Compression of mortality: the evolution in the variability in the age of death in Latin America

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Abstract

We present a preliminary analysis of the comparative quality of data that underlie national-level mortality estimates and the evolution the mortality age profile for Latin America populations over various time periods (staring year in parenthesis): Chile (1920), Mexico (1930), Brazil (1980), Argentina (1970), Colombia (1964), and Peru (1972), Costa Rica (1963), Puerto Rico (1970), Panama (1960), Guatemala (1964), Cuba (1970), Dominican Republic (1960), and Uruguay (1960) . The analysis focuses on two main points: (i) the construction of an adequate age pattern of mortality for Latin America, and (ii) evolution of the distribution of deaths over age. We also compared evolution and trends in Latin America with some Eastern European countries and use the Swedish experience as a benchmark standard. We make extensive use of mortality data available at the Latin America Human Mortality Database and the HMD. The study suggests several important conclusions concerning the quality of available mortality data; rapid change in the epidemiological profile and rapid concentration of mortality at older ages for these populations.

Keywords: mortality, Latin America, compression, variability, data quality

Preliminary draft. Comments are welcome.

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1. Introduction

We present a preliminary analysis of the comparative quality of data that underlie national-level mortality estimates and the evolution the mortality age profile for Latin America populations over various time periods (staring year in parenthesis): Chile (1920), Mexico (1930), Brazil (1980), Argentina (1970), Colombia (1964), and Peru (1972), Costa Rica (1963), Puerto Rico (1970), Panama (1960), Guatemala (1964), Cuba (1970), Dominican Republic (1960), and Uruguay (1960). The analysis focuses on two main points: (i) the construction of an adequate age pattern of mortality for Latin America, and (ii) evolution of the distribution of deaths over age. We make extensive use of mortality data available at the Latin America Human Mortality Database and the HMD. The study suggests several important conclusions concerning the quality of available mortality data; rapid change in the epidemiological profile and rapid concentration of mortality at older ages for these populations.

We also compared evolution and trends in Latin America with some Eastern European countries and use the Swedish experience as a benchmark standard. In a recent paper, Palloni and Pinto-Aguirre (2011) produce estimates of mortality curves for Latin America and investigate the contribution of changes in causes of deaths to improvements in life expectancy and how socioeconomic factors are related to changes in mortality levels. In this paper, we contribute to this discussion by estimating mortality curves by sex; investigate the distribution and variability of deaths by age for a series of Latin America countries and comparing their experience overtime with those of two countries in Eastern Europe.

We investigate the mechanisms that determine the transition from high to low mortality for several developed countries. The transition of mortality in these countries, especially Western Europe, has demonstrated, albeit with some controversy, the importance of economic development, mediated by improvements in living standards for the historical decline of mortality in these populations (McKeown & Record, 1962; Preston, 1975; Cutler & Miller, 2005; Cutler, Deaton & Lleras-Muney, 2006).

Much of the reductions in mortality would be consequence, at first, of improvements in the levels of nutrition and economic development, with some improvement in public health (Fogel, 1986, Preston, 1975). In a second stage, public health would take a more prominent role, with

improvement in sanitary conditions (Cutler & Miller, 2005) and practical personal care being the main determinants. Finally, from the mid-twentieth century, medical interventions, through development of vaccinations and antibiotics for the treatment of diseases are the most prevalent factors.

In Latin American, the decline in mortality did not follow the historical course observed in developed countries. In little more than half a century most LAC countries experienced major changes in health conditions related to structures demographic, socioeconomic and environmental processes as a result of rapid industrialization and urbanization (Palloni, 1981 Palloni & Wyrick, 1981; Palloni, 1985; Palloni, Hill & Pinto-Aguirre, 1996; Palloni & Pinto-Aguirre, 2011). Several authors indicate that the mortality transition in Latin America began around 1930 to 1940, when the transition process in developed countries was already in a much more advanced stage (Palloni, 1981, 1985). Although the rapid transition of mortality is an intrinsic feature of Latin America, there are arguments for some diversity in the process causing some countries initiate the transition before others (Palloni, 1981, 1985). Only after 1950 began a widespread reduction in mortality in Latin America, thus reducing the gap with developed countries (Palloni 1981).

Parallel to the mortality transition, epidemiological transition in Latin America occurs in a context of heterogeneous health profile, where different countries were at different stages of transition (Frenk et al, 1991). It is unlikely, however, that any of these countries are experiencing a transition stage similar to that of many developed countries. The overlapping stages, the resurgence of some diseases that had been controlled and a peculiar epidemiological polarization, both between countries and between different geographical areas and population sub-groups within a country, it would rank the epidemiological transition in Latin America, according to Frenk et al (1991) as a template and extended polarized transition. The intrinsic process of epidemiological transition in some countries produces a scenario where the incidence of communicable diseases in adult and advanced ages is relatively high compared to developed countries (Frenk et al 1991). Guatemala, for example, would be a more pre-transitional stage, with a high proportion of causes of death from diseases, while countries such as Mexico, Chile and Uruguay, were in more advanced stages (Brevis et al, 1997). Among these last three countries, Mexico present a longer transition situation similar to that observed in Brazil

(Chaimowicz, 1997), while Chile, Uruguay would be closer to a post-transitional stage (Brevis et al, 1997).

