

THEORIES AND MEASURES
OF DEMOGRAPHIC CONVERGENCE:
AN APPLICATION TO SUBNATIONAL
LEVELS IN LATIN AMERICA

TEORÍAS Y MEDIDAS DE CONVERGENCIA
DEMOGRÁFICA: UNA APLICACIÓN A NIVELES
SUBNACIONALES EN AMÉRICA LATINA

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Demographic theories often imply regional convergence in both fertility and mortality indicators. However, despite these assumptions, there has been no evidence that demographic rates across regions would persistently converge. The purposes of this paper are twofold. First, it discusses the hypotheses of convergence and divergence in mortality and fertility with special focus on subnational levels in Latin America. Second, this study proposes and examines carefully a set of mortality and fertility indicators and the metrics of disparity to assess convergence and divergence, which are further applied to Brazilian states. Results show that mortality and fertility changes do not follow a unidirectional and linear course, but rather present an interchanging process of convergence and divergence.

Keywords: Demographic convergence. Fertility. Mortality. Latin America. Brazil. Population projections

Las teorías demográficas normalmente tienen como supuestos la convergencia en fecundidad y mortalidad. Sin embargo, no existe evidencia de que las tasas demográficas entre regiones convergirían persistentemente. Este trabajo tiene dos objetivos principales. En primer lugar, se discuten las hipótesis de convergencia y divergencia en mortalidad y fecundidad con un enfoque especial a los niveles subnacionales en América Latina. En segundo lugar, este estudio propone y examina un conjunto de indicadores de mortalidad y fecundidad y medidas de dispersión para evaluar la hipótesis de convergencia y divergencia, con una aplicación a los estados de Brasil. Los resultados muestran que los cambios en mortalidad y fecundidad no siguen a un camino unidireccional y lineal, sino que se presenta un intercambio entre procesos de convergencia y divergencia.

Palabras-clave: Convergencia demográfica. Fecundidad. Mortalidad. América Latina. Brasil. Proyecciones de población

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 works, this idea was 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 potential high growth, finally achieving a uniform combination of very low fertility and mortality (low to negative growth).

Johnson-Hanks (2008) differentiates the term demographic transition, which refers to the historically specific changes in population rates, from the theories of demographic transition, which are theories regarding the causes and mechanisms of the historical changes, predominantly associated with modernization.

In any case, all these descriptions of the demographic transition imply the convergence across countries in both fertility and mortality. The second demographic transition also implies birth and death rates convergence at low levels, which would be followed by population decline in Europe (Van De Kaa, 1987).

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 counterexamples² (Patarra and Ferreira, 1986). Contradictions in the formulation of demographic change processes have generated debates about whether the demographic transition is in fact a population theory that can be generalized or just a historical description of a demographic change model. One of these contradictions

² In the French transition, for example, mortality and fertility fell almost concomitantly along the period 1790-1860.

is the fact that demographic changes in developed countries seem to have occurred as a result of development, whereas in the rest of the world demographic rates could change in the absence of social and economic progress (Patarra, 1973).

Notwithstanding this debate, most societies seem to follow this general pattern and the demographic transition has been useful in understanding population dynamics. Furthermore, 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 well as the trajectories of other countries. 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, and Jardim, 2015).

Other interests in the discussion about demographic convergence lie in the assumption that socioeconomic characteristics and behaviors tend to become more similar, leading to a demographic convergence, since demographic characteristics depend on these factors (Coleman, 2002). An additional research question on this matter is how these dimensions would interact, for instance whether the demographic convergence could coexist with socioeconomic inequalities (Rodríguez, 2001).

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

One of the key aspects of studying convergence is understanding and using the proper indicators to measure the hypotheses to be tested. Different measures will be discussed, along with the existing demographic convergence propositions. It is also important selecting the appropriate units of analysis and the temporal aspects to be used in assessing the hypotheses. While recognizing the importance of the analysis for distinct socioeconomic dimensions, this paper focuses on the regional differences. More specifically, it discusses the hypothesis of convergence and divergence

in the demographic components with focus to the 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 America. These countries are extremely unequal in many dimensions, such as income, education, access to services, and treatment by police and justice systems (De Ferranti et al., 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 and 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 its 27 Units of Federation (UF), and the implications for subnational population projections.

