Changes in World Inequality in Length of Life: 1970–2000

Ryan D. Edwards*

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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.

*Assistant Professor of Economics, Queens College and the Graduate Center, City University of New York, and NBER. Mailing address: 300 Powdermaker Hall, 65-30 Kissena Blvd, Flushing, NY 10069. redwards@qc.cuny.edu. An earlier version of this paper was presented at the 2008 annual meeting of the Population Association of America in New Orleans, LA. This work was supported by PSC-CUNY grant 60104 37 38. I am grateful to Henry (Ayodeji) Fola-Owolabi for excellent research assistance, to Michel Guillot for an electronic dataset of life tables and for helpful advice, to Shripad Tuljapurkar, and to three anonymous referees for many helpful comments. All errors and opinions are mine alone and do not reflect the views of the City University of New York, the Professional Staff Congress, or the National Bureau of Economic Research.

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, d_x, which cumulate to one minus the survivorship probability, ℓ_x. 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), who also review earlier work on within-country inequality in length of life, perform similar analysis on high-quality data from advanced countries using the Gini coefficient as their preferred index, and they report similar results. Cheung and Robine (2007) and Cheung et al. (2009) examine the standard deviation in length of life above the old-age mode and report a slowing in the compression of mortality but no signs of an upper limit to longevity in some high-income countries, while Thatcher et al. (2010) report some evidence of continuing compression.

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. These two years are likely to provide a reasonable indication of long-term trends because neither period was punctuated by large transitory shocks. It would be preferable to examine more years of mortality, but tracking down historical observations on a wide cross section of countries is not easy.

To create a broad panel dataset, I must combine high-quality data from the HMD and similar datasets, where observations are typically restricted to relatively wealthy countries, with statistics derived from model life tables applied to partial or incomplete data from poor countries. 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. I reconstruct historical estimates using these life expectancy statistics and the methods reported by the United Nations Population Division (2006). As for contemporary mortality conditions, Lopez et al. (2002) and Murray et al. (2003) have significantly improved the quality and scope of current estimates for developing countries, and the World Health Organization Life Table Database (2009) provides a broad set of life tables. I discuss details regarding the construction of the data set in the appendix.

Like Wilson (2001) and Sala-i-Martin (2006), I weight statistics by population because my focus is on global inequality in human length of life rather than inequality between countries per se. But through a decomposition analysis, I find that variation between countries has played an 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.

Methods

Inequality measures

A wide array of statistics are available to measure inequality. I focus on four that are frequently used in the literature: the standard deviation, S; the interquartile range, IQR; the Gini coefficient, G; and the Theil index, T. 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. Wilmoth and Horiuchi (1999) prefer the IQR in measuring variability in length of life, while Edwards and Tuljapurkar (2005), Cheung and Robine (2007), Cheung et al. (2009), and Tuljapurkar and Edwards (2011) prefer the standard deviation.

Broadly speaking, these four statistics measure two different types of inequality, proportional or additive, and this can become problematic when assessing trends because the two may not agree. Like the coefficient of variation, which is the ratio of the standard deviation to the mean, the Gini and the Theil index are proportional measures while the standard deviation and the IQR are additive. These two types can easily disagree on trends because the mean of the distribution is often changing. Imagine the mean μ increasing while the standard deviation remains fixed at σ. Additive measures like S and the IQR will register no change in inequality, but proportional measures like G and T will indicate a reduction in inequality because like the coefficient of variation, σ/μ, they have fallen because the mean has risen. When the variable in question is money income, economists prefer proportional measures of inequality; when it is length of life, demographers often prefer additive measures. But because the issue is open to interpretation, I calculate and report both types of statistics.

The other important characteristic of these inequality measures is that several are easily decomposed into between-group and within-group variation. Variation within and across countries is of particular interest, although the methods extend to any definition of group.

Decomposing inequality across countries

For clarity and parsimony, I choose two measures for a decomposition analysis, the standard deviation and the Theil. By the law of total variance, the global variance V in length of life τ over all individuals, which is the square of the standard deviation S, equals the sum of the expectation over the j countries of the variance across the i individuals within country j, plus the variance over countries of the within-country means across individuals:

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

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

Total versus adult mortality

Edwards and Tuljapurkar (2005) and Smits and Monden (2009) argue for separating infant and adult mortality when examining variation in length of life. 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 (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. Thus I calculate inequality statistics both on truncated distributions of length of life above age 10 as well as on 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 not be 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 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,[1] or a reduction in adult variance, or it

[1] 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

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 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 of all countries in both periods, of the subsample of 61 countries with actual rather than model life tables in 1970, and of the subsample of 33 countries represented in the Human Mortality Database (2009). I provide further details about sample construction in the appendix. Each successive sample restriction improves the quality of the underlying data and thus the confidence in results. Data quality is positively related to level of development, revealed by trends in real GDP per capita in the third row. As shown in the top row of Panel A, average life expectancy at birth, e_0, increased across all subsamples but less rapidly among the high-income countries in the HMD, where it was already high at 70.7 years in 1970.[2] Average life expectancy conditional on surviving to age 10 also increased, but the increases were smaller and more similar across subsamples. This is shown in the top row of Panel B, 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 years between 1970 and 2000 in each subsample.