At the same time, there are some evidence of important reduction in the variability of age at death in some regions of Latin America (Gonzaga, Queiroz and Machado, 2009), in a process related to what Fries (1980) called the compression of mortality hypothesis. The main idea, developed by Fries, is that survival curves would become rectangular when mortality levels decline. That is, since death concentrate in a narrow age interval, the slope of survival curve in that range becomes steeper, and the curve itself begins to appear rectangular suggesting that human life expectancy is approaching its maximum potential value (Fries, 1980; Wilmoth, 1997; Wilmoth and Horiuchi, 1999). Following Fries (1980), several authors have examined whether this hypothesis is true (Meyers & Manton, 1984a, 1984b; Go et al, 1995; Nusselder & Mackenbach, 1996; Wilmoth, 1997; Paccaud et al, 1998; Wilmoth and Horiuchi, 1999; Cheung et al; 2005; Edwards & Tuljapurkar, 2005; Cheung & Robine, 2007). The main interest of most researchers is the relation between the compression-rectangularization of the survival curve to the biological limits to the human life span. However, Wilmoth (1997) argues that the compression-rectangularization process is related for a reduction in the variability of age at death that can happen while the distribution of age at death is moving to the right. In this case, the existence of biological limits to the human life span implicates a compression-rectangularization process, but a compression-rectangularization happening does not implicate in biological limits to human lifespan (Wilmoth, 1997; Wilmoth & Horiuchi, 1999).

In contrast to epidemiological transitions and mortality in developed countries, the peculiarities of these transitions in Latin American countries suggest some more optimist conjectures for the future longevity of the population (Palloni & Pinto-Aguirre, 2004; 2011). Will some LAC countries are experiencing a reduction in the variability of age at death concomitant displacement of these deaths for ages more go along? How recent changes in the profile of causes of deaths, especially increase in external causes of deaths, could affect trends in the variability of age at death in Latin America? In addition, how could these changes inform mortality forecast? In this sense, the paper discusses old paradigms of mortality studies in Latin America (data quality) and new paradigms (variability of age at death).

2. Data and Methods

2.1 Mortality Data

In order to estimate age mortality pattern in Latin American Countries we make extensive use of the death and population data available on Human Mortality Database (HMD) and Latin American Human Mortality Database (LAHMD), and the World Health Organization (WHO) database. The LAHMD contains historical and detailed information on death and population by age and sex. The LAHMD aims at disseminating human mortality data in Latin America, in order to provide detailed information for researchers, students, policy makers and the general public interested in knowing trends and developments in the study of mortality in the region. The project is inspired by the Human Mortality Database (HMD). At present the database contains detailed information on mortality for five countries in Latin America: Argentina, Brazil, Colombia, Mexico and Peru. All information is broken down by age, sex, region and cause of death. Additionally there is information on the academic literature on the study of mortality for these same countries. The data are available for download at www.lamortalidad.org.

In addition to the countries included in the LAHMD we use mortality data obtained from the HMD and WHO database for Chile, Costa Rica, Puerto Rico, Cuba, Panama, Dominican Republic, Guatemala, and Uruguay . We also use data from Sweden and selected countries in Eastern Europe (Bulgaria and Russia), obtained from the Human Mortality Database. We include data for Eastern Europe countries to compare the evolution of mortality and trends in the variability of age at death in Latin America with countries that are also facing rapid changes in the mortality profile.

2.2. Death Distribution Methods

The first step of the paper is to evaluate the quality of mortality data available overtime in Latin America. For some countries and years, the information on death counts under-registration is already available at the Latin America Mortality Database (LAHMD), but it is necessary to perform quality control checks for countries not included in the database and for years preceding the availability of data in the LAHMD.

First, we evaluate the quality of age declaration data using digit preference measures, using Whipple Index (WI), and more elaborate measures to detect age heaping. We further investigate the quality of age reporting by applying several age heaping measures proposed several authors (Kannisto, 1994; Vaupel, Wang, Andreev and Yashin, 1997; Shyrock and Siegel, 2004). We also use different methods to investigate age overstatement in death registration records. In general, it is possible to identify distortions by comparing the observed age distributions to those or population register based estimates that are known as accurate (Kannisto, 1999; Jdanov, et.al, 2008)

Second, we evaluate the degree of death counts registration completeness. Several methods based upon equations of population dynamics have been developed to evaluate the coverage of reported deaths relative to populations. The death distribution methods (DDM) are commonly used to estimate adult mortality in a non-stable population (Timeaus, 1991). They compare the distribution of deaths by age with the age distribution of the living and provide age patterns of mortality in a defined reference period. There are three major approaches: the General Growth Balance Methods (Hill, 1987), the Synthetic Extinct Generation method (Benneth & Horiuchi, 1981), and the Adjusted Synthetic Extinct Generation method (Hill, You & Choi, 2009). The death distribution methods make several strong assumptions: that the population is closed to migration that the completeness of recording of deaths is constant by age, that the completeness of recording of population is constant by age, and that ages of the living and the dead are reported without error.

In this paper, we estimate coverage of female deaths using all three approaches, but I report the results using the General Growth Balance method (GGB) to permit comparisons to Hill et.al (2009) and Hill & Stanton (2009). It should be pointed that the results from the three methods are different, because of the assumptions involved in each of them, but reasonably consistent. This indicates that the methods are reasonable robust, but researchers should be careful when applying and analyzing estimates of adult and maternal mortality using census data.

The Bennett and Horiuchi (1981), known as Synthetic Extinct Generations (SEG) method, uses age-specific growth rates to convert an observed distribution of deaths by age into the corresponding stationary population age distribution. Since in a stationary population the

deaths above each age x are equal to the population aged x, the deaths in the stationary population above age x provide an estimate of the population of age x. The completeness of death registration relative to population is estimated by the ratio of the death-based estimate of population aged x to the observed population aged x.

