Length of Life Inequality Around the Globe: Within and Between Country Differences Disclosed and Decomposed

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Abstract

In this study, we address three basic questions about the degree to which length of life is distributed (un)equally within and among societies: (1) How large is overall inequality in length of life around the globe? (2) To what extent is this inequality caused by between-country differences and to what extent by within-country differences? (3) How is length of life inequality (LLI) related to life expectancy (LE)? To answer these questions, we first determine LE and LLI for the total adult world population in 2000 and decompose total world LLI into within and between country and geo-political region components. This analysis shows that most LLI (between 83 and 86 percent) is within country inequality. Next, we study the pattern of association between LE and LLI on the basis of a new database containing 9,053 life tables for 212 countries, covering a period of up to two centuries. The data reveal huge variation among countries and time periods in the degree to which the available years of life are distributed equally among the population. At similar levels of LE, mortality in the 15-50 age group may be 35 to 70 percent higher in the most unequal countries compared to the most equal ones. These findings make clear that not LLI as such, but LLI corrected for LE or relative length of life inequality (RLLI) is the most relevant indicator of length of life differentials within populations. Analyses of trends within countries show that countries that reached a certain LE earlier in time and countries that improved their LE more quickly experienced higher levels of RLLI.

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Acknowledgements
Earlier version of this paper were presented the spring meeting of the Research Committee on Social Stratification and Mobility (RC28) of the International Sociological Association, Neuchatel, 2004, at the Symposium on Inequalities in Population of the research Committee on Sociology of Population (RC41) of the International Sociological Association, Malta, 2005, and at Annual Meeting of the Population Association of America., New York, 2007. We are grateful to the participants of these meetings for their comments.
INTRODUCTION

One of the classic questions in the social sciences concerns the unequal distribution of resources and rewards among the members of societies. In some societies, life chances – in the broadest sense – are distributed more equally than in other societies. Socio-economic outcomes such as income, wealth, educational attainment and occupational status have been extensively studied to gain insight in the nature and causes of social inequality. For instance, there is a long research tradition that examines income distributions across societies and time (e.g. Alderson & Nielsen 2002; Firebaugh 2003; Bourguignon & Morrison 2002; UNDP 2005; Milanovic 2005). Another well-established tradition analyzes cross-national differences in educational and occupational status attainment (e.g. Treiman & Ganzeboom 1990; Araujo, Ferreira & Schady 2004; Hout & Diprete 2006). However, the ultimate expression of differences in life chances among individuals -- their differences in mortality chances -- has gotten much less attention.

Differences in health and mortality have been studied extensively in the fields of social epidemiology and public health, but the focus of most of these studies has been on differences among social groups or regions within societies (e.g. Townsend, Davidson & Whitehead 1988; Kaplan & Lynch 1997; Kunst, Groenhof & Mackenbach 1998; Wilkinson & Marmot 2003). There are much less studies that use differences in health and mortality among individuals -- independent of group membership -- as an instrument to study social inequality within and among countries. This is regrettable for at least four reasons. First, a long and healthy life is among the most highly valued and universal human goals, which makes it a useful indicator for comparing social inequality among societies that vary in economic and cultural respects. Second, it has been argued that socio-economic resources like income and wealth are instrumental for reaching other, more essential, goals of which a long and healthy life is among the most important ones (Sen 1979, 1985; Pradhan, Sahn & Younger 2003; Goesling & Firebaugh 2004). By analyzing the variation in length of life among individuals and societies, insight in the nature and causes of inequality with regard to these more essential goals is obtained. Third, inequality in length of life is more directly linked to absolute deprivation than inequality of income, education, occupation, or wealth (Pradhan et al 2003). Being poor may be a temporary state or be compensated by social redistribution mechanisms. More inequality in length of life, however, may imply that more individuals die premature; an irreversible situation. Fourth, the information needed for determining a country’s degree of inequality in length of life -- number of living persons and deaths by age group -- is more widely available and straightforward than the information needed for other inequality measures (Pradhan et al 2003; Cornia & Menchini, 2006). With inequality in length of life, therefore, a more comprehensive analysis of the causes of inequality is possible than with those other measures.

In this paper, we study the variation in the distribution of adult length of life within and among countries using a newly build database with over 9,000 life tables, covering almost all countries of the world and for many countries time periods of over a hundred years. Using this database, we aim to gain understanding of the nature of variation in adult length of life among countries and time periods in several ways. First, we establish the total world length of life inequality (LLI) for adult men and women in the year 2000 and decompose this inequality into within and between countries and geopolitical region components. Second, we disclose the full pattern of variation in adult length of life within and among countries, by plotting, for men and
women separately, LLI against life expectancy (LE) for over 4,500 country-year combinations. Third, we explore this pattern in more detail by (a) computing the magnitude of the differences in LLI within specific life expectancy categories, (b) comparing the size of these differences for selected countries, (c) highlighting trajectories of individual countries through the LE - LLI space, and by (d) studying the relation between LE and LLI over time.

