Subnational variations and convergence/divergence processes in demographic components*

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Abstract

Demographic theories frequently imply regional convergence in both fertility and mortality indicators. Despite the assumptions that demographic rates across regions would converge, there has been no evidence of this fact. This paper discusses the hypothesis of convergence and divergence in mortality and fertility with special focus on subnational levels in Latin American countries. These countries are extremely unequal in many dimensions, which are likely to be related to demographic variables. This paper also discusses the indicators used to measure mortality and fertility and the metrics of disparity to assess convergence and divergence processes, presenting a study case for Brazil. Results show that the mortality and fertility changes at subnational levels in Brazil do not follow a unidirectional and linear course, but rather present a process of convergence and divergence.

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1. INTRODUCTION

The demographic transition is one of the most important transformations in modern societies. This process can be briefly described in terms of changes in demographic regimes, from a situation where mortality and fertility are high to a regime of relatively low level of these two variables. Such changes have important consequences in population growth and age structure modifications.

Although implicit in some previous theories, this idea was first presented by Thompson (1928) in a more elaborated way, based on the interpretation of the changes in industrialized countries. Notestein (1945) argued that this was a universal process, predicting that the changes observed in developed countries would also happen in the rest of the world, as soon as technical developments make possible the mortality decline. By describing the transition in Europe, Coale (1986) presented the main trends in fertility, mortality and population growth. He summarized the movement from diverse combinations yielding low growth rates (moderate fertility and mortality), through high growth potential, achieving uniform combination of very low fertility and mortality (low to negative growth). Accordingly, all these descriptions of the demographic transition theory imply the convergence across countries in both fertility and mortality. Patarra (1994) agrees that demographic rates might, in the long-term, converge, though this hypothesis is a moot point in terms of the explanations of the transformations, resulting from distinct social processes.

Imprecisions in the classical model have been shown, in addition to questions about its generalization through counterexamples[1] (Patarra & Ferreira, 1986). However, most societies seem to follow this general pattern and the demographic transition has been useful in understanding population dynamics and the empirical regularities in mortality and fertility trends have been striking, providing a highly plausible basis for population projections (Wilson, 2013). In several past revisions of the United Nations (UN) population projections, it was assumed that countries in the transition from high to low fertility would ultimately converge to a fertility floor of 1.85 children per woman. This assumption is no longer used and the total fertility is projected based on a probabilistic method that takes into account the historical experience of the country being projected and other countries with similar fertility. Convergence in life expectancy is not an assumption in the newest UN population projections either (United Nations, 2015). National statistical agencies often assume that subnational areas' demographic rates will converge in the future. The Brazilian Institute of Geography and Statistics, for example, assumes a convergence in life expectancy and a regional convergence in fertility (Ervatti, Borges, & Jardim, 2015).

The second demographic transition theory also implies birth and death rates convergence at low levels, which would be followed by population decline in Europe (Van De Kaa, 1987).

[1] In the French transition, for example, mortality and fertility fell almost concomitantly along the period 1790-1860.

Despite the assumptions that demographic rates across countries would converge, there has been no evidence of this process, either in mortality (Vallin & Meslé, 2004) or fertility (Wilson, 2013).

Thus, the objective of this paper is to discuss the hypothesis of convergence and divergence in the demographic components, focused on subnational levels in Latin American countries.

Some authors have described the demographic transition as a process with causal effect, by which fertility declines as a result of mortality decline. According to this approach, mortality decline would act as a stimulus for the demographic responses, for instance in population rational decisions about fertility (Davis, 1963; Kirk, 1996). However, trying to understand such distinct phenomena and their interrelationship in the same explanatory model would add additional complications and would not necessarily help addressing the main research questions of this work.

