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Research Material

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Abstract

BACKGROUND
Vital statistics registration and census counts for Mexico may be incomplete, resulting in unreliable mortality indicators.

OBJECTIVE
We evaluate unadjusted mortality estimates for Mexico during 1990–2016 and compare them with other published estimates for Mexico and with the historical mortality patterns observed among the 41 Human Mortality Database (HMD) populations. Finally, we investigate the effect of various adjustments on estimated life expectancy.

METHODS
We apply the HMD methodology to the official vital statistics and census counts to construct unadjusted life table series for Mexico. Then we make adjustments by substituting revised estimates for child mortality and by fitting a log-quadratic model.

RESULTS
Adjusted estimates of mortality below age 5 derived by the UN Inter-agency Group for Child Mortality Estimation (IGME) are up to 48% higher than our unadjusted estimates. Even in 2015, the IGME-adjusted estimates of child mortality remain at least 10% higher than our unadjusted estimates. Our analysis suggests that there may also be underestimation of mortality at both prime adult ages and the oldest ages. The log-

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quadratic model produced the lowest estimates of life expectancy at birth (3.8–4.4 years lower than the unadjusted values in 1995).

CONCLUSIONS
Unadjusted estimates are likely to underestimate mortality in Mexico, even in recent years. Adjustments may improve the accuracy of the mortality estimates, but we cannot adjudicate which set of adjusted estimates is closest to reality.

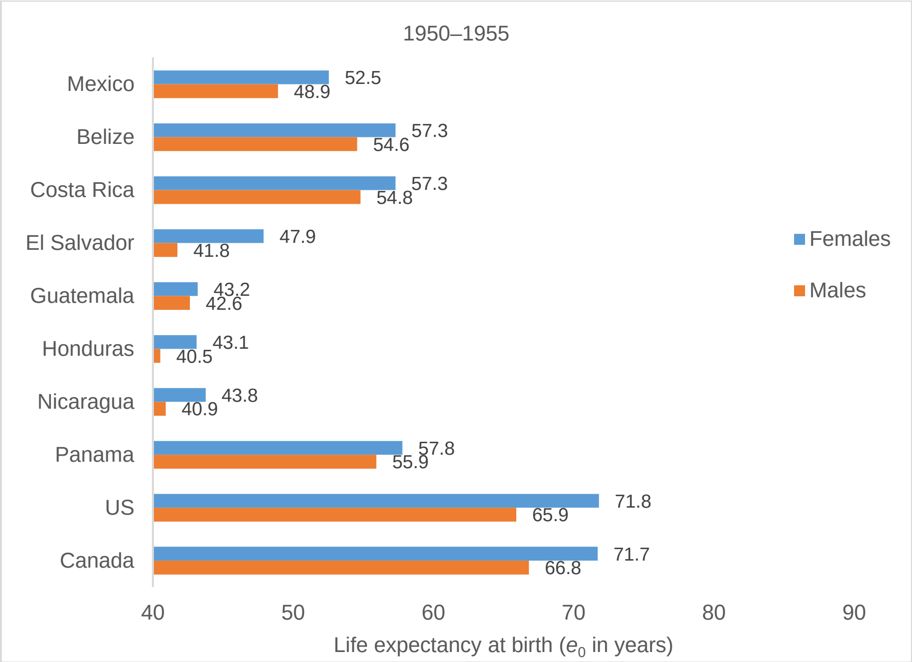
CONTRIBUTION
This is the first time the HMD methodology has been applied to the Mexican data.

1. Introduction

Life expectancy at birth (e_0) has increased dramatically in Mexico since 1950, but the biggest gains were made prior to 2000. In 1950, e_0 in Mexico was 45.9 years for men and 48.8 years for women; by 2000, men had gained 26.1 years and women 28.7 years of life (Partida Bush 2017). Between 2000 and 2015, life expectancy at birth among men declined by 0.2 years (from 72.0 to 71.8) while increasing only 0.2 years (from 77.4 to 77.6) among women (Partida Bush 2017). The stagnation and/or increased mortality since 2000 appears to be limited to adult ages; mortality rates below age 15 have continued to decline in Mexico (Canudas-Romo, García-Guerrero, and Echarri-Cánovas 2015; Gómez-Dantés et al. 2016).

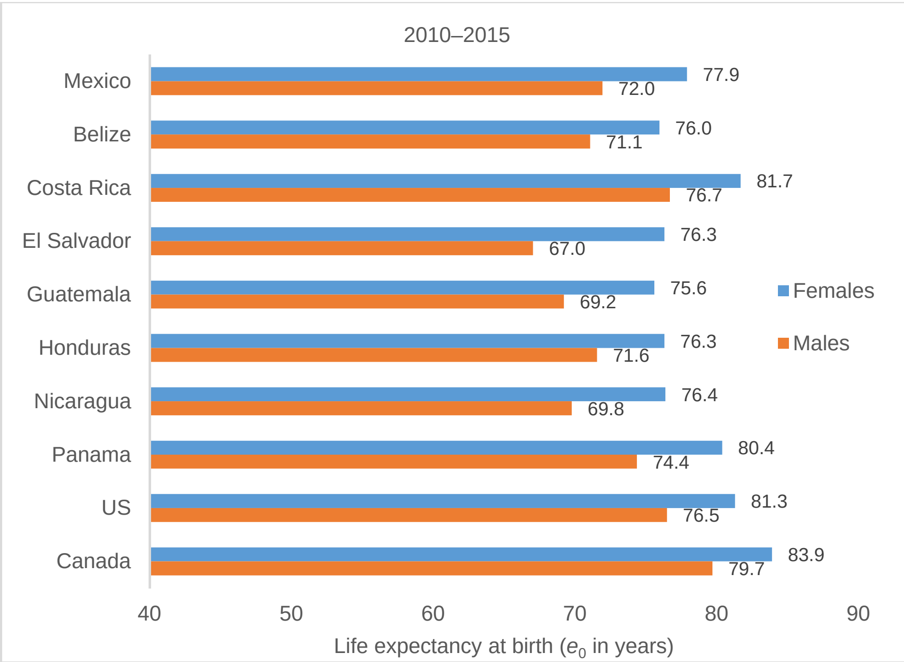
Compared with the United States, Canada, and the seven countries of Central America, Mexico ranked sixth in terms of e_0 in the early 1950s (Figure 1). Five countries (Belize, Canada, Costa Rica, Panama, and the United States) exhibited higher e_0, while four countries (El Salvador, Guatemala, Honduras, and Nicaragua) had lower e_0. By the early 2010s, Mexico was still surpassed by Canada, Costa Rica, Panama, and the United States (Figure 2). Currently, Canada boasts the highest life expectancy in the region, while Guatemala exhibits the lowest e_0 among women and El Salvador suffers the worst life expectancy among men (United Nations, Department of Economic and Social Affairs, Population Division 2019).

Figure 1: Life expectancy at birth (in years), Mexico, United States, Canada, and Central American countries, by sex, 1950–1955



Source: United Nations, Department of Economic and Social Affairs, Population Division (2019).

Figure 2: Life expectancy at birth (in years), Mexico, United States, Canada, and Central American countries, by sex, 2010–2015



Source: United Nations, Department of Economic and Social Affairs, Population Division (2019).

Although the quality of vital statistics and census counts for Mexico has improved over time, the data may be incomplete (e.g., due to under-registration of deaths or undercounting in the census), resulting in unreliable mortality indicators. Most publicly available mortality estimates for Mexico have been adjusted, including the official life table estimates published by the Consejo Nacional de Población (CONAPO). In his analyses of Mexican mortality from 1940 to 1980, Camposortega Cruz (1989) noted problems of census undercounts; deficiencies in death counts, particularly during the first year of life; and age misreporting in both census and death registration data.[5] The Global Burden of Disease (GBD) study (Wang et al. 2017; see Figure 1) estimated that death registration in Mexico was 90%–94% complete during 1990–2001 and 95% complete or higher during 2002–2016, although there is some evidence that those estimates might be too optimistic for Latin American countries (Queiroz et al. 2020a). As reported to the

[5] We were unable to obtain a copy of a later publication by Camposortega Cruz (1992) that appears to be a published version of the author's dissertation.

United Nations Statistics Division (2017) by the Mexico National Statistics Office, death registration for Mexico in 2017 was between 90% and 99%. Using an indirect method that compares the census figures with UN population projections, Borges and Sacco (2016; see Table 2) estimated that the census undercount for Mexico was 9.0% in 1950 and 9.7% in 1960 but declined to 7.2% in 1970 and to 4.5% in 1980. However, the census undercount increased again slightly, to 5.4% in 1990, 5.3% in 2000, and 5.9% in 2010. Nonetheless, the validity of those estimates depends on the accuracy of the UN projections. For the 1990 census, Vázquez (1991) estimated that the undercount was between 2.3% and 7.3%. Based on a post-enumeration survey, the Instituto Nacional de Estadística y Geografía (INEGI 2012) estimated that the 2010 census undercount was only 1.3%. The Latin American Mortality Database (LAMBdA) team estimated that relative completeness (the completeness of death registration relative to population counts) was 86% for the intercensal interval 1950–1960 but had improved to 96% by 2000–2010 (Beltrán-Sánchez et al. 2020; see Table 3.4). Other countries in the region suffer from similar data quality problems. Consequently, caution is warranted when comparing mortality trends over time for Mexico and other countries because the accuracy of the estimates is unclear.

In this paper, we restrict our analysis of the Mexican mortality data to the period since 1990 because although there are notable data quality issues after 1990, the available evidence suggests that data quality was even worse prior to 1990. We aim to address the following research questions: (1) Do unadjusted mortality estimates for 1990–2016 (based on vital statistics and census counts) display unusual patterns that may reflect data quality problems? (2) How do those unadjusted estimates compare with other published estimates (which may be based on adjusted data)? (3) How does Mexican (unadjusted) mortality compare with the historical mortality patterns observed among the 41 populations included in the Human Mortality Database (HMD)? (4) How much do various adjustments affect estimates of life expectancy for Mexico?

