10 Years After Kannisto: Further Evidence for Mortality Decline at Advanced Ages in Developed Countries

Paper prepared for the Population Association of America 2006 Annual Meeting

Session 20 "Death: Trends, Distributions, Inequality"

Roland Rau* Eugeny Soroko † Domantas Jasilionis‡ James W. Vaupel§

February 28, 2006

Introduction

Väinö Kannisto published two influential monographs in the mid-1990s in which he showed that the survival chances of people at advanced ages have considerably improved since the 1950s and especially since the 1970s (Kannisto, 1994, 1996). His conclusions of the continued progress against mortality at ages above 80 were based on data until approximately 1990. Since then

*Max Planck Institute for Demographic Research, Konrad Zuse Str. 1, D–18057 Rostock, Germany; Email: Rau@demogr.mpg.de, Phone: 0049–381–2081-109, Fax: 0049–381–2081-409

†Centre of Demography and Human Ecology, Institute for Economic Forecasting, Russian Academy of Sciences (Moscow, Russia), Email: soroko@demoscope.ru

‡Max Planck Institute for Demographic Research, Rostock, Germany; Email: Jasilionis@demogr.mpg.de

§Max Planck Institute for Demographic Research, Rostock, Germany; Email: JWV@demogr.mpg.de

10 more years of data are available. We analyzed whether survival improvements continued during the 1990s or whether we can observe a slowing down which could indicate that mortality rates are close to a biological minimum. The results from these findings are not only interesting for the individual planning her or his life. It also has important consequences for public policy: if the data appear to be in favor of the "optimistic" point of view with continued progress, policy makers need to re-consider their calculations which are typically based on conservative estimates assuming a levelling-off in survival improvements. If the point of view prevails that mortality rates hit a biological bottom, policy makers might re-distribute the spending on medical care since additional money would not improve survival chances any further.

Data & Method

Our analysis is based on the "Kannisto-Thatcher"-Database (KTDB). The database is run by the Max Planck Institute for Demographic Research and is available online via: `http://www.demogr.mpg.de/databases/ktdb`. This data collection provides population and deaths counts of more than 30 developed countries above age 80. Population as well as death counts are broken down by sex, birth year, age, and current year which enables the user to have data available for women as well as for men by "Lexis Triangle".

Three different indicators have been used for our analysis:

1. For a first overview we looked simply at *population counts*. We used all countries from the KTDB which had a continuous time series of data available from 1960 until 2000. For each year, we were using the population from 01 January 1960 and 01 January 2000 aged 80+ and aged 100+. This would translate in Figure 1 on page 4 for the year $t = 1960$ and $x = 80$ to all individual life-lines which would cross the vertical line starting in point A going upwards through D, G, ... The Average Annual Increase in Percent r has been calculated via the following equation:

$$r = \frac{\log\left(\frac{P_{2000}}{P_{1960}}\right)}{t} \tag{1}$$

   where P_{1960} and P_{2000} denote the size of the population in the years 1960 and 2000, respectively; t denotes the duration which was in our application always 40 years; log is the natural logarithm (i.e. $\log_e$).

2. The *probability of dying* denoted by $q(x)$ is following a "Cohort-Age"-Outline. That means for the probability of dying q at age x in year t in Figure 1 that the numerator is the sum of all deaths occurring in the parallelogram $ABFE$ and the denominator is the number of life-lines crossing AB. The main reason for this approach is the extinct generation method (Depoid, 1973; Vincent, 1951) which is the main method to obtain population estimates in the KTDB.

3. *Annual Improvements in Mortality*, denoted by ρ, have been calculated to estimate whether improvements in survival are accelerating. The estimation followed strictly Note 3 in the Appendix of Kannisto et al. (1994):

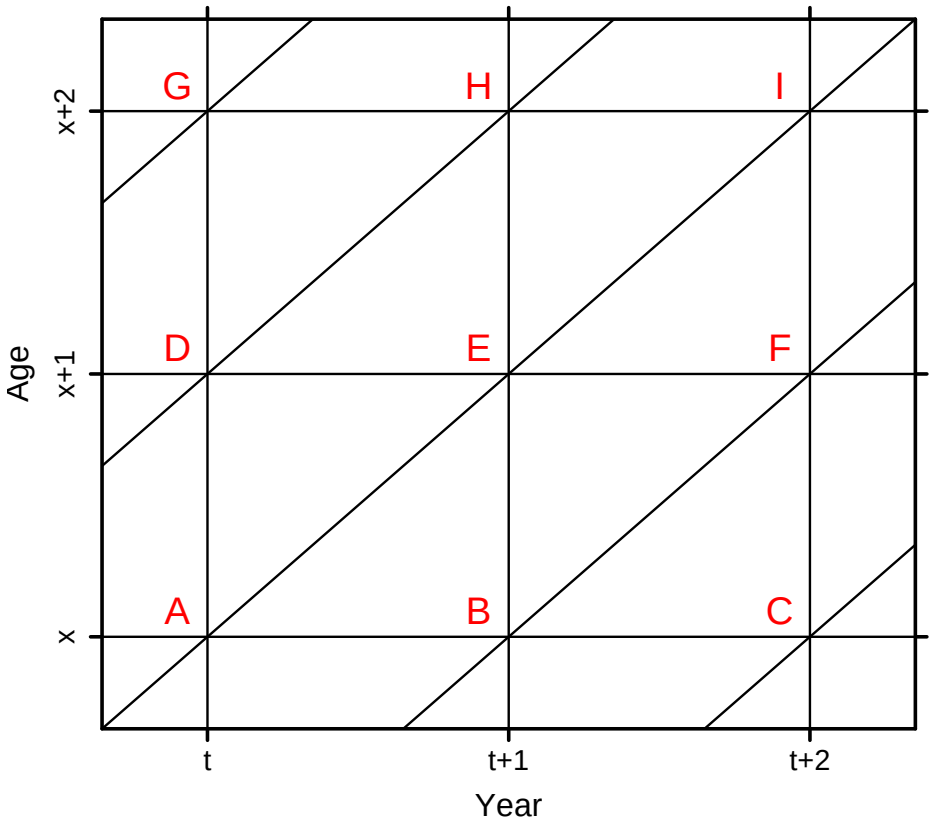
$$\rho = -\left(\left(\frac{\bar{m_2}}{\bar{m_1}}\right)^{\frac{1}{\delta}} - 1\right) \tag{2}$$

where δ denotes the length of the interval between two periods. For example, $\delta = 10$ if one compares the time period 1960–1969 with 1970–1970. The central death rates $m(x, y)$ have been calculated in the standard way:

$$m(x, y) = \frac{D(x, y)}{\frac{N(x,y)+N(x,y+1)}{2}} \tag{3}$$

This would translate in Figure 1 into the rectangle $ABED$ for the numerator and the mean of AD and BE for the denominator. These central death rates have been standardized using the Swedish population from 1950 to 1990 for ages 80 through 104 and are denoted by $\bar{m}$.

