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Trends in World Inequality in Life Span Since 1970
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ABSTRACT

Previous research has revealed much global convergence over the past several decades in life expectancy at birth and in infant mortality, which are closely linked. But trends in the variance of length of life, and in the variance of length of adult life in particular, are less well understood. I examine life-span inequality in a broad, balanced panel of 180 rich and poor countries observed in 1970 and 2000. Convergence in infant mortality has unambiguously reduced world inequality in total length of life starting from birth, but world inequality in length of adult life has remained stagnant. Underlying both of these trends is a growing share of total inequality that is attributable to between-country variation. Especially among developed countries, the absolute level of between-country inequality has risen over time. The sources of widening inequality in length of life between countries remain unclear, but signs point away from trends in income, leaving patterns of knowledge diffusion as a potential candidate.

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The past 50 years have brought an enormous amount of global convergence across countries in life expectancy at birth, e_0, the unconditional average length of human life (Wilson, 2001; Goesling and Firebaugh, 2004). There are exceptions, as remarked by Moser, Shkolnikov and Leon (2005) and Ram (2006). The impact of HIV/AIDS in Africa and the collapse of the Soviet Union in the 1990s contributed to some divergence in e_0 after 1980, even while convergence in infant mortality continued apace. But viewed over longer periods of time, the picture is one of sustained advances. During a time when life expectancy has grown very rapidly among rich countries, at a rate of about 0.2 year of life each year since 1955 (White, 2002), life expectancy in developing countries has grown even faster. The gap in average life span between the richest and poorest nations has declined from about 35 years in 1950 to 23 years today (Wilson, 2001), accounting for an additional 0.24 year of life each calendar year, or more than a doubling of the rate among advanced countries. Global convergence across countries in e_0 contrasts with divergence and bimodality in income per capita (Barro and Sala-i-Martin, 1992; Pritchett, 1997). In a widely remarked study, Becker, Philipson and Soares (2005) report that accounting for the economic value of gains in life expectancy produces more worldwide convergence across countries in “full income,” a measure that comprises both real income and the value of life expectancy.

But trends in life expectancy at birth only speak to one component of overall world inequality in length of life, namely between-country variation in the total length of life starting from birth. Within-country variation is also important and can be measured using the distribution of life-table deaths. Wilmoth and Horiuchi (1999) assess within-country variation in length of life among industrialized countries using an array of statistics including their preferred measure, the interquartile range (IQR). They show that the IQR fell dramatically in the U.S., Sweden, and Japan during the epidemiological transition that started after 1870, but that it had plateaued by 1950, suggesting little evidence of rectangularization in survivorship at an upper limit on length of life. Shkolnikov, Andreev and Begun (2003) perform similar analysis on high-quality data from advanced countries using the Gini coefficient as their preferred index, and they report similar results.

There are also important differences between unconditional variation in length of life, i.e. starting from birth, which these earlier studies have examined, and variation conditional on surviving past infancy, or “adult” variation. Edwards and Tuljapurkar (2005) show that among advanced countries in the Human Mortality Database or HMD (2009), the variance in adult length of life, which they measure with S_{10}, the standard deviation in length of life past age 10 based on the period life table, fell rapidly prior to 1960 during the epidemiological transition but remained stagnant afterward, with large differences across countries in the level of S_{10}. Edwards and Tuljapurkar also show that S_{10} is increasingly responsible for lingering divergence in mortality among advanced countries, and Edwards (2008) argues that higher adult variance represents a real welfare cost. Smits and Monden (2009) focus on mortality above age 15 in a broad cross section of countries in 2000 using new estimates developed by Lopez et al. (2002), and in a narrow panel of high-income countries over time using the HMD. They find large differences across countries in the level of within-country inequality in adult length of life, which they measure using the Gini and Theil (1967, 1979) indexes, both in the large cross section and in the subset of industrialized countries.

In this paper I assess and decompose trends in global inequality in length of life by constructing a new balanced panel dataset that covers 180 countries around 1970 and in 2000. I combine high-quality data from the HMD and similar datasets with data from model life tables, checking results for robustness to data quality. Like Wilson (2001) and Sala-i-Martin (2006), I weight statistics by population, so my focus is on global inequality in human length of life rather than inequality between countries. But through a decomposition analysis, I find that variation between countries has played a very important role in global inequality.

The data reveal that inequality in total length of life starting from birth has unambiguously decreased since 1970 for the world as a whole and for advanced countries with high-quality data. But beneath this felicitous result lie two important findings. Inequality in length of adult life has remained steady or even widened during this period, depending on the type of inequality measure I use and the subsample. And while the share of inequality attributable to within-country differences has decreased over time, as is consistent with the demographic and epidemiological transitions underway in developing countries, the share attributable to between-country inequality has unambiguously increased. Patterns of widening inequality are especially strong among developed countries with high-quality data.

Data sources

Data limitations complicate the assessment of trends in global inequality in length of life and its components. Mortality statistics in developing countries are rare and often of questionable quality even for contemporary periods, let alone historical ones. But Lopez et al. (2002) have significantly improved the quality and scope of current estimates of life tables in developing countries, work that has facilitated efforts by Smits and Monden (2009) and others to examine cross-sectional trends worldwide. The contributions of Lopez et al. (2002) and Murray et al. (2003) represent further refinements of a rich tradition of modeling life tables that notably includes the earlier work of the United Nations Population Division (1982) and Coale and Demeny (1983). Model life tables are certainly imperfect tools for assessing the shapes of survivorship curves. But they are the best tool available for many developing countries, they remain widely used, and we know they are useful for a variety of purposes. Coale (1991) and Coale and Banister (1994) use them to estimate the number of "missing females" in China and other developing countries, for example. In the absence of a mortality crisis like HIV/AIDS or that associated with the collapse of the Soviet Union, model life tables are likely to provide a reasonable indication of underlying conditions.

Many databases report historical measures of life expectancy at birth, e_0, for developing countries that are derived from model life tables, but none appear to report the full model life tables themselves. To reconstruct these estimates, I matched levels of e_0 in 1970 as reported by the United Nations Population Division (2006) to model life tables using their country-specific assumptions published in the Analytical Report. For 78 out of 180, or 43 percent of countries in the dataset, I observe a model life table in 1970, with 65 observations based on Coale and Demeny (1983) regional model life tables. Primarily located in sub-Saharan Africa, these 78 countries represented 20 percent of the world's population in 1970.

For 21 countries in 1970, I construct life tables based on vital statistics in the World Health Organization Mortality Database (2009). When appropriate, I rescaled the country's mortality schedule with a constant proportion in order to match e_0 in 1970 for both sexes combined as reported by the UN. I performed a similar type of rescaling for 20 historical life tables in order to translate the age shape of mortality measured in a later period back to where it probably was around

1970.[1] For the other 61 countries in 1970, I observe life tables based on high-quality data. Several papers in historical demography present estimates of historical life tables in developing countries (Vallin, 1975; Allman and May, 1979; Banister and Hill, 2004; Cheung et al., 2005). Murray et al. (2003) present a set of life tables compiled from the WHO collection, Preston, Keyfitz and Schoen (1972), and the United Nations Population Division (1982). High-quality life tables for 33 advanced countries are available from the Human Mortality Database (2009) over a broad range of years.

For coverage in the year 2000, I rely heavily on the World Health Organization Life Table Database (2009), which presents life tables based either on high-quality vital registration data when available, or on modeling techniques pioneered by Lopez et al. (2002). I use these life tables for 143 of the 180 countries in 2000. One observation, Puerto Rico, must be drawn from WHO Mortality data. For China and Taiwan, I use life tables from Banister and Hill (2004) and Cheung et al. (2005), to improve consistency with 1970 estimates. The remaining 33 countries in 2000 are included in the Human Mortality Database (2009).

For both years, population totals are provided by the UN Population Prospects database. When life tables for both sexes combined are unavailable, I construct them from sex-specific life table survivorship schedules weighted by sex-specific population. Similarly, life table aggregates for regions and for the world as a whole are based on population-weighted averages of country-level survivorship schedules. Appendix Table A-1 lists the 180 countries represented in the dataset, their World Bank region, the years of coverage, which sometimes differ from 1970 and 2000, and the data sources. Each country-year observation consists of a period life table for both sexes combined.

[1] When the underlying data are age-specific mortality rates, I raise or lower all mortality rates by the same proportion, a process that changes life expectancies but leaves the Gompertz slope and thus the variance in length of life unchanged (Tuljapurkar and Edwards, 2009). When the data only include survivorship, I reduce all ℓ_x above age 0 by the same additive amount, producing an additive vertical, or equivalently an additive horizontal, translation in survivorship. Both rescaling methods effectively impose additive translation of the length of life distribution, recentering life expectancies to official estimates while leaving unaffected S_{10} and other inequality measures that are invariant to additive change. Of these 41 observations I have translated to 1970, 14 are based on life tables for 1990 from the World Health Organization Life Table Database (2009), 17 are based on life tables in the early 1980s from Murray et al. (2003) or based on mortality rates from the World Health Organization Mortality Database (2009), and 10 are life tables in the early 1970s constructed using data from the WHO Mortality Database that had indicated a different e_0 than official estimates.

Methods

Inequality measures

A wide array of statistics are available to measure inequality. I focus on five that are frequently used in the literature: the standard deviation, S; the interquartile range, IQR; the Gini coefficient, G; the Theil index, T; and the average life years lost to death, $e^{\dagger}$, a measure introduced by Vaupel and Canudas-Romo (2003) that is related to life-table entropy as defined by Keyfitz (1985). Both the Gini and the Theil are widely employed in studies of income inequality, and Shkolnikov, Andreev and Begun (2003) discuss how to use the Gini to examine inequality in length of life. For present purposes, the single most important difference between these five measures of inequality is that several are invariant over proportional translations of the underlying distribution while the others are invariant over additive translations.

In a tradition dating back at least to Lorenz (1905), the literature on income inequality regards invariance over *proportional* change, also called "scale independence," as a centrally desirable characteristic (Foster and Sen, 1997). When the underlying good in question is income, which is typically measured in currency units, invariance over proportional change is desirable both from a practical perspective, given proportional exchange rates between currencies, and also from a utility-theoretic perspective (Atkinson, 1970), based on the way in which economists believe the extra enjoyment of additional money declines. Both the Gini, which is the area under the Lorenz curve plotting income shares against percentiles, and the Theil exhibit invariance over proportional change in the underlying distribution.