2. Data and methods

Unadjusted life tables for Mexico are computed following the HMD methods protocol (Wilmoth et al. 2019), using official vital statistics (Instituto Nacional de Estadística y Geografía (INEGI) 2018b, 2018c) and census counts (Instituto Nacional de Estadística y Geografía (INEGI) 2018a) as published.[6] Following the HMD protocol, birth counts by

[6] The Latin American Human Mortality Database (LAHMD, www.lamortalidad.org) also provides raw death counts (by sex and five-year age groups to age 85+ for 1936–2014) and census counts (by sex and five-year age groups to age 80+ for 1990, 2000, and 2010) for Mexico, but it does not include life table estimates or even

sex are used mainly for estimating the relative size of individual cohorts. Death counts by sex and detailed age are used for the numerator of the age-specific mortality rates. Deaths, births, and census counts – also by sex and detailed age – are used to derive intercensal population estimates below age 80 and for cohorts aged 80–90 at the end of the observation. Above age 80, population estimates are derived using the extinct cohort method for all cohorts that are extinct and by the survival ratio method for nonextinct cohorts older than 90 years at the end of the observation period. Exposure-to-risk, which serves as the denominator for computing mortality rates, is based on the population estimates. At very high ages (95+, or below if there are fewer than 100 men or women surviving in any given country-year), the mortality rates are smoothed to avoid the large random fluctuations associated with small numbers, using a technique initially proposed by Vaino Kannisto (Thatcher, Kannisto, and Andreev 2002). At these high ages, the underlying hazards are estimated by fitting a logistic curve with an asymptote at 1 to the age-specific mortality rates. The resulting age-specific death rates are combined to derive complete sex-specific life tables with an open age interval for ages 110+. The raw data for Mexico and details regarding their format are included in S1 of the Supplementary Archive.

2.1 Assessing unusual patterns in the unadjusted mortality estimates

First we graph the death rates by sex and age for each calendar year to identify evidence of age heaping. Next, we compare Mexico with Sweden in terms of the trends in life expectancy at birth (e_0) – which summarizes mortality over the entire age range – and at age 80 (e_{80}) – a summary measure of old age mortality. Although there is no reason to expect the evolution of mortality decline in Mexico to follow the historical pattern of Sweden, we use Sweden as a comparison because its demographic data are considered to be of exceptionally high quality.[7]

mortality rates. As documented in the supplemental material, we collected far more detailed raw data: (1) de jure death counts for 1990–2016 by sex and single year of age to age 120, tabulated by both year of occurrence and year of registration; (2) de jure census counts as of March 12, 1990, November 5, 1995, February 14, 2000, October 17, 2005, and June 12, 2010, by sex and single year of age to age 100+; and (3) de jure live birth counts by sex, month, and year of occurrence for 1985–2016. More importantly, we estimate age-specific mortality rates and compute life tables for every year between 1990 and 2016.

[7] There are alternative methods for evaluating the plausibility of data at the oldest ages. For example, Jdanov et al. (2008) recommend computing the ratio of T_{100}/T_{80} and the ratio of deaths at ages 105+ to deaths at ages 100+. These indicators cannot confirm that the data are wrong; they can only indicate that the data appear unusual compared with the patterns observed in other countries. As shown in Figure S1, the ratio of deaths at ages 105+ to deaths at ages 100+ is much higher in Mexico than in Sweden or Chile, the only Latin American country in the HMD. Others have described methods for estimating the expected number of centenarians in a

Finally, we use death distribution methods (DDM) to estimate the completeness of death registration relative to population counts. The general growth balance method (GGB; Brass 1975; Hill 1987; Hill, You, and Choi 2009) and the synthetic extinct generation (SEG) method (Bennett and Horiuchi 1981, 1984) are the most well-established methods. A hybrid method (GGB-SEG), developed by Hill, You, and Choi (2009), addresses the sensitivity of the SEG method to changes in coverage between consecutive censuses. Hill, You, and Choi (2009) conclude that GGB and GGB-SEG do reasonably well in the presence of age misreporting or age variation in census coverage, but neither is robust when there is substantial net migration or when the completeness of death registration varies by age, which can create large distortions (double-digit percentage errors in adult mortality probabilities). Net migration is often low enough to ignore when dealing with national populations, but caution should be exercised in interpreting the results if there is substantial net migration (IUSSP-UNFPA 2017a, 2017b). A review by Hill (2017: 18) notes that evaluations have concluded "that DDMs work very well when applied to data that conform to their assumptions, but find them sensitive to migration and errors that are not proportional by age." For populations not affected by migration, Hill, You, and Choi (2009) recommend using GGB-SEG fit to the age range 5+ to 65+, because age misreporting is more of a problem above age 65, independent from the issue of completeness per se. Murray et al. (2010) recommend using different age ranges for the different methods (40–70 for GGB, 55–80 for SEG, and 50–70 for GGB-SEG) and then computing the median from all three methods. In populations substantially affected by migration, Hill, You, and Choi (2009) argue that the GGB and GGB-SEG methods (which do not account for migration) underestimate coverage (thus overestimating mortality), whereas the SEG method does the opposite. Thus, in the presence of migration, they argue that the best strategy (for the smallest error) is to fit both GGB and SEG to the age range 30+ to 65+ and then to average the results (Hill, You, and Choi 2009). Using this higher starting age reduces the effects of migration, which tends to be concentrated at younger ages. A possible alternative, suggested by Hill (2017), is to use a wide age range (5–65) for GGB to estimate the change in census completeness but then to apply SEG using a narrower, older age range (50–70) to minimize errors resulting from migration.

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population at a given time (Gomes and Turra 2009; Nepomuceno and Turra 2020). Gomes and Turra (2009) compared the expected number of centenarians in 1991 in Brazil based on the extinct generation method with the number recorded in the 1991 census. Nepomuceno and Turra (2020) propose the variable-*r* method to estimate the likely number of centenarians. As described at the beginning of this section, we do not rely on census counts to estimate the population above age 80. Instead, our population estimates above age 80 are based on the extinct cohort method or the survival ratio method. Thus our method of estimating the population at the oldest ages is similar to the strategy used by Gomes and Turra (2009).

We use the DDM R package (Lima, Queiroz, and Riffe 2016) to compute the GGB, SEG, and GGB-SEG estimates of relative completeness for Mexico. Because the results can be sensitive to the age range used for fitting (Murray et al. 2010), we apply the methods to three age ranges: 5+ to 65+, 30+ to 65+, and the "optimal" age range as determined by the DDM package.

LAMBdA, UNPD (United Nations Population Division), and the Global Burden of Disease – Institute for Health Metrics and Evaluation (GBD-IHME) all use some form of DDM to adjust the mortality rates for relative completeness.[8] In contrast, CONAPO ultimately chose another method – derived from the general Preston and Coale (1982) model – to adjust the mortality rates.

2.2 Comparisons with other published estimates for Mexico

We assess the plausibility of the life table estimates by comparing our unadjusted estimates of life expectancy at birth and at age 80, infant mortality (q_0), the probability of dying between age 15 and 60 (${}_{45}q_{15}$), and the probability of dying between age 60 and 80 (${}_{20}q_{60}$) for Mexico with corresponding estimates produced by CONAPO (2018), GBD (Global Burden of Disease Collaborative Network 2018), LAMBdA (Palloni, Pinto-Aguirre, and Beltrán-Sánchez 2017), and UNPD (United Nations, Department of Economic and Social Affairs, Population Division 2019).

2.3 Comparing mortality patterns with those exhibited by HMD populations

To further explore the plausibility of the estimates, we compare our unadjusted life table estimates for Mexico with corresponding results for the 41 populations in the HMD (University of California, Berkeley, and Max Planck Institute for Demographic Research 2019). Specifically, we compare the trends in e_0 and e_{80} since 1990, and we plot the relationship between child mortality (represented by the probability of dying in the first five years of life, ${}_5q_0$) and older age mortality (measured by the probability of dying between ages 60 and 80) for Mexico during 1990–2016 alongside all HMD populations for the period since 1950. If the values for Mexico fall well outside the range of values observed in HMD populations during 1950–2018, there may be a data quality problem (e.g., underestimation of old age mortality).

[8] The LAHMD (www.lamortalidad.org) also provides estimates of relative death coverage for 10-year periods (1980–1990, 1990–2000, 2000–2010), but it is not clear how those estimates were derived. Consequently, it would be impossible for us to replicate those results or even to explain why the estimates differ from ours.

2.4 Data adjustments

2.4.1 Adjusting child mortality (below age 5)

We adjust mortality below age 5 by substituting the estimated death counts at ages 0 and 1–4 from the UN Inter-agency Group for Child Mortality Estimation (IGME, www.childmortality.org) in place of the registered death counts below age 5. These estimates are carefully prepared by highly qualified experts who have access to a massive database maintained at the United Nations.

To derive these estimates, IGME begins by compiling all existing nationally representative estimates of child mortality, including data from vital registration, population censuses, household surveys, and sample registration systems (United Nations Inter-agency Group for Child Mortality Estimation 2018b). Then data quality is assessed and data sources that are deemed to have substantial non-sampling errors or omissions are excluded from the analysis (United Nations Inter-agency Group for Child Mortality Estimation 2018b).

In the case of Mexico, IGME used the following data to derive estimates of mortality below age 5: (1) vital registration data for 2005–2017; (2) direct estimates based on full birth histories from the 1976 World Fertility Survey (WFS), the 1987 Demographic and Health Survey (DHS), and the 1992, 1997, and 2014 Encuesta Nacional de la Dinámica Demográfica (ENADID); and (3) indirect estimates based on summary birth histories from the 1979 Contraceptive Prevalence Survey, censuses (1980, 1990, 2000, 2005, 2010), the 2006 ENADID, and the 2015 Encuesta Intercensal. The following data sources were excluded from the dataset used to fit the model because they were deemed to have substantial non-sampling errors or omissions (note that IGME did not rely on summary birth histories if full birth histories from the same survey were available): vital registration data for earlier years (1955–2004), direct estimates based on full birth histories from the 2009 ENADID, and indirect estimates based on summary birth histories from the 1976 WFS, 1987 DHS, and 1992, 2006, and 2014 ENADID.