Figure 1: Lexis Diagram



Results & Discussion

Old Age Population Counts

Table 1 on page 6 gives estimates for the size of the populations on 01 January 1960 and 01 January 2000 aged 80+ and 100+ for all countries for which data were available for that period in the KTDB. During these 40 years the number of women and men aged 80 and older increased from less than nine million to almost 30 million people by the turn of the millennium. The increase of the number of centenarians is even more remarkable. With an annual increase in size of more than six percent, the number of centenarians was more than 11 times larger in 2000 than it was in 1960 ($P_{1960} = 8,181$; $P_{2000} = 93,307$). As one can recognize, the average annual increase in percent (column r) differed among the countries. Several characteristics should be pointed out:

- For all the countries from this list combined, the number of people aged 80 and older increased by three percent annually. The number of centenarians increased even faster: the mean increase per year is 6.09%. Since these data are largely driven by the largest country, the United States, we also calculated the median increase which is 2.61% for women and men aged 80 and older and 6.30% for centenarians.

- The number of old (80+) and very old (100+) people increased in *all* countries between 1960 and 2000 — irrespective whether the whole population increased such as in the United States from 178,6 million people to 280,8 million people or decreased such as in the former GDR from 17,3 million people to 15,2 million people.[1]

- The increase is most pronounced in Japan where the population aged 80+ increased by more than five percent per year. The number of centenarians had on average even an annual increase of more than 10 percent.

Population counts are, of course, not an ideal measurement for improvements in survival. For example, the number of old people will increase automatically with constant mortality rates when larger birth cohorts enter the

[1] Data on Population Size refers to 01 January of the respective year and has been taken from the Human Mortality Database (HMD) on 26 February 2006. The HMD is available online at `http://www.mortality.org`.

Table 1: Population Estimates for 1960 and 2000 (01. January) for Ages 80+ and 100+ and the Average Annual Increase in Percent r for All Countries from the KTDB having Data available for this Time Period

Country	80+			100+		
	1960 Counts	2000 Counts	r	1960 Counts	2000 Counts	r
Austria	121,184	270,248	2.01	25	437	7.15
Belgium	169,553	355,936	1.85	42	845	7.50
Canada	222,888	891,075	3.46	240	3,420	6.64
Czech Republic	112,376	231,544	1.81	17	172	5.79
Denmark	73,409	208,879	2.61	19	483	8.09
England & Wales	895,100	2,090,174	2.12	531	5,895	6.02
Estonia	19,249	36,157	1.58	10	58	4.39
Finland	40,594	171,111	3.60	12	246	7.55
France	908,375	2,130,879	2.13	368	7,791	7.63
Germany East	314,840	509,499	1.20	30	901	8.51
Germany West	836,131	2,428,787	2.67	117	4,925	9.35
Hungary	108,244	261,641	2.21	37	284	5.10
Ireland	58,154	95,304	1.23	28	161	4.37
Italy	674,195	2,246,433	3.01	252	5,415	7.67
Japan	639,413	4,755,732	5.02	156	11,546	10.76
Latvia	37,359	62,065	1.27	55	129	2.13
Netherlands	155,339	507,716	2.96	62	1,413	7.82
New Zealand	35,897	105,698	2.70	40	289	4.94
New Zealand (non Maori)	35,215	103,587	2.70	16	284	7.19
Norway	70,136	190,012	2.49	73	423	4.39
Portugal	107,574	337,404	2.86	107	532	4.01
Scotland	84,368	185,333	1.97	37	427	6.11
Slovakia	37,533	95,261	2.33	19	82	3.66
Spain	368,651	1,552,696	3.59	432	3,551	5.27
Sweden	137,958	436,350	2.88	73	906	6.30
Switzerland	80,693	287,200	3.17	29	675	7.87
USA	2,550,402	9,194,238	3.21	5,354	42,017	5.15
Total	8,894,830	29,740,959	3.02	8,181	93,307	6.09
Median			2.61			6.30

Source: Authors' Own Calculations,[6] Based on Data from the Kannisto-Thatcher Database

respective ages. Nevertheless, population counts are useful for at least two reasons: On the one hand, one can reject the prediction "that the number of very old persons will not increase" which was expressed by James F. Fries in an influential article in the *New England Journal of Medicine* in 1980 (Fries, 1980, p. 130). On the other hand, policy makers might feel more urged to consider the economic and social consequences of aging if they see actual population numbers than mortality rates or probabilities.