Therefore, this paper analyses the hypothesis of convergence and divergence in mortality and fertility independently, which will be presented in the sections 2 and 3. These sections also present subsections on the hypothesis about the specificities at the subnational level, with special focus on Latin American countries. These countries are extremely unequal in many dimensions, such as income, education, access to services, and treatment by police and justice systems (De Ferranti, Perry, Ferreira, & Walton, 2004), which are likely to be related to demographic variables. The demographic behavior of populations is clearly linked to social and economic inequalities they face, since material conditions and expectations people experience impacts the birth and deaths outcomes and the propensity to migrate (Wood & Carvalho, 1988). Section 4 discusses the indicators used to measure mortality and fertility and the metrics of disparity to assess convergence and divergence processes. Section 5 shows a study case for Brazil, using the measures discussed in the previous sections, in order to present the convergence and divergence processes across the 5 Major Regions and 27 states, and the implications for subnational population projections.

2. CONVERGENCE AND DIVERGENCE IN MORTALITY

A construct closely related to the demographic transition is the idea of “epidemiological transition”. This term was first used by OMRAN (1971) in order to explore the complex change in patterns of health and disease. His theory is based on the idea that degenerative and the so-called “man-made” diseases replace infectious diseases as the primary causes of morbidity and mortality. According to the author, the epidemiologic transition consists of three successive stages: i) the "Age of pestilence and famine", when mortality is high and fluctuating; ii) the "Age of receding pandemics", when mortality declines progressively; iii) the "Age of degenerative and man-made diseases", when mortality continues to decline and eventually approaches stability at a relatively low level (Omran, 1971, pp. 516–517).

These stages would vary in pattern, pace and determinants, leading to different models of the epidemiologic transition: the first one is the "classical" or Western model, which shows a gradual and progressive transition that was supposed to happen in most of the developed world. The contemporary or delayed model refers to the transition yet-to-be completed in most developing countries.

In agreement with the epidemiological transition idea, some authors have described what would be a fourth stage to the theory, called "The Age of Delayed Degenerative Diseases". This concept includes a rapid decline in mortality, concentrated mostly at advanced ages and caused by the postponement of mortality from degenerative diseases (Olshansky & Ault, 1986).

The idea of convergence inserted in a universal process, present in the demographic transition theory, is also implicitly in the third stage of the epidemiologic transition theory, when mortality would stabilize at very low levels.

However, important failures and unexpected improvements in mortality contradicts some points of the epidemiological transition theory. In this sense, Omran's "Age of degenerative and man-made diseases" does not seem to be the final stage of the transition and the successful fight against cardiovascular diseases cannot be interpreted as its fourth stage. Rather, these changes would fit in the idea of a divergence-convergence process, based on a new approach to health, where the success this field depends on societies' abilities to implement progresses (Vallin & Meslé, 2004).

This theory of convergence/divergence process assumes that every major improvement related to health would first benefit the most favored population groups, leading to a divergence in mortality outcomes. At some point, the remaining groups would also benefit of these improvements, and a new convergence process would take place, until the next major improvement occurs and starts a new process of divergence (Vallin & Meslé, 2004).

In addition to this process of catching up with the pioneers, other criticisms to the epidemiologic transition by the health transition theorists are the existence of a linear and unidirectional view of the processes and the sequence of the stages. It has been observed that actual transitions often contain many nonlinear processes, in addition to an overlapping of different patterns (Frenk, Bobadilla, Stern, Frejka, & Lozano, 1991).

Subnational mortality convergence/divergence in Latin America

There have been some works trying to describe convergence and divergence processes within countries. Ezzati et al. (2008) document regional convergences and divergences across the United States counties. After years of reducing mortality inequality, there was a steady increase between 1983 and 1999, resulting from stagnation or increase in mortality among the worst-off segment of the population. Bennett et al. (2015) find an increase in regional inequality in England and Wales. One of the mechanisms explaining this divergence is the effect of social policies in worsening economic inequalities, with consequences to health disparities. The authors claim that access to high-quality health is a key factor for limiting and reducing health inequalities, through both preventive and lifesaving acute treatments.

There have not been many comprehensive studies about internal mortality inequalities in middle-income countries. This research agenda is needed, since transformations resulting from health transition are particularly complex in these countries. In Latin America, for example, mortality improvements have been reflecting advances in medical technology, progresses in health care systems and changes in lifestyles and living conditions of the populations (Palloni & Pinto-Aguirre, 2011).