The GGB method is derived from the basic demographic balancing equation, which expresses the identity that the growth rate of the population is equal to the difference between its entry rate and exit rate. This identity holds for open-ended age segments x+, and in a closed population the only entries are through birthdays at age x. The entry rate x+ minus the growth rate x+ thus provides a residual estimate of the death rate x+. If the residual estimate can be calculated from population data from two population censuses and compared to a direct estimate using the recorded deaths, the completeness of death recording relative to population recording can be estimated (Hill, 1987; Hill, Choi & Timeaus, 2005; Hill, You & Choi, 2009).

Hill, You & Choi (2009) proposed that the combination of SEG and GGB might be more robust than either one individually. The combined method consists of first applying GGB to estimate any changes in census coverage (k1/k2), using the estimate to adjust one or other census to make the two consistent, and then applying SEG using the adjusted population data in place of the reported.

2.3 Estimates of death rates and survival curves by single age

First, we estimate five-year age group death rates to deal with possible problems of age declaration for all Latin America countries. Then, we use a relational model (Himes, Preston & Condran, 1994; Palloni & Pinto-Aguirre, 2011) to fit and extrapolate the mortality rates from 5 to 110 years old for all countries, years and sex in 7 Latin American Countries. That strategy allows us to produce a linear relationship between a logit transformation of the observed death rates and the same transformation in "standard" death rates. Then, the age pattern of mortality in the population under study can be expressed as the following linear function:

$$\Psi_{j,t}(x) = \alpha_{j,t} + \beta_{j,t}\Psi_s(x) \qquad (1)$$

Where: $\Psi_{j,t}(x)$ is a logit transformation of the death rate at age x in population j and year t; $\Psi_s(x)$ is a logit transformation of the death rate at age x in the standard and $\alpha_{j,t}, \beta_{j,t}$ are parameters to be estimated for each population and year.

In order to apply the relational model in (1) we need to find a "good standard" that can express the mortality pattern for LAC. After get the pattern we can use (1) in order to estimate the mortality rates for each country and year (separately by sex).

The strategies that we used to find the LAC Standard Mortality Patterns was very similar to that proposed by Himes, Preston and Condran (1994). Based on the pooled data with observed adjusted mortality rates by country, year, sex and age (five-year-age from 5 to 85+ or 100+ depend on the data availability for each country) we constructed the Standard by estimating the following ordinary least squares for each sex:

$$\Psi_{j,t}(x) = \delta + \sum \beta_x I_x + \sum \lambda_{j,t} CY_{j,t} \tag{2}$$

Where, $\Psi_{j,t}(x)$ is a logit transformation of the observed death rates in the country j and year t; I_x is a dummy variable for age x (=1 if the death rates relates to age x, 0 otherwise). Since we have five-age intervals, we have considered the middle of each five-age intervals from 7.5, 12.5, to 107.5. Then we have 20 dummies for age. CY_j is a dummy variable for a combination between country j and year t (=1 if the death rates relates to country/year j, t and 0 otherwise). Since we have 38 country/year combinations we have 37 dummies of witch. Chile/1920 was omitted as reference category. $\delta, \beta_x, \lambda_{j,t}$ are the parameters appropriate that need to be estimated;

After estimation of the model (2) we have one β coefficient for each age and one λ coefficient for each country/year combination. In order to get a logit of the standard death rate at age x from 7.5, 12.5,…, to 102.5 exact years old we used the mean of the λ coefficients to obtain a predict value for the entire sample. Then, as was done by Himes, Preston et al (1994), we used weighted least squares regression to fit and extrapolated the logit of the standard death rates from age 5 to 110 (one-year-age interval). The weights are the number of observations (country/period combinations) available for each age.

Those adjusted and extrapolated logit standard rates, by single ages, were used on the relational model in equation (1) in order to get smoothed logit death rates by sex and single ages for each country and year. Finally, to recover the age-specific death rates for each country and year we used the following relation:

$$\widehat{M}_{j;t}(x) = \frac{1}{\left(1+e^{\widehat{\Psi}_{j,t}(x)}\right)} \tag{3}$$

Where: $\widehat{\Psi}_{j,t}(x)$ is a smoothed logit death rate in the country j, year t and age x

and $\widehat{M}_{j;t}(x)$ is a smoothed death rate in the country j, year t and age x.

2.3 Variability of Age at Death: alternative measures

The historical decline in mortality rates in developed countries has two clear effects: the reduction in the variability of age at death and concentration of deaths at older ages (Nusselder and Mackenbach, 1996; Wilmoth and Horiuchi, 1999; Kannisto, 2000; Cheung et al, 2005; Edwards and Tuljapurkar, 2005). This reduction in the variability can be explained by mortality decline among young age groups, especially infant and child mortality; and the concentration of deaths at older ages by structural changes, and medical advances that reduce mortality by non-infectious diseases (Wilmoth and Horiuchi, 1999; Cheung et al, 2005). In the Latin American Countries it is not yet known whether the ongoing process of mortality decline will lead to the same situation.

The interquartile range (IQR) based on the survival function (l_x) is a leading indicator of the variability of age at death (Wilmoth and Horiuchi, 1999). Together with measures of central tendency of age at death, the IQR has been used to evaluate the compression of mortality hypothesis (Fries, 1980). The IQR measures the concentration of deaths between first and second quartile around median age at death. All we need to do is to find the exact ages where survival function is equal 0,75 e 0,25, respectively. Then the age range between $l_x = 0,75$ and $l_x = 0,25$ represents the IQR. Van Raalte, and Caswell (2012) provide a detail overview of different methods to calculate lifespan variation and its limitations. In this preliminary version, we show the results of variability of age at death using IQR.