CONVERGENCE AND DIVERGENCE IN MORTALITY

A construct closely related to the demographic transition is the idea of epidemiologic 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).

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 epidemiologic 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 and Ault, 1986).

The idea of convergence inserted in a universal process, presented 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 contradict some points of the epidemiologic 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 the health transition approach, where the success in this field depends on societies’ abilities to implement progresses (Vallin and Meslé, 2004).

This theory of divergence/convergence 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 and 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 et al., 1991).

Some examples of health trends that contradicts the expected path of mortality reduction, often called “reverse or counter transitions”, are:

i) rise in mortality for certain causes associated with dangerous working conditions of factories and mines and the low standard of living among industrial workers in the early stages of the industrial revolution; ii) increase in non-communicable diseases as a result of unhealthy life styles in the wealthy society, such as smoking, drinking and high-fat diet; iii) emergence or re-emergence of infectious diseases, such as HIV/AIDS, which lead to a decline in life expectancy in several African countries; iv) increase in mortality in some countries of the former Soviet Union as a result of political and economic reforms (Horiuchi, 1999).

In fact, the combination of these patterns across countries lead to processes that are even more complexes than the idea of simple convergence and divergence. The discussion on economic convergence/divergence illustrates part of these complexities and can shed some light on the debate about convergence in mortality, which tend to be related to economic development (Preston, 1975). Some authors argue that development does not occur smoothly over time, but rather emerges from conflictive and sometimes unexpected processes. Successful development processes that involve leapfrogging confirms that convergence or catching-up are therefore not an ‘end state’, but a path to a new arrangement (Burlamaqui and Kattel, 2016).

This idea is consistent with mortality changes over time. The record life expectancy, for instance, has changed considerably over the last decades (Oeppen and Vaupel, 2002) and currently belongs to Japan, which 50 years ago was not even among the 40 countries with the highest life expectancy. Countries like Norway and Denmark, which once had the post of highest life expectancy in the world, no longer appear among the top.

It is often difficult to define these changes in positions among the developed countries as convergence or divergence. The Japanese example shows that it has not only caught up with other developed countries, but leapfrogged them. South Korea and Singapore have also left behind several countries. This is also valid for the trends observed in developing countries, for instance the crossover between life expectancy in some Latin American and Asian countries compared to Eastern European countries.

These examples show that one of the main complications to the study of convergence/divergence is the change in rankings between the units of analysis.

SUBNATIONAL MORTALITY DIVERGENCE/ CONVERGENCE IN LATIN AMERICA

There have been a few 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 reversal of this trend between 1983 and 1999 since mortality stopped declining among the worst-off population groups. 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, but the complexities of the transformations resulting from health transition in these countries reaffirms the need for this research agenda.

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 and 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 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 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 emerging importance of chronic and degenerative diseases, while the burden of communicable diseases is still present.

Mortality from external causes have been also 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 infectious diseases.

Mortality from external causes are likely to be associated to processes of mortality convergence and divergence in Latin America. The region is known for being 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 particularly prone to equally affect the internal regions in a country.

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 trends across regions are extremely complex processes, with no guarantee of convergence in mortality rates, as predicted by demographic and epidemiologic transition theories.

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 be termed “post-transitional”, but not so many versions of demographic transition theory have taken a position on 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 in its projections for a long time³, 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). Dorius (2008) uses multiple measures for assessing the changing nature of intercountry fertility inequality for the post-war period 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 rather than show 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. These patterns are related to the reversal in the well-established cross-sectional associations between fertility, related behaviors and development (Kohler and Anderson, 2016).