Table 1A also displays the four inequality statistics measured over the entire distribution of length of life. Nearly all statistics, proportional and additive alike, register reductions in total inequality starting from birth in each sample during the interval. The exception is the interquartile range

early-age mortality in a birth cohort.

[2]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. My statistics differ somewhat from official sources, but official sources also do not fully agree. 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.

measured over HMD countries. The IQR registers a different trend because of the strong relationship between the mean and the variance in length of life and infant mortality, which was already very low in the HMD countries. The IQR is much less sensitive to outliers, so changes in a small probability of death in infancy change the IQR very little. All the other measures here including e_0 are capturing the strong convergence in infant mortality that I return to discuss later.

Table 1B reveals trends in the four inequality statistics measured over the adult distribution of length of life above age 10, and it is here that we see confirmation of the visual evidence in Figure 1B. The two additive measures, the standard deviation and the IQR, 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, also 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 behaves 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 Figure 1B, namely the rightward shift of densities around the old-age mode leaving variance basically unchanged. By contrast, the proportional measures of inequality, the Gini and the Theil, decline across all samples here in the bottom panel. 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, approximately the ratio of the two, must have fallen in this case because the denominator increased even though the numerator remained basically unchanged. Altogether, 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 changing in this manner, proportional indexes are poorly equipped to reveal the distinct trends in world S_{10} and other additive indexes measured over adult ages.

The stagnation in world S_{10} that we see in Figure 1B and Table 1B 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). 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 or geographic region. In the next two sections, I examine distributions first by world region as defined by the World Bank and then formally decompose total inequality into within- and between-country components to explore these questions.

Distributions by region

Decomposing the data by region is useful because it reveals geographic patterns and provides clarity by virtue of relatively low dimensionality compared with the country decomposition to follow. The seven panels in Figure 2 plot distributions of length of life from birth in 1970 and 2000 for the seven global regions defined by the World Bank, which categorizes countries based on level of development and then geography. 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. Details are provided in the appendix.

A visual comparison with Figure 1A reveals similarities and differences between global and regional trends. Trends in East Asia and the Pacific, in the high income group, and to some extent in the Middle East and North Africa, shown along the left in Panels A, C, and E, look much like the world trends visible in Panel A of Figure 1. All of 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 less obvious for Latin America and the Caribbean in Panel D, where top-coding of the life tables above age 85 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, except perhaps a small 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 the distribution above age 60.

Table 2 reports life expectancies and measures of variance for the seven regions, which confirm the visual results in Figure 2 but also reveal several more subtle trends. As shown in the upper panel, e_0 rose across all regions, but much of the gains were driven by increases in survivorship to age 10, ℓ_{10}. By contrast, adult life expectancy, M_{10}, actually fell in Europe and Central Asia and in sub-Saharan Africa. In the bottom panel, we see 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: 1.3 years in East Asia and the Pacific, and 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. Regions with high S_{10} should experience more rapid decline, but that pattern that is not apparent in Table 2. Following Wilmoth and Horiuchi (1999) and Tuljapurkar (2008), it is helpful to plot variances against means in order to explore this issue further. In such a graph, movement over time is normally downward-sloping in such a graph, as variance declines with increases in the mean before reaching a plateau toward the end of the epidemiological transition. The top panel in Figure 3 plots variances against means for world regions as measured starting from birth, while the bottom panel plots variances against means for adult mortality alone. Lines connect regions through time. As expected, Figure 3A displays a strongly downward sloping relationship in the cross section and over time, consistent with the standard story, but Figure 3B reveals that the same is not true for the variance and average above age 10. While regions are still arrayed along a downward sloping line in the cross section, that relationship is often not reflected in the experiences of individual regions over time. While convergence in infant mortality has apparently brought fairly steady and universal improvements in total inequality and in life expectancy across world regions, as shown in Figure 3A, there is evidence of divergence in adult mortality in Figure 3B.

Distributions by country

Given how a regional perspective has revealed trends in adult mortality to be interesting, it is now helpful to descend to the country level and use standard tools to assess convergence. A common approach in the literature is to plot the change in the mean versus the initial mean; a downward sloping relationship reveals evidence of convergence. It is also helpful to formally decompose the global inequality indexes into between- and within-country components and to present these results both as raw statistics and as graphics.

There is much convergence in e_0 across the 180 countries in the dataset, as revealed by a standard convergence plot in Figure 4A. The downward-sloping solid line in the plot shows the weighted-least squares relationship, equal to -0.271 and highly significant, and the model $R^2 = 0.270$. Much of this is driven by strong convergence in infant and child mortality, which is revealed in Figure 4B. There, convergence in early-life survivorship as measured by ℓ_{10} is very strong, with an estimated slope of -0.486 and an $R^2 = 0.731$. By comparison, White (2002) reports an $R^2 = 0.810$ for a regression of the change in e_0 on e_0 for high-income countries.

In contrast, Figure 5A shows markedly less convergence in country-level S_{10}, and Figure 5B reveals hardly any convergence at all in M_{10}. In the case of S_{10}, the R^2 is only 0.145, but the bivariate relationship remains relatively strong with a slope coefficient of -0.238. But for convergence in M_{10}, the model R^2 has fallen to 0.021, and the slope is -0.106 with a t-statistic of -1.97, the lowest across the four plots. Visually, these differences between convergence in mortality starting from birth and the lack of much convergence in adult mortality are striking. Figure 5A reveals that within-country inequality in adult life span might have fallen due to convergence in the average S_{10} across countries, but Figure 5B suggests that between-country inequality has probably risen because there has been much less, if any, convergence in M_{10} and thus probably no reductions in the cross-country variance in M_{10}.

