explanatory variables in the convergence equation were considered: the first one is equivalent to the augmented Solow's model without demographic change variables whereas the second one includes the demographic change variables. A third specification was also estimated using a spatial lag panel model, but the potential bias and inefficiency caused by spatial dependence in the errors were not significant.

The results suggest that the OLS fixed-effect estimation for the convergence equation provides a highly biased coefficient, underestimating the speed of convergence for the regional economic dynamics in Brazil. Considering the demographic change variables, the coefficient of the aged dependency ratio is strongly biased and could produce misleading information about the role of demographic change in the regional economic growth. Taking into account the consistent estimation obtained from the SYS-GMM method, the results show that child and aged dependency ratios have a negative and statistically significant effect on regional growth. Additionally, the coefficient of the aged dependency ratio is much higher if compared to the one estimated for the child dependency ratio, implying that demographic change could contribute to reduce regional inequality in Brazil given the spatial pattern of child and aged dependency across Brazilian regions.

In spite of the potential contribution of demographic change to reducing regional inequality, the results also suggest that economic growth for the whole country could be impaired in the future because of the ageing process implied by the demographic transition dynamics. Thus, in accordance with the growth literature, our results support the need to invest in the improvement of human capital stock to enhance productivity and growth, consequently minimizing the potential negative impact associated with the population ageing after demographic transition.

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