Social Science & Medicine 68 (2009) 1114–1123

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Length of life inequality around the globe☆

Jeroen Smits [a,*], Christiaan Monden [b]

[a] Department of Economics, Radboud University Nijmegen, PO Box 9108, 6500 HK Nijmegen, The Netherlands
[b] Department of Sociology, Tilburg University, The Netherlands

ARTICLE INFO

Article history:
Available online 26 January 2009

Keywords:
Adult mortality
Inequality
Length of life
Cross-national comparison
Life expectancy

ABSTRACT

Inequality in the distribution of adult length of life – defined as age at death in the population aged 15 and over – is studied for virtually all countries of the world using a new database with over 9000 life tables 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. Most length of life inequality (about 90%) is within-country inequality. Our findings make clear that measures of length of life inequality should be adjusted for life expectancy to get a more relevant indicator of length of life differentials across populations. At similar levels of life expectancy, substantial differences in inequality are observed, even among highly developed countries. Expressed as premature mortality, inequality may be 35–70% higher in the most unequal countries compared to the most equal ones. Countries that reached a certain level of life expectancy earlier in time than other countries, and countries that improved their life expectancy more quickly than others, experienced higher levels of inequality.

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 studied extensively to gain insight into 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. Bourguignon & Morrison, 2002; Firebaugh, 2003; Milanovic, 2005; UNDP, 2005). Another well-established tradition analyzes cross-national differences in educational and occupational status attainment (e.g. Araujo, Ferreira, & Schady, 2004; Hout & DiPrete, 2006). However, the ultimate expression of differences in life chances among individuals – the variation in length of life – has received 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. Kunst, Groenhof, & Mackenbach, 1998; Townsend, Davidson, & Whitehead, 1988; Wilkinson & Marmot, 2003). Only a few studies 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 much 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 (Goesling & Firebaugh, 2004; Pradhan, Sahn, & Younger, 2003; Sen, 1985). By analyzing the variation in length of life among individuals and societies, insight into 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,

☆ Authors are listed in reverse alphabetical order and contributed equally to the paper. A substantial part of the work on data collection and data comparability was made possible by a grant from the Netherlands Scientific Foundation, VIDI-grant number 452.03.351.

We are indebted to many colleagues and statistical offices who have made life tables available for this project, to Ellen Webbink, Janine Huisman, and Roger Smeets for their assistance in making electronic versions of the many life tables that were only available in paper form, and to Wout Ultee who long ago taught us that the same distributive mechanisms apply to years of life as to any other desirable good or resource. Earlier versions of this paper were presented at the RC28 Spring meeting in 2005 and the PAA Annual Meeting 2007. Further information on the project and the data used for this paper are available at www.lengthoflife.org.

* Corresponding author. Tel.: +31 24 3612319; fax: +31 24 3612379.
E-mail addresses: jeroen.smits@fm.ru.nl (J. Smits), c.w.s.monden@uvt.nl (C. Monden).

0277-9536/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.socscimed.2008.12.034

education, occupation, or wealth. 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 prematurely; 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 (Cornia & Menchini, 2006; Pradhan et al., 2003). 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 focus on adult length of life, defined as the total number of years persons over age 15 will live, or, similarly, the age at which these persons will die. We study the variation in the distribution of adult length of life within and among countries using a database with over 9000 life tables, covering almost all countries of the world and for many countries periods of over a hundred years. Using this database, we aim to gain understanding of the nature of the variation in adult length of life among countries and time periods in several ways. First, we establish total world life expectancy and length of life inequality by sex for 191 countries in the year 2000 and decompose this inequality into within-country and between-country components. Second, we disclose the full pattern of variation in adult length of life inequality within and among countries, by plotting length of life inequality against life expectancy for over 4500 country–year combinations. Third, we explore this pattern in more detail by (a) computing the magnitude of inequality differences within life expectancy categories, (b) comparing the size of inequality differences across selected countries, (c) highlighting changes in inequality in relation to changes in life expectancy within individual countries, and by (d) studying the association between length of life inequality and life expectancy over time.

Length of life inequality

At the individual level, length of life is simply the number of years a person has lived at the moment of her/his death. Length of life is thus synonymous with age at death. As not everybody dies at the same age, there is inequality in length of life among individuals. This inequality is in part due to genetic differences and intangible factors like good or bad luck, but also depends on the total amount of (nutritional, health and security) resources available in the society in which an individual lives and on the distribution of these resources among the population members. It is this last distributional component in which inequality researchers are mostly interested, because it potentially can be influenced by policy measures.

At the population level, length of life is closely related to life expectancy, one of the most widely used indicators of the performance of societies. Life expectancy of a population at a certain point in time reflects the average number of years an individual would live if (s)he would face during her/his entire life the age-specific mortality rates of this population at that point in time. In other words, it gives the expected average length of life based on the current mortality pattern. Because age-specific mortality rates change over time, life expectancy does not accurately predict the actual number of years an individual will live. However, because it combines information on the health situation of all age groups in a given year, it gives an excellent indication of the overall health performance of a society at a specific point in time.

Life expectancy is distributed very unequally among countries (e.g. Bourguignon & Morrison, 2002; Goesling & Firebaugh, 2004; UNDP, 2005; World Bank, 2005). According to Bourguignon and Morrison (2002), between-country variation in life expectancy 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, & Soares, 2005; Goesling & Firebaugh, 2004; Schady, 2005). However, whether total world length of life inequality has followed the same pattern is difficult to say, because most research is focused on between-country variation and little is known about the relative size of the within-country component. Research on other forms of inequality has shown that, depending on the outcome considered the within-country component can account for less than 30% (income) but also over 80% (education) of total inequality (Araujo et al., 2004; Bourguignon & Morrison, 2002; Goesling, 2001). The available indirect evidence suggests that for length of life inequality the within-country component might be quite high, in the order of 70% (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. In our analyses we will determine the size of this within-country component.