The second measure of variability of age at death refers to the shortest age interval that concentrates 50% of deaths (C50). Although, it is possible to obtain several intervals in which there is a concentration of 50% of the deaths, what is sought is the smallest of these. To follow the evolution of C50 is appropriate to use the modal age at death as a measure of central tendency in a certain age, since it is not influenced by outliers in the distribution of deaths by age. Given that an estimated modal age at death is very sensitive to the shape of the distribution of deaths by age, to ensure greater data accuracy, Kannisto suggests the following approach for calculating the modal age at death in the year fractions (2):

$$M = x + \frac{{}_nd_x - {}_nd_{x-1}}{\left[{}_nd_x - {}_nd_{x-1}\right] + \left[{}_nd_x - {}_nd_{x+1}\right]} \qquad (2)$$

The third measure of variability of age at death considered in this study relates to the DP utilizing the distribution of deaths by age in percentils. We obtain an indicator of compression considering three constant proportions in the distribution of deaths: 100%, 75% and 50%. We then estimate the number of deaths above each percentile and estimate the stardard deviation (DP) in relation to the average age at death calculated above a certain quartile. The measure is estimated as follows (3):

$$DP(p+) = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{ip+} - M_{p+}\right)^2}{n_{p+}}} \qquad (3)$$

Finally, we follow Engelman, Canudas-Romo and Agree (2010) and estimate measures of variability of age at death conditional to surviving to ages 25 and 50. According to the authors, it is relevant and important to understand what is happening with the distribution of mortality above certain ages. The analysis of the variability of age at death conditional to survivorship at certain older age might be informative about the pace of mortality change in different countries.

3. Results

In this paper, we present preliminary results of the survival curves, for males and females, for all countries and analysis of changes in the Interquartile Range for all Latin American countries. Table A.1 shows the estimates of completeness of death counts coverage for the countries included in the analysis. The results indicate that quality of mortality data is improving overtime in Latin America, but there are still some countries with quite poor data quality. We also face limitations with the assumptions of the models, as we find completeness over 100% for some countries and periods.

3.1 Evolution of Survival Curves

Figure 1 show survival curves, for males, in the first and last year of available data. The changes in the age profile are clearer for Chile and Mexico that have the longer series. In both countries it is possible to observe a movement towards a more rectangle survival curve as is observed in more developed countries. Since the curves do not show age groups below 5, one cannot observe the fast decline in infant and child mortality. It is also interesting that in some countries, more specific Brazil and Colombia, changes in the probability of survival change very slowly for young adults. This pattern is mostly explained by the increase in external causes of deaths (violence and accident) that happened in the 1980s and early 1990s in the region.

Figure 1- Estimated survival curves (Sx), Latin America, males (extreme points)
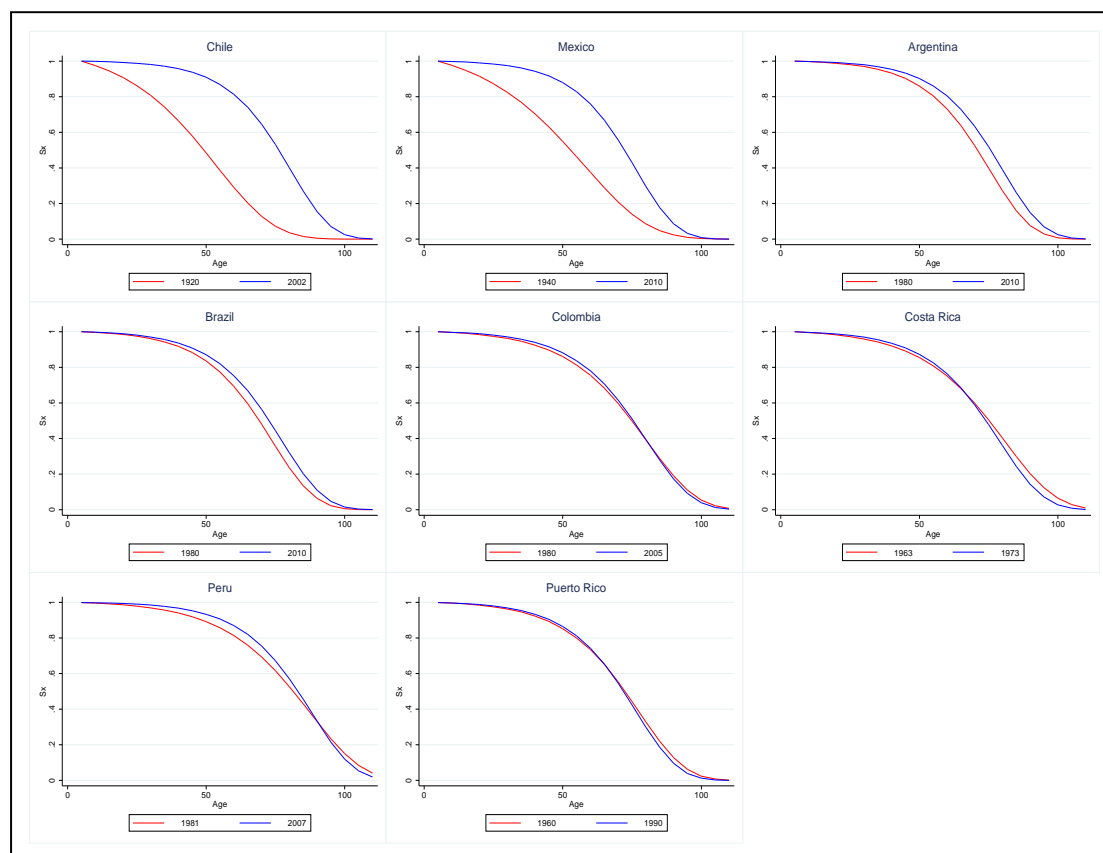
Source: Latin America Human Mortality Database (2014), Human Mortality Database (2014) and World Health Organization Database (2014)

The changes in mortality levels in Latin America implied in a rapid change in the life expectancy at birth. On average, the countries we studied observed an improvement of life expectancy at birth of almost one year (1) per decade. For instance, in Chile life expectancy went from 52 years in 1950 to about 75 years in 2005. For males, in Brazil, life expectancy at birth was about 60 years in 1980 and went to almost 70 years in 2005. Similar trend is observed for all countries and both sexes in the past few decades.