In the following sections, we first make clear what LLI is and summarize what is known about the way it varies among and within countries. Then we discuss the relationship between LLI and LE. We conclude that the variation in LLI among countries at the same level of LE, which we will call relative length of life inequality (RLLI), might be the most relevant indicator of a society’s length of life inequality. We discuss why societies might differ in relative length of life inequality and formulate hypotheses on changes over time. After that we discuss the database, methods and measurement of the variables, followed by the presentation of our findings. The paper ends with a summarizing of the findings and a discussion of their implications for social inequality and public health.

Length of life inequality

At the population level, length of life is commonly known as LE, one of the most widely used indicators of the performance of societies. There is massive evidence that LE is distributed very unequally among countries (e.g. Bourguignon and Morrison 2002; Goesling and Firebaugh 2004; UNDP 2005; World Bank 2005). According to Bourguignon and Morrison (2002), between-country variation in LE decreased steadily during most of the 20th century until the 1980s. Since then, an increase has been observed, due to deviating trends in sub-Saharan African countries (see also Becker, Philipson and Soares 2005; Goesling and Firebaugh 2004; Schady 2005). Whether total world LLI has followed the same pattern is difficult to say, because little is known about the relative size of the between-country and within-country components. Research on other forms of inequality has shown that the between-country component can be over 70 percent (income inequality) but also under 20 percent (educational inequality) (Araujo, Ferreira and Schady 2004; Bourguignon and Morrison 2002; Goesling 2001). The available indirect evidence suggests that for LLI the between-country component might well be at the low side, in the order of 30 percent (Pradhan et al 2003; World Bank 2005). If so, this would stress the importance of analyzing the way in which length of life is distributed within countries.

Most research on LLI within countries has focused on variation among subgroups of the population. This literature has revealed substantial socio-economic and regional mortality differences within countries. It has been estimated that about a quarter of the total within-country inequality in health can be captured by differences among socioeconomic groups (Wagstaff and Van Doorslaer 2004). However, this literature gives less insight into the way in which life and death are distributed among individuals irrespective of group membership, which has been called the “univariate” approach to measuring health inequality by Wolfson and Row (2001).

There are several studies that focus explicitly on LLI (e.g. LeGrand, 1987; Wilmoth & Hiriuchi, 1999; Silber, 1988; Shkolnokov et al., 2003; Cheung et al., 2005; Edwards & Tuljapurkar, 2005). These studies found substantial differences in LLI among developed countries. However, in most of these studies no attempt was made to study LLI independent of
This is problematic because there exists a very high negative correlation between LLI and LE (as high as -.69 for all men in 32 countries studied by Shkolnikov et al (2003) and over -.90 for adults found in this study).

To explain the nature of this correlation and at the same time illustrate what we mean by LLI, Figure 1 presents the distribution of length of life for men in three countries (Niger, Brazil and Japan) at different levels of development in the year 2000. This figure shows that this distribution generally has two peaks. The first peak reflects the relatively high mortality at birth or directly thereafter. This peak is very high in Niger and low in Japan, reflecting the strong reduction of infant and child mortality that countries experience in the course of their modernization process. Because we concentrate on adult mortality, the first peak is not relevant for the present study.

From ages 5-10 onwards, mortality gradually increases until a second peak is reached somewhere in the 65+ age group. After this peak, the number of persons who reach a higher age decreases quickly. The difference in LLI among the three countries is clearly reflected in the variation of the distributions around the old age peak, which is much larger in Niger than in Japan. It is this variation around the old age peak, as measured by an inequality measure, which is the subject of this study.

< FIGURE 1 about here >

An important observation from Figure 1 is that the distribution of length of life is bounded at the right side. It is not bounded in a strict sense; the proportion of people reaching a very high age increases gradually. However, in practice, the proportion of people actually reaching a high age is small. It seems that reducing mortality is increasingly difficult at higher ages, although there is no consensus in the literature about the theoretical possibilities (Oeppen & Vaupel 2002; Wilmoth & Horiuchi 1999; Cheung et al 2005). With increasing LE, length of life becomes more and more concentrated in a small age band around the second peak of the distribution and, hence, variation in length of life becomes smaller if LE increases. It is this right-boundedness of the distribution that is responsible for the high negative correlation between LLI and LE. This high correlation is not in contradiction with the so-called mean-independence of inequality measures like the Gini coefficient, which only implies that, in theory, the mean of the distribution (LE) gives no information about the variance of that distribution (LLI).