The abovementioned characteristics of the overall path through the fertility transition and the evidences of weakening the associations between fertility and other conditioning variables, complicate the analysis of convergence and divergence, suggesting contradictory interpretations.

³ In the last revisions of population projections, the UN adopted a Bayesian probabilistic method that no longer requires this assumption (Alkema et al., 2011).

The country ranking by period TFR in Europe, for instance, has changed significantly for the last 60 years. Just to give a few examples, Sweden, United Kingdom, Belgium and France, used to have the lowest fertility levels in Europe and are currently among the countries with the highest fertility rates. Poland, Republic of Moldova, Slovakia, and Portugal are examples of countries that showed the opposite trend and are currently among the European countries with the lowest TFR. These trends could be interpreted as convergence, since they show the laggards catching up with the pioneers. It could also be interpreted as divergence, as the difference in rates between countries increased, even changing in the sign. These examples of crossover are similar to those observed in mortality, but leapfrogging might not be the best term for fertility changes, since there is no clear association between fertility and development, whereas higher life expectancy is a desired goal as it means better health conditions.

SUBNATIONAL FERTILITY DIVERGENCE/CONVERGENCE 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, with even increasing fertility and motherhood in this group in several countries, are some specificities to be considered. Despite the reversal of this trends in the last decade, high inequalities within countries remain (Rodríguez-Vignoli and Cavenaghi, 2014).

Regional convergence in fertility is 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 and 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 within country in Latin America would lead to the 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.

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 the demographic components.

The most 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, the analysis of mortality by age is recommended, using Age Specific Death Rates (ASDR), or at least separating infant from adult mortality, analyzing indicators such as the infant (${}_1q_0$) or child mortality rates (${}_5q_0$) and the life expectancy at age 10 (e_{10}). The rationale for separating these two groups is also due to the fact that the determinants of mortality change varies considerably across ages.

Changes in the ASDR are not linear with changes in life expectancy though – see Keyfitz and Caswell (2005) for a discussion about this relationship. The differential in e_0 between two populations are significantly affected by differences in the age pattern of mortality and could even widen when the differences in age-specific death rates decrease (Glei and Horiuchi, 2007; Pollard, 1982).

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. Some authors have also highlighted the relevance of studying adolescent fertility separately, particularly in Latin America, due to its social implications and the special trends in rates for this age group – see, for instance, Di Cesare (2007) and Rodríguez (2011). The analysis of convergence presented in this paper could be also applied for this specific measures, but the results presented here will only illustrate the use of the TFR, in order to address solely the hypothesis of convergence in overall 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

$$\left(SD = \sqrt{\frac{\sum(X-\mu)^2}{N}} \right)$$

The Inter-Quartile Range (IQR) has the advantage of being robust, meaning that it is not influenced by outliers. All of these measures have the same unit of the indicators being measured. These statistics are useful to compare indicators in absolute rather than relative perspective, which seems to be the most adequate strategy for assessing convergence in life expectancies, for instance e_0 and e_{10} .

Measures of relative dispersion are dimensionless and cannot be interpreted in terms of the units of the indicator under analysis, e.g. TFR and e_0 . These measures should be used when the relative differences are more meaningful than the absolute ones. Some examples are the Coefficient of Quartile Deviation

$$\left(\frac{Q_3 - Q_1}{Q_3 + Q_1} \right)$$

and the Coefficient of variation

$$\left(\frac{SD}{\mu} \right)$$

The latter might be useful for measuring convergence and divergence in the ASDR and TFR. In the case of fertility, a difference of 0.5 children is thought to be less important in the pre-transitional period, when TFR is, for instance, around 6 children per woman, than when fertility is close to the replacement level (Dorius, 2008; Kohler, Billari, and Ortega, 2002). Using absolute variation to compare fertility rates is likely to misleadingly confirm the hypotheses of convergence, as shown in a study arguing that countries with high fertility rates in 1978 experienced larger declines in fertility between 1978 and 1998 than countries with lower fertility rates in 1978 (Herbertsson, Orszag, and Orszag, 2001).