A two-peaked distribution

To illustrate what we mean by length of life inequality, Fig. 1 presents the distributions of length of life (or age at death) for men in three countries (Niger, Brazil and Japan) with different levels of development in the year 2000. These distributions show the number of deaths by age that we would observe in a birth cohort of 100,000 men if they were to experience the mortality pattern of the year 2000. For instance, in Niger about 1000 males of the cohort of 100,000 die at the age of 35, whereas at that age in Brazil about 500 die and in Japan only about 100. At the age of 80 we see a reversed pattern with about 3500 male deaths in Japan and about 800 in Niger, reflecting the fact that in Japan more males survive to this age than in Niger.

The differences in length of life inequality among these countries are clearly reflected in the distributions. In Japan the number of years lived by the males who died in 2000 are much more similar than in the other countries. The majority of Japanese males reach the age of 70 and die between 70 and 90, whereas in Niger and to a lesser extent also in Brazil, the ages at death show much more variation. Hence inequality in male length of life in 2000 was lower in Japan than in Niger and Brazil.

Fig. 1 also shows that the distribution of age at death generally has two peaks. The first peak indicates infant and child mortality. This peak is high in Niger and low in Japan, reflecting the strong reduction of infant and child mortality experienced by modernizing societies. From age 10 to 15 onwards, mortality gradually increases until a second peak is reached somewhere after age 65. After this peak, the number of persons who reach a higher age decreases

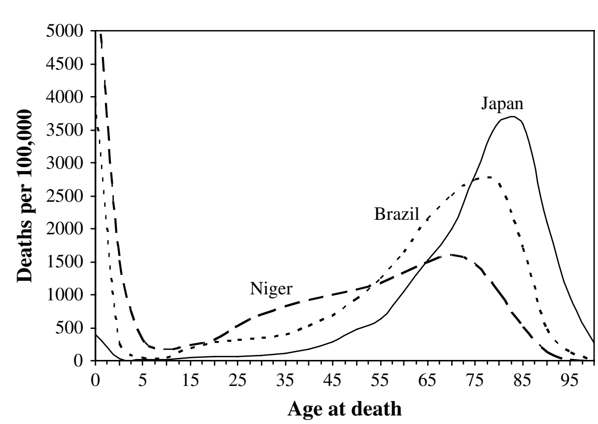

Fig. 1. Distribution of length of life for males in Niger, Brazil and Japan in 2000.

quickly. The two peaks reflect different underlying causes of variation in length of life. The reduction of infectious diseases due to sanitary practices and the introduction and diffusion of effective medicine has drastically reduced infant and child mortality in most parts of the world. However, these developments had less influence on adult mortality patterns, which tend to change more slowly and partly under influence of other mechanisms (Bloom, Canning, & Sevilla, 2003; Cutler & Meara, 2003; Marmot, 2005).

Given these differences and the fact that comparing inequality measures across two-peaked distributions is problematic – similar effects may be caused by changes in the first, the second, or both peaks – it is recommended to study inequality at each peak separately. Because we are mostly interested in social distribution mechanisms among adults, our analyses are restricted to length of life inequality among individuals aged 15 and over. For this group, length of life is measured by age of death (calculated on basis of the mortality pattern in the life table, see Data and measurement section). About 80% of all deaths in 2000 occurred in the 15+ age group (own calculations). For reasons of comparison, the figures on total world inequality and life expectancy are also presented for all age groups.

Research on length of life inequality

Most research on length of life inequality within countries has focused on variation among subgroups of the population. This literature has revealed substantial socio-economic and regional mortality differences within countries. However, it gives less insight into the way in which life and death are distributed among individuals irrespective of group membership, which Wolfson and Rowe (2001) call the "univariate" approach to measuring inequality. For instance, a Canadian study suggests that only a quarter of the total health differences among individuals is captured by differences among income groups (Wagstaff & Van Doorslaer, 2004). We argue that both approaches to measuring inequality are important and complement each other (for references to the debate about the two approaches see Asada (2006)). In this study, we focus on length of life inequality regardless of group membership.

Several studies explicitly address this form of length of life inequality (e.g. Cheung, Robine, Tu, & Caselli, 2005; Edwards & Tuljapurkar, 2005; Kannisto, 2001; LeGrand, 1987; Shkolnikov, Andreev, & Begun, 2003; Silber, 1988; Ultee, DeGraaf, & Van Puijenbroek, 1989; Wilmoth & Horiuchi, 1999). They found substantial differences in this form of inequality among developed countries. However, in most of these studies no attempt was made to study the variation in inequality among countries independent of the life expectancy of these countries. This is problematic because there exists a high negative correlation between length of life inequality and life expectancy of populations. This correlation is caused by the fact that, because life is finite, the distribution of length of life in Fig. 1 is bounded at the right side. The distribution is not bounded in a strict sense; the proportion of people reaching high ages increases gradually. However, in practice, the proportion of people actually reaching very high ages 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 (Bongaarts, 2006; Oeppen & Vaupel, 2002; Wilmoth & Horiuchi, 1999). With increasing life expectancy, age at death becomes more and more concentrated in a small band around the second peak of the distribution and, hence, variation in length of life becomes smaller. This right-boundedness of the distribution causes a high negative correlation (over -0.90 in our data) between length of life inequality and life expectancy.

The high correlation between both measures makes one wonder whether studying length of life inequality can provide new insights into social inequality, above what we already know from the study of life expectancy. There is evidence, however, that increases in life expectancy do not necessarily lead to lower inequality and that length of life inequality may differ among populations at the same level of life expectancy. Wilmoth and Horiuchi (1999) found that the trends in both measures for Sweden did not show the same patterns. Edwards and Tuljapurkar (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) showed for 32 developed countries that, in spite of high correlations between inequality and life expectancy, countries with similar life expectancy may have substantially different levels of inequality.

These studies clearly indicate that there is more to length of life inequality than life expectancy. 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 gender-specific length of life inequality in relation to life expectancy for over 9000 country–year combinations. We address the strong correlation between both measures by focusing on the variation in length of life inequality among countries at the same level of life expectancy. We call this variation *relative length of life inequality (RLI)*. Studying this part of length of life inequality not determined by life expectancy may contribute new insights to our understanding of inequality within societies. Much is already known about the causes of differences in life expectancy among countries, but it remains an open question why countries with the same level of life expectancy would vary in level of inequality.