The high correlation between both measures makes one wonder whether the study of LLI provides any new insights into social inequality, above what we already know from the study of LE. However, there is also evidence that increases in LE do not necessarily lead to lower LLI and that LLI may differ among populations at the same level of LE. Wilmoth and Horiuchi (1999) found that the trends in LLI and LE for Sweden did not show the same patterns. Edwards and Tuljaulkar (2005) decomposed differences in the distributions of age at death for Canada, Denmark, France and the United States between 1960 and 2000 and found them to be increasingly due to differences in the variances of the distributions. Shkolnikov et al. (2003, p. 339) showed for 32 high LE countries that, in spite of high correlations between LE and LLI, countries with similar LE may have substantially different levels of LLI.

These studies clearly indicate that there is more to LLI than LE. However, the number of countries examined was too small to reveal more than a glimpse of the pattern of length of life differences among them. In this study we aim to disclose the full pattern by analyzing male and
female LLI in relation to LE for over 4500 country-year combinations. We address the strong correlation between LLI and LE by focusing on the variation in adult LLI among countries with the same level of LE. This variation will be called relative length of life inequality (RLLI). We argue that studying that part of LLI that is not determined by LE contributes new insights to our understanding of inequality within societies. Much is already known about the causes of differences in LE among countries, but it remains an open question why countries with the same level of LE would vary in LLI.

It is important to stress that we restrict our analyses to adult mortality (age 15 and over). The factors that influence infant and child mortality are largely different from those affecting adult mortality (Cutler & Meara 2003; Marmot 2005; Bloom et al 2003; Wolleswinkel et al 1998). By focusing on length of life inequality among adults, a clearer picture is obtained of the inequality caused by the unequal distribution of resources, opportunities and rewards within societies (compare also Edwards & Tuljapurkar, 2005, p.648; Cutler, Deaton & Lleras-Muney 2006).

The time dimension

Given the strong association between LE and LLI, the study of trends in crude LLI over time is not particularly informative; these will almost completely reflect trends in LE. A more meaningful way to use the time dimension is by comparing relative inequality among countries that reached a certain level of LE in different years. In this way, we can test whether countries that reached a certain LE earlier, the so-called forerunner countries, have lower or higher LLI compared to countries that reached that level later. This is an important issue, because governments that want to increase LE have different strategic options. They may focus on reducing premature mortality, on reducing old age mortality, or on both. The strong negative correlation between LE and LLI suggests that the first option might be a powerful strategy for increasing LE. Any policy that is successful in reducing mortality in the younger age groups decreases LLI and increases LE at the same time. Policies that focus primarily on reducing old-age mortality, on the other hand, increase LE at the cost of higher LLI. We therefore expect countries that are successful in reducing their LLI to be among the forerunners in LE gain, and, hence, that countries that reach a certain LE earlier in time would have lower inequality at that level of LE than countries that reached that LE later. We call this expectation the forerunner hypothesis.

However, the forerunner hypothesis probably only applies to countries that are in the forefront of (public) health developments and hence have to invest much in (public) health improvements. Countries that lag behind have other strategic options. They do not need to invest in research and development, because they can take over new treatments, medicine and public health innovations developed in forerunning countries and in this way much more quickly and at lower costs achieve progress (Deaton 2004; Cutler, Deaton and Lleras-Muney 2006; Birchenall 2007). Countries that lag far behind have the additional advantage that the first steps towards increasing LE and reducing LLI are relatively easy. The costs of reducing premature mortality among adults in high mortality countries -- which is mostly due to infectious diseases, maternal mortality, traffic accidents and unhealthy work situations -- are much lower than the costs of a similar reduction in low mortality countries -- where chronic diseases are the major source of differences in length of life (Cutler and Meara 2003; Cutler,
Deaton and Lleras-Muney 2004). Thus, we formulate the diffusion hypothesis, which states that countries that reach a certain level of LE later in time will have lower LLI, because they can profit from diffusion of techniques and knowledge developed in forerunning countries.

DATA AND MEASUREMENT

The information needed to determine the degree of LLI for a given country in a certain year is available in life tables (LT), which basically contain data on total population and number of deaths in a country in a certain year broken down by age and sex. For our analyses we use 9,053 tables, representing 212 countries and many years. Most of the LT are for the period 1950-2003, but for many developed countries they reach much farther back in time, as far as the mid 19th century for Western European countries, 1806 for France and even 1750 for Sweden.

For most countries we use LT on the level of nation states. However, because China and India together comprise more than a third of the world population and have important institutional differences among their regions, we also collected LT at the province/state level for these countries. For some combinations of year, country and sex more than one source was available. In these cases, we selected one LT by using following hierarchy of the sources based on reliability and comparability: (1) Human Mortality Database (data collected by teams at Berkeley and Rostock), (2) LT from national bureau of statistics or other official publication, (3) Human Life-Table Database, (4) World Health Organization database on deaths and population, (5) International Database (IDB) of the US Bureau of the Census, (6) raw data on deaths and population from the UN and (7) WHO estimates for all countries for 2000. We removed LT that contained obvious errors, like a total LE at birth higher than the highest LE for that year as reported by Oeppen & Vaupel (2002), or with impossible values in any of the age categories.