However, the population has a very heterogeneous health profile, which leads to the development of a peculiar epidemiologic polarization, not only between countries, but also within them in different geographic areas and among different social classes. These experiences are called "prolonged polarized model" (Frenk et al., 1991). The paradigmatic examples of this "new transition model" are Brazil and Mexico. Polarization is associated with the concept of a double burden of infectious and chronic diseases, but the authors also emphasize the existence of a "protracted" period when these two kinds of diseases coexist, without a clear expectation of resolving the transition process, mostly due to the persistence of social and regional inequalities. Such inequalities reinforce the coexistence of the two stages as a result of subpopulations experiencing different stages of the transition, but these subpopulations themselves frequently also suffer from both types of diseases – infectious and degenerative – at the same time.

Thus, understanding mortality convergence and divergence processes within Latin American countries requires acknowledging the coexistence of old and new problems: the predominance of chronical and degenerative diseases, while the communicable ones still play an important role. Another example contradicting the main aspects of the classical theories is the mortality from external causes, which have been playing an important role in changing mortality patterns in the region.

The mechanisms that cause convergence and divergence in mortality require the study of mortality trends by sex, age and cause of deaths. Decline in mortality from infectious and parasitic diseases tend to benefit children; the improvements in mortality from cardiovascular diseases benefit the adult and the elderly populations; mortality from external causes occurs mostly among young adult males.

Convergence in mortality driven by decline in infectious and parasitic diseases would depend on the ability of the least favored regions and social groups to benefit of the methods available to control these diseases, such as public health measures, immunization, use of antibiotics, and improvements in general socioeconomic conditions. It would also be related to the capacity of controlling emerging and re-emerging of infectious diseases.

Mortality from external causes are likely to be associated to processes of mortality convergence and divergence in Latin American. The region is known for being as one of the most violent places in the world, and this violence is extremely segregated within countries according to socioeconomic conditions and regions. Trends in mortality from homicides, and their differentials according to regions would depend, for example, on social economic conditions and policies addressing violence. The latter is, in turn, dependent on the design of federalisms in the countries, in which these policies can be independently designed at local levels or being more nationally centered. Road traffic accident is also an important cause of mortality in Latin America. In this case, policies to address road safety issues, such as road infrastructure and education campaigns and programs (Pérez-Salas, 2015) are more likely to affect the internal regions in a country more homogenously.

Trends in regional inequalities in mortality will also depend on the ability of each region to incorporate the benefits of new technologies to treatment and, most importantly, to improve prevention, especially against cardiovascular diseases. Controlling risk factors of these diseases is also a key point to mortality from chronic and degenerative diseases.

The abovementioned examples show that mortality convergence or divergence across regions is an extremely complex process, with no guarantee of convergence in mortality rates, as predicted by demographic and epidemiologic transition theories.

3. CONVERGENCE AND DIVERGENCE IN FERTILITY

Wilson (2013) argues that the majority of the world will soon have entered a phase of demographic development that can validly be termed “post-transitional”, claiming that not so many versions of demographic transition theory have a great deal to say about what comes next. In the case of fertility trends, many researchers and institutions have assumed that fertility will tend to the replacement level. The United Nations (UN), for instance, used this assumption of convergence for its projections for a long time, anticipating a homogeneous world in which almost all demographic variety would disappear. However, the assumption of long-term convergence to replacement-level fertility has little or no basis in either empirical evidence or in demonstrably relevant theory (Wilson, 2013). In the last revisions of population projections, the UN adopts a Bayesian probabilistic method that no longer requires this assumption.

Analyzing the fertility trends for the post-war period, Dorius (2008) uses multiple measures for assessing the changing nature of intercountry fertility inequality and shows that the only definite statistical evidence for convergence is found after 1990.

Despite the disagreement concerning the causes of fertility change, the general consensus has been that, whatever the causes, the evolution of fertility includes three broad phases: a high-fertility pre-transition phase, the fertility transition itself, and a low-fertility post-transition phase. The last phase includes recovery from below-replacement fertility toward replacement fertility and oscillations around replacement-level fertility (Alkema et al., 2011). Fertility levels in this phase would never go back to pre-transitional levels though, but periods of convergence and divergence could happen temporarily if the regions are in different phases of their transition at the same time.