Probability of Dying

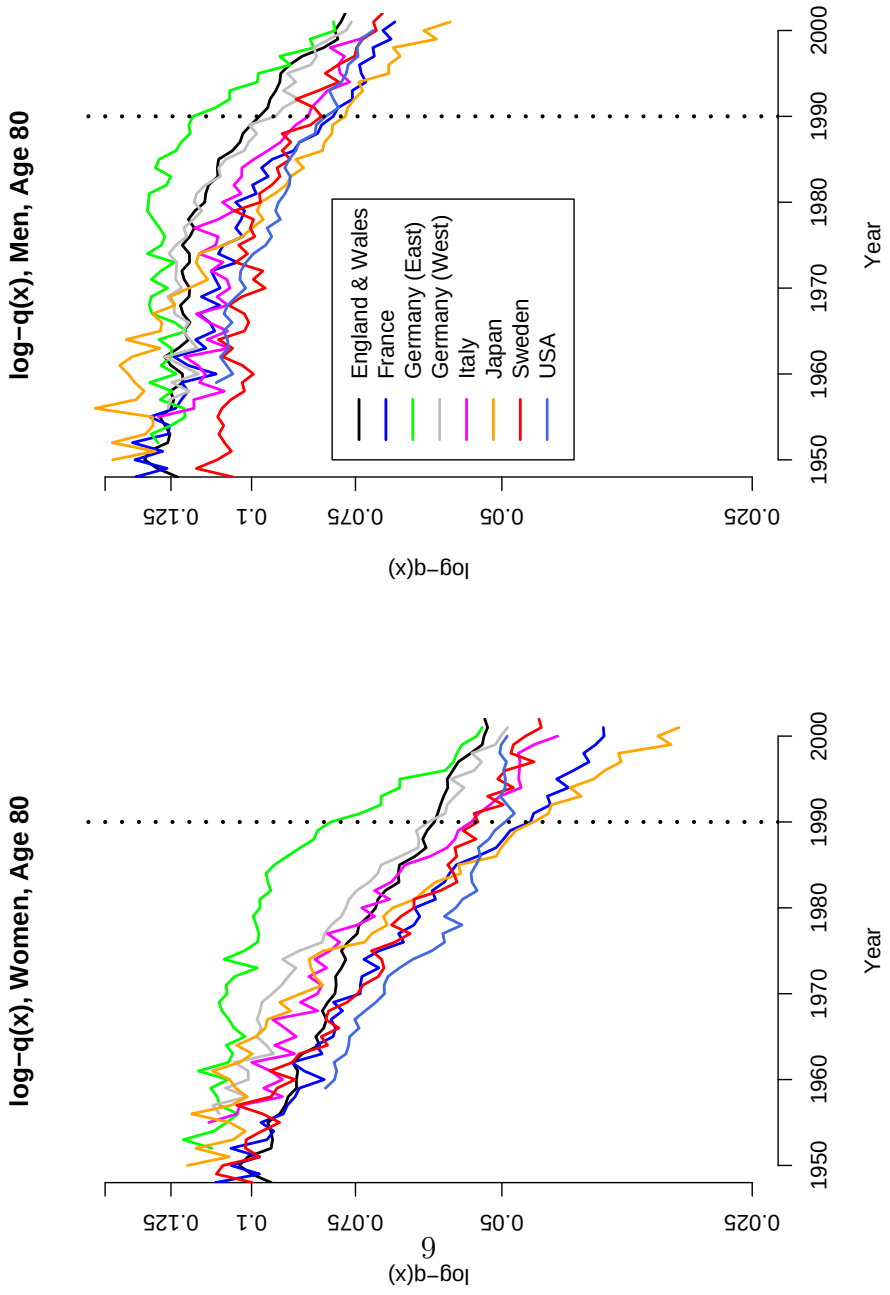
More inferences about survival improvements than with population counts can be made when one investigates probabilities of dying. Figures 2 and 3 on pages 9–10 show the logarithms of the probabilities of dying ($q(x)$) for England & Wales, France, Germany (East and West), Italy, Japan, Sweden and the USA during the period 1950–2000 for the ages 80 (Fig. 8) and 90 (Fig. 9) for women and men separately. The same plots on a "normal" scale are given in the appendix on pages 19–20.

Over time, the jagged lines became more stable after the year 1970 which reflects that more and more people reached those ages. More importantly, death probabilities do not appear to be close to a biological minimum since they are continuously decreasing. Especially Japan gives evidence for rejecting the assumption that mortality rates hit a natural lower threshold. If this was the case, Japan should not show the steepest decline in mortality rates in recent years. These findings give rather support for the idea that mortality is steadily decreasing as outlined in previous publications (e.g. Kannisto, 1994, 1996; Vaupel, 1997). Grey dotted vertical reference lines have been plotted to show that there is no change in the trend in survival improvements since 1990, the year which marks approximately the last data being available for the aforementioned articles.

This is, however, only the general trend. The performance of individual countries varies: first, Japan is still — as observed by Kannisto (1994, p. 21) — "in a class of its own" with its continued trend of the fastest survival improvements for women as well as for men for both ages shown here. Among 80-year-olds, French women show improvements which are comparable to Japanese women. Mortality in Eastern Germany and the United States developed antagonistically: the United States used to be the country with the lowest mortality at advanced ages. Since the mid-1980s a levelling off is being observed at old-age mortality in the United States. The reason is

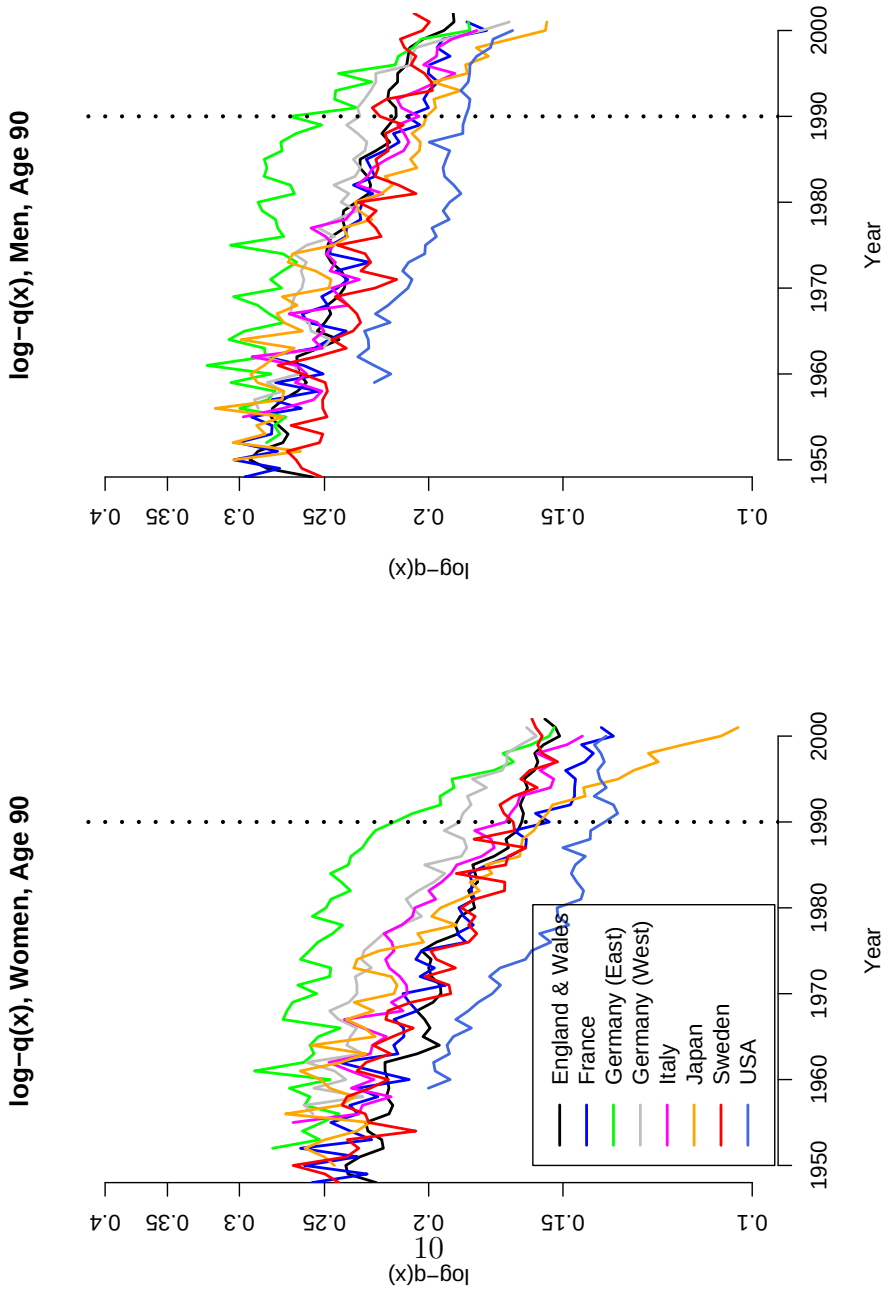
not yet understood. The opposite development has happened in the former GDR. While Kannisto reported "East Germany ranks low because of slow progress in survival" (Kannisto, 1994, p.21), it was catching up during the 1990s and is now in the range of mortality rates of other Western countries such as England & Wales, West Germany or Sweden. This development has been attributed to the social, medical, and economic improvements from re-unification (Scholz and Maier, 2003)