We use abridged LT with 5-year age intervals up to 85. LT with more detail in our database were recalculated into this form to make them comparable to the others. Shkolnikov et al. (2003, p. 318-323) show that the Gini coefficient computed over abridged 85+ LT can be a reliable indicator of LLI, if an adjustment is made for the value of the open ended interval (85+). We have followed their method and made this adjustment for all the LT in our final database. In a few cases, only LT with a lower open-end interval than 85+ were available. For 80+ LT, we estimated the 85+ values by linear regression. For the states of India, part of the regional LT were 70+ tables. In these cases, the higher values were estimated using information from 85+ tables for other years. We are aware that these estimated LT and also LT from the 18th and 19th century and of some developing countries may be less accurate than recent data from industrialized countries. However, our substantive conclusions do not change if we leave out these less reliable LT. In Appendix A, we present further information about the LT and their sources.

All LT used in this study are period LT, because we are interested in inequality at a given point in time. Period LT do not actually reflect the experiences of real birth cohorts, but give a clear indication of the experiences of a population in a given year. Although current mortality rates are also influenced by cohort effects, there is evidence that the increase in adult mortality in the second half of the last century was to a large extent due to period factors (Kannisto 1994).
Measurement

LLI is measured by computing the Gini coefficient over the distribution of age at death from age 15 onwards. LE is calculated as the mean age of death from the same 15+ distribution. The distributions of age at death were obtained by applying the age and sex-specific mortality rates (q) from the LT to a population of 100,000 individuals aged 15, thus standardizing for differences in adult population structure among countries and time periods.

The Gini coefficient is a widely used inequality measure (Cowell 1995; Sen 1973). It can be computed by taking the mean of the difference in age at death (length of life) between every possible pair of individuals in the population, divided by the mean age at death (Cowell 1995). The Gini coefficient varies between zero and one, with zero indicating a situation of maximum equality -- everybody has the same age at death -- and one indicating maximum inequality. The choice of the inequality measure for computing LLI is not a critical one. The use of different inequality measures leads to similar results (Wilmoth and Horiuchi 1999). We use Gini as it most sensitive to the complete distribution. However, in order to be able to decompose properly, we also calculate Theil over the distribution of length of life when necessary.

In the decomposition analysis, an adjustment is made for natural variation in length of life. Perfect equality would imply that all member of a population die at the exact same age. However, even if all external causes of mortality would be eliminated, there would be some variation in length of life due to genetic differences. This means that there will always be a certain degree of within-country inequality. If we ignore this when decomposing, the between-country factor will be underestimated (Pradhan et al. 2003). Therefore we adjust our decomposition for a minimal level of within-country inequality. In doing so, we follow the approach by Pradhan et al. (2003). Obviously, the real genetic variation is unknown; however we know that it cannot be higher than the variation we observe in the most equal LT in our database. For men this was Iceland and for women Japan. In our analyses we assume the natural variation to be one-third lower than observed in these most equal LT. Taking into account natural variation in this way decreases the within-country component by 6 percent for women and 4 percent for men.

In our trend analyses, we use relative length of life inequality (RLLI) as dependent variable. RLLI is measured by standardizing LLI scores within one-year ranges of LE. In others words, RLLI represents the deviation from the average LLI at a certain level of LE in units of one standard deviation. Measured in this way, RLLI is not correlated with LE and is comparable across levels of LE.

The average number of LT per one-year level of LE is 199 for men and 174 for women. A reliable measure of RLLI can only be calculated at levels of LE for which we have a substantial number of country-year combinations. We set the cut-off point at 50 tables from at least 10 different countries. This means that we can calculate RLLI for countries that have a LE between 56 and 78 for men and between 58 and 83 for women. As a result of this restriction, measures of RLLI in the year 2000 are available for 157 countries for men and 153 countries for women.
RESULTS

Length of life inequality

Table 1 presents LE and LLI for the total world and for geo-political regions in the year 2000. The figures are based on a set of LT for virtually all countries in the world, consisting of real LT for the countries for which they were available and best estimates produced by the WHO on the basis of surveys and region-specific models for the remaining countries (Lopez et al. 2001). The resulting set of LT for 191 countries covers over 99 percent of the world population in the year 2000 and thus provides us with the possibility to calculate the total world LE and LLI for that year. Note that for computing the figures countries were weighted by their population size.

Table 1 shows that the worldwide LE at age 15 for men in the year 2000 was 68.6 years, more than four less than the 73 years for women. (Total world LE at birth in 2000 was 63.8 for men and 68.0 for women, according to our data. These figures are lower than at age 15, because of relatively high mortality rates among infants and children, even in the most developed countries of the world.) With regard to LLI, we see that length of life is more unequally distributed among men than among women (Gini coefficient of .128 and .115 respectively). Most LLI can be ascribed to within-country inequality. About 86% of total male LLI and 83% of total female LLI is due to within countries differences in length of life. Because the populations of India and China are so much larger than those of other countries, we also analyzed a set of LT where we substituted the single tables for China and India with LT at the province level for China (33 provinces) and state level for India (16 states). Differentiation within China and India did not influence the estimation of total world LLI much.