3.2. Variability of age at death

We show the interquartile range (IQR), in Figure 2, as a measure of variability at age of death for countries in this paper. Wilmoth and Horiuchi (1999) discussed different measures of variability and compression and argue for IQR and the more objective and simple one. We also plot estimates for Sweden from 1920 to 2010 in order to compare the changes in the mortality

variation and concentration in Latin America. We obtained data for Sweden from the Human Mortality Database. Wilmoth and Horiuchi (1999) studied the compression of mortality in Sweden in more detail.

In the early 1920s, for both sexes, the IQR in Sweden was higher than Chile, the only LAC country with available data in the early 1900s. This higher variability in age at death could be explained by high incidence of young adult mortality due to tuberculosis (Horiuchi, 1999). It is also possible that since infant and child mortality in Chile, around 1920, were so much higher than in Sweden that those who survived the first few years of live went on to die in more concentrated ages. On the contrary, deaths in Sweden were more distributed across the age range in the same period of time, especially for young adults. However, the levels of IQR in Sweden fell very rapidly during the following decades. Among Latin America countries the reduction in the variability of age of death was much slower. For instance in Chile significant declines in IQR starts 20 years after Sweden for females. For males, more significant decline in the variability of the age at death started only in the 1960s.

Figure 2: Interquartile Range (IQR), Latin America, by sex, 1920-2010
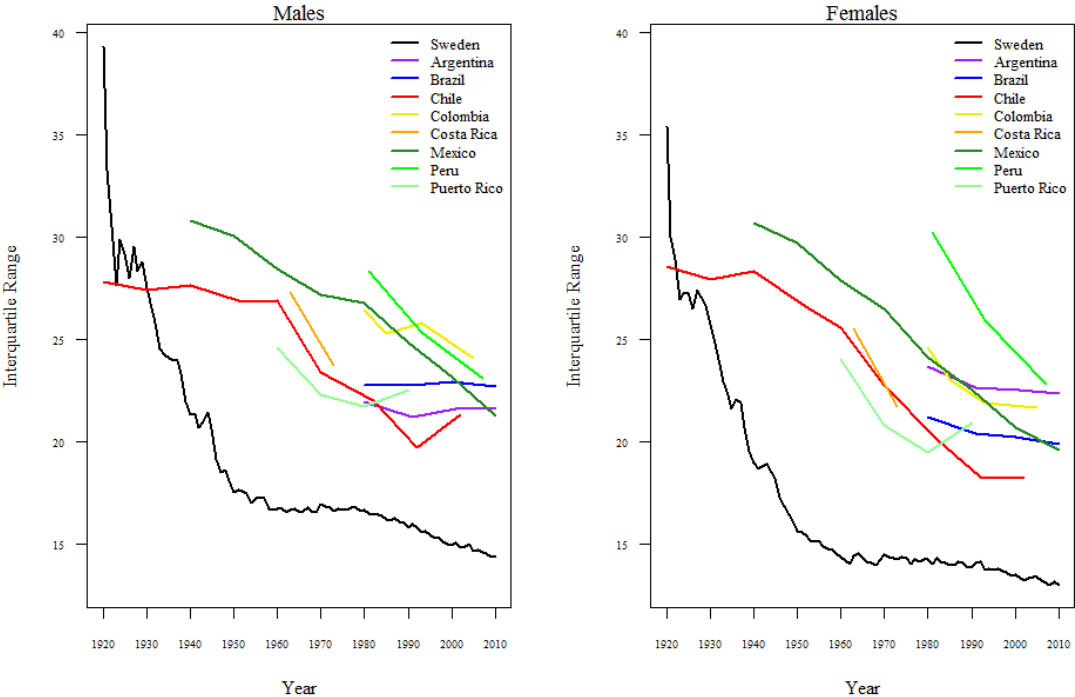
Source: Latin America Human Mortality Database (2014) and Human Mortality Database(2014) and World Health Organization (2014)

Despite the short period of analysis, Costa Rica shows the strongest IQR decline among all countries we investigated. Despite not having access to a longer series of mortality data for Costa Rica, we observed the country is moving rapidly to a variability level compared to more developed countries in later stages of the demographic and epidemiological transition. It was also noted in a recent paper, by Rosero-Bixby (2008), the concentration of mortality at older ages in Costa Rica and the low levels of mortality for those aged 90+ in comparison to a series of developed countries.

In Mexico, for both sexes, we also observed significant changes in the variability of age at death. The variability of age at death decreased from more than 30 years (for both sexes) to under 20 years for females and 21 years among males. That represents almost 10 years compression of mortality in 70 years period. It is interesting, and somewhat surprising, that trends for both sexes follow similar pattern. It is also interesting to note that we could not find any significant impact of the recent rise in the number of deaths by external causes among young adults, as noted in a paper to be presented in the IUSSP meeting by Canudas-Romo.

Chile shows an unusual development in the mortality compression indicator, at least among males in recent years. Between 1990 and 2000, the interquartile range showed a considerable rise, that is, an increasing trend in the variability of age at death. The same tendency is observed in Porto Rico for both sexes. This fact holds perhaps due to association with external causes of death that are also increasing in both countries, and that is avoiding further development of mortality compression.