When the good in question is length of life, invariance over *additive* change appears to be the preferred characteristic among demographers and other social scientists. Level differences in life expectancy between groups defined by race (Preston and Taubman, 1994), sex (Glei and Horiuchi, 2007), education (Meara, Richards and Cutler, 2008) or some characteristic are the focus, not proportional differences.[2] The standard deviation, the IQR, and the average years lost to death,

[2] The precise reasons for this preference are unclear. Proportional differences in age-specific mortality rates roughly translate into additive change in life expectancy (Vaupel and Canudas-Romo, 2003), but the fact this correspondence is true offers no particular normative justification for why such a measure should be a preferred indicator of inequality. In advanced countries, temporal trends in mortality rates are roughly proportional (Lee and Carter, 1992), while they are approximately linear in life expectancy (White, 2002). If our definition of stable inequality meant that all groups experienced the same trend in their mortality or survivorship, then we should prefer measures of inequality that are invariant over additive change in the case of life expectancy or over proportional change in the case of mortality rates.

$e^\dagger$, are all invariant over additive change in the distribution of length of life.

All five measures, whether invariant over proportional or over additive change in the underlying distribution, may agree on trends in inequality in length of life. But it is equally possible that the additive and proportional measures might disagree. Suppose for example that the long-lived and the short-lived within a population were both to gain the same number of average life years through a reduction in old-age mortality that increased each group's life expectancy by the same amount, without any change to the shape of either length of life distribution.[3] Additive measures of inequality like the standard deviation, $e^\dagger$, and the IQR would register no change in inequality; each group gains the same level amount, so inequality would be unchanged. But proportional measures like the Gini and Theil would decrease because the short-lived have gained proportionately more life years than the long-lived, having started with fewer. Demographers are likely to interpret the fixed gap in life expectancy from this example as indicative of stable rather than narrowing inequality, but the issue is open to interpretation.

Decomposing inequality across countries

Several of these five measures are decomposable into within and between-group components. I choose two measures for a decomposition analysis, the standard deviation and the Theil, because the former is invariant to additive change and the latter to proportional change. Technically speaking, it is the square of S, or the variance, V, that is additively decomposable into within and between-country components, but I report the standard deviation because its level is more intuitive. The global variance of length of life τ over all individuals equals the sum of the expectation over the j countries of the variance across individuals within country j, plus the variance over countries of the within-country mean across individuals:

$$V[\tau] = E_j\left[V_i(\tau|j)\right] + V_j\left[E_i(\tau|j)\right], \tag{1}$$

From a utility-theoretic perspective, canonical economic models of intertemporal preferences and behavior suggest that invariance over additive change would be a preferable characteristic of any measure of inequality over length of life (Edwards, 2008, 2009).

[3] This would appear as a rightward (additive) shift in the length of life distribution. Such a dynamic is not the historical pattern in mortality decline during the demographic transition, when reductions in infant and child mortality are very important, but it broadly fits patterns in advanced countries since 1960 (Edwards and Tuljapurkar, 2005). Bongaarts (2005) proposes a model of mortality forecasting that embeds such a principle.

where the moments are all weighted by the populations of the i countries. This decomposition is neatly intuitive: the average variance in the first term is the within-country component, while the variance in the country means in the second term is the between-country component.

The Theil (1967, 1979) entropy measure used by Pradhan, Sahn and Younger (2003), Smits and Monden (2009), and others is defined for country j as the expectation across individuals of the log of the within-country expectation divided by length of life:

$$T|j = E_i \left[\log \left(\frac{E_i[\tau|j]}{\tau} \right) \right]. \tag{2}$$

The Theil also additively decomposes into within and between-country inequality:

$$T = E_j \left[T|j \right] + E_j \left[\log \left(\frac{E[\tau]}{E_j[\tau]} \right) \right], \tag{3}$$

where the first term is the population weighted average across countries of the within-country Theil, and the second is the Theil computed on the variation in average τ between countries relative to the global average. As before, the first term is the within-country inequality, and the second is the between-country.

As discussed by Smits and Monden (2009), within-country inequality in length of human life tends to be the larger component of the two. In addition to inequality between homogeneous subgroups within a country, however defined, the measure will also capture all "natural" inequality one might find within any homogeneous subgroup of humans. The relative universality of the Gompertz Law within living organisms (Finch, Pike and Witten, 1990), or positive and finite increases in mortality through age, suggests that such natural inequality could be relatively large.[4]

Total versus adult mortality

Edwards and Tuljapurkar (2005) and Smits and Monden (2009) argue for treating infant and adult mortality separately. The two are etiologically distinct, and we also know that patterns of cross-country convergence in infant mortality and e_0 have not always agreed during recent decades

[4] As discussed by Tuljapurkar and Edwards (2009), there is an inverse relationship between the Gompertz slope of log mortality and the variance in length of life. Thus the fact that the Gompertz slope is always finite in living organisms suggests that some "natural" inequality in length of life is unavoidable. One could interpret this natural inequality as inherent uncertainty about health deriving from internal biological processes.

(Moser, Shkolnikov and Leon, 2005). The incidence of HIV/AIDS is a good example of why we should examine infant and adult mortality separately; while the disease can affect very young children through prenatal exposure, it is primarily transmitted between adults. Because infant mortality is always fixed in a particular age range, including it in measures of inequality of length of life tends to draw attention away from important trends in the distribution of adult life span.

In order to isolate trends in adult mortality, I calculate inequality statistics on truncated distributions of length of life above age 10, in addition to measuring inequality using the entire unconditional distribution. As Edwards and Tuljapurkar (2005) discuss, age 10 is an arbitrary but perfectly reasonable cutoff age; the important issues are that the cutoff age be not so small as to pick up the influences of infant mortality, and not so large as to impart bias through the rightward shifting of the old-age mode.

Results

World distributions of length of life

The world distributions of length of life in 1970 and 2000 are depicted graphically in Panel A of Figure 1. These curves are the probability distributions of world life-table deaths in each year, derived from population-weighted survivorship probabilities by age averaged across the 180 countries in the dataset. Panel B of Figure 1 shows the probability distributions above age 10, each of which have been rescaled so that the sum of density above age 10 equals 1.

Three dynamics are visible in Panel A, but only one is echoed in Panel B, which is restricted to adult mortality. First, Panel A reveals large reductions in infant and child mortality between 1970 and 2000, as evidenced by the shortening of the left-hand mode at age 0. Second, the old-age mode centered roughly around age 70 has risen in height over time, reflecting more density heaped on and around the old-age mode. This could reflect either the reduction in infant mortality,[5] or a reduction in adult variance, or it could reflect both dynamics. Third, the distribution around the old-age mode appears to have shifted rightward by about 4 or 5 years at most ages, although it is difficult to be precise because the data are arrayed in 5-year age groups. Technically, the mode in

[5] I am implicitly assuming that death in infancy is independent from death at older ages, which is likely true only in the synthetic cohort of a period life table. Finch and Crimmins (2004) and others have demonstrated that old-age mortality is often related to early-age mortality in a birth cohort.

both years is at ages 75 to 80.

Of these three dynamics visible in Panel A, only the last appears in Panel B. That is, once I condition out the large reductions in infant mortality during the period, the dominant pattern is a rightward, additive translation of densities around the old-age mode that appears not to have significantly changed the spread. While infant mortality has declined dramatically and no doubt brought down total world inequality in length of life, variance in the length of adult life seems not to have declined by much at all.

The visual story that emerges is confirmed by statistics. The columns of Table 1 report characteristics of the full sample in both periods, of the subsample of 61 countries with actual rather than model life tables in both periods, and of the subsample of 33 countries represented in the Human Mortality Database (2009). Each successive sample restriction improves the quality of the underlying data, and as usual, data quality is positively related to level of development, revealed by trends in real GDP per capita in the bottom row of the top panel. As shown in the top row of the middle panel, average life expectancy at birth, e_0, increased across all subsamples, from 58.8 to 66.9 or 8.1 years in the full dataset, from 61.4 to 69.9 or 8.4 years in the sample without model life tables, and from 70.7 to 75.8 or 5.1 years in the high-quality HMD.[6] Average life expectancy conditional on surviving to age 10 also increased, but the increases were smaller and more stable across subsamples. This is shown in the top row of the bottom panel, which reports the mean length of life above age 10, M_{10}. This measure, which equals remaining life expectancy at age 10 plus 10 years, rose by roughly 4 between 1970 and 2000 in each subsample.

The middle panel of Table 1 displays the five inequality statistics measured over the entire distribution of length of life. Nearly all statistics, proportional and additive alike, register reductions in total inequality in each sample during the period. The exception is the interquartile range measured over HMD countries. The IQR registers a different trend because of the strong relationship between unconditional variation in length of life and infant mortality, which was already very low in the HMD countries; changes in a very small probability of death in infancy change the IQR very little. In all 180 countries and in the subset of 61 countries with actual life tables, increases

[6] By comparison, the World Bank's World Development Indicators database reports world e_0 at 59.1 in 1970 and 67.3 in 2000, while the United Nations Population Division (2006) lists statistics for five-year time intervals that imply world $e_0 = 57.2$ in 1970 and $e_0 = 65.0$ in 2000. The annual rates of increase in e_0 implied by these figures are 0.270 for all 180 countries, 0.282 for the 61 with no model life tables, and 0.170 for the HMD countries. White (2002) reports an average rate of 0.208 per year for 21 OECD countries between 1955 and 1996.

in survivorship at age 10, ℓ_{10}, were substantial, as shown in the bottom row of the middle panel. Survivorship at age 10 began the period around 0.87 and rose 7 percentage points in both of these samples, but for the HMD countries, ℓ_{10} rose only about 2 percentage points, from 0.972 to 0.990.

The bottom panel in Table 1 reveals trends in the five inequality statistics measured over the conditional distribution of length of life above age 10. The three additive measures, the standard deviation, the IQR, and the average life years lost, $e^{\dagger}_{10}$, register either roughly steady or even increasing inequality for all samples, a notable departure from earlier results. The standard deviation above age 10, S_{10}, falls by 0.2 year from 17.0 to 16.8 in the full sample, by 0.2 year in the sample with no model life tables, and actually rises from 15.1 to 15.4 among HMD countries. The IQR and $e^{\dagger}_{10}$ behave similarly, falling only slightly in the broader samples and rising among the HMD countries. The stagnation in inequality implied by these additive measures reflects what we saw in the Panel B of Figure 1, namely the rightward shift of densities around the old-age mode that left variance basically unchanged.