Figure 2: Log-Probabilities of Dying ($q(x)$) at Age 80 for Women and Men in England & Wales, France, Germany (East and West), Italy, Japan, Sweden and the USA during the period 1950–2000



Source: Kannisto-Thatcher Database, Own Calculations

Figure 3: Log-Probabilities of Dying ($q(x)$) at Age 90 for Women and Men in England & Wales, France, Germany (East and West), Italy, Japan, Sweden and the USA during the period 1950–2000



Source: Kannisto-Thatcher Database, Own Calculations

Annual Survival Improvements

Probably the most relevant indicator to measure whether improvements in survival are slowing down is given by the calculation of average annual improvements in mortality. Table 2 on page 11 shows a comparison of annual improvements in mortality in 19 countries between successive decades from the 1950s to the 1990s. Generally speaking, we can see that improvements in mortality become faster over calendar time. While there was an annual survival improvement of 0.81 percent for men in their 80s when comparing the 1960s with the 1950s, survival improved much faster during the 1990s in comparison the 1980s. This trend is even more pronounced for women where the average annual improvement was 2.45% for octogenarians during the most recent period.

Table 2: Average Annual Improvement in Mortality (in percent) for males and females and for octogenarians and nonagenarians of 19 countries from the 1950s to the 1990s

Period	Males		Females	
	Age 80–89	Age 90–99	Age 80–89	Age 90–99
1950s–1960s	0.81	0.32	0.91	0.27
1960s–1970s	0.89	0.94	1.35	0.85
1970s–1980s	1.20	1.13	2.00	1.31
1980s–1990s	1.88	0.71	2.45	1.28

Source: Kannisto-Thatcher Database, Own Calculations

Figures 4–5 on pages 15–16 support our findings from Table 2: Figure 4 shows the average annual improvements for 28 countries which have been made in survival in successive decades starting from the 1930s until the 1990s for ages 80–99 for women and males. Clearly, one can recognize for women and men alike, annual improvements have been increasing over time on average. As one could have concluded already from the figures plotting probabilities of death, Japan is for women and men among the top-performing countries since the 1960s. The most pronounced progress has been made during the 1990s in comparison to the 1980s in Eastern Germany. Mortality fell each calendar year by more than three percent for women between the 1980s and 1990s; men's survival improvements were close to 2.5%. Figure 5 displays

for women and men in the four countries performing among the best in terms of life expectancy at birth (Japan, France, Sweden, Switzerland) how survival improved by five-year-age-groups. The first point compares the period 1960–69 with the period 1950–59, the last plotted information relates 1990-99 to 1980-89. Especially for women (solid lines), we can see that survival does not only improve annually, it is even accelerating. This development did not change during the most recent decade which is separated by a black horizontal reference line marking roughly the last observations used in Kannisto et al. (1994). With the exception of men aged 95–99, one can also detect an acceleration of the improvement in survival — albeit at a slower pace than women.

If death rates are close to a biological minimum, one should assume that countries with the lowest current death rates should display lower annual improvements in survival. From our data, we can not make any such inferences. In Figure 6 on page 17, the average death rate in the 1980s has been plotted against the average annual improvement during the 1990s. If death rates are reaching a natural threshold, one should detect a positive trend. Even when disregarding Japan, we can not establish such a relationship. It rather seems that annual improvements are made relative independently from death rates.

Figure 7 on page 18 displays the average annual improvement in mortality by single years of age separately for women and men. The left panel shows an aggregation of 10 countries,[2] while the right panel shows the development of the four countries with relatively high life expectancy: France, Japan, Sweden and Switzerland. The solid lines indicate the average annual improvement between the 1990s and the 1980s whereas the dashed lines refer to the two previous decades (1980s vs. 1970s).
Generally speaking, the annual improvements in mortality are lower the higher the ages. The highest values are obtained in both panels by women as well as by men for both time periods at age 80 and are decreasing the higher the age of the people.
For the first time we do not observe a favourable trend. If one compares on the left panel the development over time (i.e. comparing the dashed (=old) with the solid (=more recent) lines) one recognizes the steeper slope during

[2]Austria, Denmark, England & Wales, Finland, France, Germany (West), Japan, Norway, Sweden, Switzerland.

the latter period. This implies on the one hand that left of the crossover points (roughly age 90 for men, age 94 for women) that further improvement have been during the 1990s. At the highest ages, however, mortality rates are still improving but at slower pace than in the 1980s. Might this be an indication that reduction mortality rates is reaching a limit? We argue that this is not the case. The right panel for the countries which are performing very well in terms of life expectancy shows no such crossover for men (blue). For women (in red), there is even an acceleration visible across all ages.