When we decompose total LLI by geo-political regions instead of individual countries, we obtain similar results. Using the regions listed in Table 1, we capture between 85 and 90 percent of the between-country component. South Asia (notably Afghanistan, Pakistan, Bangladesh, and India) and sub-Saharan Africa stand out, because in these regions inequality among women is equal to or larger than inequality among men. Notice also that the gender differences are particularly large in Eastern Europe and Russia. The mortality crisis in this region has especially hit middle-aged and younger men (McKee and Shkolnikov 2001).

To get an intuitively appealing idea of the magnitude of these differences in LLI, we have translated them into numbers of deaths in the 15-50 age group. A higher level of LLI implies that more persons reach a high age, but also that more persons die premature, e.g. before age 50. Because premature mortality has a more dramatic societal impact than longevity, we focus on the premature mortality figures. These figures are presented for heuristic reasons. They give an impression of the size of the mortality differences, but cannot be interpreted as inequality measures themselves, because as such they are not comparable across populations with different levels of LE. If two populations with the same Gini have different levels of LE, premature mortality is lower in the population with the highest LE. In the next sections therefore premature mortality rates are only compared within LE groups.

Table 1 shows that even though the between-country component comprises only one-sixth to one-seventh of all variation in LLI, there is huge variation in premature mortality between
men and women and among regions. At the total world level, the number of premature male
deaths (139 per 1,000) is about one third higher than the number of premature female deaths.
Among the geopolitical regions, the differences are even higher, ranging from 42 to 384 deaths
per 1,000 for men and from 20 to 364 for women.

Relative length of life inequality

The correlation between LLI and LE, as discussed in the theoretical section, can clearly be seen
in Table 1. Regions with a higher LE have lower LLI. The association becomes even clearer if
we plot LE against LLI for all available country-year combinations, as is done in Figure 2.
Each dot represents a male or female LT for a certain country in a certain year. In total, 9,063
LT for 212 countries are used. Figure 2 is restricted to more or less normal situations; country-
year combinations with extremely low LE due to severe calamities (wars, epidemics, famines)
are excluded. (Figures including calamities can be presented in an online supplement)

For both men and women, the dots are concentrated in an elongated cigar-like cloud
running from the upper left to the lower right, thus reflecting an extremely strong negative
correlation between LE and LLI (over -0.9). This correlation is higher than has been found in
earlier research on all-age LLI in high LE countries (Skolhnikov et al 2003). It suggests that for
adults an increase in LE may result in lower LLI.

Figure 2 also shows that at each level of LE the degree of LLI can differ greatly among
societies. For example, for populations with a LE of 65 (marked A in Figure 2), male LLI
varies roughly between 0.11 and 0.16 and for populations with a LE of 73 (marked C) between
0.08 and 0.12. Similar variation is observed for women. This variation implies that the way in
which length of life in a society is distributed among the population members varies among
societies and time periods even if the total number of years of life is similar.

Figure 2 also demonstrates that the absolute level of LLI, which has been used in earlier
studies (e.g. LeGrand 1987; Silber 1988; Edwards and Tuljapurkar 2005) is a less informative
measure, because whether a specific level of LLI is high or low depends on the level of LE. A
LLI of 0.12 is relatively low in male populations with a LE of 65, but it is high in populations
with a LE of 73. To obtain a more meaningful indication of LLI for a given population, it is
therefore necessary that LLI in a population is compared with LLI in other populations at the
same level of LE. This degree of LLI in comparison with other populations at the same level of
LE is what we have called RLLI.

Magnitude of differences

Before moving on to the analyses of cross-national differences in RLLI, it is important to get
an idea of the magnitude of the variation in this form of inequality. What does it mean that in a
population with a certain LE the Gini coefficient for LLI is, for instance, 0.03 higher than in
another population with a similar LE? Is this a large disparity? Translating these differences
into numbers of premature deaths in the 15-50 age-group (as in Table 1) gives a more
appealing impression of their magnitude. In Figure 3, we present number of premature deaths
by RLLI quintiles for men and women at three arbitrary levels of LE, marked A, B, and C in Figure 2. Because they refer to populations with similar LE, the premature mortality rates presented here are well comparable.

Figure 3 shows that at the same level of LE, substantial differences in premature mortality exist. In populations with a male LE of 73 (72.5 - 73.5), the average number of men dying before age 50 is 58 per 1,000 in the 20% most equal societies. This number increases by each quintile until it reaches a level of 92 per 1000 in the 20% most unequal societies. This means that at a LE of 73, premature mortality among men is as much as 34 per 1000 or 59% higher in the most unequal societies compared to the most equal ones. For societies with a LE of 69, the difference in premature mortality between the lowest and highest quintiles of RLLI is almost the same: 58%. At a LE of 65, the difference is somewhat lower, but with 37% still substantial. For women we find similar differences, ranging from 33% at a LE of 70, to 72% at a LE of 74. These huge differences in premature mortality (all significant at p<0.001) stress the importance of RLLI as an indicator of mortality differences among populations.