By contrast, the proportional measures of inequality, the Gini and the Theil, decline across all samples in the bottom panel of Table 1, which conditions out infant and child mortality. This follows intuitively from the combination of roughly stable additive inequality, S_{10}, and increases in the average length of life, M_{10}. Proportional inequality, which can be conceptualized as approximately the ratio of the two, must have fallen in this case because the denominator increased even though the numerator remained basically unchanged. This is a different story than what emerged in the middle panel of Table 1, where additive and proportional measures of total inequality from birth were both decreasing in tandem. In that case, proportional inequality fell for two reasons: the numerator, S_0, was falling while the denominator, e_0, was rising. Because average length of life is typically rising over time in this manner, proportional indexes are poorly equipped to reveal the underlying trend of stagnation in S_{10} and other additive indexes measured over adult ages.

The stagnation in world S_{10} that we see in Figure 1 is a novel finding that could reflect a variety of potentially countervailing influences. One possibility is that all region or country-specific distributions of length of life above age 10 have shifted rightward by roughly equal amounts, leaving both the within and between-country components, as well as total inequality, unchanged. Recent trends in S_{10} among advanced countries suggest this story might fit at least that subset (Edwards and Tuljapurkar, 2005), and the evidence in Table 1 is partially supportive. But such a scenario seems unlikely to fit a broad panel of rich and poor countries. We know that the epidemiological transition typically brings with it a large amount of mortality compression (Wilmoth and Horiuchi, 1999; Edwards and Tuljapurkar, 2005). Stagnation in world S_{10} could also result from diverging but perfectly offsetting trends in the within and between-country components of inequality in adult length of life. Or the story may vary by level of development. In the next sections, I examine distributions by world region and decompose total inequality into within and between-country components to explore these questions.

Distributions by region

The seven panels in Figure 2 plot distributions of length of life from birth in 1970 and 2000 for the seven regions defined by the World Bank.[7] A visual comparison with Panel A in Figure 1 reveals some similarities between world and regional trends in several cases, and also a number of notable differences. Trends in East Asia and the Pacific, trends in the high income group, and to some extent trends in the Middle East and North Africa, shown in Panels A, C, and E, look much like the world trends visible in Panel A of Figure 1. All these plots show declining infant mortality combined with a rightward and upward shifting of densities around the old-age mode. A similar dynamic is present but not as clearly visible for Latin America and the Caribbean, shown in Panel D, where top-coding of the life tables at ages 85 and over, which produces a heaping of density, is prevalent in 1970. In South Asia, shown in Panel F, variance around the old-age mode appears to have remained relatively high, but the mode has still shifted rightward as infant mortality has fallen.

The notable differences here are in Europe and Central Asia, shown in Panel B, and in sub-Saharan Africa, in panel G. In the former, which comprises Russia and the former Soviet republics, European countries previously behind the Iron Curtain, and Turkey, there is little visual evidence of any change in the distribution between 1970 and 2000. What little there is suggests a widening. In sub-Saharan Africa, we see a reduction in infant, child, and adolescent mortality, but a sharp increase in the probability of death between ages 20 and 60, and a very slight rightward shift of

[7] The World Bank categorizes countries based on geography and level of development. The "high income" group shown in Panel C consists of 47 geographically dispersed countries that roughly correspond to the OECD plus several developed countries in the Middle East and Taiwan. The other six regions comprise developing countries organized by geographic proximity. See Table A-1 for a listing of countries by region.

the distribution above age 60. In both of these world regions, mortality reductions appear to have been slight if not nonexistent.

Table 2 reports life expectancies and measures of variance for these regional distributions of life span. These statistics largely confirm the visual findings but also reveal several more subtle trends. As shown in the upper panel, average life expectancy at birth rose across all regions, but much of the gains were driven by increases in survivorship to age 10, ℓ_{10}. Adult life expectancy, measured here by the average length of life conditional on survival to age 10, M_{10}, actually fell in Europe and Central Asia and in sub-Saharan Africa. As shown in the bottom panel, gains against infant mortality produced reductions across the board in the standard deviation measured from birth, S_0, and in the Theil index measured from birth. But trends in S_{10} are more interesting. In two regions, S_{10} fell by relatively large amounts: by 1.3 years in East Asia and the Pacific, and by 2.7 years in the Middle East and North Africa. In four others, it either was largely unchanged or fell more gradually: by 0.6 in the high income countries, by 0.1 in Latin America and the Caribbean, by 0.6 in South Asia, and 0.4 in sub-Saharan Africa. And in Europe and Central Asia, S_{10} rose by 0.3 year. The Theil index above age 10 registers similar trends, agreeing on the increase in inequality in Europe and Central Asia but registering larger declines than in S_{10} for all other regions. This is because the mean length of life above age 10, M_{10}, was increasing for five of the seven regions.

It is striking that changes in S_{10} varied so much across regions and generally not in the manner suggested by historical patterns of development. As discussed by Wilmoth and Horiuchi (1999) and Edwards and Tuljapurkar (2005), the epidemiological transition ushered in monotonic declines in the IQR and in S_{10} for industrialized countries that ended around 1960. Based on this, one would expect countries or regions with high S_{10} to experience more rapid decline, a pattern that is not apparent in Table 2. A graphical exposition confirms this departure from historical patterns in the case of adult mortality. The two panels in Figure 3 depict scatter plots of the evolving relationship between the mean and standard deviation in length of life for world regions. Panel A graphs the relationship between S_0 and e_0, which is strongly downward sloping in the cross section, and regions have also moved down and to the right along the locus over time. That is, when measured from birth, variance has fallen and the average has risen monotonically for all regions over time. But Panel B reveals that the same is not true for the variance and average above age 10. Although the regions are still arrayed along a downward sloping line in the cross section, that relationship is not always reflected in the experiences of individual regions over time. Some regions gained higher average adult life expectancy and lower adult variance, moving southeast in the plot, while others gained only higher average and moved due east. Others either remained stationary or even lost ground on both fronts. While convergence in infant mortality has apparently brought fairly steady and universal improvements in total inequality and in life expectancy, there is evidence that adult mortality is diverging across regions.

Distributions by country

Some of the divergence in adult mortality that we see across world regions could reflect regional covariation among countries; those with high mortality probably occupy the same impoverished regions, for example. There is little evidence of any convergence in M_{10} or S_{10} among the seven World Bank regions shown in Panel B of Figure 3, but whether this is due to strong regional covariation or to small sample size is unclear. Across all 180 countries in the dataset, it turns out that there is evidence of convergence in S_{10}. This is shown in Panel A of Figure 4, which plots the change in S_{10} against its level in 1970 for all countries, with a superimposed trend line that I estimate with weighted least squares. The R^2 is only 0.145, but the bivariate relationship is strong; the slope coefficient of -0.238 has a t-statistic of -5.5. Because it contrasts with regional patterns, this evidence of convergence in within-country inequality in length of adult life tentatively suggests that region-wide sources of geographic variation may be important.[8]

Although within-country inequality appears to have fallen, between-country inequality has not. Considerably less cross-country convergence is apparent in Panel B of Figure 4, which plots the change in M_{10} versus its starting level. Here, the R^2 is 0.021, the slope is -0.106, and its t-statistic is -1.97, all reductions from the S_{10} regression. The variance in country-specific M_{10} represents the between-country component of inequality in adult length of life. In sum, Figure 4 reveals that within-country inequality in adult life span might have fallen due to convergence in S_{10}, but between-country inequality has probably risen because there has been much less, if any, convergence in M_{10}.

Especially the latter of these two patterns contrasts markedly with stronger convergence across

[8] If I include dummy variables for regions in the convergence regressions of changes on levels, the slope and the t-statistic in the S_{10} regression roughly double in magnitude. In the M_{10} regression, they increase by a factor of five. In both cases, regional dummies are highly statistically significant predictors of the change in M_{10} or S_{10}.

countries in life expectancy at birth, e_0, and in infant and child mortality, as shown in Figure 5. Panel A plots the change in e_0 against its initial level, while Panel B shows the same for survivorship to age 10, ℓ_{10}. In both cases, the weighted least squares trend lines are steeper, -0.271 and -0.486, the t-statistics on their slopes are -8.11 and -22.01, and the model R^2's are 0.270 and 0.731. There are outliers in each graph, but the relationships are demonstrably tighter than in Figure 4.

For a more formal analysis, I can decompose global variation in length of life into within and between-country elements using equations (1) and (3). I report the results in Table 3, where as before, I separately examine the full dataset of 180 countries and two higher-quality subsamples. The top panel shows decompositions of inequality in length of life starting from birth using the Theil and the standard deviation, and the bottom panel does the same for inequality above age 10. Because the square of the standard deviation is additively decomposable, the squares of the within and between-country components sum to the square of the total standard deviation; I report the proportion of total variance attributable to each piece.

The between-country share of inequality has grown in nine of the twelve decompositions depicted in Table 3, and in many cases, its absolute level has also grown. Both the Theil and the standard deviation register increases in the between-country share in most subsamples; the exception is the subset of 61 countries without model life tables. When the inequality measure is S_{10}, the between-country share still increases even in that subsample. The within-country share always remains significantly larger at usually more than 90 percent of the total, consistent with the findings of Smits and Monden (2009), but growth in the between-country share was often considerable. This was particularly true in the HMD subsample, which consists of relatively rich countries that had already completed their demographic and epidemiological transitions by 1970. Among those countries, both the Theil and the standard deviation, regardless of whether they are measured from birth or from age 10, record increases in the between-country share and in its absolute level.

The trends in the within and between-country components of world S_{10} can be viewed graphically in Figure 6. Panels A and C on the left show histograms of country-specific S_{10}, the average of which is the within-country variation. The weighted mean fell from 16.5 to 15.9 apparently due to faster reductions at the high end of the distribution, which was bimodal in 1970 but by 2000 had only a fat right tail. While this is not rapid convergence, it is more than we see in the between-country component, which is shown along the right in Panels B and D. There, the histogram of country-specific M_{10}, the variance of which is the between-country component of total S_{10}, clearly widened, with a fat left tail emerging by 2000. Visual evidence of convergence is practically nonexistent here; rather, it appears that some countries benefited from increases in adult life expectancy while others did not.

An open question is whether regional variation may be more important than country-level variation, in that one categorization may define more more homogeneous subgroups. One way to assess the importance of regional covariation across countries in explaining global inequality is to repeat the same decomposition exercise using world regions instead of countries and then compare results. If regional covariation is more important, in that similar countries are clustered together geographically, we would expect the between-region component of world S_{10} to be larger than the between-country component. In unreported results, I decomposed inequality by region and found that the between-region components were if anything slightly smaller than between-country components. It would appear that national boundaries are at least as useful as regional boundaries in describing the evolution of world inequality in length of life. This result is consistent with the result shown in Table 3 that between-country inequality is rising even among the uniformly high-income countries of the HMD, which roughly occupy a single region.