The time dimension

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

The forerunner hypothesis probably only applies to countries that are in the forefront of (public) health developments and 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 use new treatments, medicine and public health innovations developed in forerunning countries and in this way achieve progress more quickly and at lower costs (Birchenall, 2007; Cutler, Deaton, & Lleras-Muney, 2006; Deaton, 2004). Countries that lag far behind have the additional advantage that the first steps towards increasing life expectancy and reducing inequality 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 & Meara, 2003; Cutler et al., 2006). Thus, we formulate the *diffusion hypothesis*, which states that countries that reach a certain level of life expectancy later in time will have lower length of life inequality, 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 length of life inequality for a given country in a certain year is available in life tables, 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 9053 tables, representing 212 countries and many years. Most of the life tables 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 and the 1750s for Sweden and Finland. For most countries we use life tables 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 life tables at the province/state level for these countries.

If more than one source was available for a combination of year, country and sex, we gave preference to the more reliable source in the following order (high to low): (1) Human Mortality Database (www.mortality.org), (2) national bureaus of statistics or other official national publications, (3) Human Life-Table Database (www.lifetable.de), (4) WHO database on deaths and population (www.who.int/healthinfo/morttables), (5) International database of the US Bureau of the Census (http://www.census.gov/ipc/www/idb), (6) raw data on deaths and population from UN (UN, 2000) and (7) WHO estimates for the year 2000 (Lopez et al., 2001). We removed life tables that contained obvious errors, like a life expectancy at birth higher than the highest life expectancy for that year as reported by Oeppen and Vaupel (2002), or with impossible values in any age category.

We use abridged life tables with 5-year age intervals up to 85. Life tables with more detail were recalculated into this form to make them comparable. Shkolnikov et al. (2003, pp. 318–323) show that the Gini coefficient computed over abridged 85+ life tables can be a reliable indicator of length of life inequality, 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 our life tables. In a few cases, only life tables with intervals up to 80 were available. For these life tables, we estimated missing information using OLS regression on all 85+ life tables in our database (see Supplementary online materials). Part of the regional life tables for India were 70+ tables. In this case, missing information was estimated using information from Indian 85+ tables for other years. We are aware that these estimated life tables, some very old life tables and those of some developing countries may be less accurate than life tables from industrialized countries. However, our substantive conclusions do not change if we leave out these less reliable life tables. In the Supplementary online materials (Electronic Table A), further information about the life tables and their sources is presented. Detailed information on the project and the data used are available at www.lengthoflife.org.

All life tables used in this study are period life tables, because we are interested in inequality at a given point in time. Period life tables do not reflect the experiences of real birth cohorts, but give a clear indication of the situation of a population in a given year. Kannisto (1994) showed that the increase in adult mortality in the second half of the last century was to a large extent due to period factors.

Measurement

Length of life inequality is measured by computing the Gini coefficient or Theil index over the distribution of age at death. For our analyses of adult mortality, the distribution from age 15 onwards is taken. Life expectancy is calculated as the mean age of death from the same distribution. The distributions of age at death were obtained by applying the age and sex-specific mortality rates (q) from the life table to a population of 100,000 individuals (newborn or aged 15), the usual method of standardizing for differences in population structure among countries and time periods.

The Gini coefficient and Theil index are widely used inequality measures (Cowell, 1995) that can be used to indicate how unequal or equal resources or rewards are distributed among the members of a population. Both measures have zero as lowest value, indicating maximum equality, which in our case would mean that everybody has the same length of life. For Gini the highest value is one, meaning very high inequality; for the Theil index the maximum value depends on the population size (Cowell, 1995). The choice of inequality measure for computing length of life inequality at the country level is not a critical one. Wilmoth and Horiuchi (1999) show that different measures in this context yield similar results. We prefer Gini as it is most sensitive to the complete distribution. However, we use Theil in the decomposition analysis because, unlike the Gini coefficient, the Theil index for total world inequality is additively decomposable. This means that it can show us to what extent total world length of life inequality is due to differences between countries and to difference among individuals within countries (Pradhan et al., 2003).

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

A reliable measure of RLI can only be calculated at levels of life expectancy 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 could calculate RLI for countries that had a life expectancy between 56 and 78 for men and between 58 and 83 for women. The average number of life tables per one-year level of life expectancy is 199 for men and 174 for women.

Results

Length of life inequality

Table 1 presents life expectancy and length of life inequality for the total world in the year 2000. The figures are based on a set of life

Table 1
Life expectancy and length of life inequality for the world as a whole in 2000.

	Total population		Age 15+	
	Men	Women	Men	Women
Life expectancy	63.8	68.0	68.6	73.0
Length of life inequality				
Gini coefficient	0.189	0.177	0.128	0.115
Theil index	0.097	0.093	0.031	0.028
Inequality components				
Between-country	8.7%	10.8%	9.9%	13.8%
Within-country	91.3%	89.2%	90.1%	86.2%

tables for 191 countries, covering over 99% of the world population. For countries for which no real life tables were available, we used best estimates produced by the WHO on the basis of surveys and region-specific models (Lopez et al., 2001). Note that for computing the figures in Tables 1 and 2 countries were weighted by their population size. For reasons of comparison, Table 1 presents results for all age mortality and adult mortality. All other analyses and figures in this paper concern the adult (15+) population.

Table 1 shows that the worldwide life expectancy at birth for men in the year 2000 was 63.8 years, more than four years less than the 68 years for women. Life expectancy for the 15+ population was about 5 years higher, due to the relatively high mortality rates among infants and children. Both Gini and Theil values show that length of life is more unequally distributed among men than among women. About 90% of total inequality in length of life was due to within-countries' differences. The within-countries component was somewhat smaller for the 15+ population and for women.

Because the populations of India and China are so much larger than those of other countries, we also analyzed a set of life tables where we substituted the single tables for China and India with life tables at the province level for China (33 provinces) and state level for India (16 states). Differentiation within China and India hardly influenced the estimation of total world length of life inequality.

When we decompose total adult length of life inequality by geopolitical regions (according to Goesling & Firebaugh, 2004) instead of individual countries, as in Table 2, we capture 85–90% of the between-country component. India, South-Asia 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 & Shkolnikov, 2001).