Conclusion

Our paper shows that survival improvements at the highest ages in developed countries still continued since 1990, the last year on which Kannisto's analyses were based. We looked at survival improvements from various angles: pure population counts at advanced ages, the development of the probability of dying, and annual improvements made against mortality. The general trend is promising: the number of old people is increasing in all countries, mortality rates are decreasing and survival improvements are either constant over time or even accelerating. Of course, this general trend shows some exceptions: the number of old people is not increasing with the same rate in all countries; several countries deviate from the trend in mortality reductions, especially the United States with a levelling off and the former GDR with a catching up. Also our results for annual improvements in survival do not give any support for the hypothesis that mortality levels are reaching a biological minimum: especially in countries with the lowest mortality, annual improvements in mortality decreased at an even faster pace during the 1990s than in the 1980s.

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dence from 28 developed countries. Monographs on Population Aging, 1. Odense, DK: Odense University Press.

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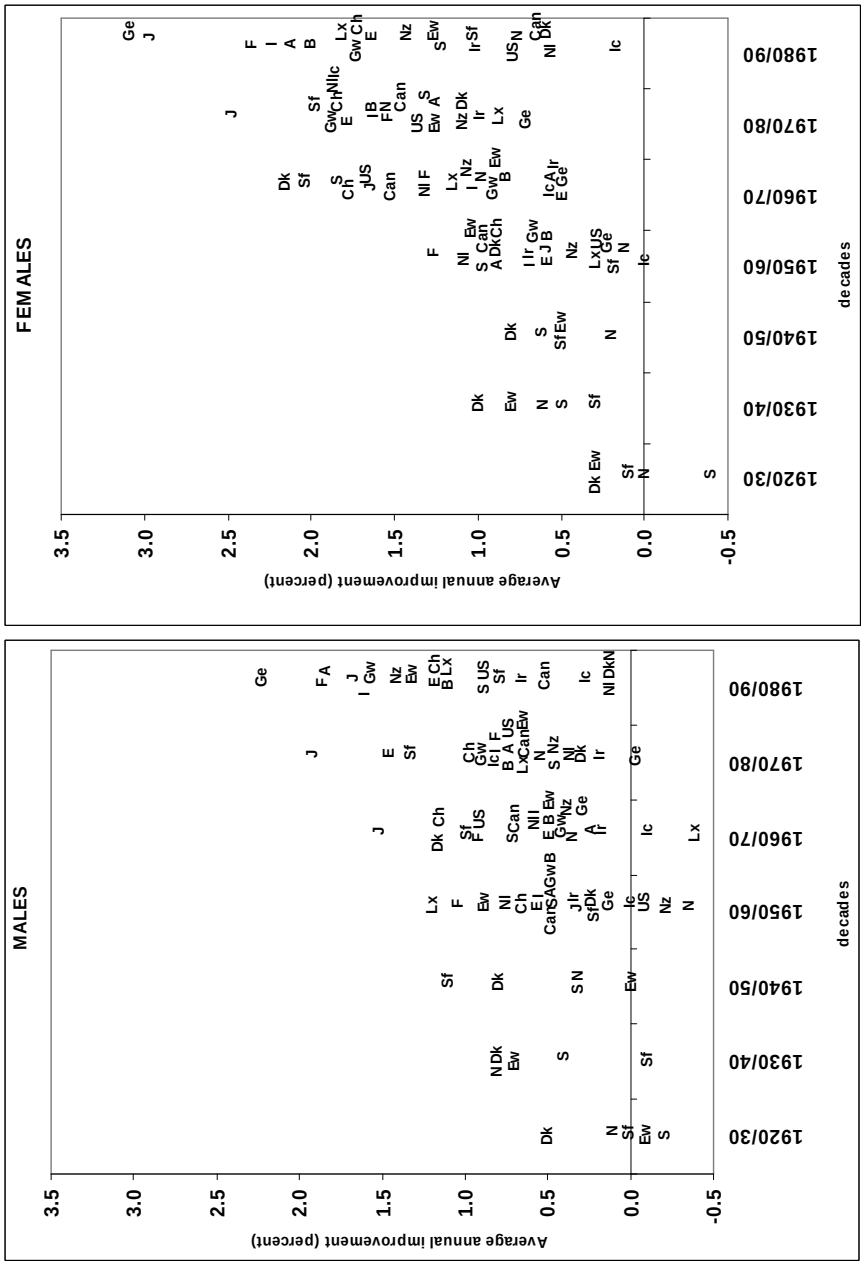
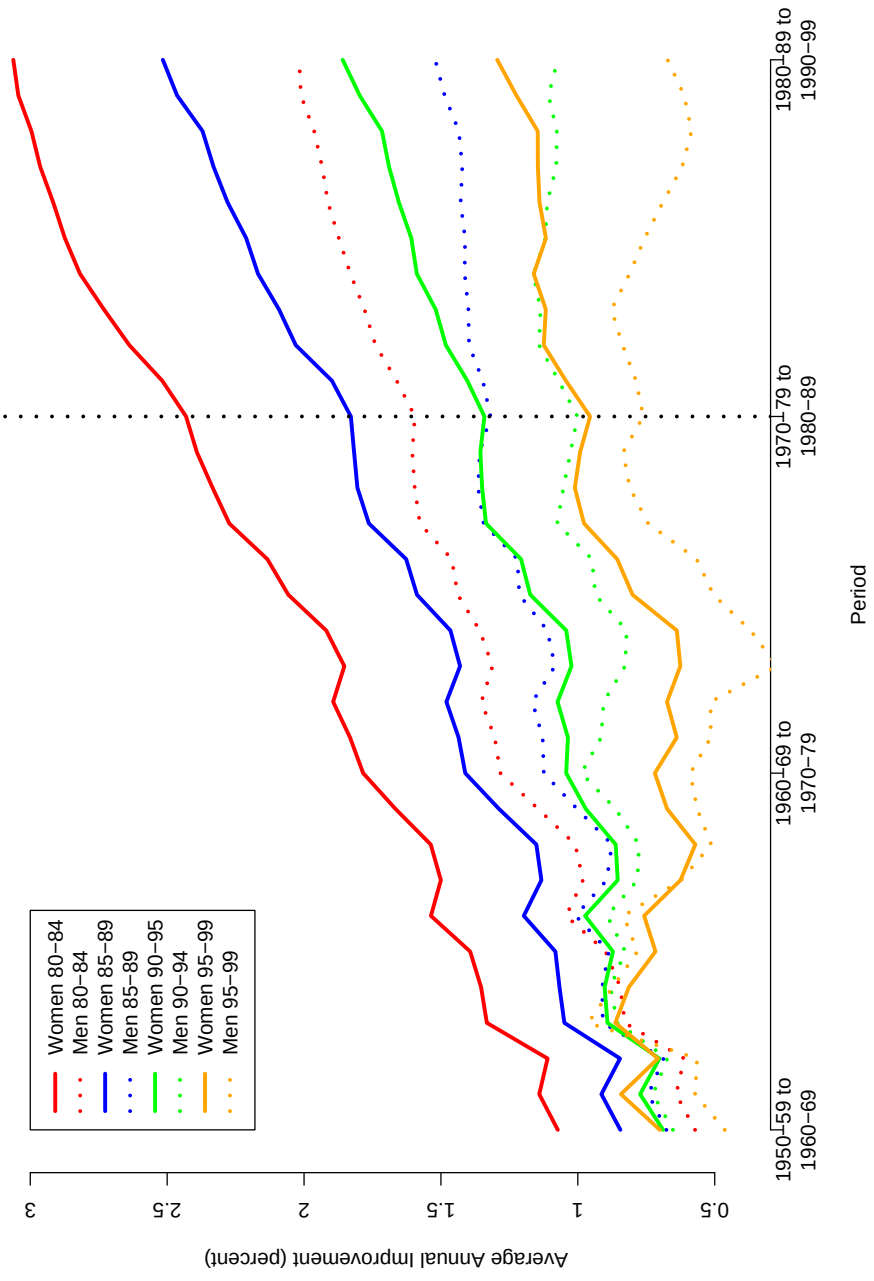
Figure 4: Average Annual Improvement in Mortality from Decade to Decade for Ages 80–99 Combined, Males and Females