The reduction in the disparities across regions, indicated by the measures of statistical dispersion, would lead to what is called σ -convergence. If the preferred indicator is the Standard Deviation (SD), for instance, the σ -convergence is given by the difference in the SD between the two years under analysis, divided by the time lapse between the two years:

$$(SD_{t_1} - SD_{t_0})/t$$

Another concept, often used to measure inequality trends in income across countries (Sala-i-Martin 1996), is the β -convergence, which occurs when there is 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 the disparity across region, β -convergence is a measure of the rate of change and it is given by:

$$\ln\left(\frac{Y_{i,t_1}}{Y_{i,t_0}}\right)/t = \alpha + \beta \ln(Y_{i,t_0}) + \varepsilon_i$$

where α 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 (β -convergence), while a positive coefficient indicates laggards are falling farther behind (β -divergence) (Dorius, 2008).

This formulation is useful when the main interest is on the relative change. The formula can be adapted to measure β -convergence in absolute terms, for instance for life expectancy, by changing the left-hand side of the formula to

$$(Y_{i,t_1} - Y_{i,t_0})/t.$$

The use of the logarithm is also not necessary on the right-hand side of the formula.

There has been some criticism in the economic literature about the use of β -convergence (Quah 1993) and it is now largely recognized that β -convergence is a necessary but not sufficient condition for σ -convergence. Sala-i-Martin (1996) sustains that both measures are interesting and should be analyzed empirically, giving some examples where β -convergence should be analyzed even in the absence of σ -convergence.

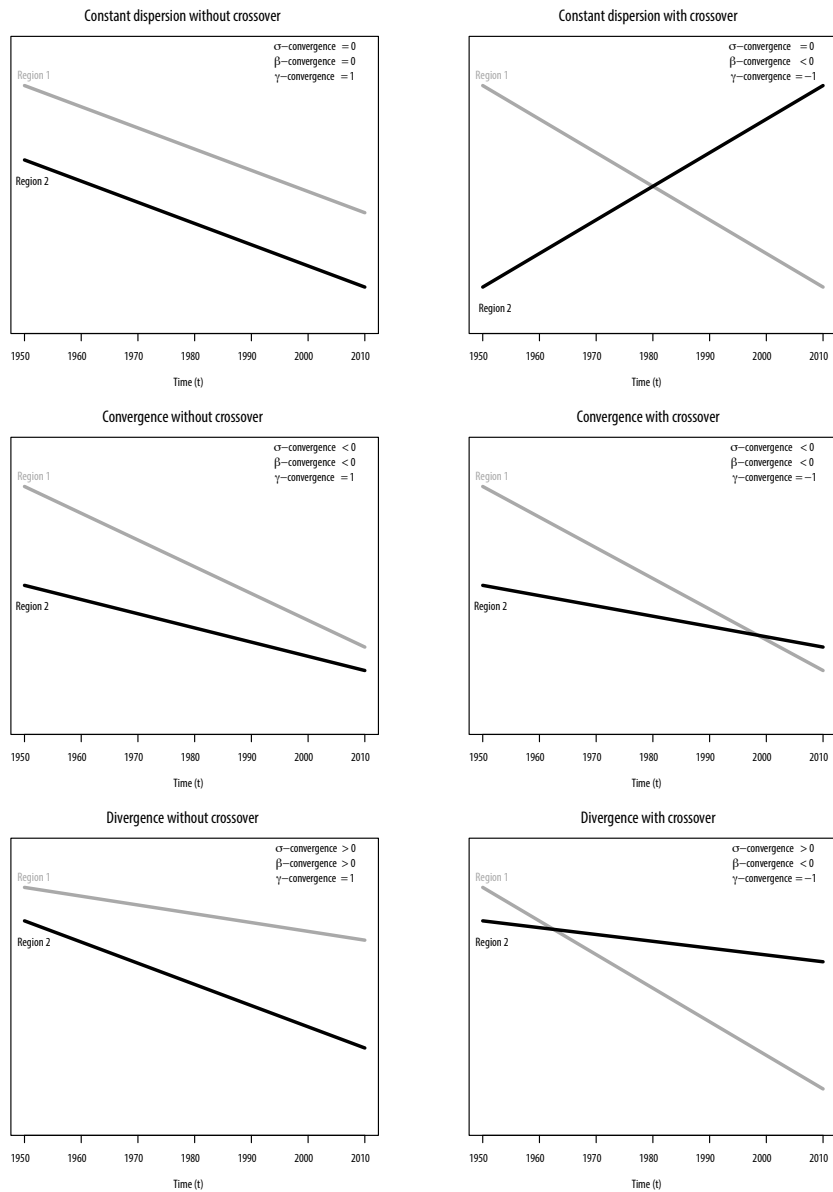
Inkeles (1998) points out that much of the difficulty of dealing with the issue of convergence is to distinguish precisely different elements of extremely complex societies, which may change at different speeds or even move in opposite directions. He also argues that convergence and divergence can assume different forms. For instance, in addition to simple movements from diversity to uniformity and from uniformity to diversity, there could be convergence with crossover, where lines first meet and then start to diverge.