For a formal analysis of these issues, I next decompose global variation in length of life into within- and between-country elements using the law of total variance and the Theil decomposition, as shown in equations (1) and

(3). I report the results in Table 3, and as in Table 1, I first examine the full dataset of 180 countries and then two higher-quality subsamples. Panel A shows decompositions of inequality in length of life starting from birth using the Theil and the standard deviation, and the Panel B does the same for inequality above age 10, for a total of twelve different decompositions. The between-country share of inequality has grown in nine of the twelve, and in many cases, its absolute level has also grown. The Theil and the standard deviation agree on increases in the between-country share in most subsamples. An exception is the subset of 61 countries without model life tables, where the Theil above age 10 shows a decrease in between-country inequality while S_{10} registers an increase in that component. The within-country share always remains significantly larger, usually more than 90 percent of the total, which is consistent with the findings of Smits and Monden (2009). But growth in the between-country share was 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, register increases in the between-country share and in its absolute level.

These trends in 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 in 1970 and 2000 of country-specific S_{10}, the average of which is the within-country variation. As shown, 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 even as it moved rightward, with a fat left tail emerging by 2000. Visual evidence of convergence between countries is practically nonexistent here; rather, it appears that some countries benefited from increases in adult life expectancy while others did not, and still others experienced declines.

In unreported results, I formally decomposed inequality by region rather than by country and found that the between-region components were if anything slightly smaller than between-country components. Thus it appears 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 finding in Table 3 that between-country inequality is rising even among the uniformly high-income countries of the HMD, which occupy a single World Bank region.

Discussion

Less global convergence in mortality

This study reveals that convergence in length of life is not as universal a phenomenon as it may at first appear. To be sure, global 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; Wilson, 2011). 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 mortality, 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, another additive index, registers a similar plateau in world inequality. Because they are proportional indexes, the Gini and Theil often show declines in inequality of adult length of life because the mean has increased while the variance has not. But among high-income countries, even the Gini and Theil reveal barely any progress against inequality in adult length of life, while S_{10} and the IQR both register increases.

Regardless of the choice of measure, or whether we are considering length of life from birth or from age 10, the between-country share of inequality appears to be rising in most subsamples over time, and in the case of adult mortality, the absolute level of between-country inequality has risen. This is a provocative and disturbing result, and it contrasts while also coexisting with the previous finding of Smits and Monden (2009) that in the cross section, the within-country component of inequality in length of human life tends to be much larger than the between-country component. In addition to inequality between subgroups within a country, however defined, the within-country measure will also capture all "natural" inequality one might find within even a completely homogeneous subgroup of humans. The relative universality of the Gompertz Law within living organisms (Finch, Pike and Witten, 1990), which is inversely related to the variance in length of life (Tuljapurkar and Edwards, 2011), suggests that such natural inequality could be relatively large. Viewed this way, within-country inequality seems even less salient than between-country inequality.

While I find that the average variance within countries has fallen over time in almost every instance, increases in the between-country component have often been large enough 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. That is, of the two results regarding within- and between-country inequality, it is the widening of the latter in which we should have more confidence.[3]

Comparisons to earlier findings

Before 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 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

[3]My approach to assessing statistical confidence here is rudimentary and could be improved in future work. I have only compared results across subsamples of the data arrayed in quality tiers. Firebaugh (2006) pursues a more rigorous approach toward assessing statistical significance among trends in global income inequality. He exploits expert opinion on measurement error in the income statistics to construct confidence intervals. A similar approach could be tried here if quantitative assessments of data quality were available. Future efforts might explore such an approach.

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.

Sources of rising inequality

The collapse of communism or HIV/AIDS

Are there trends in the underlying determinants of mortality that might help us understand these results? In addition to the epidemiological transition underway in developing countries, there have been two other broad developments in world mortality since 1970 that may have been important for rising inequality. 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. Also, 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. That is, even among Western nations, there were increases in between-country inequality during this period, implying that the fall of communism cannot be a central explanation.

There is somewhat more support for HIV/AIDS as 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 subsample and analyzing the remaining set of countries with high-quality data does not qualitatively change the results at all. In the HMD subsample without the three countries hardest-hit by HIV/AIDS — the U.S., Russia, and the Ukraine — between-country inequality still rises from 1.6 to 2.7, while within-country inequality falls, from 14.3 to 13.9. It would appear 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. While it is tempting to search for a single explanation for these patterns, these insights 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.

Socioeconomic gradients

A natural question is whether well-known gradients in socioeconomic status within and between countries might explain the results. But 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. Thus 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.[4] Still, extant patterns in income and education bear some tentative implications for understanding these trends in life-span inequality, at least by revealing what is not responsible.

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 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 precisely the reverse of the pattern in length of adult life. Incongruent time trends suggest something else must be important for inequality in 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 OECD countries. 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 determi-

[4]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.

nants in general seem unlikely to have driven the trends in the distribution of length of adult life.

Technology

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. Indeed, the depiction in Figure 6 is somewhat supportive of this notion, given the visible expansion in the spread of adult life expectancy in Panel D compared with Panel B and the clear presence of outliers in the left tail. But reality could easily be a mixture of leaders and laggards, 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.