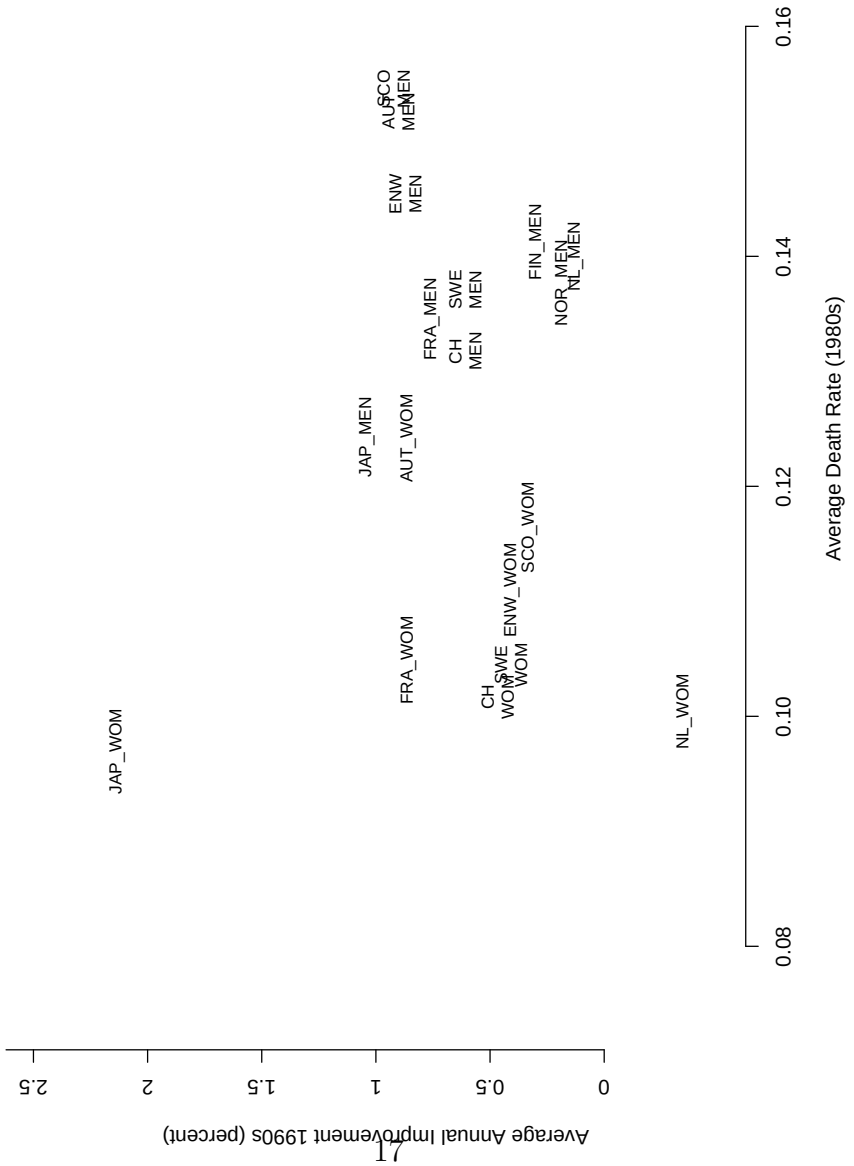
Source: Kannisto-Thatcher Database, Own Calculations

Figure 5: Average Annual Improvement in Mortality between Successive Ten-Year-Periods for Women and Men for 5-year-age-groups, aggregating the Top-4-Countries in Life Expectancy: Japan, France, Sweden, Switzerland