In Argentina and Brazil, we observed a slightly reduction in female variability of age at death between 1980 and 1990 but, for more recent years, the IQR is quite stable and almost unchangeable. Furthermore, Argentina is the only where the variability in age at death is higher among females compared to males. Of course, we need to be cautious and do not jump into harsh conclusions since data quality maybe play a role in these results. The most striking result is found in Peru, which shows a later onset in mortality compression followed by a fast decline in IQR during the following years. In 26 years, the mortality has been compressed by 5 to 7 years. This means that for each 1 year that has passed, the variability in age at death was reduced by 2 to 3 months.

Figure 3 and Figure 4 shows that as life expectancy at birth increase we observe a decline in the variability of the age at death. This finding holds with Canudas-Romo (2008) conclusion, which states the increasing modal age at death illustrates changes from a dominance of child mortality reductions to a dominance of adult mortality reductions. This process has been described as a shifting mortality process where the bulk of deaths around the modal age at death move toward older ages. Probably, this process has taken place in many Latin American and Caribbean countries for the last fifty years.

However, countries in Latin America are at different stages of this transition. Peru, for example, still presents high levels of child mortality if compared to other Latin American and Caribbean countries, like Chile and Costa Rica (Guzman et al., 2006). But, Peru has also showed the most expressive gains in mortality reduction in the last five decades (Guzman et al., 2006). Moreover, these gains might, in the future, imply in the continuous increase in life expectancy together with a concentration of deaths around one age.
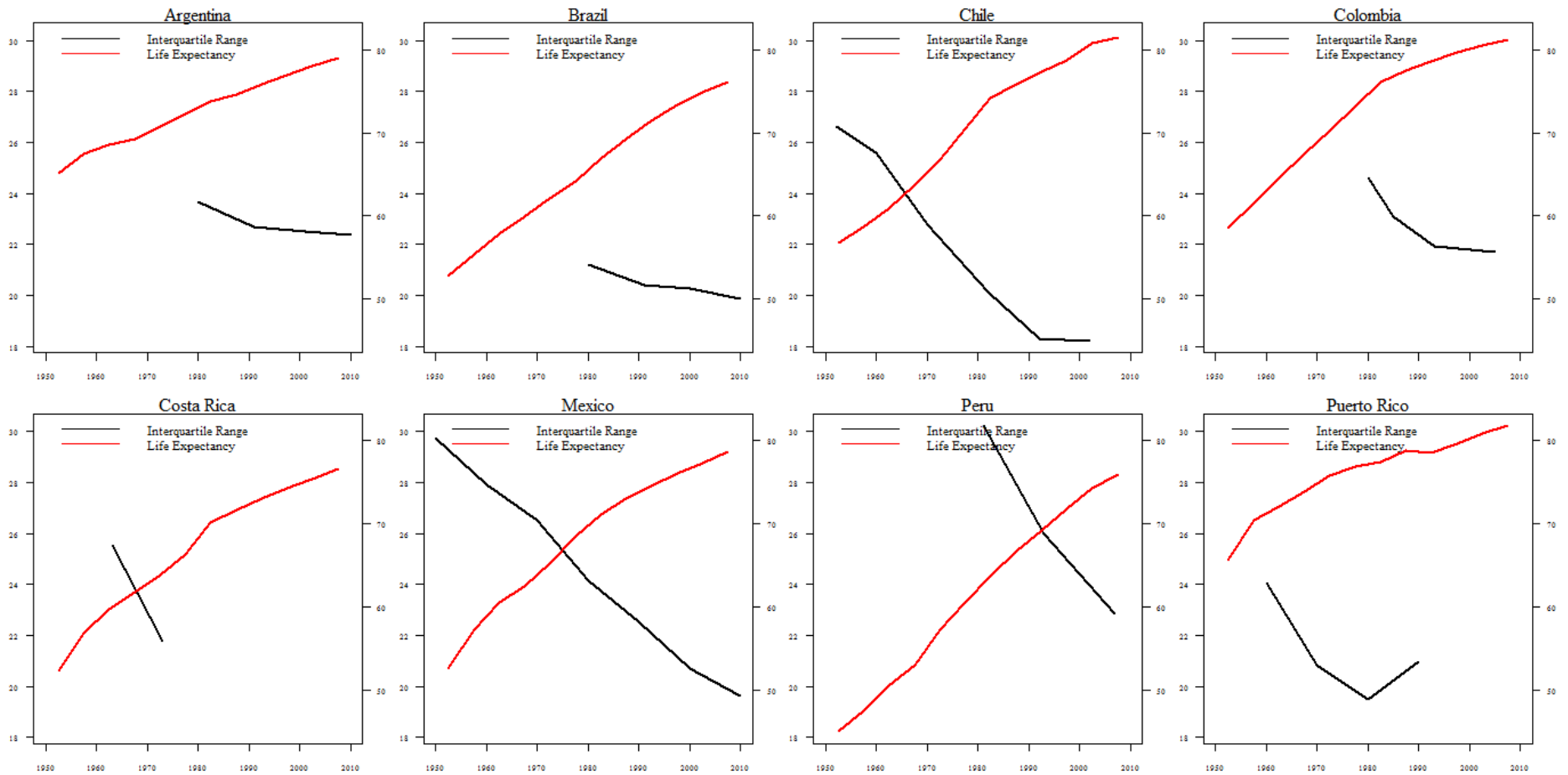
Figure 3: Interquartile range and life expectancy at birth, Latin America, 1920-2010, males
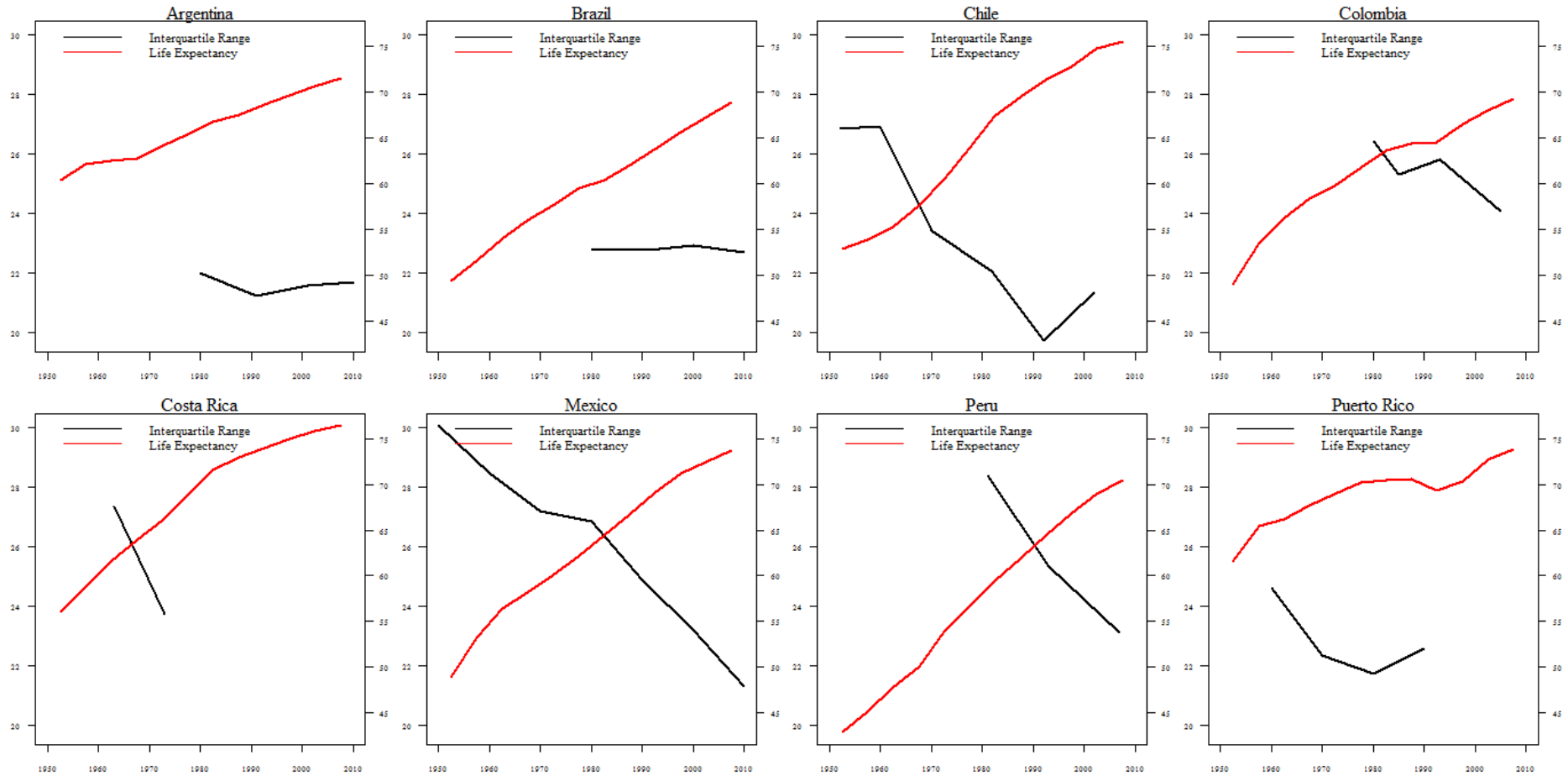
Source: Latin America Human Mortality Database (2014), Human Mortality Database (2014) and World Health Organization Database (2014)