Implications

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.

Appendix: Data sources

Each country-year observation consists of a period life table for both sexes combined. As described in the text, I assemble life tables for 180 countries in 1970 and 2000 using a variety of sources. The highest-quality source is the Human Mortality Database (2009), from which I draw 33 mostly high-income countries represented in both years. This is the "HMD only" group in Tables 1 and 3. An additional 28 countries are represented in other databases with historical life tables from 1970 or an adjacent period, for a total of 61 countries in the dataset that do not have model life tables or adjustments of any variety. This is the "no model life tables" group in Tables 1 and 3. For the 28, I use results from several papers in historical demography: Vallin (1975), Allman and May (1979), Banister and Hill (2004), and Cheung et al. (2005). Also, Murray et al. (2003) present a set of life tables compiled from the WHO collection, from Preston, Keyfitz and Schoen (1972), and from the United Nations Population Division (1982).

Life tables for the remaining 119 countries are recovered either from reconstructed model life tables [78 of 119], from vital statistics in the World

Health Organization Mortality Database (2009) with adjustment to match period life expectancy in 1970 as reported by the United Nations Population Division (2006) [21 of 119], or from historical life tables for different periods such as 1982 or 1961, etc. with adjustment to match period life expectancy in 1970 [20 of 119].

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. I match e_0 in 1970 as reported by the UN to the model life table in the collection specified by the UN in their Analytical Report. 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 rescale 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. That is, I calculate life tables based on the WHO mortality data and then compare e_0 to the UN control. Using an iterative process, I identify a single constant that reproduces the UN e_0 when the former multiplies all age-specific mortality rates. This process changes life expectancies but does not affect the Gompertz slope of log mortality through age, and thus it does not affect the variance in length of life (Tuljapurkar and Edwards, 2011).

I performed a similar type of additive rescaling of the distribution of life span 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. 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. This method also recenters the distribution so as to match official estimates of life expectancy while leaving unaffected S_{10} and other inequality measures that are invariant to additive change. Of the 41 countries whose life tables I have translated in these ways, 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.

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 vital registration data when available, or on modeling techniques applied to survey or other data that were 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.

The World Bank categorizes countries into regions based first on income and then geography. Table A1 lists the countries in the dataset by region and denotes their presence in the three quality tiers. An asterisk marks the 33 HMD countries, a dagger denotes the additional 28 countries with no model life tables, and the remaining 119 countries are unmarked. In Table A2, which is a spreadsheet available upon request, I list the 180 countries represented in the dataset, their World Bank region, the years of coverage, which sometimes differ from 1970 and 2000, and the sources.

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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
A. 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
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
B. 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
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.

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 birth, 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: World Bank regions are defined by income and then geography, as described in the text. Table A1 lists the countries in each region.

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

	All countries		No model life tables		HMD only	
A. 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%
B. 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%

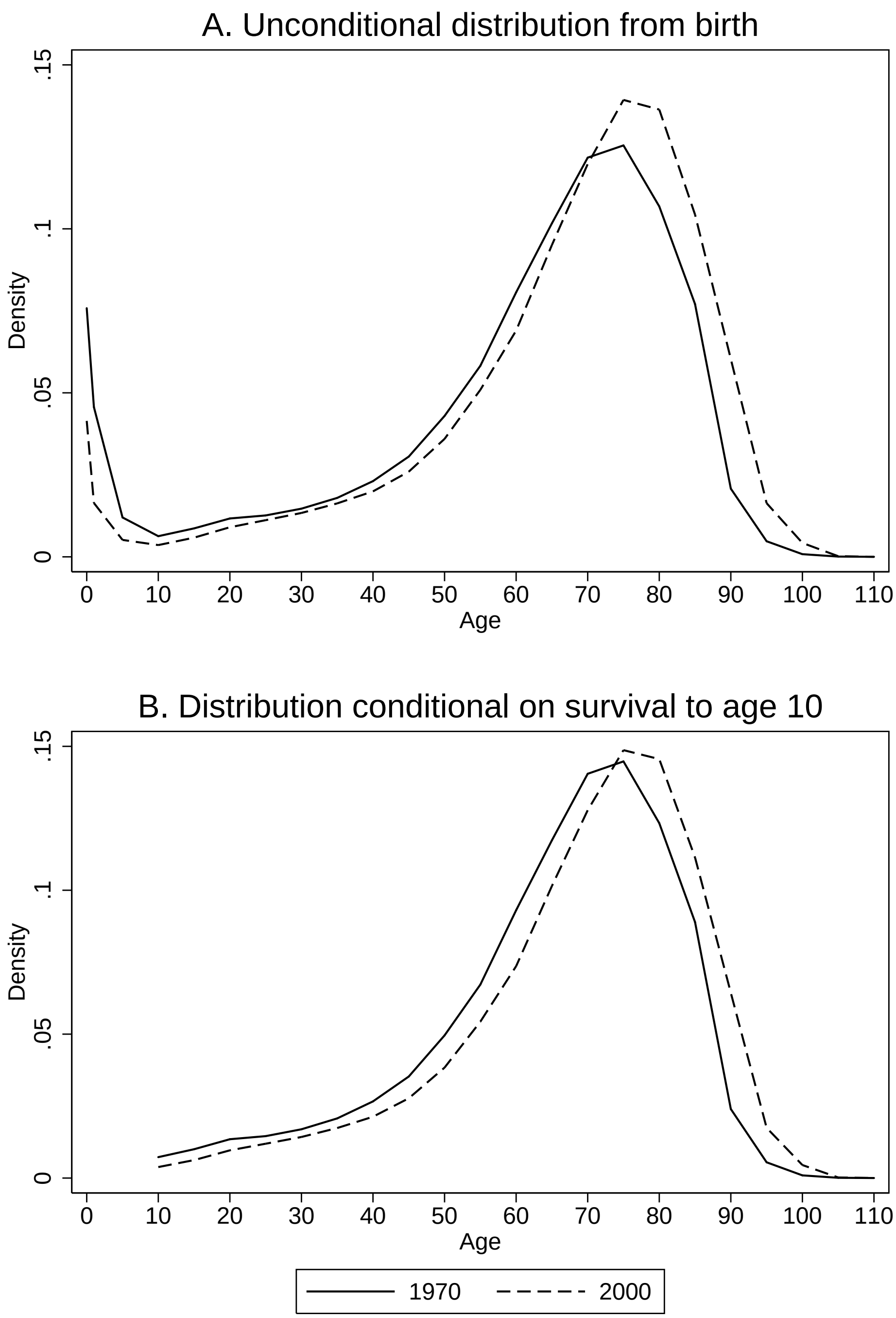
Notes: The source is author's calculations based on the dataset described in the paper. HMD stands for Human Mortality Database (2009), the highest-quality source. Probability densities are the life-table deaths, ${}_nd_x$. Statistics measured above age 10 are calculated conditional on survival to age 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.