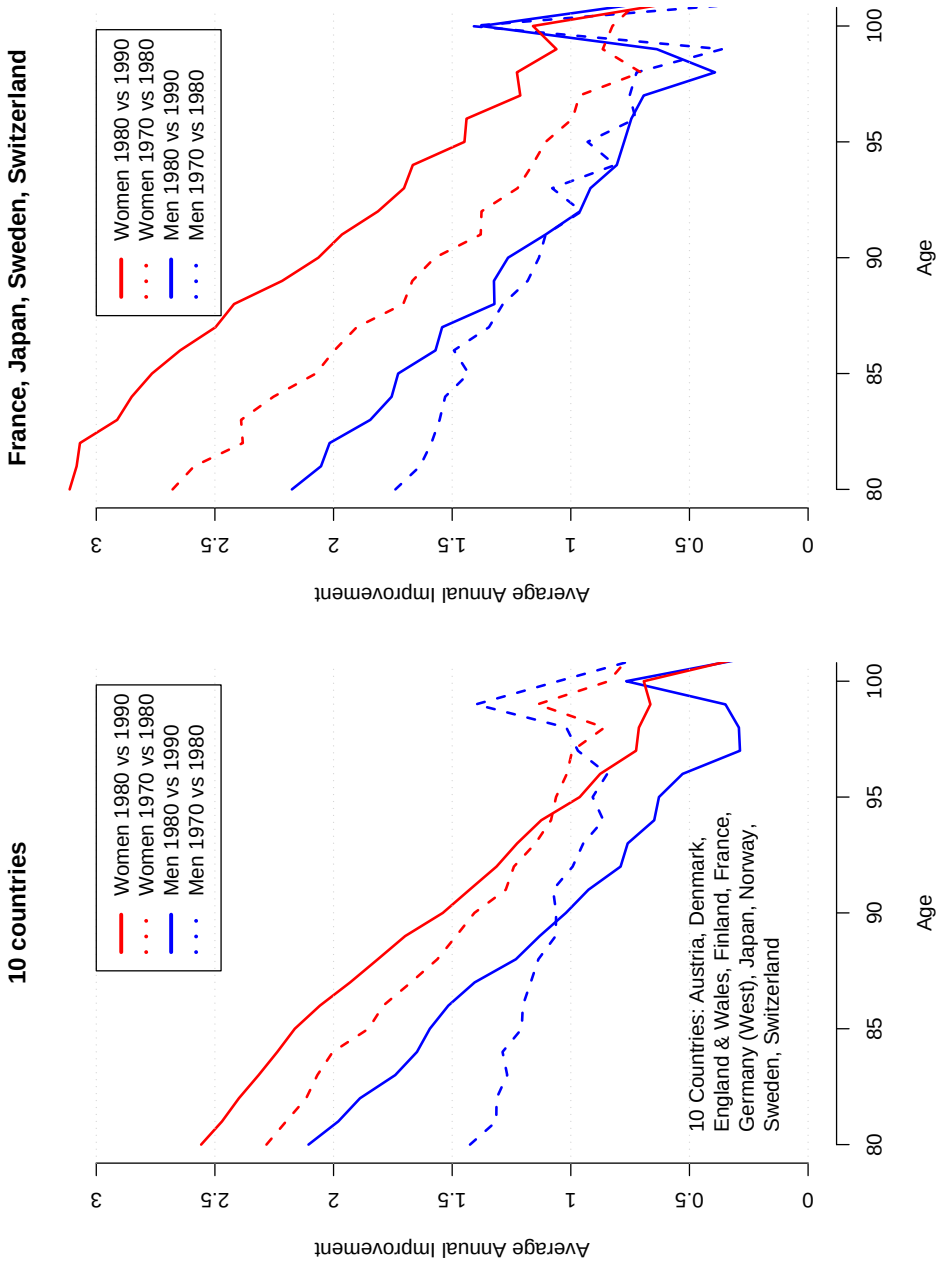
Source: Kannisto-Thatcher Database; Own Calculations; The curves plot the annual average improvement in mortality between one ten-year period and the next. The last point on the curves gives the rate of improvement between 1980–89 and 1990–99.

Figure 6: Average Annual Improvement by Average Death Rate, Women and Men, 10 countries



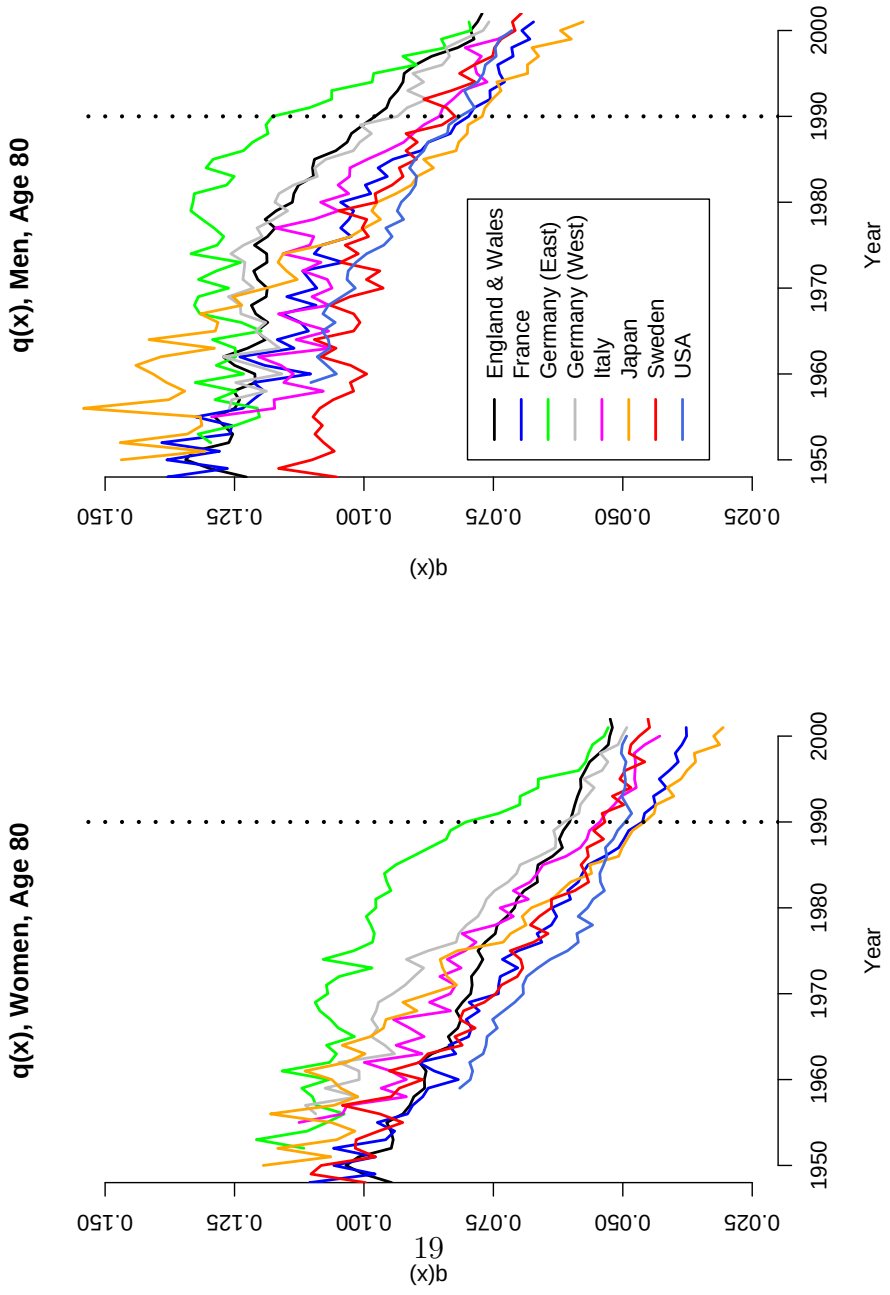
Source: Kannisto-Thatcher Database, Own Calculations; Average Death Rate in the 1980s Compared with Average Annual Improvement in Mortality from the 1980s to the 1990s for males and females. AUT=Austria, CH=Switzerland, ENW= England & Wales, FIN=Finland, FRA=France, JAP=Japan, NL=the Netherlands, NOR=Norway, SCO=Scotland, SWE=Sweden.