To estimate the probability of dying between birth and age 5 (expressed per 1,000 live births), IGME fitted a Bayesian B-splines bias-adjusted (B3) model with global smoothing to the dataset for Mexico (United Nations Inter-agency Group for Child Mortality Estimation 2018a). Infant (age < 1) mortality (per 1,000 live births) was estimated for Mexico based on the Coale–Demeny West model life table with no global smoothing (United Nations Inter-agency Group for Child Mortality Estimation 2018a). Sex-specific trends in child mortality were not estimated because fewer data sources are available by sex. Instead, IGME estimated the time trend in the sex ratio of child mortality. The final death counts were derived by applying the estimated mortality rates to the live birth counts from World Population Prospects (United Nations Inter-agency Group for Child Mortality Estimation 2019).

2.4.2 Modeling mortality across the entire age range

Finally, we applied a flexible system of model life tables proposed by Wilmoth et al. (2012) to estimate Mexican mortality across the entire age range. Wilmoth et al. (2012) demonstrated that their two-dimensional model outperforms both the Coale–Demeny and UN model life tables. Using 719 sex-specific life tables from the HMD, they modeled m_x, which denotes the mortality rate at age x (age groups 0, 1–4, 5–9, 10–14,…105–109, 110+) for each sex, as follows:

$$\log(m_x) = a_x + b_x h + c_x h^2 + v_x k, \tag{1}$$

where h represents the logarithm of the child mortality rate, $\log({}_5q_0)$, and has a quadratic relationship with the logarithm of age-specific mortality rates; k is a real number that typically ranges from –2 to 2 and reflects the magnitude and direction of deviations from a typical age pattern of mortality; and a_x, b_x, c_x, and v_x are age-specific parameters estimated by the modeling procedure. This model is known as the log-quadratic model.

We use the R program provided by Wilmoth et al. (2012)[9] to compute the estimated sex-specific life tables for Mexico in a given year based on the log-quadratic model. The software uses the estimated coefficients for a_x, b_x, c_x, and v_x from Wilmoth et al. (2012, Table 3). The one-parameter version of the model uses an estimate of child mortality (${}_5q_0$) as the only input and assumes that $k = 0$. The two-parameter version of the model uses a measure of adult mortality (e.g., ${}_{45}q_{15}$) as a second input. As explained by Wilmoth et al. (2012: 11), an iterative procedure is used to choose a value of k that reproduces the input value of ${}_{45}q_{15}$ exactly.[10]

Then the estimated age-specific mortality rates across age are obtained using the following formula:

$$\widehat{m}_x = e^{\hat{a}_x + \hat{b}_x h + \hat{c}_x h^2 + \hat{v}_x k}. \tag{2}$$

Finally, the software uses those rates to construct a complete life table. We use the adjusted ${}_5q_0$ provided by IGME as the input for the one-parameter log-quadratic model.

[9] Retrieved from https://u.demog.berkeley.edu/~jrw/LogQuad/ on July 15, 2019.

[10] Wilmoth et al. (2012: 11) says, "For a given set of age-specific coefficients and a known value of 5q0, we choose a value of k in order to reproduce the observed value of 45q15 exactly. Calculation of k in this situation is fairly simple but requires an iterative procedure. Note that we fitted the model to the HMD data-set using the usual least squares criterion of the singular value decomposition; therefore, the fit is not optimized for 45q15 in particular. However, in using the model for the indirect estimation of mortality, we propose that k should be chosen to match an estimate of 45q15, if available." See the appendix to Wilmoth et al. (2012) for more details.

For the two-parameter log-quadratic model, we use adjusted values of ${}_{45}q_{15}$ (for 1995 and 2005)[11] from LAMBdA as the second input.

The LAMBdA estimates are based on a complex methodology that adjusts for relative completeness and age misreporting (Beltrán-Sánchez et al. 2020). More specifically, the LAMBdA methodology involves three steps. First, mortality below age 5 is estimated by modeling (using local area regressions and splines applied to a pooled set of national values including direct estimates based on vital registration and census counts as well as indirect estimates based on birth histories from surveys and microcensus samples). Second, mortality above age 5 is adjusted using the GGB method to adjust census data for completeness; then the SEG method is implemented to further adjust for completeness of death registration; finally, age misstatement is corrected assuming a systematic pattern of overstatement. Third, child mortality estimates derived from the first step are combined with mortality estimates for ages 5 and above derived from the second step to produce a full set of age-specific death rates and, from those, complete life tables.

3. Do unadjusted mortality estimates display unusual patterns?

In most cases, we cannot say definitively that the mortality data are biased because we do not know what the true estimates should be. We can only note unusual patterns that suggest there may be problems with data quality. When the patterns we observe for Mexico deviate substantially from those exhibited by a wide range of countries with high-quality data (including those with a level of life expectancy similar to Mexico's), it raises questions about data accuracy.

3.1 Age misreporting

The Mexican death rates prior to 2000 display obvious age heaping at ages ending in 0 and 5 (as demonstrated in Figure S2 for 1990). Some age heaping persists post-2000 among men aged 25–40 (see Figure S3 for 2010). When the deaths and census counts are examined separately (see Figures S4 and S5), we find age heaping in both, but it is more pronounced in the death counts. A'Hearn and colleagues (2009, 2016) suggest that age heaping may be related to education, numerical skills, or culture (e.g., age awareness or a willingness or commitment to report age accurately).

[11] For the period since 1990, LAMBdA has published life table estimates for Mexico only for 1995 and 2005.

Age heaping is primarily a concern because it suggests there may be more serious but insidious forms of age misreporting. Indeed, age heaping is typically associated with age exaggeration, with people increasingly reporting or being reported as older than they really are as they age, especially in societies where aging comes with additional respect and consideration (Condran, Himes, and Preston 1990). Demographers have demonstrated that age misreporting leads to the underestimation of mortality at older ages regardless of its pattern (age overstatement, age understatement, or symmetric age misreporting) (Preston, Elo, and Stewart 1999). An early analysis found severe age overstatement in a number of Latin American countries, including Mexico at least up to the 1970s; age exaggeration resulted in the underestimation of mortality (Dechter and Preston 1991). Given the age heaping demonstrated in Figures S1 and S2, we suspect that age misreporting and associated underestimation of mortality at older ages continued to affect the Mexican demographic data at least up to the 1990s and possibly until the early years of the 21st century for older cohorts.

3.2 Trends in life expectancy at birth and at age 80 compared with Sweden

Although there is no reason to expect Mexico to follow the same pattern of mortality decline as Sweden, we focus here on patterns that appear suspicious. For example, if e_0 is substantially lower in Mexico than in Sweden, then we would expect e_{80} to also be lower in Mexico. Throughout the period 1990–2016, e_0 was much lower in Mexico than in Sweden (Figure 3), yet estimates of life expectancy at age 80 were *higher* in Mexico than in Sweden for men prior to 2015 and for women prior to 2007 (Figure 4). In Mexico, the lack of improvement in e_{80} after 2000 is also suspicious. Life expectancy generally increases over time as population health and mortality conditions improve. In contrast, age misreporting typically declines over time as literacy rates increase (A'Hearn, Baten, and Crayen 2009; A'Hearn, Delfino, and Nuvolari 2016), birth registration improves, and birthdays are emphasized more. If the accuracy of age reporting improves and artificially inflates mortality rates enough to offset the actual gain in life expectancy, then old age survival may appear (misleadingly) to stagnate or even decline (as suggested by Figure 4 for Mexico after 2005).

Figure 3: Expectation of life at birth in Mexico and in Sweden by sex, 1990–2016

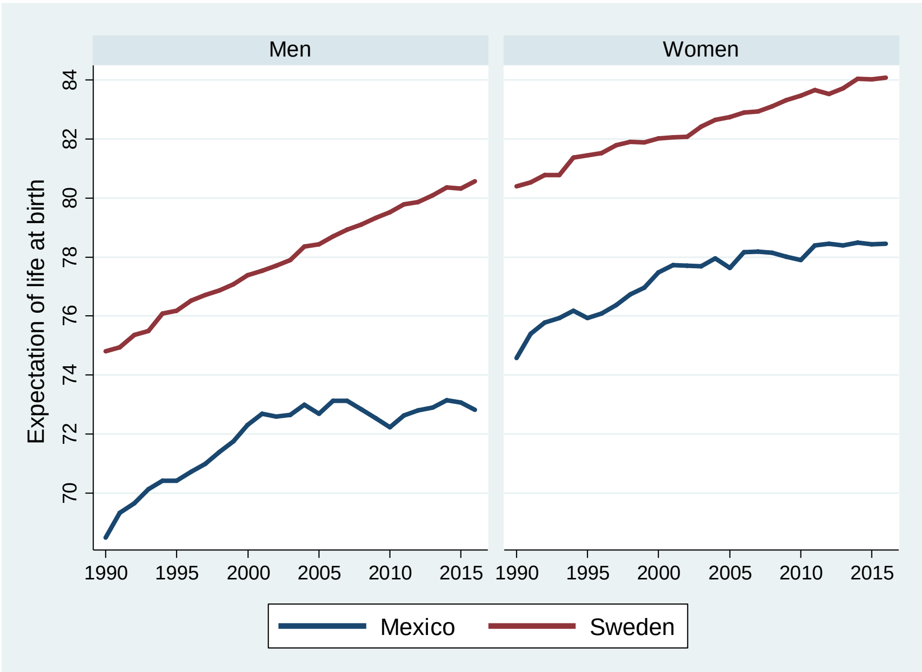
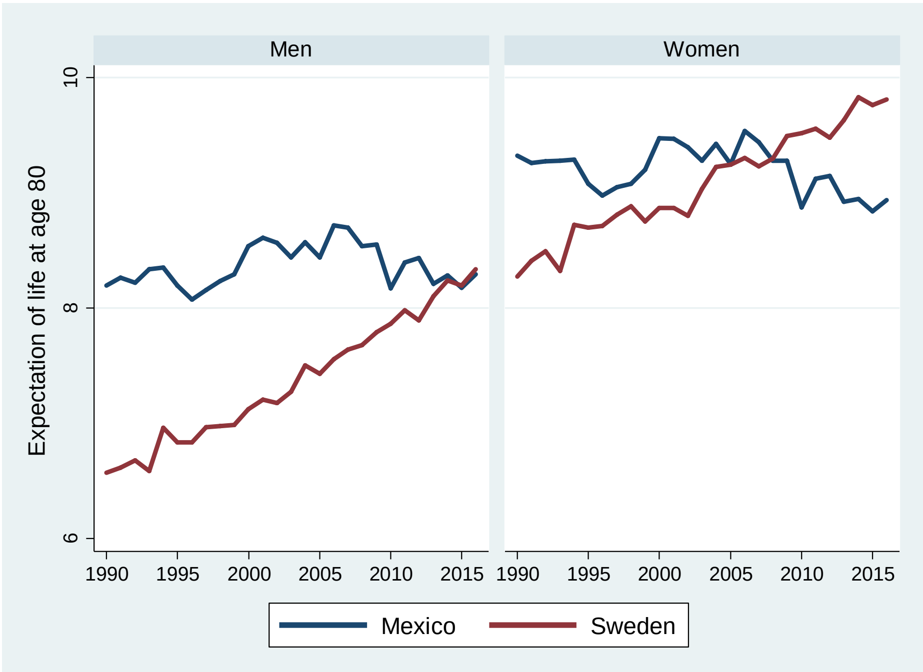