Discussion

This study reveals that convergence in length of life is not as universal a phenomenon as it may at first appear. To be sure, inequality in infant mortality appears to have fallen unambiguously, and trends in life expectancy at birth, which depend heavily on trends in infant mortality, generally imply much convergence over the past several decades (Moser, Shkolnikov and Leon, 2005; Wilson, 2001; White, 2002). But even the degree of global convergence in life expectancy from birth can depend on the choice of subsample and the inequality measure. Among rich countries with high-quality demographic data in the Human Mortality Database, for example, one measure of total inequality in length of life from birth, the inter-quartile range, registered an increase between 1970 and 2000. This is probably because infant mortality was already so low in those countries that the IQR is effectively measuring the spread in adult length of life.

When the focus shifts to adult length of life, as it ultimately must over the natural course of the mortality transition, there is considerably less evidence of convergence overall. The world distribution of length of life above age 10 shifted outward by an equal amount at all ages, roughly 4 years between 1970 and 2000, maintaining a stable world standard deviation of length of life above age 10, S_{10}, of about 16.9 years. The IQR and average life years lost, $e^{\dagger}_{10}$, register similar plateaus in world inequality. Because they are proportional indexes, the Gini and Theil often show declines in inequality surrounding adult length of life because the mean has increased while the variance has not. But among high-income countries, even the Gini and Theil show barely any progress against inequality in adult length of life, while S_{10}, the IQR, and $e^{\dagger}_{10}$ all register increases.

Regardless of the choice of measure, or whether we are considering length of life from birth or from age 10, it turns out that the between-country share of inequality appears to be rising in most subsamples over time. In the case of adult mortality, the absolute level of between-country inequality has risen. While we find that the average variance within countries has actually fallen over time in almost every instance, increases in the between-country component have been large, even large enough in some subsamples to raise total inequality in adult length of life. This result should be particularly troubling because the average variance within countries, which depends on the shape of the life table, is based on data of lower quality in the broad cross section, which includes countries with model life tables. And patterns of increasing between-country inequality are stronger among countries with high-quality data. Aggregating the country-level data into geographic regions defined by the World Bank region ultimately reveals a similar picture. There appears to be strong regional covariation among similar countries because they are located near one another, but the between-region variation in total inequality is no greater than the between-country variation.

In discussing the implications of these patterns, it is important to assess whether they reflect developments of which we were already aware. Wilmoth and Horiuchi (1999) and Edwards and Tuljapurkar (2005) both describe the inequality plateaus reached around 1960 by advanced countries that had completed their demographic transitions. Results here are unexpectedly reminiscent of those findings in some ways, but as such they are in fact provocative. There is little reason to expect developments in high income countries, which have reached more advanced stages of the demographic transition and represent only 15–20 percent of the world's population, to be at all representative of global trends. One would expect developing countries to experience reductions in S_{10} or the IQR during their epidemiological transitions. But while countries in some regions have, many others apparently have not. Aside from continued gains against infant mortality, the aggregate picture of world inequality in length of adult life since 1970 looks much like that of advanced countries. This is not a pattern we would normally expect to see unfolding during the natural course of the demographic and epidemiological transition.

The decomposition analysis is helpful in understanding this odd result. It turns out that the within-country component of total adult inequality has indeed been declining, as transition theory suggests it should. As high levels of variance within developing countries have declined, the average variance across countries has also fallen. While the decline in within-country inequality has perhaps not been as rapid as one might expect, the more pressing question seems to be why between-country inequality in adult length of life has risen across many subsamples.

In addition to the epidemiological transition underway in developing countries, there have been two other significant developments in world mortality since 1970 that are more like idiosyncratic shocks and less like general trends. The rise of HIV/AIDS starting in the 1980s ultimately led to a massive increase in adult mortality in an array of countries, especially in sub-Saharan Africa but not limited to that region. The collapse of communism in the early 1990s swept away social and political structures in much of Central and Eastern Europe and Asia and brought with it much economic and psychological upheaval. Either or both of these shocks, which typically affected adults more than infants and children and impacted some countries far more greatly than others, are clear candidates for explaining the rise in between-country inequality in adult length of life.

In both cases, these shocks can explain some of the patterns we see, but the robustness of results across subsamples complicates any attempt to decisively attribute between-country divergence to either explanation. In unreported results, I restricted the HMD subsample to the 22 countries that were not behind the Iron Curtain. I found that the standard deviation in M_{10} among this subgroup rose from 1.5 to 1.8, while the average S_{10} fell from 14.7 to 14.2. Even among Western nations, there were increases in between-country inequality.

In the case of HIV/AIDS, there is somewhat more evidence in favor of a blanket explanation, at least for developing countries. The United Nations Population Division (2006) identifies 60 countries as hardest-hit by HIV/AIDS, including much of Sub-Saharan Africa, China, and the U.S. Removing them from the analysis lowers both the within and between-country inequality components of S_{10}, and both components are falling over time, from 16.1 to 15.3 and from 5.3 to 4.7. But by contrast, removing countries hardest-hit by HIV/AIDS from the HMD sample, a subgroup that includes the U.S., Russia, and the Ukraine, does not qualitatively change results at all. In the HMD subsample without those three countries hardest-hit by HIV/AIDS, between-country inequality still rises from 1.6 to 2.7, while within-country inequality falls, from 14.3 to 13.9. It appears that HIV/AIDS can help explain between-country divergence in the broad cross section of rich and poor countries, but not in the subsample of rich countries alone.

It is tempting to search for a single explanation for these patterns, but the insights provided here imply that between-country divergence in average length of adult life may be associated with very different factors across different groups of countries or regions. Part of the phenomenon seems to be associated with advanced countries, which have reached a low-variance plateau and are now experiencing some divergence in the average length of adult life. Another part is attributable to developing countries languishing at high levels of variance and low average life expectancy, probably because of the ravages of HIV/AIDS. The underlying etiologic causes of between-country divergence thus seem likely to be distinct at different levels of development.

Still, extant patterns bear some tentative implications for understanding these trends, at least by revealing what is not responsible. If socioeconomic determinants of mortality were responsible for increasing variance between countries, one would expect them also to have raised variance within countries. Increased alcoholism, crime, or poverty would reduce the mean length of life within a country but probably should also raise the variance because each contributes to heightened uncertainty. As revealed by Edwards and Tuljapurkar (2005), lower socioeconomic status within the U.S. is consistently associated with reduced mean and increased variance in length of adult life, for example. We see some evidence of reduced average life coupled with increased variance in regional trends in Europe and Central Asia, but that is not the dominant trend. Reductions in within-country inequality coupled with increases in between-country inequality, such as we see in the data, are not particularly consistent with a story about socioeconomic determinants.[9]

In addition, trends in the world distribution of adult length of life appear to be quite different from trends in the world distribution of income. Theil (1979) and Sala-i-Martin (2006) report

[9]By this logic, the spread of HIV/AIDS also seems like less of a coherent explanation because communicable infectious diseases also simultaneously lower the mean and raise the variance of length of life. We see traces of this within sub-Saharan Africa, but even there the evidence is not entirely compelling. If HIV/AIDS were singularly important, we would expect to find increases in both within and between-country components of inequality, and reality is more complicated.

that the within-country component of world income inequality is smaller than the between-country piece, which is the reverse of what we see here. More importantly, Sala-i-Martin (2006) reveals that the within-country component has been increasing over time while the between-country component has fallen, also the reverse of the pattern in length of adult life. Incongruent time trends suggest something else must be important for population health.

Education is another key covariate of health, but it is more difficult to measure than either income or mortality, and studies of global inequality in education have offered mixed results. Many have explored only between-country variation in education, possibly because of data quality but also because there is much interest in explaining convergence in income per capita across countries. Using the dataset compiled by Barro and Lee (2001) for example, Sab and Smith (2002) study human capital accumulation and report convergence across 84 countries between 1970 and 1990 in average education, life expectancy, and infant mortality. Also examining the Barro and Lee (2001) data, de Gregorio and Lee (2002) show that within-country inequality in education, as measured by the average across countries in the standard deviation of educational attainment, rose between 1965 and 1990 everywhere except in Latin America. But between-country inequality, indexed by the standard deviation in average education, also rose except among the OECD. Crespo Cuaresma (2006) argues there are notable differences across datasets in decadal fluctuations in average education across OECD countries, but no data that he examines register a net increase in between-country inequality from 1970 and 2000. Given conflicting results, it is difficult to reject the hypothesis that trends in education inequality, if measured correctly, might be important for trends in life-span inequality. But taken as a whole, the evidence suggests that socioeconomic determinants in general seem unlikely to have driven the trends in the distribution of length of adult life.

It would help to characterize the widening gap between countries as one in which either some countries are increasingly lagging behind the pack or others are increasingly leaving the pack behind. But reality could easily be a mixture of both dynamics, with one or the other prevailing at a particular level of development and disease environment. If inequality between countries in length of adult life were due to uneven diffusion of healthy practices and technology across political boundaries, one could readily imagine a world in which there emerged leaders and followers among countries, at the same time there is falling inequality within countries. A similar story might also predict varying levels of exposure across countries to the spread of new infectious diseases like HIV/AIDS, if the latter tended to affect everyone within a uniformly ill-prepared country.

An emerging view in health economics is that knowledge and technology are simultaneously important for gains against mortality and also likely to produce inequality at least in the short run (Cutler, Deaton and Lleras-Muney, 2006), while income appears to be relatively less important. But this argument is based on historical patterns within countries of technology adoption, of the diffusion of knowledge and inequality in education, and of the within-country health gradient. While the basic outline of that story may loosely fit what I have revealed about trends in between-country inequality in this paper, it is not immediately clear why technological diffusion should be faster within countries than between them, as it would have to be in order to fit my results. Still, this perspective seems like it is worth exploring further, especially if outcomes reflect some combination of factors including technology and other influences. Global convergence in incomes, for example, could be driving down within-country inequality in length of life, while divergent access to life-saving technologies could account for the widening of between-country inequality.