We give another example to illustrate the magnitude of differences in RLLI among developed Western societies. Recent data for the US (2003) show a male LE of 75.56 and a LLI of 0.102. When France reached the same level of LE (in 1999) its LLI was quiet similar (0.099). However, when Sweden and England & Wales (E&W) reached that LE (in 1990 and 1997 respectively), LLI was much lower, namely 0.089 and 0.088. Expressed in terms of premature mortality, the higher RLLI in the US and France translates into about 70 premature deaths per 1,000, compared to about 49 in E&W and Sweden. Thus, while the average number of years of life available to the population members was the same in these four societies, the number of premature deaths was about 40% higher in countries with high RLLI.

Trajectories of countries

An illuminating extension of the foregoing can be obtained by highlighting the trajectories described by individual countries through the dotted areas in Figure 2. Such trajectories for men from England and Wales, France, the United States and Sweden are presented in Figure 4. This figure shows that the country-specific trajectories are not steadily decreasing chronological lines, but that, depending on what happens in the country in a given year, the trajectory may move forward and backward through the LLI - LE space. For example, for three of the four countries, the first observation at the upper left corner is not for the first observed year (e.g. for Sweden it is 1790 instead of 1751). Even after 1950, there are many years in which LE is slightly lower than in the preceding year. For the four countries in Figure 5, such a decrease was observed for 28% (men) and 23% (women) of the annual changes since 1950.

The trajectories reveal interesting variations, both within and among countries, like changes into the direction of more or of less equality and periods of acceleration and deceleration. There are also huge differences in whether and when such changes took place and in which year a country reached a certain level of LE or LLI. The trajectory for England and Wales is mostly located near the lower boundary, indicating that during most of the 160-year period, RLLI among men in this country was low. The French observations, on the other hand, were
located in the upper part of the cloud for a substantial part of time. Thus, over most of the period observed, male RLLI was higher in France than in England and Wales. For the United States, we see high levels of RLLI in the 19th and early 20th century, followed by a period of moderate inequality until the 1970s, after which RLLI rises again to reach a relatively high level in the 1990s. Sweden shows much variation in the 18th and 19th century, followed by a period of high RLLI in the first half of the 20th century. After World War II, Sweden moves towards the lower part of the cloud, reaching a level of relatively low inequality in 2005.

In Figure 5, comparable trajectories are presented for women. The pictures are quite similar to those for men. However, since WWII, RLLI for women in England and Wales was less favorable than for men, whereas in France it was more favorable than for men.

Highlighting the trajectories of individual countries is a powerful instrument for detecting variations in RLLI among countries and time periods. By relating these variations to processes taking place within the countries, insight can be gained into the factors responsible for the (unequal) distribution of life within societies, or into what has been called “the causes of the causes” (Marmot 2005; Rose 1992).

The time dimension

The finding that Sweden and England and Wales reached a certain level of LE earlier and with lower inequality than the United States and France might imply that policies aimed at increasing LE are more efficient if they focus on reducing health inequalities. This would be in line with the forerunner hypothesis. To test this hypothesis and the diffusion hypothesis more formally, Figure 6 shows the result of a regression analysis of RLLI on year and year square for all country-year combinations in the period 1900-2000 for which we have data (again excluding calamities). For both men and women, RLLI decreased in the course of this century in a nonlinear way. The decrease is strongest in the beginning of the century and slows down over time. This means that countries that reached a certain level of LE earlier in time had higher levels of inequality than countries that reached that level later in time. These results are in line with the diffusion hypothesis and contradict the forerunner hypothesis. They suggest that the observed difference between Sweden and England and Wales on the one hand and the United States and France on the other hand, is an exception rather than the rule.

Another way to test the forerunner hypothesis is by correlating speed of within-country changes in LE with within-country changes in RLLI. We use observations from 1950 onwards for 31 countries in the Human Mortality Database (being the most complete year-to-year data). The correlation between speed of improvement in LE within the countries over five year periods and the changes in RLLI within the same periods are 0.50 for men and 0.42 for women. Similar results were obtained by a fixed effects panel model with lagged effects. This implies that countries that were most successful in improving LE during a five-year period
experienced a deterioration of RLLI in that period. This result is clearly not in line with the forerunner hypothesis.