Figure 4: Expectation of life at age 80 in Mexico and in Sweden by sex, 1990–2016



3.3 Relative completeness of death registration

Estimates of relative completeness derived from death distribution methods are expressed as a ratio indicating the completeness of death registration relative to population counts. For Mexico, the SEG estimates tend to be lower than the GGB or GGB-SEG estimates (Table S1). For example, the SEG estimate for men in 2000–2005 fit to ages 5+ to 65+ was 0.86, suggesting that deaths are 14% under-registered relative to the population, whereas the corresponding GGB estimate was 1.26 (i.e., deaths are 26% over-registered relative to the population – or conversely, the population is 21% undercounted relative to registered deaths). Furthermore, for any given method, the estimated relative completeness varies depending on the age range used to fit the model. For example, for men in 1995–2000, the GGB estimate is 1.64 when fitted to the age range 5+ to 65+ but is 1.37 based on ages 30+ to 65+.[12]

Annual net migration estimates by sex and single year of age (Partida Bush 2018) suggest out-migration during 1990–2015 in both sexes. The estimates indicate negative net migration at all ages below 48, but the highest levels of out-migration occurred between ages 15 and 20 in the 1990s and early 2000s (–2% to –2.5% among men and –1.2% to –1.5% among women). If we apply the strategy recommended by Hill, You, and Choi (2009) when there is substantial migration (average the results based on GGB and SEG fit to the age range 30+ to 65+), the estimates suggest that deaths are slightly under-registered relative to the census counts in 1990–1995 (0.97 for both sexes) but indicate the opposite in 1995–2000 (1.24 for men and 1.25 for women; Table S1). These estimates imply that the census undercount was much greater than under-registration of deaths in the late 1990s. In subsequent years, the estimates of relative completeness are also somewhat higher than 1.0.

In other work, when we applied GGB and GGB-SEG to the mortality data for Costa Rica (Glei, Barbieri, and Santamaría-Ulloa 2019), some of the results seemed suspicious, leading us to wonder if they might be biased by violations of the assumptions. Lima et al. (2017) applied GGB, SEG, and GGB-SEG to all the HMD populations since the 1940s. Their results also displayed some surprising patterns. For example, the relative completeness for men in the United States in the 2000s and Canada in the 1990s was only slightly higher than 90%, whereas the estimates for Icelandic men in the 2000s suggest nearly 20% over-registration of deaths.

DDM can be useful for evaluating data quality, which is how many others have used it (Peralta et al. 2019; Queiroz et al 2020b). However, Murray et al. (2010) cautioned that estimates of completeness based on DDM carry a lot of uncertainty (at least +/–20%) and thus are unlikely to be useful for monitoring mortality trends. Li and Gerland (2019) find that DDM estimates are more sensitive at lower levels of mortality because relative errors in the population enumerations are magnified.

The sensitivity of the DDM estimates and the potential biases resulting from violations of the assumptions lead us to conclude that DDM is not reliable enough to justify using those methods to adjust adult mortality in Mexico. Furthermore, we do not see any reason to believe that alternative methods that incorporate estimates of migration would improve the estimates enough to justify using DDM to adjust the mortality estimates. Even if we were to apply the method outlined by Hill and Queiroz (2010) to adjust for migration, we would have no way of knowing whether such estimates are actually better than any other estimates. The validity of any such adjusted estimates would depend on the accuracy of the migration data, which we have no means of

[12] Wilmoth, You, and Queiroz (2004) applied DDM to mortality data for Mexico between 1930 and 2000. They also found wide variation in the results depending on the choice of methods.

verifying. For example, estimates of migration to/from the United States vary a lot depending on the source (e.g., Encuesta Nacional de Ocupación y Empleo, US Census Bureau, American Community Survey, or Current Population Survey). Azose and Raftery (2019) show substantial discrepancies between estimates based on different methods and sources (e.g., minimum migration, pseudo-Bayes, or Pew Research Center) and considerable uncertainty in the estimates of migration from the United States to Mexico and from Mexico to the United States. They conclude, "Despite the importance of international migration, estimates of between-country migration flows are still imprecise" (Azose and Raftery 2019: 116). If the migration data are inaccurate, there is no reason to believe that alternative DDM estimates that incorporate those data would be any better than our current estimates. More importantly, we would have no way of determining which estimates are the most reliable.

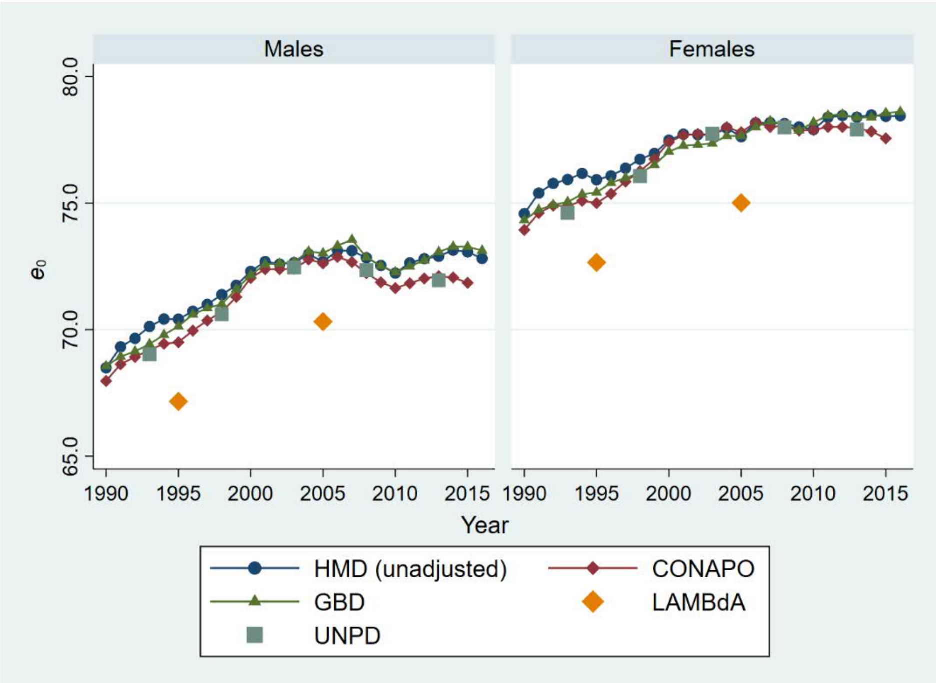
4. How do unadjusted estimates compare with other published estimates?

Variability in mortality estimates provides some idea of the degree of uncertainty. We compare our unadjusted life table estimates with corresponding estimates published by CONAPO (Consejo Nacional de Población 2018), GBD (Global Burden of Disease Collaborative Network 2018), LAMBdA (Palloni, Pinto-Aguirre, and Beltrán-Sánchez 2017), and the UNPD (United Nations, Department of Economic and Social Affairs, Population Division 2019), all of which have been adjusted to some degree.

In terms of overall life expectancy, our unadjusted estimates are much higher (implying lower mortality) than the adjusted estimates provided by LAMBdA (Figure 5). Prior to 2000 and after 2006, they are also higher than the estimates from CONAPO. Compared with estimates from GBD and UNPD, our estimates of e_0 are higher prior to 1995 among men and prior to 2005 among women. However, starting in the mid-2000s, our unadjusted estimates are very similar to those from GBD.[13]

[13] Camposortega Cruz (1997) also provided estimates of e_0 for 1990, 1995, and 2000, which appear to be similar to our unadjusted estimates. Using historical data for 1960–2005 deaths and population, García Guerrero and Ordorica Mellado (2012) apply the Lee–Carter method to project mortality for 2000–2050. Their estimates of *e0* in 1990 (Figures 6 and 14) appear to be similar to ours, although their estimates for 2000 are slightly lower than ours.