Although specific policy recommendations would require a much deeper understanding of its causes, the rising importance of between-country variation in adult length of life over time bears very different implications than the standard finding in the literature examining cross-sectional evidence on health inequality. Those papers find that within-country variation in health is the larger component of global health inequality (Pradhan, Sahn and Younger, 2003; Smits and Monden, 2009). While that is still true, and the variance in length of life faced by an individual is indeed large and costly, this new finding about the trend toward increasing inequality between countries suggests a newly emerging priority for health surveillance and policy. Much progress has been made in reducing infant mortality worldwide, and there are also signs of reductions in adult variance within countries, as is consistent with the demographic and epidemiological transition. But we appear now to be facing a new challenge during an era of considerable uncertainty about socioeconomic well-being and new contagious diseases: rising between-country inequality in adult length of life. At this early stage of our understanding, these results can only suggest that a newfound importance surrounds efforts to facilitate the diffusion across countries of healthy practices, knowledge, and medical technologies that extend average adult life.

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Table 1: Characteristics of the world distribution of length of life in 1970 and 2000

	All countries		No model life tables		HMD only	
Sample characteristics	**1970**	**2000**	**1970**	**2000**	**1970**	**2000**
Number of countries	180	180	61	61	33	33
Total population in millions	3,712	6,099	2,688	4,030	964	1,147
GDP per capita in 2000 US$	4,360	7,505	5,168	9,617	11,821	22,775
Characteristics of length of life from birth						
Life expectancy at birth, e_0	58.8	66.9	61.4	69.9	70.7	75.8
Standard deviation from age 0, S_0	27.4	23.5	26.1	21.5	18.9	17.0
Interquartile range (IQR)	22.4	20.6	21.0	19.2	18.0	18.5
Avg. years lost due to death, $e^{\dagger}$	20.6	17.7	19.4	16.2	14.7	13.8
Gini coefficient	0.247	0.180	0.221	0.156	0.135	0.116
Theil index	0.442	0.242	0.370	0.182	0.125	0.060
Survivorship to age 10, ℓ_{10}	0.867	0.937	0.888	0.956	0.972	0.990
Characteristics of length of life above age 10						
Mean length of life above age 10, M_{10}	67.5	71.3	68.9	73.0	72.7	76.5
Standard deviation above age 10, S_{10}	17.0	16.8	16.3	16.1	15.1	15.4
IQR above age 10	20.6	20.0	19.7	18.9	17.8	18.4
Avg. years lost above age 10, $e^{\dagger}_{10}$	14.5	14.3	14.0	13.7	13.1	13.2
Gini coefficient above age 10	0.137	0.127	0.128	0.118	0.111	0.108
Theil index above age 10	0.046	0.039	0.040	0.033	0.029	0.027

Notes: Each column presents statistics based on population-weighted averages across countries in the given subsample. Inequality statistics are based on the aggregate probability distribution of length of life for the subsample, where densities are the life-table deaths, ${}_nd_x$. HMD stands for Human Mortality Database (2009), the highest-quality source. Statistics measured above age 10 are calculated conditional on survival to age 10. The mean length of life above age 10, M_{10}, is equal to $e_{10} + 10$. The Gini coefficient is calculated per Shkolnikov, Andreev and Begun (2003). The Theil index is constructed per Pradhan, Sahn and Younger (2003). The interquartile range (IQR) is calculated using cubic splines on the original 5-year life tables taken to tenths of a year. Average life years lost due to death, $e^{\dagger}$, is calculated per Vaupel and Canudas-Romo (2003).

Table 2: Characteristics of regional distributions of length of life in 1970 and 2000

	Life expect. at birth, e_0		Avg. life above age 10, M_{10}		Survivorship at age 10, ℓ_{10}		Population (millions)	
World Bank region	**1970**	**2000**	**1970**	**2000**	**1970**	**2000**	**1970**	**2000**
East Asia & Pacific	58.3	69.7	66.6	72.6	0.871	0.959	1,133	1,819
Europe & Central Asia	67.3	68.2	71.0	70.3	0.947	0.970	359	448
High income	70.6	77.7	72.6	78.3	0.971	0.992	801	1,007
Latin America & Caribbean	60.4	71.5	68.4	74.0	0.881	0.965	275	516
Middle East & North Africa	53.7	67.7	65.0	71.4	0.822	0.947	127	277
South Asia	47.8	60.9	62.5	67.6	0.757	0.898	731	1,363
Sub-Saharan Africa	45.8	50.7	61.0	60.9	0.741	0.827	286	668

	Std. dev. from age 0 S_0		Std. dev. above age 10, S_{10}		Theil index from birth		Theil index above age 10	
World Bank region	**1970**	**2000**	**1970**	**2000**	**1970**	**2000**	**1970**	**2000**
East Asia & Pacific	26.5	20.5	16.4	15.1	0.419	0.169	0.044	0.030
Europe & Central Asia	21.9	19.8	15.9	16.2	0.211	0.139	0.035	0.036
High income	19.0	15.9	15.0	14.4	0.130	0.050	0.029	0.022
Latin America & Caribbean	26.8	21.1	16.8	16.7	0.428	0.157	0.043	0.035
Middle East & North Africa	29.2	21.5	17.9	15.2	0.605	0.210	0.056	0.031
South Asia	30.1	25.7	17.7	17.1	0.720	0.369	0.058	0.045
Sub-Saharan Africa	30.9	28.4	19.8	19.4	0.776	0.553	0.077	0.066

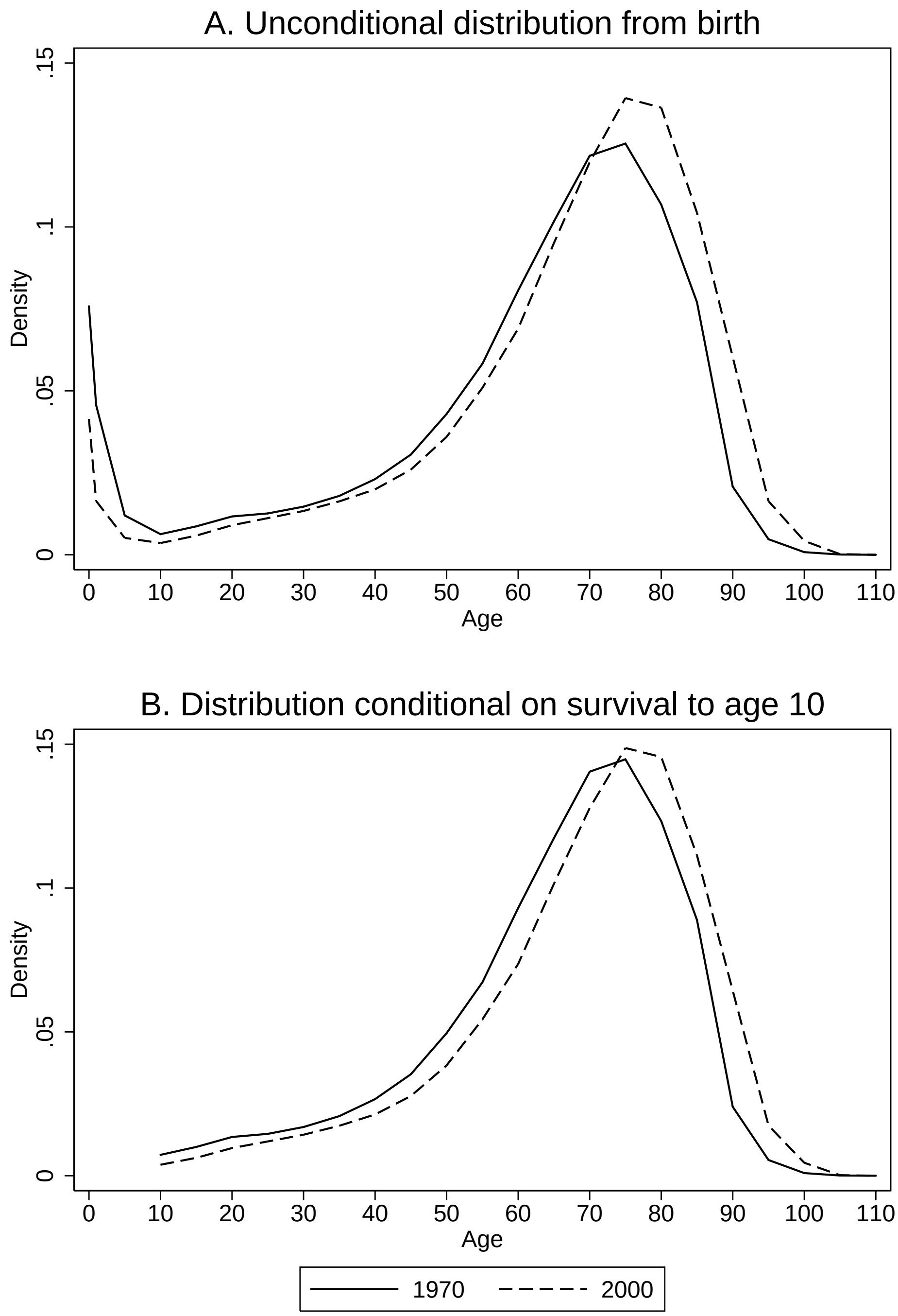
Notes:

Table 3: Cross-country decompositions of world variance in length of life, 1970 and 2000

	All countries		No model life tables		HMD only	
Inequality in length of life from birth	**1970**	**2000**	**1970**	**2000**	**1970**	**2000**
Theil index	0.442	0.242	0.370	0.182	0.125	0.060
Within-country	0.428	0.233	0.359	0.177	0.125	0.059
Between-country	0.014	0.008	0.010	0.005	0.000	0.001
Share due to between-country	3.1%	3.5%	2.8%	2.6%	0.1%	1.3%
Standard deviation from age 0, S_0	27.4	23.5	26.1	21.5	18.9	17.1
Within-country	25.7	21.9	24.6	20.5	18.9	16.4
Between-country	9.4	8.4	8.8	6.4	1.7	4.8
Share due to between-country	11.9%	12.8%	11.4%	8.9%	0.8%	7.8%
Inequality in length of life above age 10						
Theil index above age 10	0.046	0.039	0.040	0.033	0.029	0.027
Within-country	0.043	0.036	0.038	0.032	0.029	0.026
Between-country	0.002	0.003	0.002	0.002	0.000	0.001
Share due to between-country	6.6%	7.2%	4.5%	4.5%	0.7%	6.2%
Standard deviation above age 10, S_{10}	17.0	16.8	16.3	16.1	15.1	15.4
Within-country	16.4	15.9	15.8	15.4	15.0	14.8
Between-country	4.6	5.3	3.9	4.4	1.5	4.4
Share due to between-country	7.2%	10.1%	5.8%	7.6%	0.9%	8.3%