CONCLUSIONS

LLI can be viewed as one of the fundamental forms of inequality in the world. However, until now little was known about the nature and patterns of within-country LLI. We compiled a large database to analyze the variation in LLI within and among virtually all countries of the world. Our descriptive analysis for the world as a whole and for 13 major geopolitical regions showed that total world LE for persons aged 15 and over in the year 2000 was 68.6 years for men and 73 years for women. The Gini coefficient for total world LLI was 0.128 for males and 0.115 for females, which, translated into premature deaths, boils down to 139 and 104 deaths per 1000 persons aged 15-50 respectively. Hence women not only live longer but also experience less differences in length of life than men.

The decomposition analysis showed that most of the variation in adult LLI (86 percent for men and 83 percent for women) in 2000 was within-country variation. The between-country component is in the same order as that for educational inequality, but much smaller than the about 70 percent for income inequality (Araujo, Ferreira and Schady 2004; Bourguignon and Morrison 2002; Goesling 2001). It is somewhat smaller than the 30 percent found by Pradhan et al. (2003) for inequality in stunting among children. Most of the between-country variation (over 80 percent) consists of variation among 13 major geopolitical regions of the world. These findings suggest that the major causes of adult LLI should be sought in unequal distribution processes within countries. It should be kept in mind that this not necessarily needs to be the case for all-age LLI. Given the large variation in infant and child mortality among countries, the between-country component of all-age mortality probably is higher.

Our detailed analysis of the pattern of association between LLI and LE on the basis of more than 9,000 LT revealed a strong association between LLI and LE. This indicates that an increase in LE generally results in lower LLI. The analysis also made clear that the absolute level of LLI, as used in earlier research, is not an informative measure if analyzed on its own. Our results showed that whether a country’s level of LLI should be considered high or low depends on the LE of that country. This implies that for assessing the performance societies with respect to LLI, their level of inequality should be compared to this level in other societies with similar LE. We proposed to call this Relative length of life inequality or RLLI.

Our analyses revealed large differences in RLLI among the populations studied. Within country-year combinations with the same LE, premature mortality was found to be 30% to 70% higher in the 20 percent most unequal societies compared to the 20 percent most equal ones. Differences of this size were not only found among developing countries, but also among the most highly developed countries of the world (like the USA, France, Sweden, and UK).

The existence of such large differences in RLLI, even among highly developed countries, raises questions about the mechanisms responsible for them. As these countries differ little in technological development and genetic differences probably are too small to play a role of importance, it seems that behavioral differences and social distribution mechanisms play a major role. There may for example be differences in the accessibility of the health care system, in redistribution systems, like social security and pension schemes, in violence, in environmental and traffic safety, or in eating, drinking and smoking habits. The difference
between England & Wales and France might be due to a greater accessibility of the English health care system, but just as well to the more exuberant lifestyle of the French men (compare Mesle and Vallin 1998). It is a great challenge to identify the factors that are responsible for these differences and to find out which social and behavioral changes might be associated with gains in RLLI.

To make a first step in this direction, we supplemented our descriptive analyses with a trend analyses in which two hypotheses on changes in LE and LLI were tested. The first of these hypotheses, called the forerunner hypothesis, supposes countries that reach a certain level of LE earlier in time to have lower inequality, because reducing premature mortality would lead to more gains in LE than reducing old-age mortality. The second hypotheses, called the diffusion hypothesis, supposes countries that lag behind in LE to have lower levels of inequality at any LE, because they can profit of the new treatments, more effective medicines and public health innovations developed in forerunning countries. Our analyses indicated that forerunner countries have higher levels of RLLI. This suggests that these best performers focused on reducing old-age mortality, while accepting relative high levels of mortality in the younger age groups. Hence reducing inequality and gaining increases in LE seem to be alternative goals that require different policy measures to be achieved. This finding, together with the fact that higher inequality means more people dying too young, implies that policy measures aimed at increasing LE of the old should be supplemented with social redistribution policies that make the health care system better accessible to the poor.

Monitoring RLLI besides other performance measures of societies might become essential in the coming decades. RLLI reflects generic inequality in length of life brought about by the impact of many social and behavioral determinants of health. It shows the overall performance of a country with regard to the distribution of resources needed for a long life and the creation of healthy life conditions, compared to other countries at the same level of LE. As advancements in biomedical sciences reduce mortality from diseases, non-medical factors, like unequal social distribution mechanisms, become increasingly important as obstacles to further gains in LE. When new possibilities to live longer are only available to selects groups in society, LE of these groups will rise, but the country’s overall performance will not improve much. This might be exemplified by the performance of countries like France and the US, where the gain in male LE has been modest over the last decades and RLLI has increased, in spite of the fact that per capita health expenditures have been high in both countries (in the US even highest of the world (WHO 2005)). Is this because health resources have not been sufficiently redistributed among the entire population, or are other mechanisms playing roles?