To get an intuitively appealing idea of the magnitude of these differences in length of life inequality, we have translated them into numbers of premature deaths (defined here as deaths in the 15–50 age group). Given a certain life expectancy in a population, a higher level of inequality implies that more persons reach a high age, but also that more persons die at younger ages. Because premature mortality has a more dramatic societal impact than longevity, we focus on the premature mortality figures. These figures are only presented for heuristic reasons. They give an impression of the size of the mortality differences, but cannot be interpreted as inequality measures themselves, because they are not comparable across populations with different levels of life expectancy. In the next sections therefore premature mortality rates are only compared within life expectancy groups.

Table 2 shows that even though the between-country component comprises only 10% of all variation in inequality, there is huge variation in premature mortality between men and women and among the geopolitical regions, ranging from 42 to 384 deaths per 1000 for men and from 20 to 364 for women.

Table 2
Life expectancy and length of life inequality age 15+ and premature mortality by geopolitical regions in 2000.

	Men			Women		
	Life expectancy	Theil	Premature mortality	Life expectancy	Theil	Premature mortality
Japan	77.20	0.016	42	83.35	0.009	20
Western Europe	74.99	0.018	56	80.69	0.011	26
Western offshoots	74.40	0.021	68	79.33	0.014	35
China	71.56	0.020	73	75.94	0.018	53
Middle-east and North Africa	70.41	0.024	90	73.80	0.019	63
Latin America & Caribbean	69.96	0.032	126	75.76	0.019	61
Pacific islands	68.69	0.027	115	72.54	0.023	84
East Asia (excl China and Japan)	68.64	0.031	129	73.22	0.023	82
South-Asia (excl. India)	66.91	0.032	150	68.78	0.033	135
Central Asia	66.62	0.033	153	72.00	0.025	90
India	66.19	0.031	144	70.16	0.031	118
Eastern Europe & Russia	64.74	0.035	181	74.50	0.018	59
Sub-Saharan Africa	56.65	0.058	384	58.08	0.071	364

Notes: Theil index for length of life inequality. Premature mortality: deaths per 1000, age 15–50.
Western offshoots: US, Canada, Australia and New Zealand.

Relative length of life inequality

The correlation between length of life inequality and life expectancy, as discussed in the theoretical section, can clearly be seen in Table 2. Regions with a higher life expectancy have lower inequality. The association becomes even clearer if we plot life expectancy against length of life inequality for all available country–year combinations, as in Fig. 2. Each dot represents a male or female life table for a certain country in a certain year. In total, 9063 life tables for 212 countries are used. Fig. 2 is restricted to more or less normal situations; country–year combinations with extremely low life expectancy due to severe calamities (wars, epidemics, famines) are excluded (but are available at our website www.lengthoflife.org).

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 a very strong negative correlation between life expectancy and length of life inequality (over −0.9). This correlation shows that for adults an increase in life expectancy may result in lower inequality. Fig. 2 also makes clear that at each level of life expectancy the degree of inequality can differ greatly among societies. For example, for populations with a life expectancy of 65 (marked A in Fig. 2), male length of life inequality varies roughly between 0.11 and 0.16 and for populations with a life expectancy 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 is distributed among the population members may vary among societies and time periods at the same level of life expectancy.

Fig. 2 also demonstrates that the absolute level of length of life inequality, which has been used in earlier studies (e.g. Edwards & Tuljapurkar, 2005; LeGrand, 1987; Silber, 1988) is a less informative measure, because whether a specific level of inequality is high or low depends on the level of life expectancy. A Gini of 0.12 is relatively low in male populations with a life expectancy of 65, but it is high in populations with a life expectancy of 73. To obtain a more meaningful inequality indicator for a given population, the degree of inequality in that population should therefore be compared with

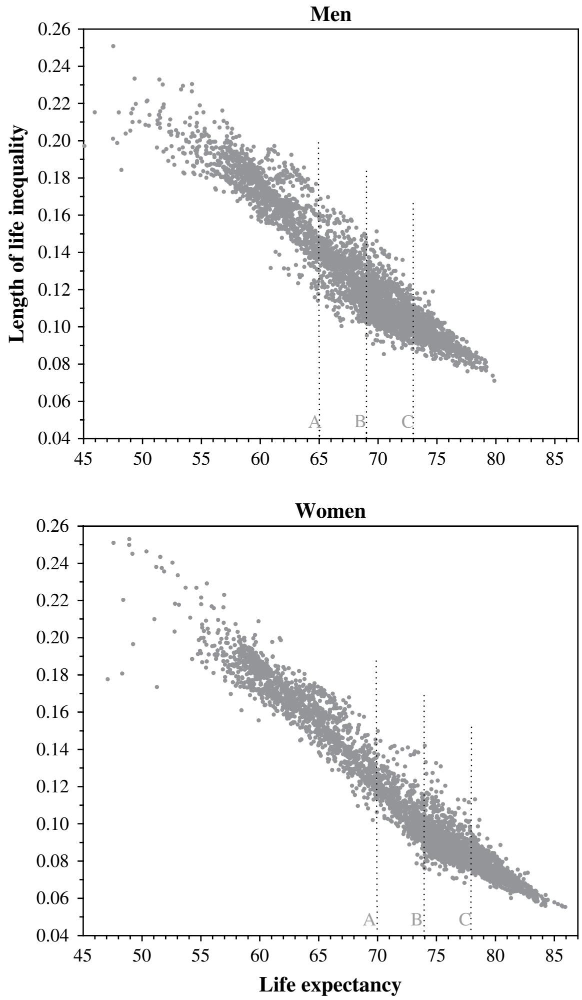

Fig. 2. Length of life inequality by life expectancy for adult men and women (age 15+) based on 9063 life tables for 212 countries.

inequality in other populations at the same level of life expectancy, as is done by our RLI measure.