Figure 4: Interquantile range and life expectancy at birth, Latin America, 1920-2010, females

Source: Latin America Human Mortality Database (2014), Human Mortality Database (2014) and World Health Organization Database (2014)

The relationship of IQR and life expectancy is also clear when we look at the countries like Colombia and Puerto Rico. Between early 1980s and mid-1990s, the male life expectancy in Colombia, for example, has almost stabilized around 65 years, and during the same period the IQR varied between 26.4 to 25.8 years. After 1993, life expectancy increased again and the interquartile range declined to 24.07 years. Moreover, in Puerto Rico, between 1980 and 1990, life expectancy even decreased and that reflected in an increase IQR from 21.7 to 22.6 years.

4. Discussion and Conclusion

In this article, we evaluate the quality of information on deaths available for a series of Latin America countries in the past half-century. We contributed to the analysis of data quality, following Palloni and Pinto-Aguirre (2011), by producing estimates for males and females separately. The results indicate that the quality of mortality data is improving over time for all countries included in this study, and could be considered of high quality and can be a very useful tool for studies of mortality in Latin America. We

We also examined the changes in the mortality pattern of the population in each country in the past few decades, in order to identify changes in the variability of age at death. A reduction in this variability, accompanied by a shift in the distribution of deaths for older ages, would indicate that the process of compression of mortality, observed today in most countries experiencing low levels of mortality. The analysis of reduced variability of age in some developed countries such as Japan and the U.S., indicated that the reduction in variability was also low, as observed for most of Latin America countries. For example, for Japan, between 1961 and 1971 (life expectancy at birth, respectively, 69.4 and 73.5, close to what is observed in Latin America in recent years) the variation in IQR (17.5 and 15.9, respectively) was 1.60. In the case of USA, between 1951 and 1981 (life expectancy at birth, respectively, 69.1 and 74.5) the variation in IQR (20.6 and 19.4, respectively) was 1.20.