Table A1: Countries in the dataset by World Bank region and quality

East Asia & Pacific	**High income**	**Latin America**	**Middle East**	**Sub-Saharan Africa**
Cambodia	* Australia	**& Caribbean**	**& North Africa**	Angola
†China	* Austria	†Argentina	†Algeria	Benin
Fiji	Bahamas, The	Belize	Djibouti	Botswana
Indonesia	Bahrain	Bolivia	Egypt, Arab Rep.	Burkina Faso
Korea, Dem. Rep.	Barbados	Brazil	Iran, Islamic Rep.	Burundi
Lao PDR	* Belgium	†Chile	Iraq	Cameroon
Malaysia	Brunei Darussalam	†Colombia	Jordan	Cape Verde
Micronesia, Fed. Sts.	* Canada	†Costa Rica	Lebanon	Central African Republic
Mongolia	Cyprus	†Cuba	Libya	Chad
Myanmar	* Czech Republic	Dominica	Morocco	Comoros
Papua New Guinea	* Denmark	Dominican Republic	Syrian Arab Republic	Congo, Dem. Rep.
†Philippines	Equatorial Guinea	Ecuador	Tunisia	Congo, Rep.
Samoa	* Estonia	†El Salvador	Yemen, Rep.	Cote d'Ivoire
Solomon Islands	* Finland	†Guatemala		Eritrea
†Thailand	* France	†Guyana		Ethiopia
Tonga	* Germany	†Haiti		Gabon
Vanuatu	†Greece	†Honduras		Gambia, The
Vietnam	†Hong Kong, China	Jamaica		Ghana
	* Hungary	†Mexico		Guinea
	* Iceland	Nicaragua		Guinea-Bissau
	†Ireland	†Panama		Kenya
	†Israel	Paraguay		Lesotho
	*Italy	†Peru		Liberia
Europe & Central Asia	* Japan	St. Lucia		Madagascar
Albania	†Korea, Rep.	St. Vincent and		Malawi
Armenia	†Kuwait	the Grenadines		Mali
Azerbaijan	* Luxembourg	Suriname		Mauritania
* Belarus	Malta	Uruguay		Mauritius
Bosnia and Herzegovina	* Netherlands	Venezuela, RB		Mozambique
* Bulgaria	* New Zealand			Namibia
Croatia	* Norway			Niger
Georgia	Oman			Nigeria
Kazakhstan	* Portugal			Rwanda
Kyrgyz Republic	Puerto Rico			Sao Tome and Principe
* Latvia	Qatar			Senegal
* Lithuania	Saudi Arabia			Sierra Leone
Macedonia, FYR	†Singapore			Somalia
Moldova	* Slovak Republic			†South Africa
* Poland	Slovenia		**South Asia**	Sudan
†Romania	* Spain		Afghanistan	Swaziland
* Russian Federation	* Sweden		Bangladesh	Tanzania
Serbia and Montenegro	* Switzerland		Bhutan	Togo
Tajikistan	* Taiwan		†India	Uganda
Turkey	†Trinidad and Tobago		Maldives	Zambia
Turkmenistan	United Arab Emirates		Nepal	Zimbabwe
* Ukraine	* United Kingdom		Pakistan	
Uzbekistan	* United States		Sri Lanka	