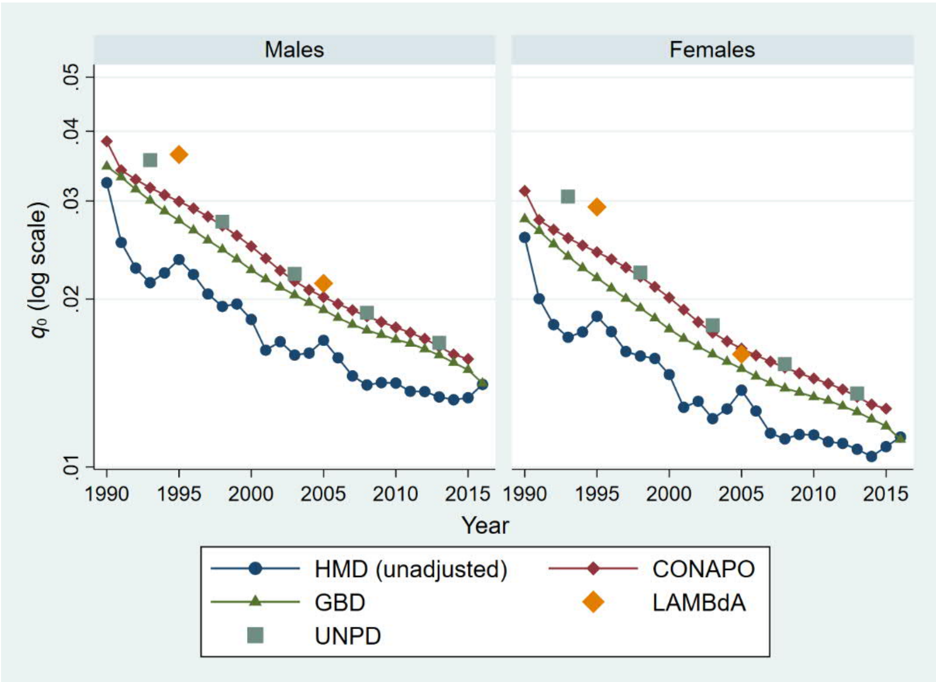
Figure 5: Comparison of life expectancy at birth (e_0, in years) with external estimates by sex, Mexico, 1990–2016



Sources: CONAPO (Consejo Nacional de Población 2018); GBD (Global Burden of Disease Collaborative Network 2018); LAMBdA (Palloni, Pinto-Aguirre, and Beltrán-Sánchez 2017); UNPD (United Nations, Department of Economic and Social Affairs, Population Division 2019).
Note: Estimates from the UNPD are based on life tables for five-year periods and are plotted at the midpoint of the period.

Infant mortality is often a strong driver of e_0. Not surprisingly, we find large discrepancies across various estimates of the probability of dying in the first year of life (q_0) (Figure 6). For example, compared with our unadjusted estimates of q_0 for boys in 1995, the GBD estimates are 18% higher, the CONAPO estimates are 27% higher, and the LAMBdA estimates are 54% higher.

Figure 6: Comparison of infant mortality (q_0) with external estimates by sex, Mexico, 1990–2016



Sources: CONAPO (Consejo Nacional de Población 2018); GBD (Global Burden of Disease Collaborative Network 2018); LAMBdA (Palloni, Pinto-Aguirre, and Beltrán-Sánchez 2017); UNPD (United Nations, Department of Economic and Social Affairs, Population Division 2019).
Note: Estimates from the UNPD are based on life tables for five-year periods and are plotted at the midpoint of the period.

During prime adult ages (15–60), our unadjusted mortality estimates (${}_{45}q_{15}$) are lower than estimates produced by LAMBdA (Figure 7). For example, among women in 2005, our estimate of midlife mortality is nearly 13% lower than LAMBdA's estimate. Our estimates are generally similar to those from CONAPO up to 2013 but are more than 5% lower than CONAPO's estimates thereafter. In contrast, our estimates are at least as high as those from GBD.

The discrepancies in older age mortality – between ages 60 and 80 (${}_{20}q_{60}$) – are even bigger (Figure 8). These comparisons suggest that we may be underestimating the probability of dying at older ages (60–80) by as much as 20% (i.e., among women in 2005 compared with LAMBdA).

As mortality declines, old age survival becomes increasingly important in determining overall life expectancy. When we compare our unadjusted estimates of e_{80}

with other estimates, the results suggest that our figures may be overestimated (Figure 9). For example, compared with our unadjusted estimate of e_{80} for women in 1995 (9.1 years), the LAMBdA estimate is 24% lower (6.9 years), the GBD estimate is 11% lower (8.1 years), and the CONAPO estimate is 4% lower (8.7 years).[14]

5. Mexican mortality compared with the historical patterns observed in the 41 HMD populations

5.1 Life expectancy at birth

At the beginning of the data series (1990), unadjusted life expectancy at birth in Mexico fell near the bottom of the range defined by HMD populations (ranking 28th among men and 36th among women out of 39 HMD populations with available data; Figure 10). By 2013, Mexico ranked 33rd out of 41 among men with an unadjusted e_0 of 72.9 years, which tied it with Slovakia and placed it just below Estonia. Among women, Mexico ranked 38th, with an unadjusted e_0 of 78.4 years, just above Belarus but below Bulgaria.

5.2 Life expectancy at age 80

In contrast with e_0, e_{80} looks surprisingly high for Mexico (Figure 11). In 1990, our unadjusted estimates imply that the remaining length of life at age 80 among Mexican men (8.2 years) was notably higher than in any HMD country (Iceland and Israel were tied at 7.7 years with the highest e_{80} among men), while Mexico ranked second highest among women (9.3 years; just behind Iceland at 9.5 years). Compared with their US counterparts, e_{80} was more than one year higher among Mexican men and 0.2 years higher among Mexican women in 1990. Between 1990 and 2016, e_{80} in Mexico virtually stagnated. Such stagnation may be a result of improved data quality (i.e., the tendency to overstate age progressively declined over time). By 2013, Mexico had fallen in rank to 15th among men (tied with the United Kingdom) and 29th among women (tied with Estonia).

[14] The LAMBdA estimates imply much higher levels of mortality than any of the other estimates, as indicated by higher levels of ${}_{15}q_{45}$ (Figure 7) and ${}_{20}q_{60}$ (Figure 8) and lower values of e_0 (Figure 5) and e_{80} (Figure 9). LAMBdA uses various indirect estimation methods to produce its mortality estimates. We cannot determine exactly which of the many adjustments made by LAMBdA may account for the discrepancies. Such a detailed analysis is beyond the scope of this paper (and would be better addressed by a researcher at LAMBdA who fully understands the methodology and has access to the programs for implementing those adjustments).

5.3 Relationship between child and older age mortality

Figure 12 shows the relationship between child mortality (${}_{5}q_{0}$) and older age mortality (${}_{20}q_{60}$) for Mexico and all HMD populations for the period since 1950. Over time, the estimates for a given country generally progress from the upper right corner of the graph (high child and high older age mortality) toward the lower left corner (lower levels of both child and older age mortality).

Among men, Mexico is a clear outlier: Compared with HMD populations at a similar level of child mortality, unadjusted mortality between ages 60 and 80 falls below the range of HMD estimates in 1990 and remains below the range of HMD populations in 2016. Old age mortality for Mexican women also falls near the bottom of the range of HMD populations at a similar level of child mortality. These unusual patterns could reflect a problem of data quality. Underestimation of mortality between the ages of 60 and 80 years is more likely than overestimation of child mortality. Incomplete coverage of death registration or age exaggeration, which has been shown to be widespread in Latin America (Beltrán-Sánchez et al. 2020), could cause underestimation of older age mortality.

6. How do various adjustments affect estimated life expectancy?

6.1 Adjusting child mortality (below age 5)

Given evidence that infant mortality rates are underestimated (see Figure 6), we used the estimated death counts at ages 0 and 1–4 published by IGME to adjust mortality below age 5. As shown in Figure 13, the adjusted estimates are higher than the CONAPO estimates prior to 2000, but they appear to be slightly lower than CONAPO in the most recent years.

In 1990, the adjusted estimates of ${}_{5}q_{0}$ are 25% higher than the unadjusted estimates for boys and 27% higher for girls (Table 1). The gap widens considerably between 1990 and 1995 (adjusted estimates in 1995 are 45% higher than unadjusted estimates for boys and 48% higher for girls; Table 1). However, the estimates begin to converge after 2000. By 2015, the adjusted estimates are only 11% higher than the unadjusted estimates for boys and 10% higher for girls, suggesting that vital registration of infant and child deaths has been progressively improving in Mexico since the mid-1990s.

Table 1: Unadjusted and adjusted estimates of child mortality ($_5q_0$) by sex, Mexico, 1990, 1995, 2000, 2005, 2010, and 2015

	Boys			Girls		
	HMD unadjusted	IGME adjusted[a]	Difference (%)	HMD unadjusted	IGME adjusted[a]	Difference (%)
1990	0.0425	0.0491	25%	0.0352	0.0416	27%
1995	0.0286	0.0385	45%	0.0231	0.0320	48%
2000	0.0218	0.0293	41%	0.0177	0.0241	42%
2005	0.0201	0.0226	25%	0.0165	0.0185	24%
2010	0.0169	0.0189	17%	0.0138	0.0156	17%
2015	0.0157	0.0162	11%	0.0129	0.0133	10%

Note: [a] Based on IGME adjusted death counts below age 5.

Adjustment of child mortality reduces the HMD estimates for e_0 in 1995 by 0.9 years for men and 0.8 years for women (Table 2). Nonetheless, life expectancy at birth is still much higher than in LAMBdA. For example, among women in 1995, the HMD child mortality adjusted estimate of e_0 is 75.1 years, versus 72.7 from LAMBdA. In 2005, there is still a 2.3-year gap (77.3 versus 75.0, respectively). Since 2010, adjustment for child mortality has little effect on the HMD estimates for e_0 (Figure 14).