Magnitude of differences

To get a more appealing impression of the magnitude of the inequality differences among countries at the same level of life expectancy, Fig. 3 presents the number of premature deaths by RLI quintiles for men and women at the three arbitrary levels of life expectancy, marked A, B, and C in Fig. 2. Because they refer to populations with similar life expectancy, these premature mortality rates are very comparable. The figures make clear that at the same level of life expectancy substantial differences in premature mortality exist. In populations with an adult male life expectancy of 73 (72.5–73.5), the average number of men dying between age 15 and 50 is 58 per 1000 in the most equal quintile of societies. This number increases by each quintile until it reaches a level of 92 per 1000 in the most unequal quintile of societies. This means that at a life expectancy of 73, premature mortality among adult 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 life expectancy of 69, the difference in premature mortality between the lowest and highest quintiles of RLI is almost the same: 58%. At a life expectancy of 65, the difference is somewhat lower, but with 37% still substantial. For women we find similar differences, ranging from 33% at a life expectancy of 70, to 72% at a life expectancy of 74. These huge differences in premature mortality (all significant at $p < 0.001$) stress the importance of RLI as an indicator of mortality differences among populations.

We give another example to illustrate the magnitude of differences in RLI among developed Western societies. Our own calculations on 2003 US data show an adult male life expectancy of 75.6 and a length of life inequality of 0.102. When France reached the same level of life expectancy (in 1999) its level of inequality was quiet similar (0.099). However, when Sweden and England & Wales reached that life expectancy (in 1990 and 1997 respectively), their level of inequality was much lower, namely 0.089 and 0.088. Expressed in terms of premature mortality, the higher RLI in the US and France translates into about 70 premature deaths per 1000, compared to about 49 in England & Wales 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 the high RLI countries.

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 Fig. 2. Such trajectories for men from England & Wales, France, the US and Sweden are presented in Fig. 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 cloud of dots. 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 life expectancy is slightly lower than in the preceding year. For the four countries in Fig. 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. The trajectory for England & Wales is mostly located near the lower boundary, indicating that during most of the 160-year period, RLI 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 RLI was higher in France than in England & Wales. For the US, we see high levels of RLI in the 19th and early 20th century, followed by a period of moderate inequality until the 1970s, after which RLI 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 RLI 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 Fig. 5, comparable trajectories are presented for women. The pictures are quite similar to those for men. However, since WWII, RLI for women in England & Wales was less favorable than for men, whereas in France it was more favorable. Trajectories for other countries can be found at our website www.lengthoflife.org

Highlighting the trajectories of individual countries is a powerful instrument for detecting variations in RLI 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).

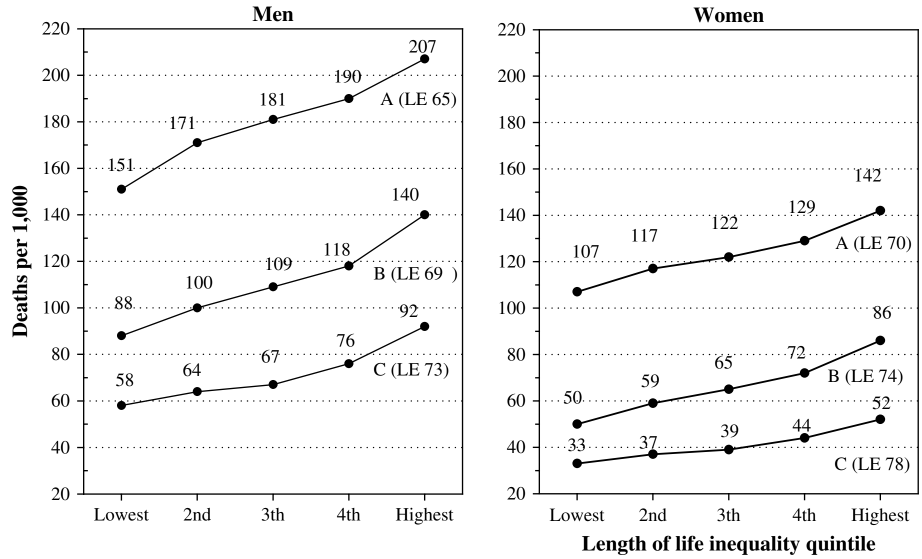

Fig. 3. Number of premature deaths (age 15–50) per 1000 men or women by length of life inequality quintile for three levels of life expectancy (LE).