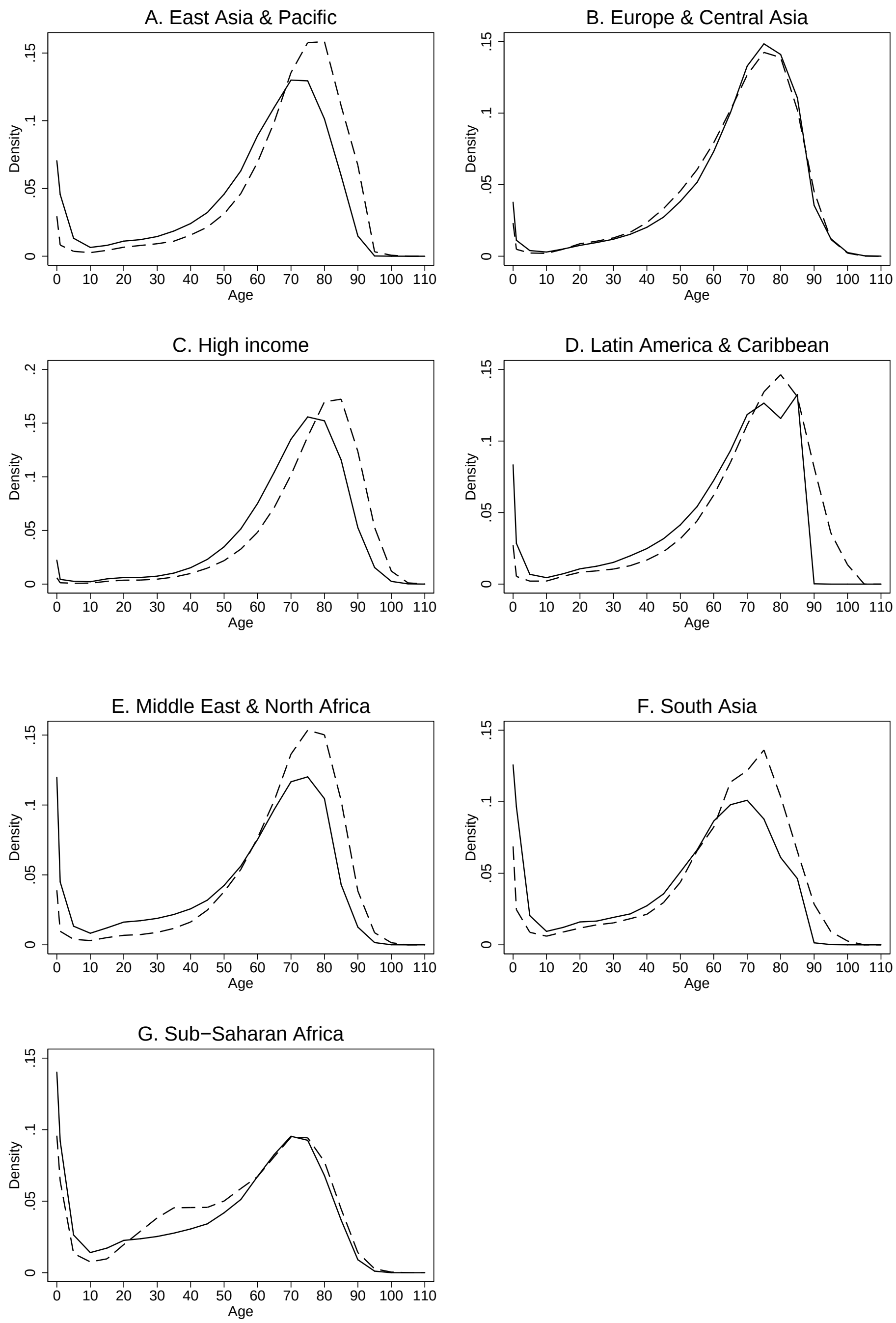
Notes: The source is author's calculations based on the data described in Appendix Table 1. HMD stands for Human Mortality Database (2009), the highest-quality source. Probability densities are the life-table deaths, ${}_nd_x$. Statistics measured above age 10 are calculated conditional on survival to age 10. The Theil index is constructed per Pradhan, Sahn and Younger (2003). The within and between-country components of the standard deviation are the square roots of the components of the variance. The share of the standard deviation attributable to between-country inequality is the analogous share of the variance.

Figure 1: World distributions of length of life in 1970 and 2000



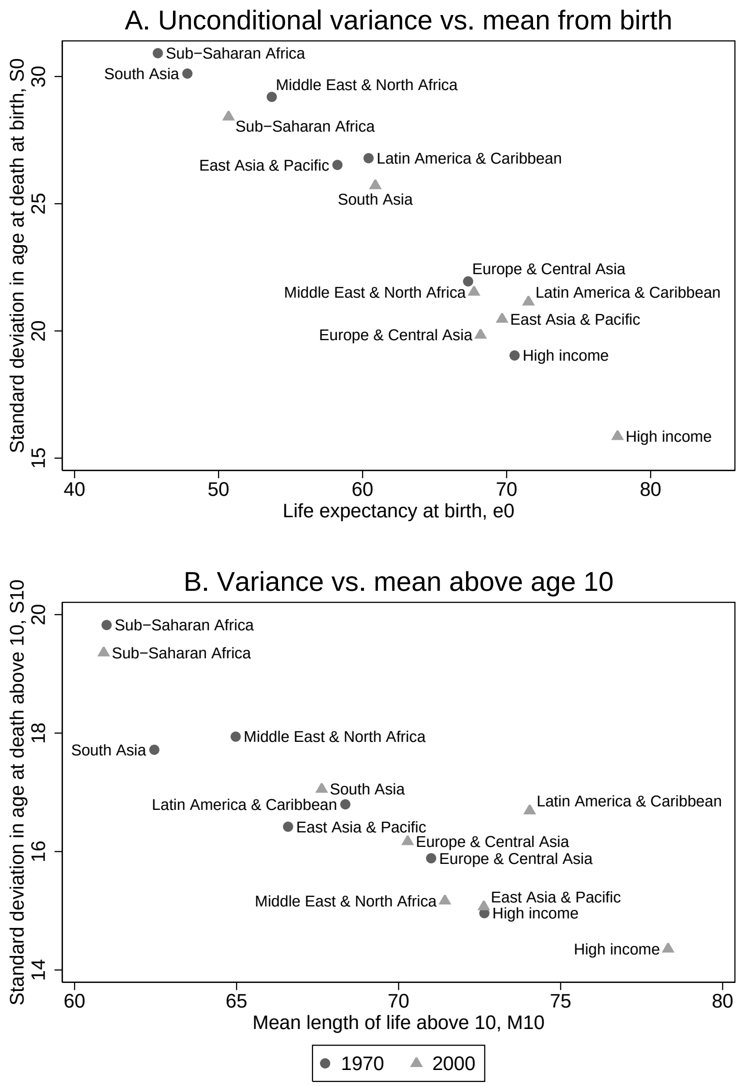
Notes: Data are life-table deaths (${}_nd_x$) for the world population around the year 1970 or in 2000 constructed from the life tables and populations of 180 countries observed in both periods, as described in the text. Panel A plots the entire distribution across all ages; Panel B rescales death probabilities to sum to unity above age 10.

Figure 2: Distributions of length of life in 1970 and 2000 by world region



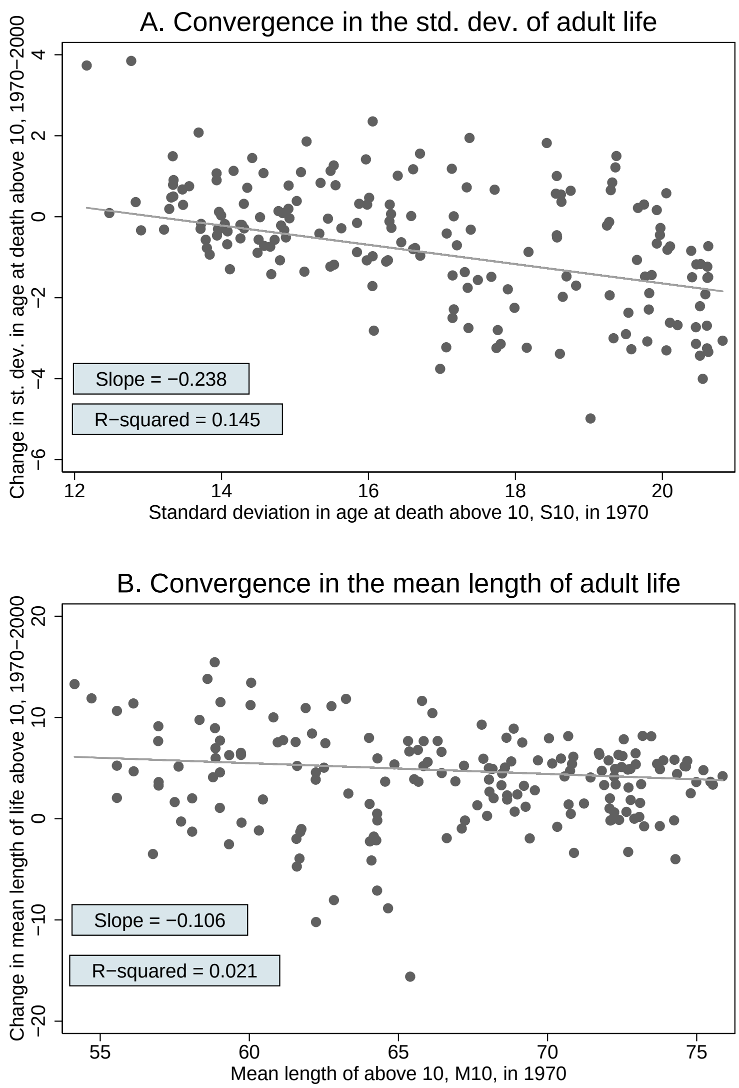
Notes: Data are life-table deaths ($_nd_x$) for populations in seven world regions around the year 1970 or in 2000 constructed from the life tables and populations of 180 countries observed in both periods, as described in the text. Regions are defined on the basis of development and geography by the World Bank.