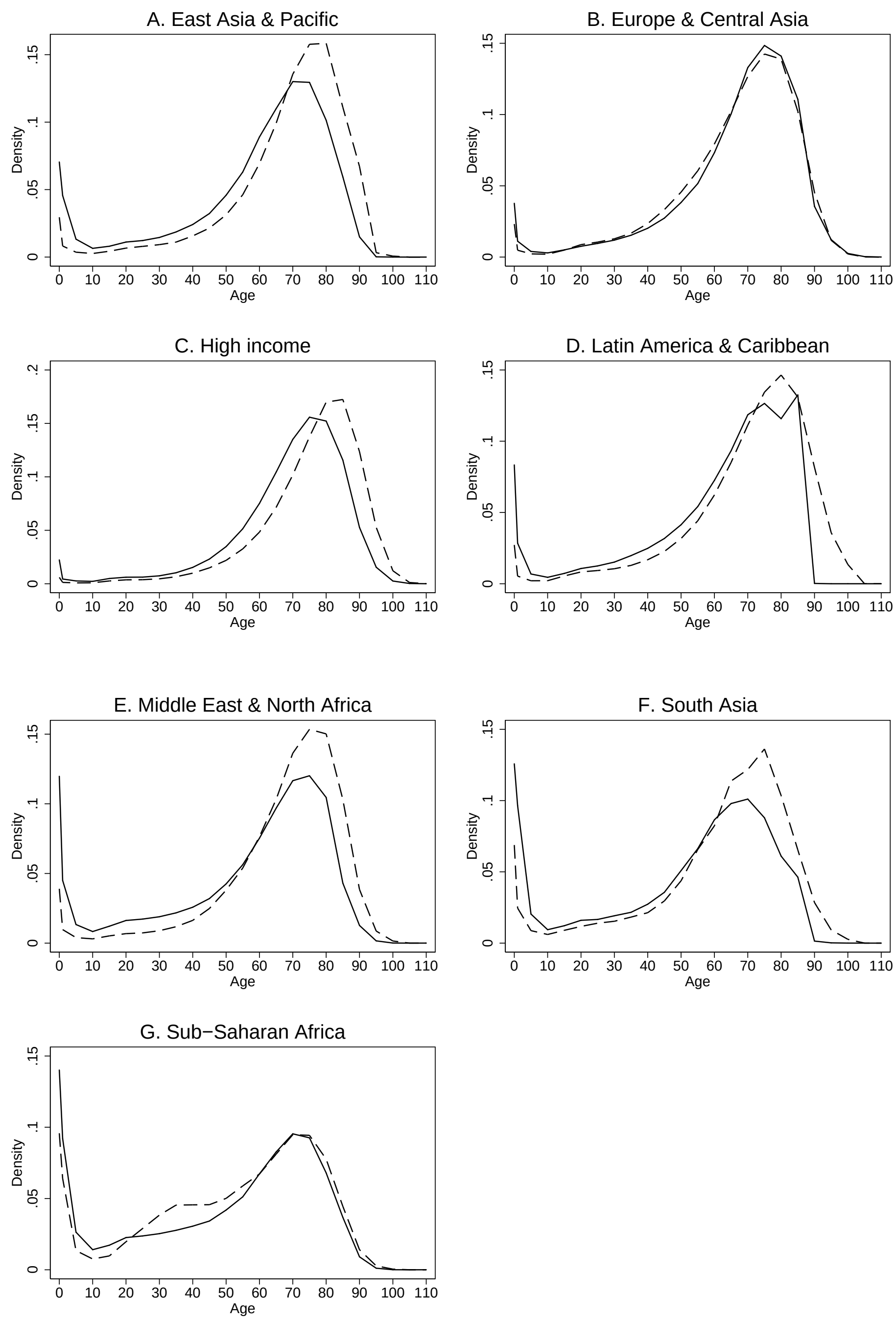
Notes: Countries whose names are preceded by an asterisk (*) are in the Human Mortality Database (2009) or "HMD" quality tier. That group of 33 countries plus the 28 countries whose names are preceded by a dagger (†) compose the "No model life tables" group. The latter subgroup of 28 are drawn from a variety of sources as described in the data appendix.

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



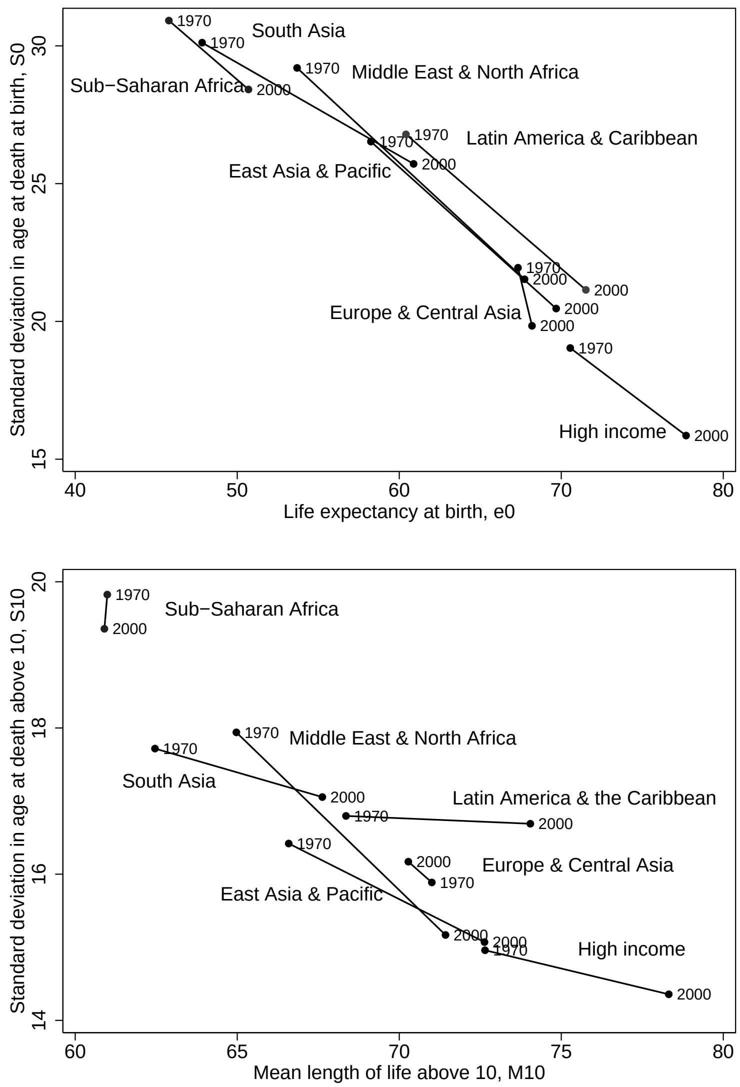
Notes: Data are life-table deaths ($_nd_x$) for the world population around the year 1970 or in 2000 constructed from the life tables and populations of 180 countries observed in both periods, as described in the text. Panel A plots the entire distribution across all ages; Panel B rescales death probabilities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