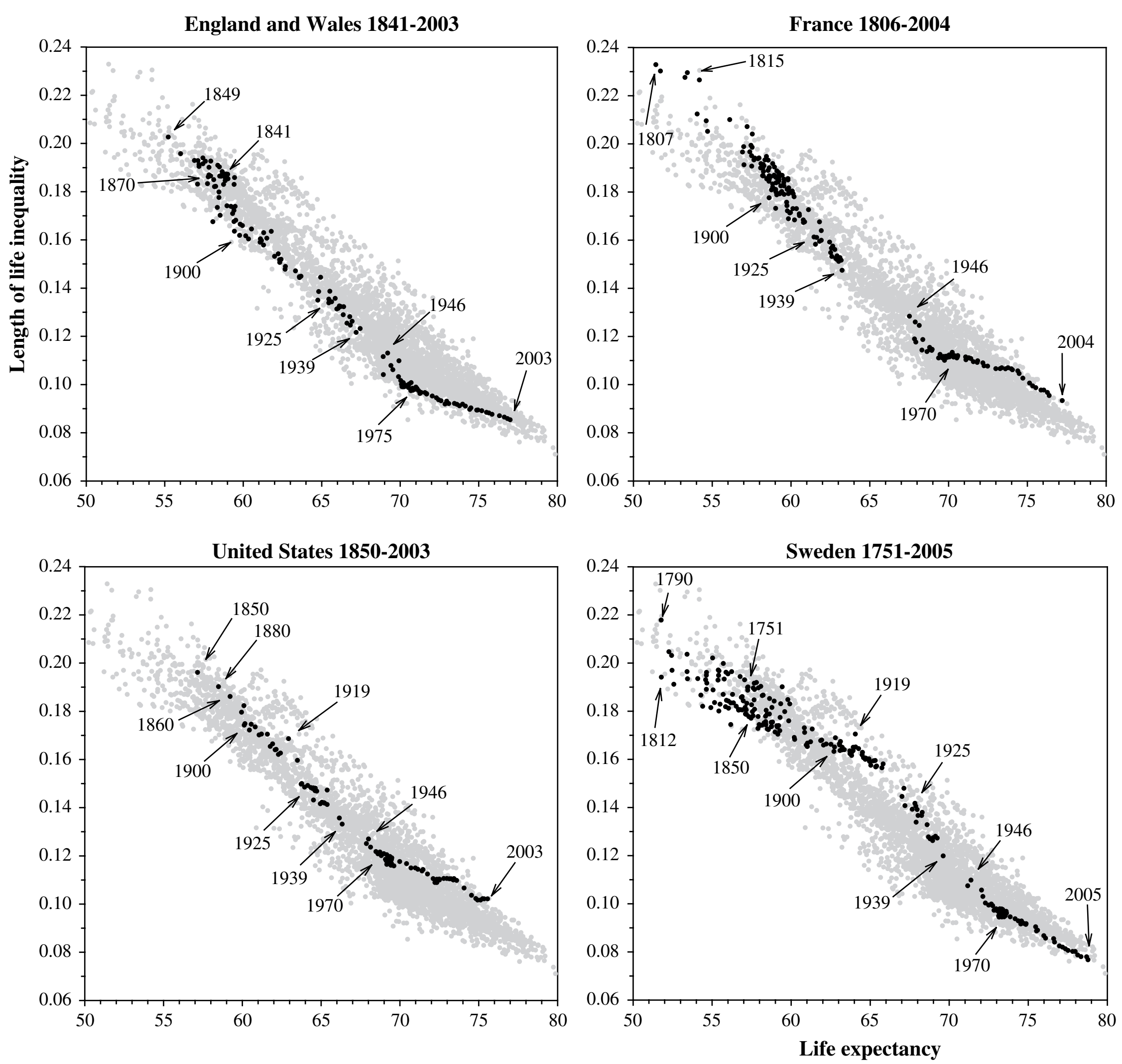

Fig. 4. Trajectories of length of life inequality and life expectancy for adult men (age 15+) in England & Wales, France, United States and Sweden.

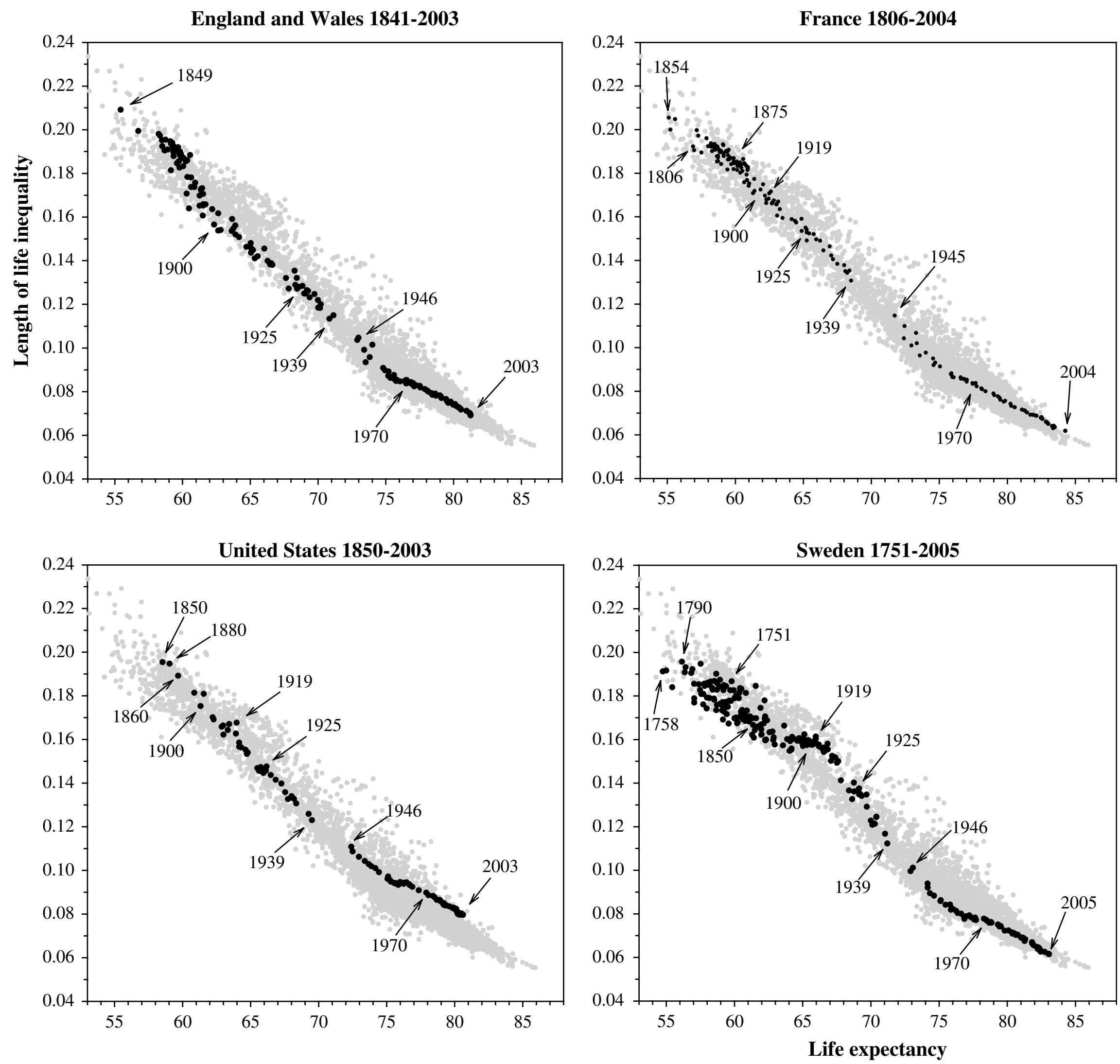

Fig. 5. Trajectories of length of life inequality and life expectancy for adult women (age 15+) in England & Wales, France, United States and Sweden.