Figure 3: Trends across world regions in the mean and standard deviation in length of life since 1970



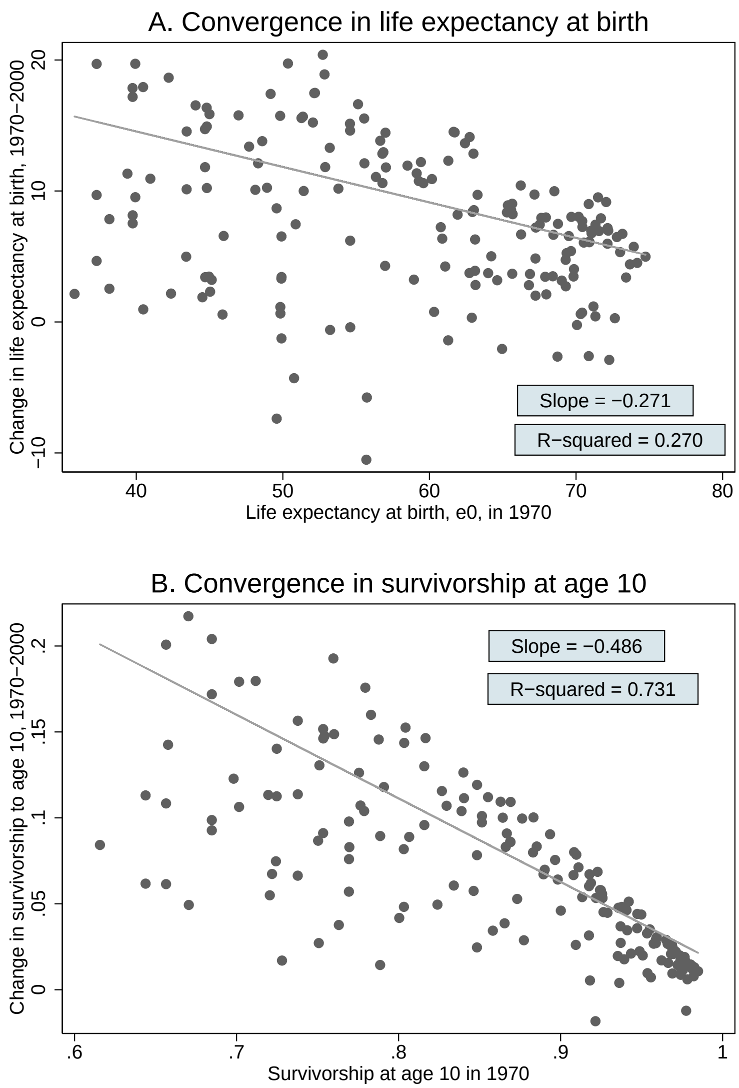
Notes: Data are means and standard deviations of length of life in world regions based on distributions of life-table deaths (${}_nd_x$). Regions are defined on the basis of development and geography by the World Bank. The unconditional standard deviation of length of life at birth is S_0, while the standard deviation above age 10 is S_{10}. The mean length of life starting from birth is e_0, life expectancy at birth. The mean length of life above age 10, M_{10}, is equal to $e_{10} + 10$.

Figure 4: Convergence across countries in the mean and standard deviation in length of adult life, 1970 to 2000



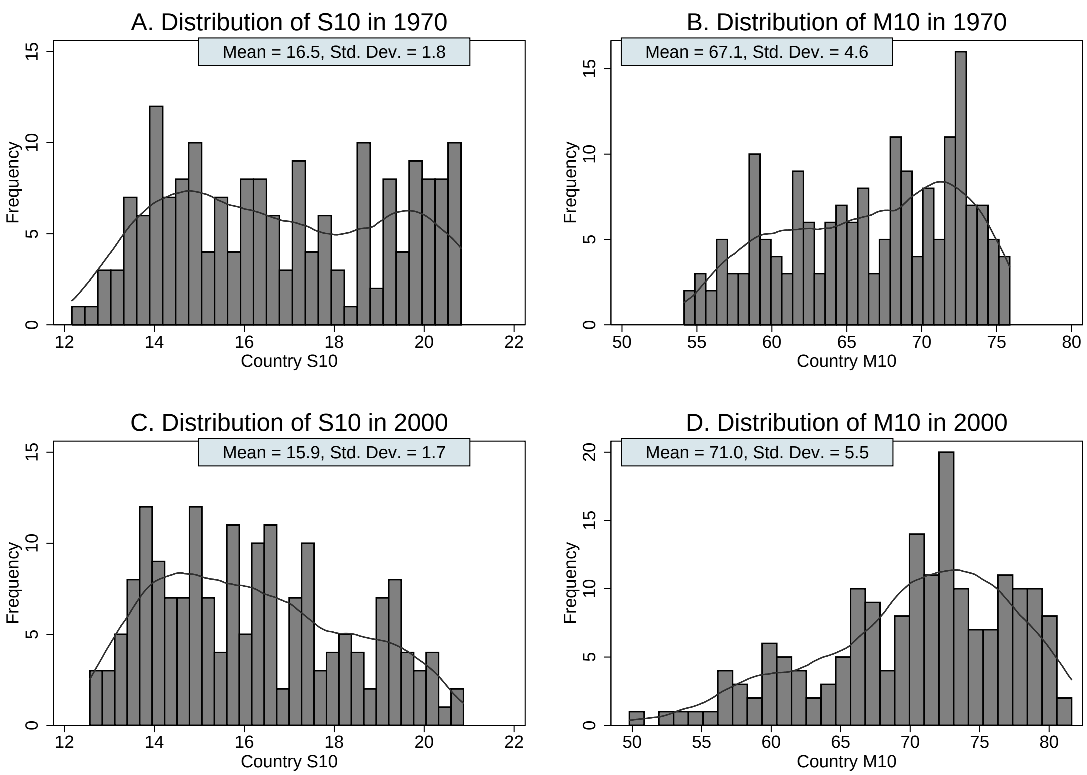
Notes:

Figure 5: Convergence across countries in life expectancy at birth and survivorship at age 10, 1970 to 2000



Notes:

Figure 6: Histograms of the standard deviation in length of life above age 10, S_{10}, in 1970 and 2000



Notes: Graphs are histograms of country-level observations of S_{10}, the standard deviation in length of life above age 10. Means and standard deviations of S_{10} are weighted based on population. The lines plot kernel density estimates.

Appendix: Data sources

Table A-1: Dataset contents

Country	Code	World Bank Region	Year 1	Source	Year 2	Source	Quality
Cambodia	KHM	East Asia & Pacific	1970	10	2000	4	C
China	CHN	East Asia & Pacific	1964-82	7	2000	7	B
Fiji	FJI	East Asia & Pacific	1970	11	2000	4	C
Indonesia	IDN	East Asia & Pacific	1970	10	2000	4	C
Korea, Dem. Rep.	PRK	East Asia & Pacific	1970	11	2000	4	C
Lao PDR	LAO	East Asia & Pacific	1970	10	2000	4	C
Malaysia	MYS	East Asia & Pacific	1990	4*	2000	4	C
Micronesia, Fed. Sts.	FSM	East Asia & Pacific	1970	10	2000	4	C
Mongolia	MNG	East Asia & Pacific	1990	4*	2000	4	C
Myanmar	MMR	East Asia & Pacific	1970	11	2000	4	C
Papua New Guinea	PNG	East Asia & Pacific	1970	11	2000	4	C
Philippines	PHL	East Asia & Pacific	1970	2	2000	4	B
Samoa	WSM	East Asia & Pacific	1970	11	2000	4	C
Solomon Islands	SLB	East Asia & Pacific	1970	11	2000	4	C
Thailand	THA	East Asia & Pacific	1970	2	2000	4	B
Tonga	TON	East Asia & Pacific	1970	11	2000	4	C
Vanuatu	VUT	East Asia & Pacific	1970	11	2000	4	C
Vietnam	VNM	East Asia & Pacific	1990	4*	2000	4	C
Albania	ALB	Europe & Central Asia	1990	4*	2000	4	C
Armenia	ARM	Europe & Central Asia	1981	5*	2000	4	C
Azerbaijan	AZE	Europe & Central Asia	1981	5*	2000	4	C
Belarus	BLR	Europe & Central Asia	1970	1	2000	1	A
Bosnia and Herzegovina	BIH	Europe & Central Asia	1982	2*	2000	4	C
Bulgaria	BGR	Europe & Central Asia	1970	1	2000	1	A
Croatia	HRV	Europe & Central Asia	1982	2*	2000	4	C
Georgia	GEO	Europe & Central Asia	1981	5*	2000	4	C
Kazakhstan	KAZ	Europe & Central Asia	1981	5*	2000	4	C
Kyrgyz Republic	KGZ	Europe & Central Asia	1981	5*	2000	4	C
Latvia	LVA	Europe & Central Asia	1970	1	2000	1	A
Lithuania	LTU	Europe & Central Asia	1970	1	2000	1	A
Macedonia, FYR	MKD	Europe & Central Asia	1982	2*	2000	4	C

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Table A-1 – continued from previous page

Country	Code	World Bank Region	Year 1	Source	Year 2	Source	Quality
Moldova	MDA	Europe & Central Asia	1981	2*	2000	4	C
Poland	POL	Europe & Central Asia	1970	1	2000	1	A
Romania	ROM	Europe & Central Asia	1970	2	2000	4	B
Russian Federation	RUS	Europe & Central Asia	1970	1	2000	1	A
Serbia and Montenegro	SCG	Europe & Central Asia	1982	2*	2000	4	C
Tajikistan	TJK	Europe & Central Asia	1981	5*	2000	4	C
Turkey	TUR	Europe & Central Asia	1970	10	2000	4	C
Turkmenistan	TKM	Europe & Central Asia	1981	5*	2000	4	C
Ukraine	UKR	Europe & Central Asia	1970	1	2000	1	A
Uzbekistan	UZB	Europe & Central Asia	1981	5*	2000	4	C
Australia	AUS	High income	1970	1	2000	1	A
Austria	AUT	High income	1970	1	2000	1	A
Bahamas, The	BHS	High income	1980	5*	2000	4	C
Bahrain	BHR	High income	1990	4*	2000	4	C
Barbados	BRB	High income	1970	10	2000	4	C
Belgium	BEL	High income	1970	1	2000	1	A
Brunei Darussalam	BRN	High income	1990	4*	2000	4	C
Canada	CAN	High income	1970	1	2000	1	A
Cyprus	CYP	High income	1990	4*	2000	4	C
Czech Republic	CZE	High income	1970	1	2000	1	A
Denmark	DNK	High income	1970	1	2000	1	A
Equatorial Guinea	GNQ	High income	1970	10	2000	4	C
Estonia	EST	High income	1970	1	2000	1	A
Finland	FIN	High income	1970	1	2000	1	A
France	FRA	High income	1970	1	2000	1	A
Germany	DEU	High income	1970	1	2000	1	A
Greece	GRC	High income	1970	2	2000	4	B
Hong Kong, China	HKG	High income	1971	8	2000	8	B
Hungary	HUN	High income	1970	1	2000	1	A
Iceland	ISL	High income	1970	1	2000	1	A
Ireland	IRL	High income	1970	2	2000	4	B
Israel	ISR	High income	1975	2	2000	4	B
Italy	ITA	High income	1970	1	2000	1	A