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



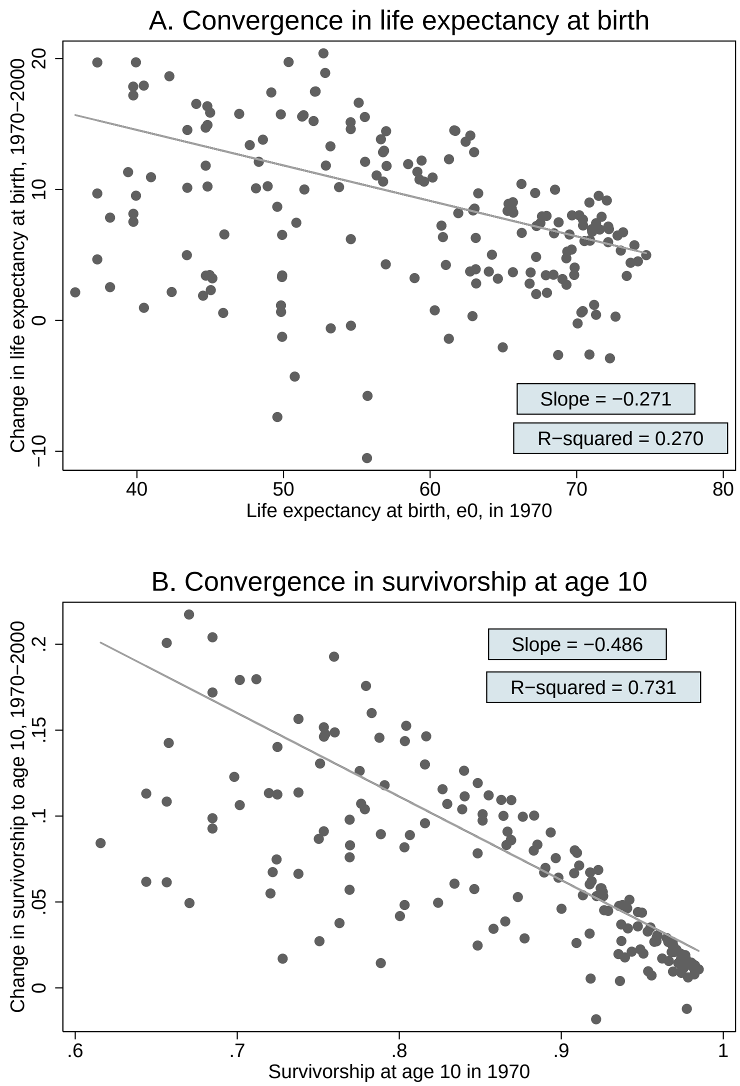
Notes: Data are life-table deaths ($_n d_x$) for populations in seven world regions around the year 1970 or in 2000 constructed from the life tables and populations of 180 countries observed in both periods, as described in the text. Regions are defined on the basis of development and geography by the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