Table 2: Unadjusted and adjusted estimates of e_0 by sex, Mexico, 1995, 2005, and 2015

	1995		2005		2015	
	Men	Women	Men	Women	Men	Women
Estimates of e_0						
Unadjusted	70.4	75.9	72.7	77.6	73.1	78.4
Adjusted mortality below age 5[a]	69.5	75.1	72.3	77.3	72.9	78.3
1-parameter log-quadratic model[b]	66.4	**71.6**	69.3	74.9	**70.9**	**76.5**
2-parameter log-quadratic model[c]	**66.0**	72.1	**69.0**	**74.7**	N/A	N/A
LAMBdA estimates	67.2	72.7	70.3	75.0	N/A	N/A
Difference (unadjusted – adjusted)						
Adjusted mortality below age 5[a]	–0.9	–0.8	–0.4	–0.3	–0.2	–0.1
1-parameter log-quadratic model[b]	–4.0	**–4.3**	–3.4	–2.7	**–2.2**	**–1.9**
2-parameter log-quadratic model[c]	**–4.4**	–3.8	**–3.7**	**–2.9**	N/A	N/A
LAMBdA estimates	–3.2	–3.2	–2.4	–2.6	N/A	N/A

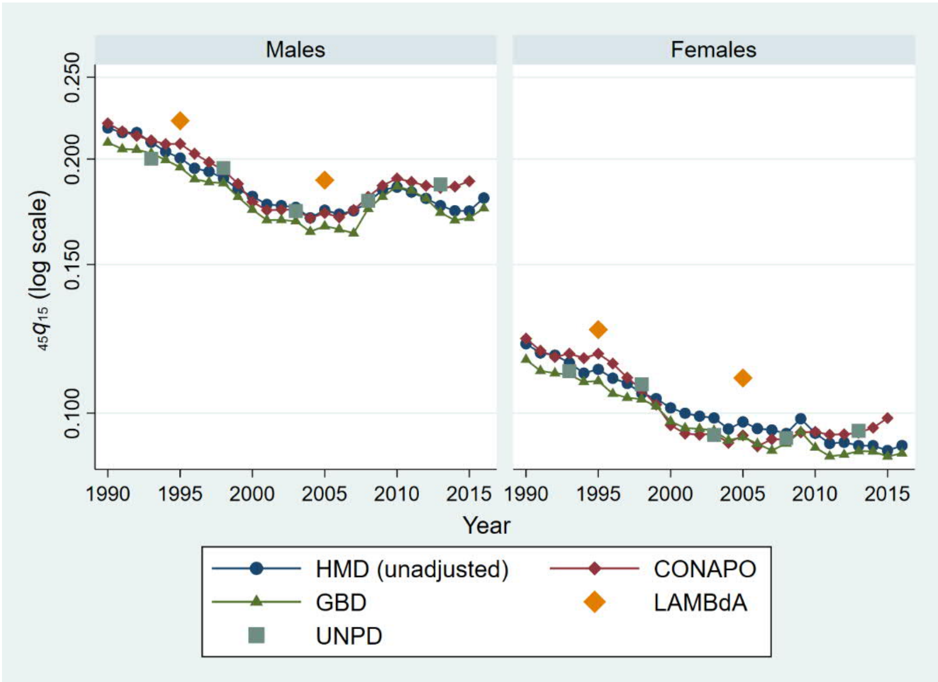
Note: The lowest estimate for each sex-year is shown in bold type. N/A = not available.
[a] We substitute IGME adjusted death counts below age 5 in place of the unadjusted death counts.
[b] Using the adjusted $_5q_0$ (based on IGME; see Table 1) as the input, with k set to 0.
[c] Using both the adjusted $_5q_0$ (based on IGME) and LAMBdA estimates of $_{45}q_{15}$ (see Table 3) as the inputs.

6.2 Modeling mortality across the entire age range

When we use the one-parameter log-quadratic model to adjust mortality across the entire age range, we find even lower estimates of e_0. For example, in 1995 the one-parameter log-quadratic model estimate of e_0 is 4.0 years lower than the unadjusted estimate for men and 4.3 years lower for women (Table 2).

We also fit the two-parameter log-quadratic model, using ${}_{45}q_{15}$ from LAMBdA as the second input. Note that we can compute these adjusted life tables only for 1995 and 2005 because LAMBdA estimates are not available for other years. The comparisons shown in Figure 7 demonstrate that LAMBdA produces the highest estimates of ${}_{45}q_{15}$. In 1995 the LAMBdA estimates were 11% higher than the HMD unadjusted estimates, while in 2005 the LAMBdA estimates were 9% higher for men and 13% higher for women (Table 3). We use the LAMBdA estimates as the second input to obtain the widest possible range of estimates; we cannot judge whether they are the most accurate estimates. The estimates of e_0 from the two-parameter log-quadratic model are generally similar to the one-parameter estimates.

Figure 7: Comparisons of estimated probability of dying between age 15 and 60 ($_{45}q_{15}$) by sex, Mexico, 1990–2016



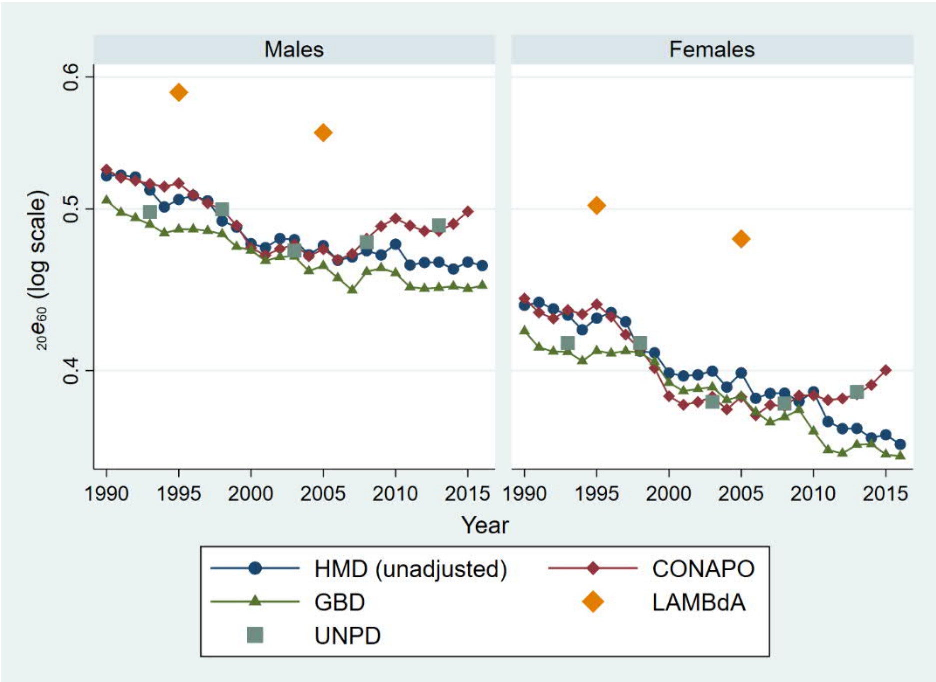
Sources: CONAPO (Consejo Nacional de Población 2018); GBD (Global Burden of Disease Collaborative Network 2018); LAMBdA (Palloni, Pinto-Aguirre, and Beltrán-Sánchez 2017); UNPD (United Nations, Department of Economic and Social Affairs, Population Division 2019).
Note: Estimates from the UNPD are based on life tables for five-year periods and are plotted at the midpoint of the period.

Table 3: Unadjusted and adjusted estimates of midlife mortality ($_{45}q_{15}$) by sex, Mexico, 1995 and 2005

	Midlife mortality ($_{45}q_{15}$)		Difference relative to unadjusted (%)
	HMD unadjusted	LAMBdA adjusted[a]	
Men			
1995	0.2005	0.2220	11%
2005	0.1739	0.1888	9%
Women			
1995	0.1127	0.1256	11%
2005	0.0976	0.1101	13%

Note: [a] Based on LAMBdA estimates.

Figure 8: Comparisons of estimated probability of dying between age 60 and 80 ($_{20}q_{60}$) by sex, Mexico, 1990–2016

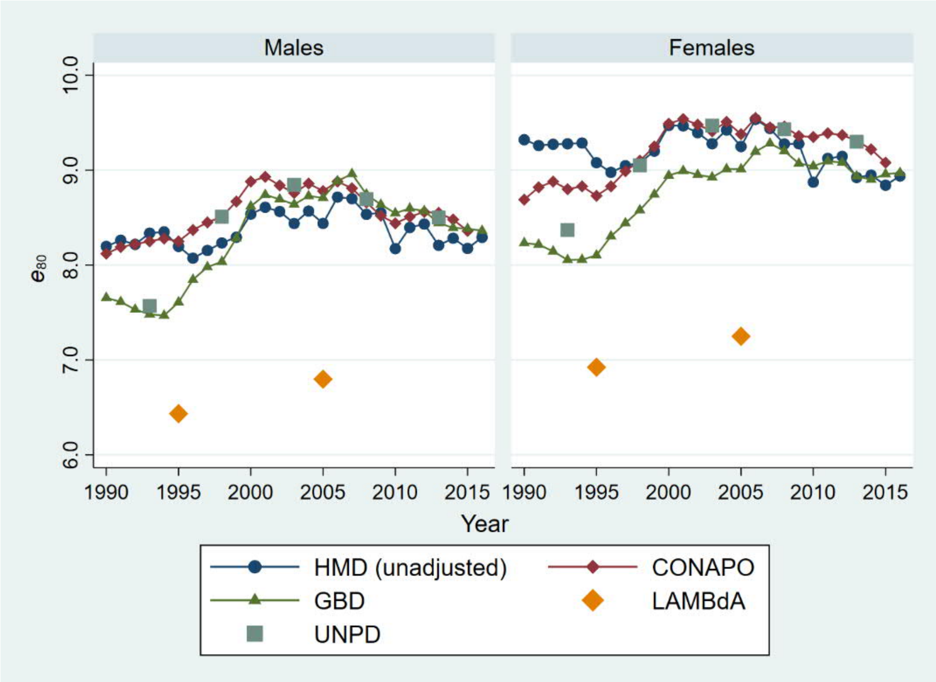


Sources: CONAPO (Consejo Nacional de Población 2018); GBD (Global Burden of Disease Collaborative Network 2018); LAMBdA (Palloni, Pinto-Aguirre, and Beltrán-Sánchez 2017); UNPD (United Nations, Department of Economic and Social Affairs, Population Division 2019).
Note: Estimates from the UNPD are based on life tables for five-year periods and are plotted at the midpoint of the period.