The analysis by sex indicates that variability of age at death for females is less significantly less than for males. This difference in variability of age at death corroborates historical analyzes performed in developing countries. This may be associated with a lower risk exposure or a lower socio-economic heterogeneity and biological among women. Another interesting aspect of the analysis by sex is the

clearest trend among men in the process of compression of mortality. One possible explanation would be the fact that, among women, the gains in survival at older ages were higher than among men, as observed in this study and also corroborated by other studies. This would indicate that the distribution curve of female deaths is undergoing a shift toward more apparent older ages.

The study of compression of mortality and variability of age at death are very important and contribute to a better understanding of the evolution of health status of the elderly population, especially regarding the duration of active and disable years of life around the age of death. In fact, a reduction in the variability of age at death concomitantly with the increase in the average age of death is of crucial importance for public health planners, since the diseases that affect these individuals are chronic, mostly requiring monitoring of conditions these elderly health over a long period of time. As pointed by Canudas-Romo, et.al (2010) delay mortality implies that a more heterogeneous group of the population is reaching older ages and we can expected that health differential and disparities that we common in early life in Latin America are now moving towards older age groups. In the near future, health systems in Latin America, and families, will have to deal with a larger and more diverse group, regarding health status, at older ages. This might imply larger costs and more complex interventions to mitigate the differences.

This is a preliminary investigation of the variability of the age at death in Latin America. Additional studies, including more countries and other measures, should be pursued. A better understanding of trends in the variability of age at death (dispersion of life span, modal age at death, compression) might be very informative and useful to produce better mortality forecasts.

An important limitation of the study is related to the data sources used to produce the estimates of survival curves. In addition to the under-registration of death counts in most of the vital registration systems in Latin America, we might find problems with errors in the age declaration of age, which may occur in the source of deaths and population. The tendency to over-state the age is lower in death records compared to live population. In this case, considering that defective age declaration is higher in the census than in the registration of deaths, at advanced ages, where the errors are larger,

an over-statement of ages in the census may underestimate the specific mortality rates and the result would be a lower number of estimated deaths at these ages. If the trend in the census is to declare an age lower than the true number of deaths at older ages could be over-estimated, leading to the false impression of a higher concentration of deaths at advanced ages. However, it is reasonable to assume that the standard errors of the old statement has been roughly constant over time, the results would not be compromised, because the changes in the variability of age at death are related to changes in the structure of mortality and not on their level. An additional limitation refers to the use of period data to estimate compression of mortality in a period of declining mortality. The trends would be better observed if we had available cohort mortality data. But, as pointed by others, our results provide, at least, a conservative measure of the compression of mortality in Latin America.

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Acknowledgments

Table A.1 – Estimates of Completeness of Death Counts, Latin America, Males and Females

Country	Intercensus period	Males	Females
Argentina	1960-1970	1.99	2.20
Argentina	1970-1980	0.77	0.46
Argentina	1980-1991	1.03	1.14
Argentina	1991-2000	1.00	1.00
Argentina	2000-2010	1.00	1.00
Brasil	1980-1991	0.84	0.76
Brasil	1991-2000	0.95	0.90
Brasil	2000-2010	0.98	0.96
Chile	1920-1930	1.15	1.22
Chile	1930-1940	1.15	1.23
Chile	1940-1952	1.14	1.39
Chile	1952-1960	1.16	1.23
Chile	1960-1970	1.23	1.26
Chile	1970-1982	1.13	1.14
Chile	1982-1992	1.07	1.07
Chile	1992-2002	1.00	1.00
Chile	2002-2012	1.00	1.00
Colombia	1951-1964	1.35	1.74
Colombia	1964-1973	0.98	1.02
Colombia	1973-1985	1.09	1.14
Colombia	1985-1993	1.11	1.03
Colombia	1993-2005	0.98	1.12
Costa Rica	1951-1963	0.70	0.56
Costa Rica	1963-1973	0.87	0.87
Costa Rica	1973-1984	0.89	0.83
Costa Rica	1984-2000	1.02	1.16
Cuba	1953-1970	1.34	1.41
Cuba	1970-1981	1.05	1.01
Cuba	1981-1993	0.98	0.98
Cuba	1993-2002	1.00	1.00
Dominican Republic	1950-1960	0.81	1.19
Dominican Republic	1960-1970	0.67	0.86
Dominican Republic	1970-1981	1.07	1.23
Dominican Republic	1981-1993	1.22	0.87

Guatemala	1950-1964	1.38	1.49
Guatemala	1964-1973	1.10	1.11
Guatemala	1973-1981	1.30	1.31
Guatemala	1981-1994	1.31	1.33
Mexico	1930-1940	1.10	1.26
Mexico	1940-1950	1.35	1.51
Mexico	1950-1960	1.20	1.28
Mexico	1960-1970	1.13	1.37
Mexico	1970-1980	1.10	1.19
Mexico	1980-1990	1.11	1.15
Mexico	1990-2000	1.00	0.98
Mexico	2000-2010	1.00	1.00
Panama	1950-1960	1.23	1.00
Panama	1960-1970	1.03	1.07
Panama	1970-1980	0.91	0.99
Panama	1980-1990	0.92	0.89
Panama	1990-2000	0.87	0.87
Panama	2000-2010	1.00	1.00
Peru	1961-1972	1.05	1.10
Peru	1972-1981	0.83	0.78
Peru	1981-1993	0.72	0.73
Peru	1993-2005	0.77	0.81
Puerto Rico	1960-1970	1.39	1.72
Puerto Rico	1970-1980	1.99	1.23
Puerto Rico	1980-1990	1.28	1.20
Puerto Rico	1990-2000	1.16	1.05
Puerto Rico	2000-2010	1.00	1.00

Source: Latin America Human Mortality Database (2014), Human Mortality Database (2014) and
World Health Organization Database (2014)