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Table A-1 – continued from previous page

Country	Code	World Bank Region	Year 1	Source	Year 2	Source	Quality
Japan	JPN	High income	1970	1	2000	1	A
Korea, Rep.	KOR	High income	1973	2	2000	4	B
Kuwait	KWT	High income	1975	3	2000	4	B
Luxembourg	LUX	High income	1970	1	2000	1	A
Malta	MLT	High income	1970	5*	2000	4	C
Netherlands	NLD	High income	1970	1	2000	1	A
New Zealand	NZL	High income	1970	1	2000	1	A
Norway	NOR	High income	1970	1	2000	1	A
Oman	OMN	High income	1990	4*	2000	4	C
Portugal	PRT	High income	1970	1	2000	1	A
Puerto Rico	PRI	High income	1970	5*	2000	5	C
Qatar	QAT	High income	1990	4*	2000	4	C
Saudi Arabia	SAU	High income	1970	10	2000	4	C
Singapore	SGP	High income	1970	2	2000	4	B
Slovak Republic	SVK	High income	1970	1	2000	1	A
Slovenia	SVN	High income	1982	2*	2000	1	C
Spain	ESP	High income	1970	1	2000	1	A
Sweden	SWE	High income	1970	1	2000	1	A
Switzerland	CHE	High income	1970	1	2000	1	A
Taiwan	TWN	High income	1970	1	2000	1	A
Trinidad and Tobago	TTO	High income	1960	3	2000	4	B
United Arab Emirates	ARE	High income	1970	10	2000	4	C
United Kingdom	GBR	High income	1970	1	2000	1	A
United States	USA	High income	1970	1	2000	1	A
Argentina	ARG	Latin America & Caribbean	1970	2	2000	4	B
Belize	BLZ	Latin America & Caribbean	1970	11	2000	4	C
Bolivia	BOL	Latin America & Caribbean	1970	11	2000	4	C
Brazil	BRA	Latin America & Caribbean	1980	5*	2000	4	C
Chile	CHL	Latin America & Caribbean	1970	2	2000	4	B
Colombia	COL	Latin America & Caribbean	1964	2	2000	4	B
Costa Rica	CRI	Latin America & Caribbean	1970	2	2000	4	B
Cuba	CUB	Latin America & Caribbean	1970	2	2000	4	B
Dominica	DMA	Latin America & Caribbean	1969	5*	2000	4	C

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Table A-1 – continued from previous page

Country	Code	World Bank Region	Year 1	Source	Year 2	Source	Quality
Dominican Republic	DOM	Latin America & Caribbean	1970	5*	2000	4	C
Ecuador	ECU	Latin America & Caribbean	1970	5*	2000	4	C
El Salvador	SLV	Latin America & Caribbean	1971	2	2000	4	B
Guatemala	GTM	Latin America & Caribbean	1964	2	2000	4	B
Guyana	GUY	Latin America & Caribbean	1960	3	2000	4	B
Haiti	HTI	Latin America & Caribbean	1970-71	6	2000	4	B
Honduras	HND	Latin America & Caribbean	1974	2	2000	4	B
Jamaica	JAM	Latin America & Caribbean	1981	5*	2000	4	C
Mexico	MEX	Latin America & Caribbean	1970	2	2000	4	B
Nicaragua	NIC	Latin America & Caribbean	1990	4*	2000	4	C
Panama	PAN	Latin America & Caribbean	1960	2	2000	4	B
Paraguay	PRY	Latin America & Caribbean	1990	4*	2000	4	C
Peru	PER	Latin America & Caribbean	1970	2	2000	4	B
St. Lucia	LCA	Latin America & Caribbean	1972	5*	2000	4	C
St. Vincent and the Grenadines	VCT	Latin America & Caribbean	1970	10	2000	4	C
Suriname	SUR	Latin America & Caribbean	1971	5*	2000	4	C
Uruguay	URY	Latin America & Caribbean	1970	5*	2000	4	C
Venezuela, RB	VEN	Latin America & Caribbean	1970	5*	2000	4	C
Algeria	DZA	Middle East & North Africa	1969-70	9	2000	4	B
Djibouti	DJI	Middle East & North Africa	1970	10	2000	4	C
Egypt, Arab Rep.	EGY	Middle East & North Africa	1970	10	2000	4	C
Iran, Islamic Rep.	IRN	Middle East & North Africa	1970	10	2000	4	C
Iraq	IRQ	Middle East & North Africa	1970	10	2000	4	C
Jordan	JOR	Middle East & North Africa	1990	4*	2000	4	C
Lebanon	LBN	Middle East & North Africa	1970	10	2000	4	C
Libya	LBY	Middle East & North Africa	1970	11	2000	4	C
Morocco	MAR	Middle East & North Africa	1970	10	2000	4	C
Syrian Arab Republic	SYR	Middle East & North Africa	1970	10	2000	4	C
Tunisia	TUN	Middle East & North Africa	1970	10	2000	4	C
Yemen, Rep.	YEM	Middle East & North Africa	1970	10	2000	4	C
Afghanistan	AFG	South Asia	1970	10	2000	4	C
Bangladesh	BGD	South Asia	1970	10	2000	4	C

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Table A-1 – continued from previous page

Country	Code	World Bank Region	Year 1	Source	Year 2	Source	Quality
Bhutan	BTN	South Asia	1970	10	2000	4	C
India	IND	South Asia	1971	2	2000	4	B
Maldives	MDV	South Asia	1990	4*	2000	4	C
Nepal	NPL	South Asia	1970	10	2000	4	C
Pakistan	PAK	South Asia	1970	11	2000	4	C
Sri Lanka	LKA	South Asia	1970	10	2000	4	C
Angola	AGO	Sub-Saharan Africa	1970	10	2000	4	C
Benin	BEN	Sub-Saharan Africa	1970	10	2000	4	C
Botswana	BWA	Sub-Saharan Africa	1982	10	2000	4	C
Burkina Faso	BFA	Sub-Saharan Africa	1970	10	2000	4	C
Burundi	BDI	Sub-Saharan Africa	1970	10	2000	4	C
Cameroon	CMR	Sub-Saharan Africa	1970	10	2000	4	C
Cape Verde	CPV	Sub-Saharan Africa	1970	10	2000	4	C
Central African Republic	CAF	Sub-Saharan Africa	1970	10	2000	4	C
Chad	TCD	Sub-Saharan Africa	1970	10	2000	4	C
Comoros	COM	Sub-Saharan Africa	1970	10	2000	4	C
Congo, Dem. Rep.	ZAR	Sub-Saharan Africa	1970	10	2000	4	C
Congo, Rep.	COG	Sub-Saharan Africa	1970	10	2000	4	C
Cte d'Ivoire	CIV	Sub-Saharan Africa	1970	10	2000	4	C
Eritrea	ERI	Sub-Saharan Africa	1970	11	2000	4	C
Ethiopia	ETH	Sub-Saharan Africa	1970	10	2000	4	C
Gabon	GAB	Sub-Saharan Africa	1970	10	2000	4	C
Gambia, The	GMB	Sub-Saharan Africa	1970	10	2000	4	C
Ghana	GHA	Sub-Saharan Africa	1970	10	2000	4	C
Guinea	GIN	Sub-Saharan Africa	1970	10	2000	4	C
Guinea-Bissau	GNB	Sub-Saharan Africa	1970	10	2000	4	C
Kenya	KEN	Sub-Saharan Africa	1970	10	2000	4	C
Lesotho	LSO	Sub-Saharan Africa	1970	10	2000	4	C
Liberia	LBR	Sub-Saharan Africa	1970	10	2000	4	C
Madagascar	MDG	Sub-Saharan Africa	1970	10	2000	4	C
Malawi	MWI	Sub-Saharan Africa	1970	10	2000	4	C
Mali	MLI	Sub-Saharan Africa	1970	10	2000	4	C
Mauritania	MRT	Sub-Saharan Africa	1970	10	2000	4	C

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Table A-1 – continued from previous page

Country	**Code**	**World Bank Region**	**Year 1**	**Source**	**Year 2**	**Source**	**Quality**
Mauritius	MUS	Sub-Saharan Africa	1970	5*	2000	4	C
Mozambique	MOZ	Sub-Saharan Africa	1970	10	2000	4	C
Namibia	NAM	Sub-Saharan Africa	1970	10	2000	4	C
Niger	NER	Sub-Saharan Africa	1970	10	2000	4	C
Nigeria	NGA	Sub-Saharan Africa	1970	10	2000	4	C
Rwanda	RWA	Sub-Saharan Africa	1990	4*	2000	4	C
So Tom and Principe	STP	Sub-Saharan Africa	1970	10	2000	4	C
Senegal	SEN	Sub-Saharan Africa	1970	10	2000	4	C
Sierra Leone	SLE	Sub-Saharan Africa	1970	10	2000	4	C
Somalia	SOM	Sub-Saharan Africa	1970	10	2000	4	C
South Africa	ZAF	Sub-Saharan Africa	1960	2	2000	4	B
Sudan	SDN	Sub-Saharan Africa	1970	10	2000	4	C
Swaziland	SWZ	Sub-Saharan Africa	1970	10	2000	4	C
Tanzania	TZA	Sub-Saharan Africa	1970	10	2000	4	C
Togo	TGO	Sub-Saharan Africa	1970	10	2000	4	C
Uganda	UGA	Sub-Saharan Africa	1970	10	2000	4	C
Zambia	ZMB	Sub-Saharan Africa	1970	10	2000	4	C
Zimbabwe	ZWE	Sub-Saharan Africa	1970	10	2000	4	C
1							

Notes: An asterisk appears to the right of each life table that is rescaled so that it matches period life expectancy at birth for both sexes combined in 1970 as reported by the United Nations Population Division (2006). The variance in adult length of life remains essentially unchanged. See the text for details.

Sources: 1 Human Mortality Database (2009)

2 Murray et al. (2003)

3 United Nations Population Division (1982) UN Life Table Collection

4 World Health Organization Life Table Database (2009)

5 World Health Organization Mortality Database (2009)

6 Allman and May (1979)

7 Banister and Hill (2004)

8 Cheung et al. (2005)

9 Vallin (1975)

10 Coale and Demeny (1983) Model Life Tables

11 United Nations Population Division (1982) UN Model Life Tables