Growing evidences have shown that European countries are likely to be characterized by remarkable differences in fertility trends during the next decades, instead of presenting a convergence in fertility patterns. "Divergent demographic destinies" will thus be a key aspect of the social, economic, social, cultural and policy environment in Europe with profound implications (Kohler & Anderson, 2016).

Subnational mortality convergence/divergence in Latin America

Fertility patterns in Latin America have been extremely different from the transition observed in European countries. In addition to a more rapid fertility decline, phenomena such as the high levels among young women, and even increase in fertility and motherhood in this group in several countries in the region, are some specificities to be considered. Despite the reversal of this trends in the last decade, high inequalities within countries remain (Rodríguez-Vignoli & Cavenaghi, 2014).

Regional convergence in fertility are present in diffusion theories of fertility, by which reproductive behaviors would spread across populations, being influenced by components of social interaction: social learning and social influence (Montgomery & Casterline, 1996). This would lead to a convergence process in fertility, reinforced by the cultural similarities within countries. On the other hand, the extreme socioeconomic inequalities in Latin American countries would lead to persistence of differentials in fertility. Differences in the educational level, a commonly used predictor of fertility, would play an important role in maintaining these differentials.

4. MEASURING CONVERGENCE AND DIVERGENCE IN DEMOGRAPHY

Choosing the mortality and fertility indicators to be compared is the first issue to be addressed in order to measure inequalities in demographic components.

The most commonly used measure to represent overall mortality levels is the life expectancy at birth (e_0). This summary indicator hides, however, important patterns by age. A convergence in e_0 across regions can be driven, for example, by a convergence in infant mortality concomitantly with a divergence in adult mortality. In this sense, it is recommended the analysis of mortality by age, using Age Specific Death Rates, or at least separating infant from adult mortality, analyzing indicators such the IMR (Infant Mortality Rate) and the life expectancy at age 10 (e_{10}).

The Total Fertility Rate (TFR) is by far the most used fertility indicator, giving a good picture of period fertility. Age Specific Fertility Rates (ASFR), cohort measures, such as CFR, and decomposition of changes in period fertility rates into tempo and quantum variations are additional measures that might help understanding fertility variations. However, given the availability of the data for subnational levels in Latin America, the TFR might be sufficient for the analysis necessary to address the hypothesis of convergence in fertility.

In order to assess convergence or divergence in mortality and fertility indicators, measures of statistical dispersion should be used. The most common examples are the range $(Max - Min)$, Inter-Quartile Range $(Q_3 - Q_1)$ and population standard deviation $\left(\sigma = \sqrt{\frac{\sum(X-\mu)^2}{N}}\right)$. The Inter-Quartile Range (IQR) has the advantage of being robust, meaning that it is not influenced by outliers. All these measures have the same unit of the indicators being measured.

Measures of relative dispersion can more useful in comparative research, since they are dimensionless quantities. Some examples are the Coefficient of Quartile Deviation $\left(\frac{Q_3-Q_1}{Q_3+Q_1}\right)$ and the Coefficient of variation $\left(\frac{\sigma}{\mu}\right)$. These indicators might be useful when measuring convergence and divergence in the TFR, for example. A difference of 0.5 children may be less important in the pre-transitional period, with fertility around 6 children per woman, for instance, than when fertility is around the replacement level.

Another concept, often used to measure inequality trends in income across countries (Sala-i-Martin, 1996), is the β-convergence, which means a negative relation between the growth rate of the indicator measured and the initial level. Differently from the σ-convergence, which would mean a decline in standard deviation across region, β-convergence is a measure of the rate of change and it is given by:

$$ln\left({Y_{i,t}}/{Y_{i,0}}\right)/t = \alpha + \beta ln\left(Y_{i,0}\right) + \varepsilon_i$$

where $Y_{i,t}$ is the indicator to be measured for region i and time t and β is the convergence coefficient. A negative sign on the convergence coefficient indicates that lagging countries are catching up with leading countries (converging), while a positive coefficient indicates laggards are falling farther behind (diverging) (Dorius, 2008). When using demographic indicators, like TFR and e_0 (unlikely economic indicators, such as income), β-convergence could be also measured more simply by a negative correlation between change and initial level, and without the log scale. Standardizing the change and initial level measures before calculating the slope is another alternative to allow better comparison across time and space.