Among all the adjustments tested, the log-quadratic model produces the lowest estimates of e_0. Indeed, they are even lower than the LAMBdA estimates (Table 2). In 1995 the difference in life expectancy between the lowest adjusted estimate and the unadjusted estimate exceeded four years.

There are also substantial differences between unadjusted and adjusted estimates of old age life expectancy (e_{80}; Table 4). Again, the log-quadratic model estimates of e_{80} are even lower than the LAMBdA estimates. In 1995 the log-quadratic model estimates are nearly three years lower than the unadjusted estimates, and they are only slightly closer in 2005.

Figure 9: Comparison of life expectancy at age 80 (e_{80}) with external estimates by sex, Mexico, 1990–2016



Sources: CONAPO (Consejo Nacional de Población 2018); GBD (Global Burden of Disease Collaborative Network 2018); LAMBdA (Palloni, Pinto-Aguirre, and Beltrán-Sánchez 2017); UNPD (United Nations, Department of Economic and Social Affairs, Population Division 2019).
Note: Estimates from the UNPD are based on life tables for five-year periods and are plotted at the midpoint of the period.

Figure 10: Life expectancy at birth (e_0) by sex, Mexico (unadjusted estimates) compared with HMD populations, 1990–2016

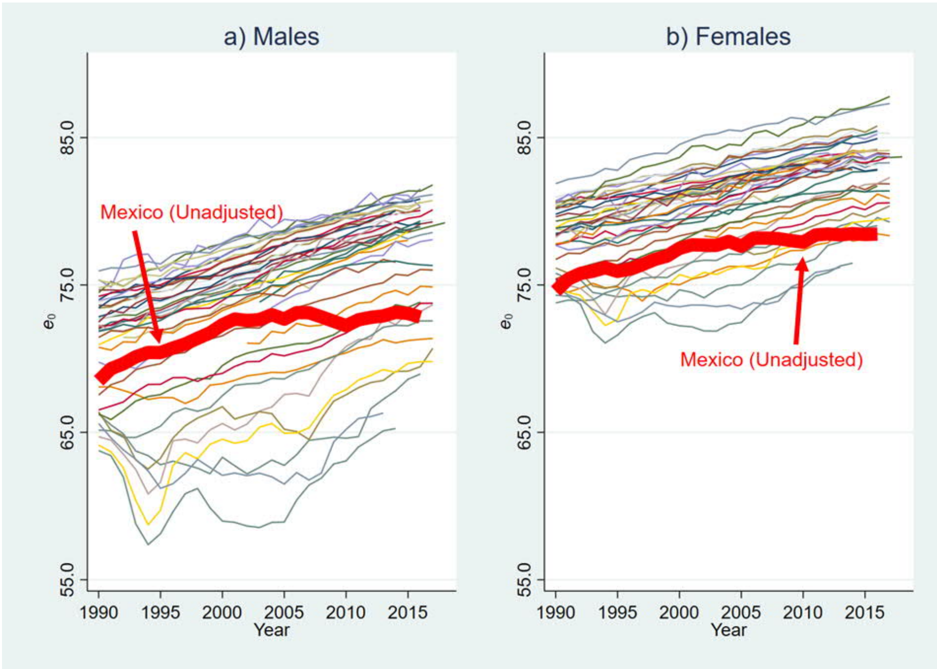
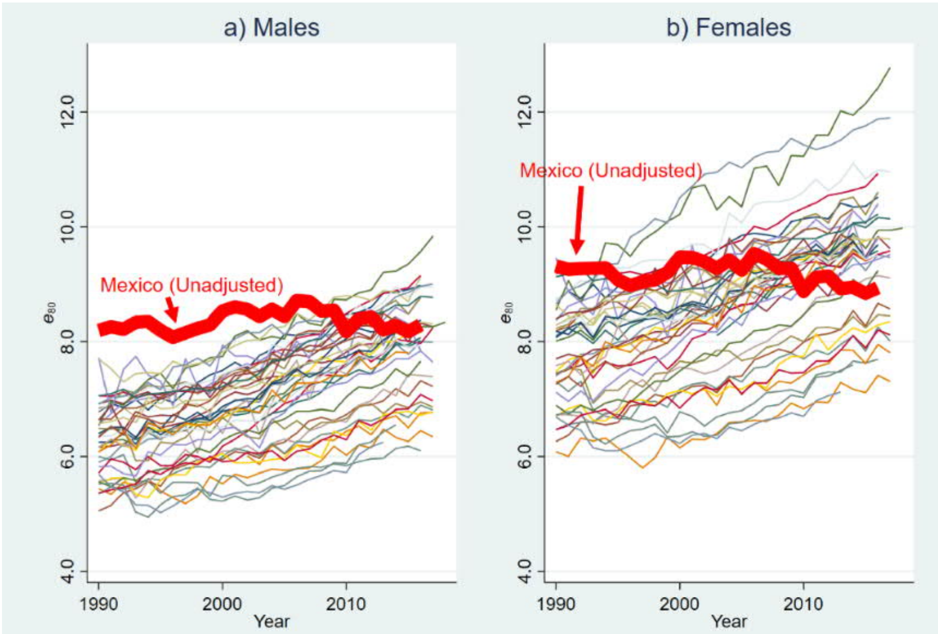


Table 4: Unadjusted and adjusted estimates of e_{80} by sex, Mexico, 1995, 2005, and 2015

	1995		2005		2015	
	Men	Women	Men	Women	Men	Women
<u>Estimates of e_{80}</u>						
Unadjusted	8.2	9.1	8.4	9.2	8.2	8.8
1-parameter log-quadratic model[a]	5.4	6.2	5.7	6.7	6.0	7.1
2-parameter log-quadratic model[b]	5.4	6.2	5.8	6.7	N/A	N/A
LAMBdA estimates	6.4	6.9	6.8	7.2	N/A	N/A
<u>Difference (unadjusted – adjusted)</u>						
1-parameter log-quadratic model[a]	–2.8	–2.9	–2.7	–2.5	–2.2	–1.7
2-parameter log-quadratic model[c]	–2.8	–2.9	–2.7	–2.5	N/A	N/A
LAMBdA estimates	–1.8	–2.2	–1.6	–2.0	N/A	N/A

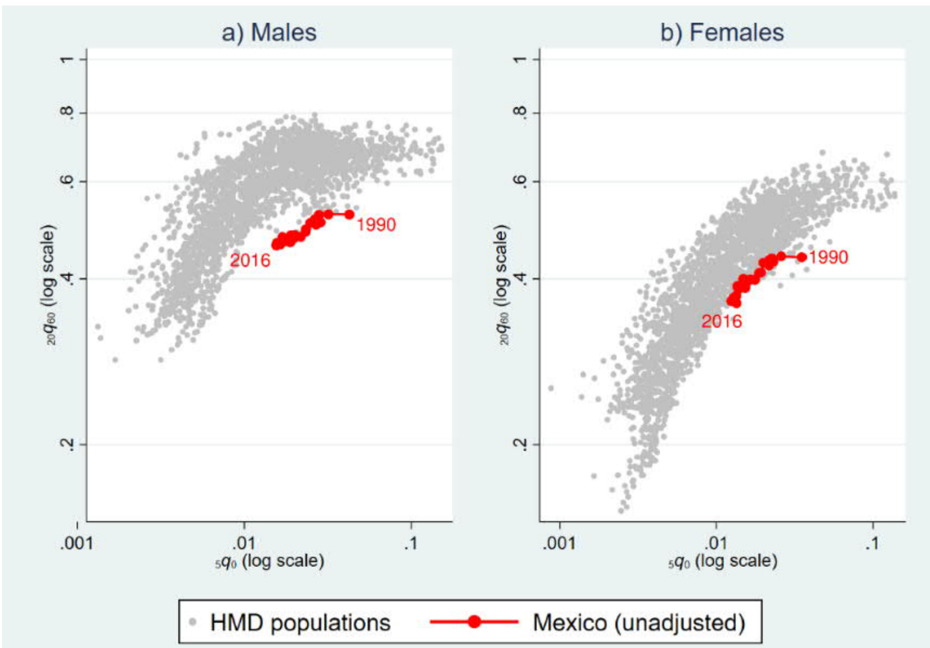
Note: N/A = not available.
[a] Using the adjusted $_5q_0$ (based on IGME; see Table 1) as the input, with *k* set to 0.
[b] Using the adjusted $_5q_0$ (based on IGME) and LAMBdA estimates of $_{45}q_{15}$ (see Table 3) as the inputs.

Figure 11: Life expectancy at age 80 (e_{80}) by sex, Mexico (unadjusted estimates) compared with HMD populations, 1990–2016