In order to account for the criticisms about the β -convergence, particularly the possibilities of crossover, some authors have proposed the use of a measure which captures the change in rankings, sometimes called γ -convergence (Boyle and McCarthy, 1997). This measure helps the interpretation of σ and β -convergence. It has been mostly applied to test convergence in income levels and has not been used to mortality and fertility indicators. However, given changes in the ordinal ranking of countries in these variables described in the previous sections, this might be useful for these contexts. Slightly different from the original proposition, this paper adopts the Kendall tau-b coefficient. This indicator ranges from -1 to 1.

Results equal to 1 indicate that the rank position is the same in the two years analyzed, whereas -1 indicates that the ranking at time t is the exactly the opposite as the rank at time o .

All the indicators described in this section could, then, be used identically six different patterns of convergence/divergence: constant dispersion, convergence and divergence, which, in turn, can be classified as trend with crossover or without crossover. Figure 1 illustrates these patterns with a two-region example, showing the convergence indicators that lead to each of these arrangements. Constant dispersion without crossover refer to a parallel change with no σ or β -convergence and no changes in the ranking of the regions across time (γ -convergence = 1). Constant dispersion with crossover happen when there is no σ -convergence (the statistical measure of dispersion shows no temporal variation), but there is β -divergence. This apparent contradiction can be explained by the changes in the position of the regions (γ -convergence = -1). Convergence (with and without crossover) is expressed by both σ and β -convergence, whereas divergence without crossover has σ and β -divergence and divergence with crossover is expressed by σ -divergence and β -convergence.

Figure 1
Illustration of different patterns of convergence/divergence
over time and convergence indicators



Source: simulated data

RESULTS

This section shows a study case for Brazil, presenting divergence and convergence processes in mortality and fertility across Units of Federation (UF), and the implications for subnational population projections.

FERTILITY DIVERGENCE/CONVERGENCE IN BRAZILIAN STATES

Table 1 depicts the summary indicators and measures of dispersion of the Total Fertility Rates for the 27 Brazilian UF 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: TFT of about 4 children per woman.

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

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

Source: IBGE

All the measures of dispersion 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), show a similar trend, reaching the maximum dispersion in 1980 and 1991 and sharp reduction in 2000 and 2010.

The comparison between the years 1950 and 2010 illustrate how the use of measures of absolute and relative dispersion can lead to different interpretations. The Coefficient of Variation in 2010, for instance, is the same as the one of 1950, although the absolute measures of dispersion declined significantly in this period. This means that the relative difference in fertility between Brazilian states in 2010 is the same as that in 1950, although the absolute difference is lower due to the lower fertility levels.