Figure 7: Average Annual Improvement In Old-Age-Mortality for Women and Men by Single Year of Age



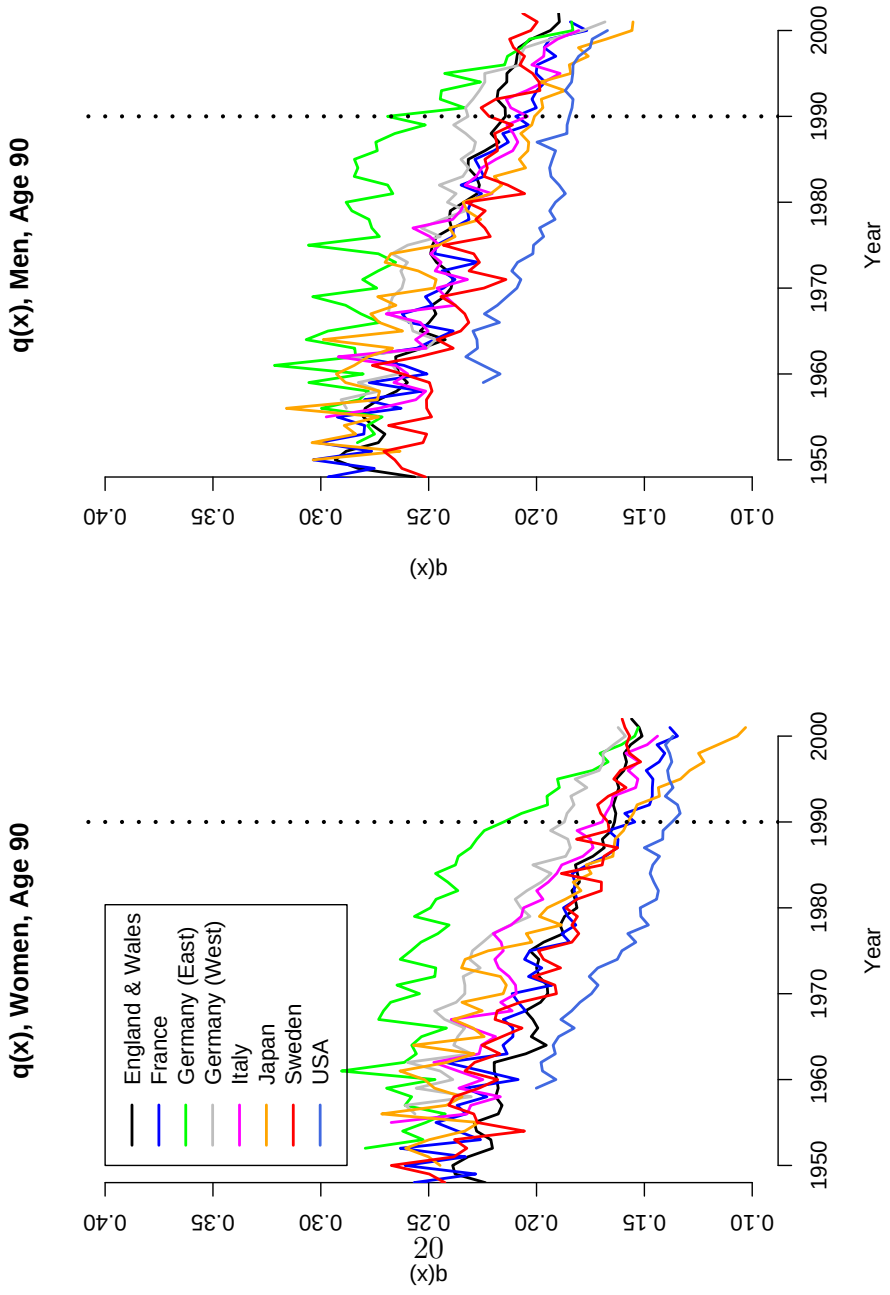
Source: Kannisto-Thatcher Database, Own Calculations; The left panel shows and aggregation for the countries: Austria, Denmark, England & Wales, Finland, France, Germany (West), Japan, Norway, Sweden, Switzerland. The solid lines compare the 1990s with the 1980s; the dashed lines are comparing the 1980s with the 1970s

Figure 8: Semi-Logarithmic Plot of Probabilities of Dying ($q(x)$) at Age 80 for Women and Men in England & Wales, France, Germany (East and West), Italy, Japan, Sweden and the USA during the period 1950–2000



Source: Kannisto-Thatcher Database, Own Calculations

Figure 9: Semi-Logarithmic Plot of Probabilities of Dying ($q(x)$) at Age 90 for Women and Men in England & Wales, France, Germany (East and West), Italy, Japan, Sweden and the USA during the period 1950–2000



Source: Kannisto-Thatcher Database, Own Calculations