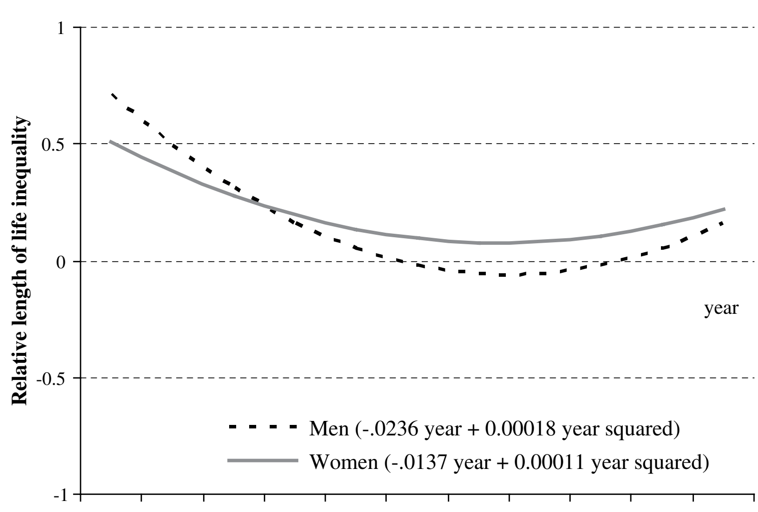

Fig. 6. Relation between year in which a level of life expectancy was reached and relative length of life inequality.

The time dimension

The finding that Sweden and England & Wales reached a certain level of adult life expectancy both earlier and with lower inequality than the US and France might imply that policies aimed at increasing life expectancy 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, Fig. 6 shows the result of a regression analysis of RLI on year and year squared for all country–year combinations in the period 1900–2000 for which we have data (again excluding calamities). For both men and women, RLI 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 life expectancy 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 & Wales on the one hand and the US and France on the other hand, is an exception rather than the rule.

Another way to test the forerunner hypothesis is by correlating within-country changes in life expectancy with within-country changes in RLI. 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 improvement in life expectancy and change in RLI within countries over 5 year periods is 0.50 for men and 0.42 for women. Similar results are obtained when we regress within-country changes in life expectancy between year T and $T+1$ on within-country changes in RLI between year T and $T-1$ (e.g. a fixed effects panel model with a lagged effect of changes in RLI on changes in life expectancy). This implies that currently developed countries that were successful in improving life expectancy in a certain period experienced an increase in RLI in that period. This result is clearly not in line with the forerunner hypothesis.

Conclusions

Length of life inequality can be viewed as one of the most fundamental forms of inequality in the world. However, until now little was known about the nature and patterns of the within-country variation in this form of inequality. We studied the variation in length of life inequality within and among virtually all countries of the world using a large database. Our descriptive analysis for the world as a whole showed that total world life expectancy in the year 2000 was 63.8 years for men and 68 years for women. For the group of persons aged 15 and over, on which this paper focuses, these figures were 68.6 years and 73 years. The Gini coefficient for total world length of life inequality among persons aged 15+ was 0.128 for males and 0.115 for females, which, translated into premature deaths, equates to 139 and 104 deaths per 1000 persons aged 15–50 respectively. Hence, women not only live longer but also experience smaller differences in length of life than men.

The decomposition analysis showed that about 90% of the variation in adult length of life inequality in 2000 was within-country variation. The within-country component is slightly smaller for women than for men and among adults than among the total population. It is of the same order as for educational inequality, but much larger than for income inequality (Araujo et al., 2004; Bourguignon & Morrison, 2002; Goesling, 2001). It is also larger than the 70% found by Pradhan et al. (2003) for inequality in stunting among children. Most of the between-country variation (over 80%) consists of variation among 13 major geopolitical regions of the world. These findings suggest that the major causes of length of life inequality should be sought in unequal distribution processes within countries and that inequality among geopolitical regions (especially the very poor performance in sub-Saharan Africa) is responsible for most of the remaining part.

Our detailed analysis of the pattern of association between length of life inequality and life expectancy among adults on the basis of over 9000 life tables revealed a strong negative association between inequality and life expectancy. Hence an increase in life expectancy is generally accompanied by a decrease in inequality. This finding implies that the absolute level of length of life inequality, as used in earlier research, is not an informative measure on its own. Whether a country's level of inequality should be considered high or low depends on the life expectancy of that country. Hence, for assessing the performance of societies with respect to length of life inequality, their level of inequality should be compared among societies with similar life expectancy. We proposed to call this *Relative length of life inequality* or RLI.

Our analyses revealed large differences in adult RLI across populations. Within country–year combinations with the same life expectancy, premature mortality was found to be 30–70% higher in the most unequal quintile of societies compared to the most equal quintile. Differences of this size were not only found among developing countries, but also among the most highly developed countries of the world (like the US, France, Sweden, and UK).

The existence of such large differences in RLI, 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 French men, which is characterized by higher levels of smoking and alcohol consumption (compare Meslé & 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 RLI.

To make a first step in this direction, we supplemented our descriptive analyses with a trend analysis in which two hypotheses were tested. The *forerunner hypothesis* supposes countries that reach a certain level of life expectancy earlier in time to have lower inequality, because reducing premature mortality would lead to more gains in life expectancy than reducing old-age mortality. The *diffusion hypothesis* supposes countries that lag behind in life expectancy to have lower levels of inequality at any level of life expectancy, because they can take advantage of the new treatments, more effective medicines and public health innovations developed in forerunning countries. Our analyses showed that forerunner countries had higher levels of RLI. This indicates that these best performers were more successful in reducing old-age mortality, while accepting relative high levels of mortality in the younger age groups. Although the results are based on historic data for currently developed countries, they suggest that reducing inequality and gaining increases in life expectancy might be alternative goals that require different policy measures to be achieved. Higher inequality means more people dying too young. This implies that, if the finding of the trend analysis can be generalized to currently developing countries, policy measures aimed at increasing life expectancy of the old should be supplemented with social redistribution policies that make the health care system better accessible to the poor.

Monitoring RLI besides other performance measures of societies might become increasingly important in the coming decades. RLI 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 life expectancy. 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 life expectancy. When new possibilities to live longer are only available to select groups in society, life expectancy of these groups will rise, but the country's overall performance need not improve much. This might be exemplified by the performance of countries like France and the United States, where the gain in male life expectancy has been modest over the last decades and RLI has increased, in spite of the fact that per capita health expenditures have been high in both countries. 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) that "Distribution should be put at the center of strategies for human development" (p. 71), we conclude that focusing on life expectancy alone might not be sufficient to truly evaluate a society's overall performance with regard to mortality: RLI should be studied as a separate and fundamental aspect of the mortality patterns of societies. Analyzing the relationship between a country's RLI 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.