In line with the conclusion of the 2005 Human Development Report (UNDP 2005) that “Distribution should be put at the center of strategies for human development” (p. 71), we conclude that focusing on LE alone might not be sufficient to truly evaluate a society's overall performance with regard to mortality: RLLI should be studied as a separate and fundamental aspect of the mortality patterns of societies. Analyzing the relationship between a country's RLLI and its health and social policies, as well as other social and economic factors will enhance our understanding of the social determinants of health, or the 'causes of the causes' that produce health differences within and among countries.
REFERENCES


Figure 1. Distribution of length of life for males in Niger, Brazil and Japan in 2000
Figure 2. Length of life inequality by life expectancy for adult (15+) men and women based on 9,063 life tables for 212 countries.
Figure 3. Number of premature deaths (age 15-50) per 1,000 men or women by quintile of length of life inequality (LLI) and different levels of life expectancy (LE)
Figure 4. Trajectories through the LLI-LE space for men in the England & Wales, France, United States and Sweden.
Figure 5 Trajectories through the LLI-LE space for women in the England & Wales, France, United States and Sweden
Figure 6. Relation between year in which a level of life expectancy was reached and relative length of life inequality
Table 1. Life expectancy and length of life inequality age 15+ and premature mortality for the world as a whole and for geo-political regions in 2000

<table>
<thead>
<tr>
<th>Region</th>
<th>Life expectancy Men</th>
<th>Gini</th>
<th>Theil</th>
<th>Premature mortality</th>
<th>Life expectancy Women</th>
<th>Gini</th>
<th>Theil</th>
<th>Premature mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>68.58</td>
<td>0.128</td>
<td>0.031</td>
<td>139</td>
<td>73.03</td>
<td>0.115</td>
<td>0.028</td>
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<td>Japan</td>
<td>77.20</td>
<td>0.016</td>
<td>0.102</td>
<td>42</td>
<td>83.35</td>
<td>0.009</td>
<td>0.082</td>
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<td>Western Europe</td>
<td>74.99</td>
<td>0.018</td>
<td>0.094</td>
<td>56</td>
<td>80.69</td>
<td>0.011</td>
<td>0.070</td>
<td>26</td>
</tr>
<tr>
<td>Western offshoots</td>
<td>74.40</td>
<td>0.021</td>
<td>0.110</td>
<td>68</td>
<td>79.33</td>
<td>0.014</td>
<td>0.093</td>
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<td>China</td>
<td>71.56</td>
<td>0.020</td>
<td>0.108</td>
<td>73</td>
<td>75.94</td>
<td>0.018</td>
<td>0.105</td>
<td>53</td>
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<tr>
<td>Middle-east and North Africa</td>
<td>70.41</td>
<td>0.024</td>
<td>0.110</td>
<td>90</td>
<td>73.80</td>
<td>0.019</td>
<td>0.097</td>
<td>63</td>
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<tr>
<td>Latin America &amp; Carribean</td>
<td>69.96</td>
<td>0.032</td>
<td>0.128</td>
<td>126</td>
<td>75.76</td>
<td>0.019</td>
<td>0.098</td>
<td>61</td>
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<tr>
<td>Pacific islands</td>
<td>68.69</td>
<td>0.027</td>
<td>0.122</td>
<td>115</td>
<td>72.54</td>
<td>0.023</td>
<td>0.112</td>
<td>84</td>
</tr>
<tr>
<td>East Asia (excl China and Japan)</td>
<td>68.64</td>
<td>0.031</td>
<td>0.126</td>
<td>129</td>
<td>73.22</td>
<td>0.023</td>
<td>0.107</td>
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<tr>
<td>South Asia</td>
<td>66.91</td>
<td>0.032</td>
<td>0.133</td>
<td>150</td>
<td>68.78</td>
<td>0.033</td>
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<tr>
<td>Central Asia</td>
<td>66.62</td>
<td>0.033</td>
<td>0.135</td>
<td>153</td>
<td>72.00</td>
<td>0.025</td>
<td>0.114</td>
<td>90</td>
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<tr>
<td>India</td>
<td>66.19</td>
<td>0.031</td>
<td>0.136</td>
<td>144</td>
<td>70.16</td>
<td>0.031</td>
<td>0.137</td>
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<tr>
<td>Eastern Europe &amp; Russia</td>
<td>64.74</td>
<td>0.035</td>
<td>0.140</td>
<td>181</td>
<td>74.50</td>
<td>0.018</td>
<td>0.095</td>
<td>59</td>
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<tr>
<td>Sub-saharan Africa</td>
<td>56.65</td>
<td>0.058</td>
<td>0.190</td>
<td>384</td>
<td>58.08</td>
<td>0.071</td>
<td>0.207</td>
<td>364</td>
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</table>

Decomposition of total world inequality

<table>
<thead>
<tr>
<th></th>
<th>% within country inequality</th>
<th>% between country inequality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>86.2%</td>
<td>13.8%</td>
</tr>
</tbody>
</table>

Note: Gini= Gini coefficient for length of life inequality; Theil=Theil coefficient for length of life inequality; Premature mortality=deaths per 1,000 age 15-50. Decomposition based on Theil coefficient