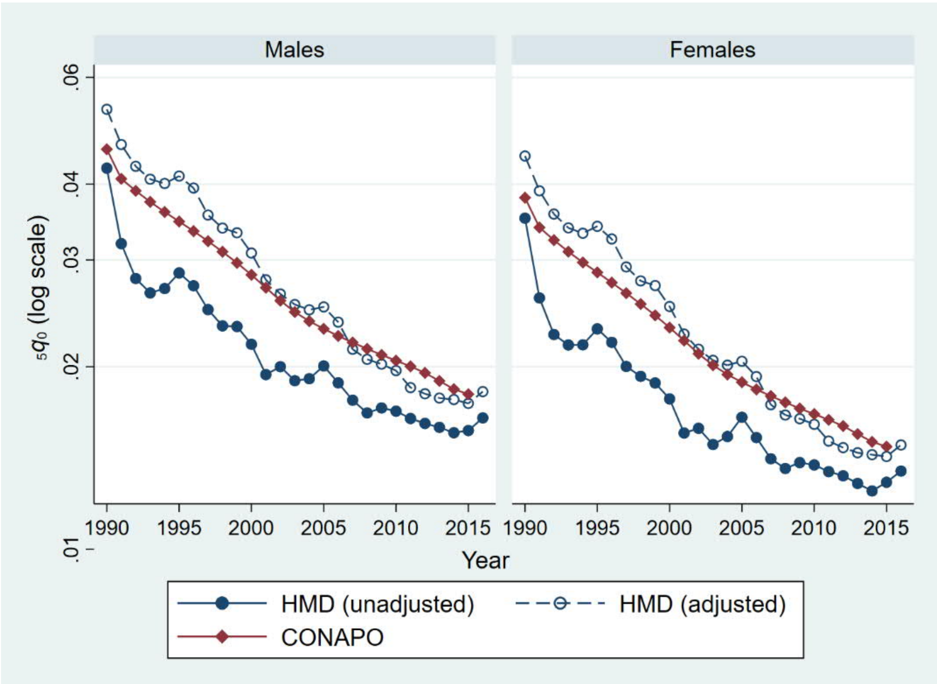
It is comforting that the estimates based on the one-parameter and two-parameter log-quadratic models are similar, yet we suspect that the one-parameter model may still underestimate mortality in young to mid-adulthood, particularly in recent years among men. Aburto and Beltrán-Sánchez (2019) reported that homicides between ages 15 and 49 played the biggest role in the slowdown in recent gains in life expectancy among males. In fact, the effect of homicide in Mexico is likely to be underestimated because of undercounting, underreporting, and the disappearances of large numbers of people (Aburto et al. 2016; Steinburg 2011, 2013). Although homicide rates among men declined between 1995 and 2006, they surged again after that, more than doubling between 2007 and 2012 (Aburto and Beltrán-Sánchez 2019). Thus the age pattern of mortality in Mexico may be atypical (with midlife mortality higher relative to old age mortality than is observed in most countries of the world). Consequently, the log-quadratic model may not fit well for Mexico in the same way that Wilmoth et al. (2012) found it did not fit well for the Soviet Union and Eastern Europe, where working-age adults have had higher relative mortality than other high-income populations. Although the two-parameter version might better replicate the age pattern of mortality in Mexico, it requires that we have reliable estimates of midlife mortality.[15] Thus the estimates based on the log-quadratic model could be biased for two primary reasons: (1) the estimates of mortality at young to mid-adult ages may be underestimated, especially among men in recent years, because of undercounts of homicide; and (2) the model may not fit well for Mexico because the ratio of mortality at younger ages (15–49) relative to older ages may be much higher than the patterns observed prior to 2008 in the high-income countries that were originally used to fit the log-quadratic model.

Figure 12: Child mortality ($_5q_0$) by old age mortality ($_{20}q_{60}$) by sex, Mexico (unadjusted, 1990–2016) compared with HMD populations (post-1950)



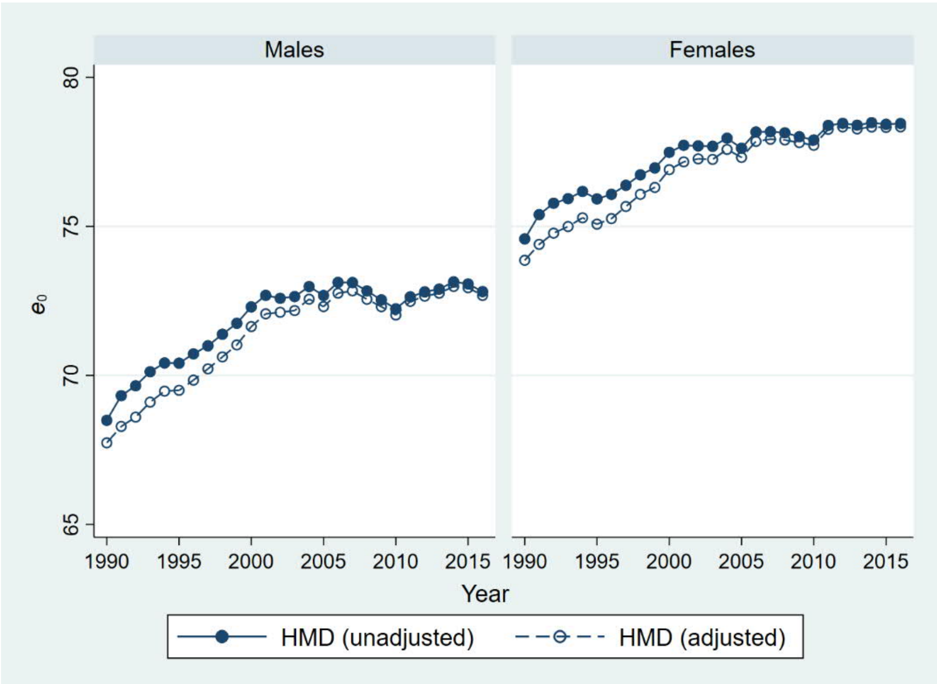
[15] Clark (2019) proposed an alternative singular value decomposition component-based model (SVD-Comp) to estimate single-year-of-age mortality schedules using either child mortality ($_5q_0$) or both $_5q_0$ and adult mortality ($_{45}q_{15}$) as predictors. However, it is not clear to us how that alternative method would address the problem of exceptionally high mortality among young adults. One would still need a reliable estimate of mortality at those ages. In one of his example applications, Clark (2019) applies his SVD-Comp method to Mexico in 1983–1985; he finds that the results are nearly identical to those produced by the log-quadratic model (Wilmoth et al. 2012). Clark uses an estimate of $_{15}q_{45}$ extracted from the Human Life Table Database. There is no way of verifying the accuracy of that estimate; if the estimate is biased, then the results from either model (log-quadratic or SVD-Comp) are biased.

Figure 13: Comparison of $_5q_0$ (unadjusted and adjusted) with CONAPO estimates by sex, Mexico, 1990–2016



Note: HMD estimates were adjusted for child mortality (below age 5) by substituting the estimated death counts at ages 0 and 1–4 from IGME (www.childmortality.org) in place of the registered death counts below age 5.

Figure 14: Comparison of e_0 (unadjusted and adjusted) by sex, Mexico, 1990–2016



Note: HMD estimates were adjusted for child mortality (below age 5) by substituting the estimated death counts at ages 0 and 1–4 from IGME (www.childmortality.org) in place of the registered death counts below age 5.

7. Conclusion and discussion

The unadjusted mortality rates for Mexico look suspiciously low at all ages, but especially at the beginning of life. The age pattern of mortality (i.e., the relationship between child and old age mortality) also appears unusual compared with the 41 HMD populations, especially for men. Unadjusted estimates based solely on registered deaths and census counts are likely to underestimate mortality in Mexico, even in recent years.[16]

[16] Although migration can affect the accuracy of census and death counts, it is likely to be more of a problem for data at the regional level than at the national level. The timing of the census is likely to be important because many emigrants return to Mexico in November for the holidays and then emigrate to the United States in

We find evidence that infant and child mortality is substantially underestimated. All the external estimates for q_0 (from CONAPO, LAMBdA, UNPD, and IGME) have been adjusted using a variety of direct and indirect methods. Adjusted estimates of mortality below age 5 derived by IGME using direct and indirect methods are up to 48% higher (among girls in 1995) than our unadjusted estimates. Even in 2015, the IGME adjusted estimates remain at least 10% higher than our unadjusted estimates.

Our analysis suggests that unadjusted rates may also underestimate mortality at prime adult ages, but it is difficult to determine the magnitude because adjusted estimates vary depending on the methods. Our unadjusted estimates of mortality between ages 15 and 60 are at least as high as those published by GBD and the UNPD, but they are notably lower than estimates by LAMBdA. Adjusted estimates of mortality between ages 15 and 60 are up to 13% higher than our unadjusted estimates. We cannot determine which sets of estimates are the most accurate, but the wide range of estimates indicates a high level of uncertainty.

Finally, mortality rates at the oldest ages also appear to be underestimated. Evidence of age heaping and suspicious patterns in comparisons of the levels and trends in e_0 and e_{80} lead us to suspect age exaggeration. For example, our estimates of e_{80} for Mexico prior to 2010 are higher than for Sweden even though e_0 is far lower. Unadjusted estimates of mortality at older ages (${}_{20}q_{60}$) are also notably lower than adjusted estimates published by LAMBdA. Between ages 60 and 80, the LAMBdA estimates are as much as 20% higher than our unadjusted estimates. Similarly, our estimates of e_{80} tend to be higher (implying *lower* mortality) than most other estimates, especially prior to 1995. LAMBdA estimates of life expectancy above age 80 are up to 24% lower than our unadjusted estimates.

In this paper, we tested various adjustments to mortality. First, we substituted IGME-adjusted estimates for child mortality (below age 5), which reduced e_0 in 1995 by 0.9–0.8 years. Second, we fit the log-quadratic model based on IGME estimates for child (age < 5) mortality and LAMBdA estimates for midlife (ages 15–60) mortality, which yielded estimates of e_0 in 1995 that were 3.8–4.4 years lower than the unadjusted values. We used LAMBdA estimates for this adjustment to provide the widest possible range of estimates; we do not intend to imply that they are the most reliable estimates. In terms of

February or March. The last two censuses (October 17, 2005, and June 12, 2010) were conducted outside of the holiday migration period, but some previous censuses were conducted in February (February 14, 2000), March (March 12, 1990), and November (November 5, 1995). All the census counts (and vital statistics) represent the de jure population. Thus all permanent residents of Mexico should be included in census and vital statistics, even if the individual is living outside of Mexico at the time of the census or death. However, censuses conducted between November and March are more likely to fully capture the population that migrates to the United States every year. If a permanent resident of Mexico dies in another country, it is possible that their death is not recorded in the national vital statistics system in Mexico. Although we have no way of estimating the magnitude of the potential error, we suspect it is fairly small because most migrants are healthy, working-age adults.

the effects on old age mortality, the log-quadratic model again produced the lowest estimates of e_{80}, which were nearly three years lower than the unadjusted estimates in 1995.

Such adjustments may improve the accuracy of the mortality estimates, but it is impossible to fully validate the results. We cannot adjudicate whether one set of adjusted estimates is closer to reality than another. Given variability in the level of mortality estimated by diverse institutions and evidence of unusual mortality patterns, we are unlikely to be able to definitely determine the level of life expectancy in Mexico until the reliability of basic national statistics improves.

8. Acknowledgments

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