Appendix. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.socscimed.2008.12.034.

References

Araujo, C., Ferreira, F., & Schady, N. (2004). *Is the world becoming more unequal? Changes in the world distribution of schooling*. Washington, DC: World Bank.

Asada, Y. (2006). Is health inequality across individuals of moral concern? *Health Care Analysis, 14*(1), 25–36.

Becker, G., Philipson, T., & Soares, R. (2005). The quantity and quality of life and the evolution of world inequality. *American Economic Review, 95*(1), 277–291.

Birchenall, J. (2007). Economic development and the escape from high mortality. *World Development, 35*, 543–568.

Bloom, D., Canning, D., & Sevilla, J. (2003). *The demographic dividend*. Santa Monica: RAND.

Bongaarts, J. (2006). How long will we live? *Population and Development Review, 32*(4), 605–628.

Bourguignon, F., & Morrison, C. (2002). Inequality among world citizens: 1820–1992. *American Economic Review, 92*(4), 727–744.

Cheung, S., Robine, J., Tu, E., & Caselli, G. (2005). Three dimensions of the survival curve. *Demography, 42*, 243–258.

Cornia, G., & Menchini, L. (2006). *Health improvements and health inequality during the last 40 years*. Research Paper No. 2006/10. Oxford: UNU-WIDER.

Cowell, F. (1995). *Measuring inequality*. London: Prentice-Hall.

Cutler, D., Deaton, A., & Lleras-Muney, A. (2006). The determinants of mortality. *Journal of Economic Perspectives, 20*(3), 97–120.

Cutler, D., & Meara, E. (2003). Changes in the age distribution of mortality over the twentieth century. In D. Wise (Ed.), *Perspectives on the economics of aging*. Chicago: University of Chicago Press.

Deaton, A. Health in an age of globalization. NBER Working Paper No. W10669.

Edwards, R., & Tuljapurkar, S. (2005). Inequality in life spans and a new perspective on mortality convergence across industrialized countries. *Population and Development Review, 31*(4), 645–674.

Firebaugh, G. (2003). *The new geography of global income inequality*. Cambridge: Harvard University Press.

Goesling, B. (2001). Changing income inequalities within and between nations: new evidence. *American Sociological Review, 66*, 745–761.

Goesling, B., & Firebaugh, G. (2004). The trend in international health inequality. *Population and Development Review, 30*(1), 131–146.

Hout, M., & DiPrete, T. (2006). What we have learned: RC28's contributions to knowledge about social stratification? *Research in Social Stratification and Mobility, 24*(1), 1–20.

Kannisto, V. (1994). *Development of oldest-old mortality, 1950–1990*. Odense: Odense University Press.

Kannisto, V. (2001). Mode and dispersion of the length of life. *Population, 13*(1), 159–172.

Kunst, A., Groenhof, F., & Mackenbach, J. (1998). Mortality by occupational class among men 30–64 years in 11 European countries. *Social Science & Medicine, 46*(11), 1459–1476.

LeGrand, J. (1987). Inequalities in health. Some international comparisons. *European Economic Review, 31*, 182–191.

Lopez, A., Ahmad, O., Guillot, M., Inoue, M., Ferguson, B., & Salomon, J. (2001). *Life tables for 191 countries for 2000: Data, methods, results*. GPE Discussion No. 40. World Health Organization.

McKee, M., & Shkolnikov, V. (2001). Understanding the toll of premature death among men in eastern Europe. *British Medical Journal, 323*, 1051–1055.

Marmot, M. (2005). Social determinants of health inequalities. *Lancet, 365*, 1099–1104.

Meslé, F., & Vallin, J. (1998). Évolution et variations géographiques de la surmortalité masculine. *Population, 6*, 1079–1102.

Milanovic, B. (2005). *Worlds apart: International and global inequality 1950–2000*. Princeton: Princeton University Press.

Oeppen, J., & Vaupel, J. (2002). Broken limits to life expectancy. *Science, 296*, 1029.

Pradhan, M., Sahn, D. E., & Younger, S. (2003). Decomposing world health inequality. *Journal of Health Economics, 22*, 271–293.

Rose, G. (1992). *Strategy of preventive medicine*. Oxford: Oxford University Press.

Schady, N. (2005). *Changes in the global distribution of life expectancy and education*. Washington, DC: World Bank.

Sen, A. (1985). *Commodities and capabilities*. Amsterdam: North Holland.

Shkolnikov, V., Andreev, E., & Begun, A. (2003). Gini coefficient as a life table function. *Demographic Research, 8*, 305–357.

Silber, J. (1988). On inequality before death and life table summary measures. *Genus, 44*, 25–39.

Townsend, P., Davidson, N., & Whitehead, M. (1988). *Inequalities in health: The black report and the health divide*. London: Penguin Books.

Ultee, W., DeGraaf, N., & Van Puijenbroek, R. (1989). Healthy questions about ill-health. In L. Gunning-Schepers (Ed.), *Socioeconomic inequalities in health*. Rijswijk: WVC.

UN. (2000). *Demographic yearbook, historical supplement 1948–1998*. New York: United Nations.

UNDP. (2005). *Human development report 2005*. New York: UNDP.

Wagstaff, A., & Van Doorslaer, E. (2004). Overall versus socioeconomic health inequality. *Health Economics, 13*, 297–301.

Wilkinson, R., & Marmot, M. (2003). *Social determinants of health: The solid facts*. Copenhagen: World Regional office for Europe.

Wilmoth, J., & Horiuchi, S. (1999). Rectangularization revisited: variability of age at death within human populations. *Demography, 36*, 475–495.

Wolfson, M., & Rowe, G. (2001). On measuring inequalities in health. *Bulletin of the World Health Organization, 79*(6), 553–560.

World Bank. (2005). *World development report 2006*. Washington, DC: The World Bank.