Another issue to be considered is weighting the regions according to their population sizes. There has also been debates about treating each unity (in this case, subnational entities, such as states or provinces) equality or weighting by their population sizes (Dorius, 2008).

5. PRELIMINARY RESULTS

This section shows a study case for Brazil, presenting convergence and divergence processes in mortality and fertility across regions and states, and the implications for subnational population projections.

Fertility convergence/divergence in Brazilian states

Table 1 depicts the summary indicators and measures of dispersion of the Total Fertility Rates for the Brazilian Federation Units from 1940 to 2010. The Brazilian fertility started to decline in the 1960s, but in 1940 there was already an important dispersion among the Brazilian states, with some states presenting fertility of more than 8 children per woman, while the fertility transition had already started in the more developed states in the South and Southeast regions, with fertility rates of about 4 children per woman.

Table 1 – Summary statistics and measures of dispersion – Total Fertility Rate, Brazilian Federation Units, 1940-2010

Indicator	1940	1950	1960	1970	1980	1991	2000	2010
	Summary Statistics							
Minimum	4.41	4.38	4.53	3.80	2.94	2.09	2.00	1.65
1st quartile	6.59	6.86	6.83	6.29	4.29	2.64	2.22	1.75
Median	6.75	7.39	7.33	7.48	6.00	3.47	2.58	1.96
3st quartile	7.60	8.06	7.98	7.86	6.43	3.95	3.03	2.20
Maximum	8.71	9.68	10.40	9.90	6.97	4.90	3.88	2.81
Average	6.90	7.29	7.42	7.09	5.34	3.41	2.68	2.03
	Measures of dispersion							
Range	4.30	5.30	5.87	6.10	4.03	2.81	1.87	1.17
IQR	1.01	1.21	1.14	1.57	2.13	1.31	0.81	0.46
St Dev	1.07	1.21	1.35	1.50	1.30	0.83	0.52	0.34

CQD	0.07	0.08	0.08	0.11	0.20	0.20	0.15	0.12
CV	0.15	0.17	0.18	0.21	0.24	0.24	0.19	0.17

Figure 1 shows the five measures of dispersion presented in Table 1, normalized in order to show the changes over time in the same scale. All the measures show a broadly similar shape, with an increase in the dispersion when the more developed regions presented fertility decline, while many states remained with high fertility. In the last decades, fertility has also declined sharply in the less developed states, reducing the disparity across states. The two dimensionless indicators, Coefficient of Quartile Deviation (CQD) and the Coefficient of Variation (CV), present a similar trend, reaching the maximum dispersion in 1980 and 1991 and sharp reduction in 2000 and 2010.

Figure 1 – Normalized measures of dispersion – Total Fertility Rate, Brazilian Federation Units, 1940-2010