Table 2 shows the three measures of convergence: σ -convergence, β -convergence and γ -convergence. The decennial β -convergence indicator shows that fertility decline among states which started their fertility transition earlier was more rapid than among the leading states until 1980. During the 1980s, 1990s and 2000s, the negative signs on the β -convergence coefficient indicate that the lagging states were 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. A negative sign for the period 2010/1950 indicates that the states with higher fertility levels in 1950 had a more rapid fertility decline than the states that had already lower fertility rates. This is an interesting example of β -convergence without σ -convergence. The γ -convergence indicator for this period (0.43) confirms that the β -convergence was largely due to crossover between states. The fertility changes in Brazilian states between 1950 and 2010 can be thus classified as constant dispersion with crossover, though different patterns emerge in every decennial interval. The γ -convergence for the other decennial periods show figures much closer to the unity, indicating just small changes in rankings.

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. Crossovers are also likely to happen, although the official population projections assume regional convergences but with persistent differences between regions, reproducing the ranking observed in 2000 and 2010 (Campos and Borges, 2015).

Table 2
Brazilian Federation Units, 1940-2010: σ -convergence, β -convergence and γ -convergence – Total Fertility Rate

Indicator	1950/ 1940	1960/ 1950	1970/ 1960	1980/ 1970	1991/ 1980	2000/ 1991	2010/ 2000	2010/ 1950
σ -convergence	0.001	0.002	0.003	0.003	-0.000	-0.005	-0.003	0.000
β -convergence	0.006	0.003	0.016	0.003	-0.010	-0.030	-0.019	-0.008
γ -convergence	0.78	0.83	0.73	0.68	0.85	0.86	0.81	0.43

Source: IBGE

MORTALITY CONVERGENCE/DIVERGENCE IN BRAZILIAN STATES

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. From 1940 to 1960, the difference between the life expectancies in Southeast and Northeast 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 (Borges, 2017).

A convergence process in adult mortality, measured by 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. These trends show that the idea of convergence implicit in the demographic and epidemiologic transition theories might not apply to the Brazilian case. Despite some long-term trends showing reducing regional inequalities, there have been some periods of divergence in life expectancy at different ages. The health 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 (Borges, 2017).

Table 3 shows the summary indicators and measures of dispersion of the child mortality rates and life expectancies at age 10 for males and females for the 27 Brazilian Federation Units from 1980 to 2010. Differently from the fertility indicator, the mortality series analyzed in this paper starts in 1980, which is the first years for which life tables using vital registration data is available.

Table 3

Brazilian Federation Units, 1980-2010: Summary statistics and measures of dispersion – child mortality (${}_5q_0$), life expectancy at age 10 (e_{10}) for males and females

Indicator	Summary Statistics											
	${}_5q_0$ – both sexes				e_{10} – male				e_{10} – female			
	1980	1991	2000	2010	1980	1991	2000	2010	1980	1991	2000	2010
Minimum	0.040	0.025	0.018	0.013	51.90	54.80	54.50	57.10	56.49	60.20	60.84	64.13
1st quartile	0.064	0.038	0.027	0.017	53.40	56.70	57.30	59.30	58.38	62.43	63.95	66.59
Median	0.075	0.050	0.035	0.023	54.70	57.60	58.60	60.60	59.30	64.33	65.43	67.94
3st quartile	0.103	0.086	0.049	0.026	56.20	58.70	59.80	62.60	61.51	65.07	66.67	69.66
Maximum	0.155	0.137	0.086	0.033	57.90	59.90	61.50	64.70	64.21	67.05	67.60	71.36
Average	0.087	0.062	0.039	0.022	54.90	57.60	58.50	60.90	59.95	63.89	65.27	68.04
Indicator	Measures of dispersion											
	${}_5q_0$ – both sexes				e_{10} – male				e_{10} – female			
	1980	1991	2000	2010	1980	1991	2000	2010	1980	1991	2000	2010
Range	0.115	0.112	0.068	0.020	5.955	5.109	7.076	7.570	7.719	6.851	6.764	7.230
IQR	0.039	0.048	0.022	0.009	2.724	1.972	2.465	3.353	3.122	2.638	2.720	3.075
St Dev	0.032	0.029	0.017	0.006	1.812	1.281	1.646	2.116	2.193	1.885	1.741	1.961
CQD	0.236	0.385	0.286	0.208	0.025	0.017	0.021	0.028	0.026	0.021	0.021	0.023
CV	0.372	0.467	0.432	0.259	0.033	0.022	0.028	0.035	0.037	0.030	0.027	0.029