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



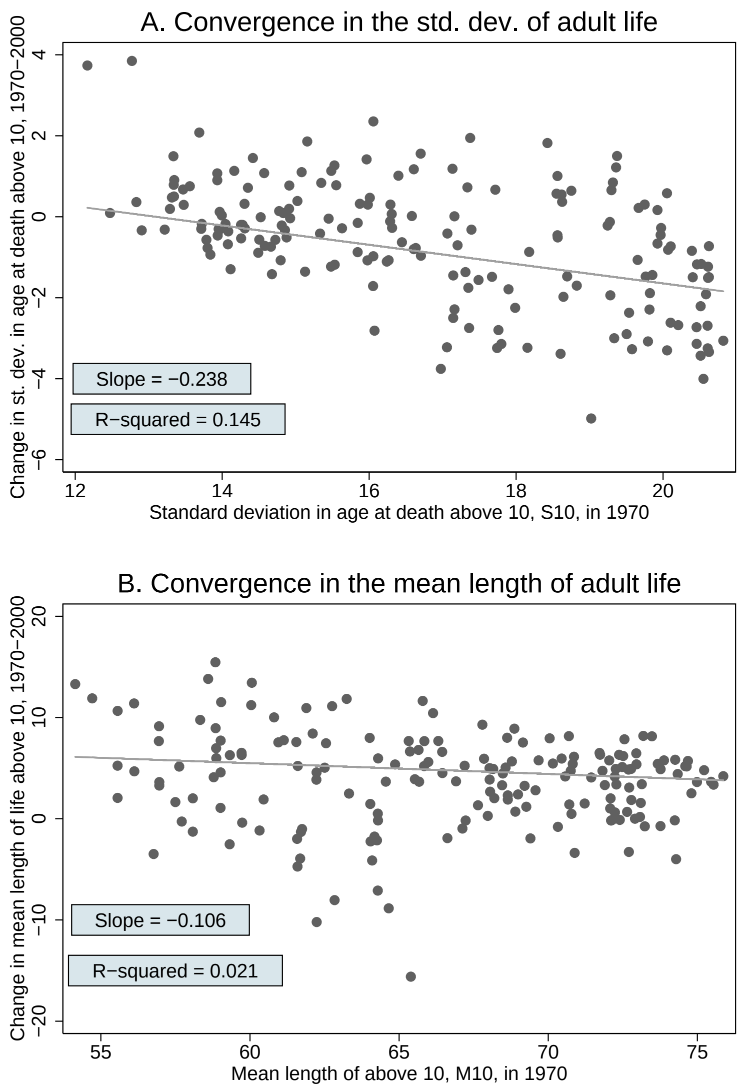
Notes: Data are means and standard deviations of length of life in world regions based on distributions of life-table deaths ($_nd_x$). Regions are defined on the basis of development and geography by the World Bank. The unconditional standard deviation of length of life at birth is S_0, while the standard 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 life expectancy at birth and survivorship at age 10, 1970 to 2000



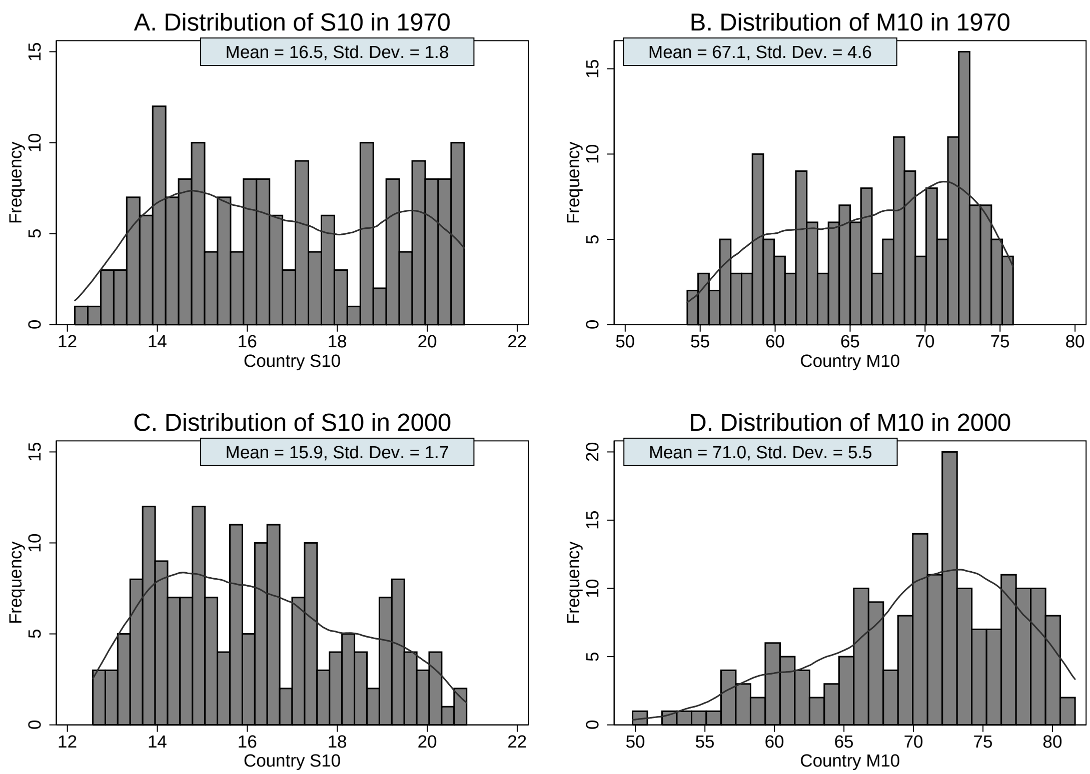
Notes: Data are period life expectancy at birth, e_0, and survivorship to age 10, ℓ_{10}, for 180 countries in the dataset described in the paper observed around 1970, and the changes in those variables for each country between 1970 and 2000. The lines are weighted-least squares trend lines using countries' populations as weights.

Figure 5: Convergence across countries in the mean and standard deviation in length of adult life, 1970 to 2000



Notes: Data are the standard deviation of length of life above age 10, S_{10} and the mean length of life above age 10, M_{10}, for 180 countries in the dataset described in the paper observed around 1970, and the changes in those variables for each country between 1970 and 2000. The lines are weighted-least squares trend lines using countries' populations as weights.

Figure 6: Histograms of the standard deviation and mean length of life above age 10, S_{10} and M_{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.