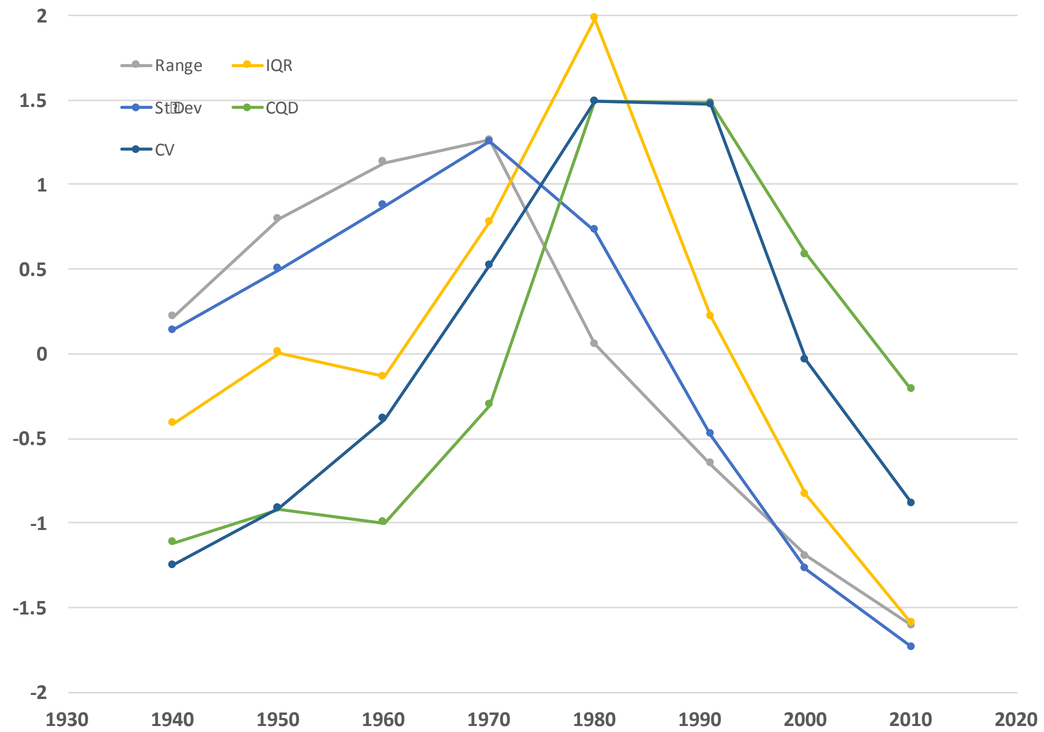


Table 2 shows the Beta-convergence and the correlation between fertility change and initial level, indicating that fertility decline among states which started the fertility transition earlier was more rapid than among the leading states until 1980. During the 1980s, 1990s and 2000s, the negative signs on the convergence coefficient indicate that the lagging states are catching up with leading states (converging). Coefficients closer to zero for the period 2010/2000 show that convergence in this decade was slower than in the previous intercensal period.

Table 2 – Beta-convergence and correlation between fertility change and initial level – Total Fertility Rate, Brazilian Federation Units, 1940-2010

Indicator	1950/	1960/	1970/	1980/	1991/	2000/	2010/

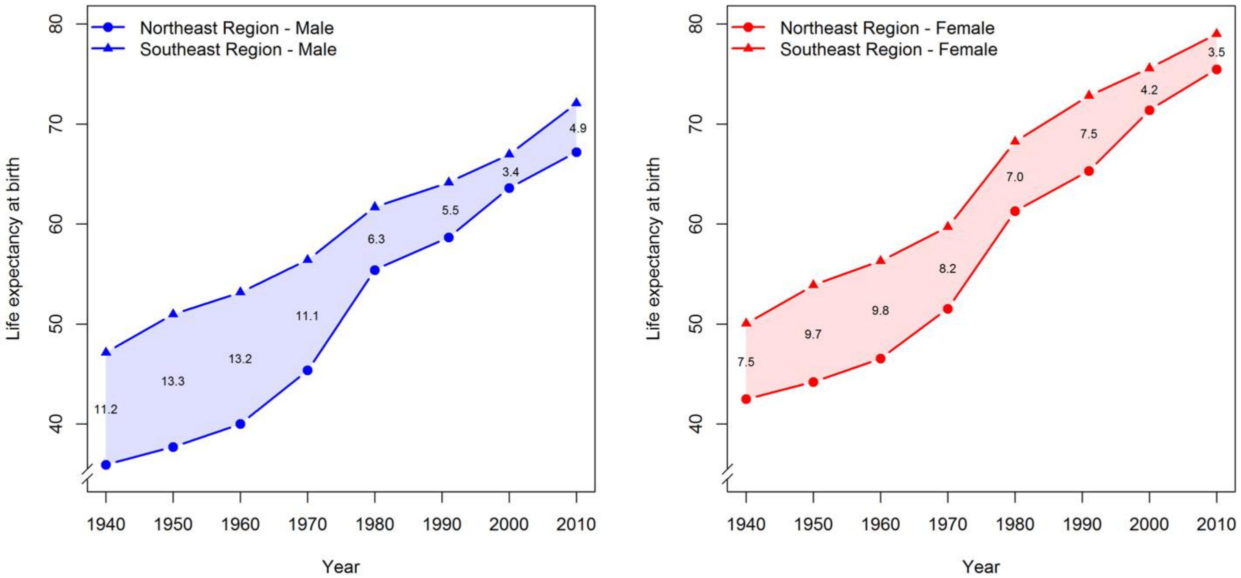
	1940	1950	1960	1970	1980	1991	2000
Beta-convergence	0.006	0.003	0.016	0.003	-0.010	-0.030	-0.019
Correlation	0.121	0.166	0.285	0.072	-0.331	-0.740	-0.605