Source: IBGE

Child mortality has declined consistently during this period. The first decade analyzed here was a period of increasing discrepancies between states. The CV increased from 0.372 to 0.467, leading to an annual σ -convergence of 0.009 (Table 4). The following two decades were periods of reduction in the differences between states, in both absolute and relative

term, though the period 2000/2010 was the period that presented the most impressive improvements.

Contrarily to child mortality, the indicator of adult mortality (e_{10}) showed first a period of convergence (from 1980 to 1991) and then a period of divergence (from 1991 to 2010), more pronounced for males.

The β -convergence indicator for child mortality confirms the first period of divergence followed by two periods of convergence. The γ -convergence indicator shows that, in addition to strong σ -convergence, the last period experienced important changes in the ranking of the states.

There have been much more changes in rankings in the measure of adult mortality, particularly among males. The years between 1991 and 2000, for instance are characterized by σ -divergence and β -convergence and could be classified as a period of *divergence with crossover*.

Table 4

Brazilian Federation Units, 1980-2010: β -convergence and γ -convergence – child mortality (${}_5q_0$), life expectancy at age 10 (e_{10}) for males and females

Indicator	${}_5q_0$ – both sexes			e_{10} – male			e_{10} – female		
	1991/1980	2000/1991	2010/2000	1991/1980	2000/1991	2010/2000	1991/1980	2000/1991	2010/2000
	σ -convergence	0.009	-0.004	-0.017	-0.048	0.041	0.047	-0.028	-0.016
β -convergence	0.019	-0.010	-0.046	-0.055	-0.021	-0.017	-0.036	-0.037	0.004
γ -convergence	0.82	0.87	0.61	0.42	0.49	0.52	0.55	0.58	0.77

Source: IBGE

CONCLUSIONS

This paper has discussed the hypothesis of convergence and divergence in the demographic components, more specifically fertility and mortality, by proposing a set of indicators to measure these trends and regional variations. It has been argued that the debate about the existing demographic theories about convergence, combined with statistical indicators to assess the existence of this hypothesis is essential for understanding demographic changes in Latin American, particularly the differences at the subnational level.

The application of these analyses to Brazilian data has shown that the idea of convergence in demographic vital rates, as largely used in population projections and predicted by the demographic and epidemiologic

transition, is insufficient to explain demographic variations across regions over time. In fact, the existence of converge and divergence depends on the indicator used to measure these trends and, most importantly, the temporal perspective and unit of analysis.

These contradictions to the classical demographic formulations are particularly important for the Latin American context, where persistent socioeconomic inequalities have affected differently the health conditions and reproductive behavior of the different population groups.

Mortality trends across regions, for example, are extremely complex processes, and the existence of divergence or convergence would depend essentially on the socioeconomic inequalities which affect the capacity of each region to combat infectious and parasitic diseases and to implement improvements in mortality from non-communicable diseases, including controlling risk factors. The changes in regional variation has been also largely due mortality from external causes.

This paper has shown that periods of divergence also alternate with period of convergence in fertility. The overall path through the fertility transition and the evidences of weakening the associations between fertility and other conditioning variables indicate these patterns are likely to remain in the future, contrarily to the converging single-path predicted by the demographic transition.

This article has also highlighted that the terms convergence and divergence fail to fully capture all the trends and regional variations. Demographic changes do not occur smoothly over time and processes involving changes ranking has to be taken into account as well.

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 and future works should focus on methods that do not necessarily require the assumption of convergence.

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