The main question regarding population projections is whether fertility among states will maintain the convergence process observed in the last three decades or a new process of divergence will appear when recovering start to take place in same states.

Mortality convergence/divergence in Brazilian states[2]

Life expectancy has increased substantially in Brazil since the 1930s, presenting more rapid improvements than those observed in the European countries when they had the same mortality levels. However, there have been persistent regional inequalities, even though the long-term trends show reducing differences. In the 1930s, life expectancy in the South Region was around 50 years, 15 years higher than the figure observed in the Northeast Region. Despite the long-term convergence trend, mortality decline has happened unequally in all Brazilian regions. Figure 3 shows life expectancy at birth by sex, from 1940 to 2010 for the Southeast and Northeast Regions. From 1940 to 1960, the difference between the life expectancies in these two regions increased from 11.2 to 13.2 for males and from 7.5 to 9.8 years for females. This difference reduced significantly after 1960, but a new divergence emerged for males in the last period of analysis, when the difference in life expectancies increased from 3.4 to 4.9 years.

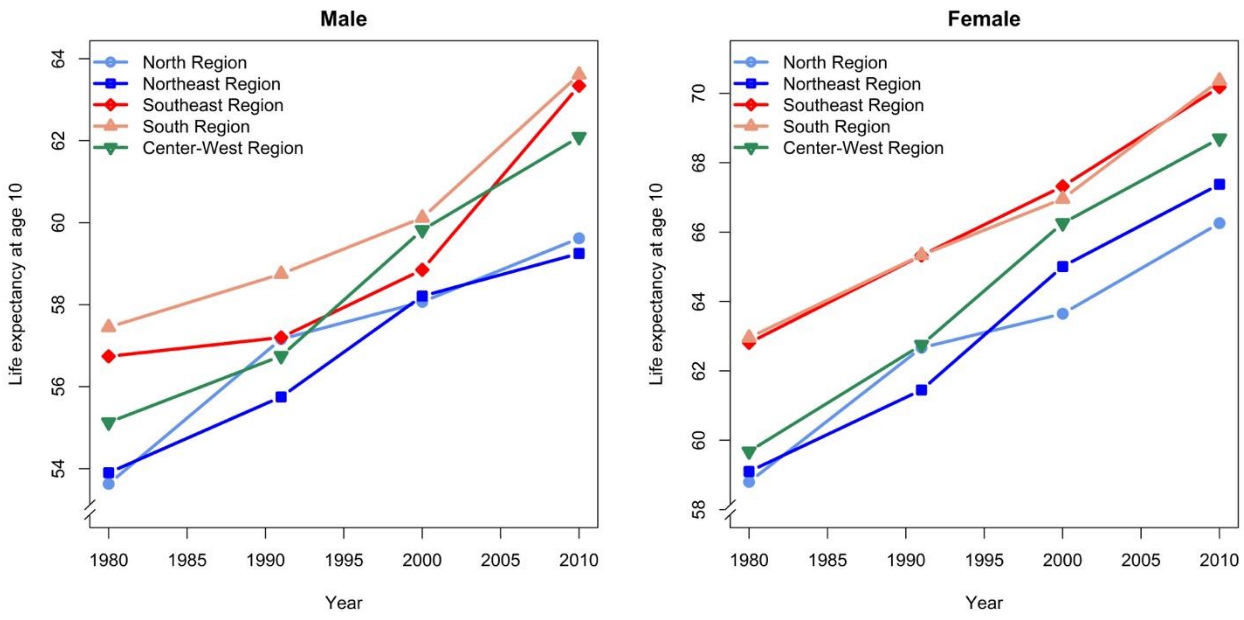
Figure 2 – Life expectancy at birth (e_0) by sex – Southeast and Northeast Regions - 1940/2010



[2] Section based on Borges (2016).

Life expectancy at birth is often taken as an index of overall mortality, but gives a poor idea of lifespan, since it is heavily affected by infant mortality. In order to show the regional differences in mortality without the effect of infant mortality, Figure 4 shows the life expectancy at age 10 (e_{10}), by sex, for all regions, from 1980 to 2010.

Figure 3 – Life expectancy at age 10 (e_{10}) by sex and Major Region - 1980/2010



A convergence process in e_{10} happened from 1980 to 2000, which is shown by the narrowing difference between the life expectancies in the less developed regions (North and Northeast) and the more developed regions (South and Southeast). In the last decade, however, there was a divergence in adult mortality, much clearer for males than for females: the difference in e_{10} between the Southeast and Northeast regions increased from 0.6 to 4.1 years between 2000 and 2010.

Females' e_{10} for the South and Southeast regions have been presenting very similar patterns, whereas for males they have been significantly higher in the South Region than for those in the Southeast, with a great divergence during the 1980s and 1990s. In the last decade, life expectancy for males in the Southeast have increased more than five years, leading to a new convergence between these regions.

These results have shown that the idea of convergence implicit in the demographic and epidemiologic transition theories might not apply to the Brazilian case during the period under study. Despite some long-term trends showing reducing regional inequalities, there have been some periods of divergence in life expectancy at different ages, for instance between the Southeast and the North and Northeast Regions.

The transition itself does not lead to a reduction in inequalities, which will be more dependent on policies that focus on the least favored regions and social groups, or on rapid transmission of improvements in health and wellbeing throughout society.

A new mortality convergence process between the less and more developed regions in the future would only be possible if the North and Northeast Regions could sustain the important declines in infant mortality observed in the last decades, and if mortality among young adult males could be better controlled. Furthermore, differences in mortality among the elderly persist, for both males and females. Thus, future trend in regional inequalities in mortality will also depend on the ability of each region to incorporate the benefits of new technologies to treatment and, most importantly, to improve prevention, especially against cardiovascular diseases. Controlling risk factors of these diseases is also a key point to mortality from chronic and degenerative diseases. In this sense, the use of data on biomarkers as health and disease predictors, for instance to monitor trends in risk factors for these diseases, is of fundamental importance.

6. CONCLUSIONS AND DISCUSSION

This paper has discussed the hypothesis of convergence and divergence in the demographic components, more specifically fertility and mortality, focused on subnational levels in Latin American countries. It has been shown that there is no evidence of convergence in this variables, as largely used in population projections and predicted by the demographic transition theory.

Understanding the distinct historical processes of mortality and fertility convergence and divergence in different geographic and temporal contexts shed light on the possible future trends in the demographic components. This brings important contributions to the assessment of the underlying hypothesis in the population projections. Although these hypotheses of convergence have been proved inappropriate in most cases, there has not been many technical approaches to incorporate these issues in population projections.

These results also lead to a discussion about the hypothesis of convergence in the age structure of the population. The particular demographic processes in each region, reflecting the historical regional inequalities, indicate a multiplicity of current demographic structure by age and sex. In this sense, given the existing differentials in the age structure of the populations, a convergence in the population age structure is a very unlikely hypothesis. The demographic momentum “carried” by each population states that, regardless the convergence in the demographic rates (fertility, mortality and migration), a convergence in the age structure of the population would not occur until the replacement of many generations.

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