Maximum Life Expectancy and Highest Age-Specific Survival Rates

Jacques Vallin[1] and France Meslé[2]
INED, Paris

Introduction

In their well known *broken limits of life expectancy,* Oeppen and Vaupel (2002) showed that the best life expectancy observed in a given year has increased linearly from 1840 up to now. However, life expectancy has increased as the result of the decline in mortality at different ages, the weight of which has changed dramatically over time. What are the trends in the lowest age-specific survival rates? Do they follow a straightforward pattern? HMD data will be enriched by other life tables collected by INED and MPIDR. We shall discuss first the gain obtained when using a larger set of data: is the Oeppen-Vaupel straight line still fitting the reality? Then, in a second section, to select significant large age groups, the difference between life expectancy at birth of the best-performing country and the mean life expectancy of the other countries will be broken down according to the weight of each age, around 1850, 1900, 1950, and 2000. Trends in highest survival rates within each significant large group or in highest life expectancies from the starting points of these age groups will be analysed. Finally, taking in account the importance of old age mortality for future changes in life expectancy, Kannisto-Thatcher database will permit us to carry on with life expectancy at age 80, and also to realize that the case of New-Zealand is perhaps the Achilles' heel of the Oeppen-Vaupel line. The straight line will appear to have to be broken into three or four segments that correspond to the main historical phases of the health transition.

1. Can we get with more data?

The precise universe on which Oeppen and Vaupel's line relies is unknown[3] and it will not be possible to reassess the line on the basis of the original data and, even less, to compare any new results got with a different approach from that original universe to both original results and new results based on an enlarged universe. However, it is possible to look at different results that we can get today by using different universes more or less homogeneous according to the quality of data, and then to compare the best result that we can get today to the Oeppen-Vaupel's original results.

---

[1] vallin@ined.fr
[2] mesle@ined.fr
[3] James Oeppen, who collected the data, told us that he built his set of life expectancies at birth which was available from the *Human Mortality Database* at the time, enriched by additional series of e_0 he gathered from different sources in a personal file that he has been continuously updating since *Science* paper was published. He gently provided us with the current version of that file. Obviously if we redo what was done for their article (HMD+Oeppen's personal file) we get a larger universe than the original one, since both sources grew up.

A) Data used

In spite of the fact that some advanced developing countries already reached very high levels of life expectancy, we decided to limit our study to Europe, North America, Japan, Australia and New-Zealand. Indeed a quick test showed that no developing country is at the eve to catch up current Japanese levels and more ancient data are very rare outside the area just described.

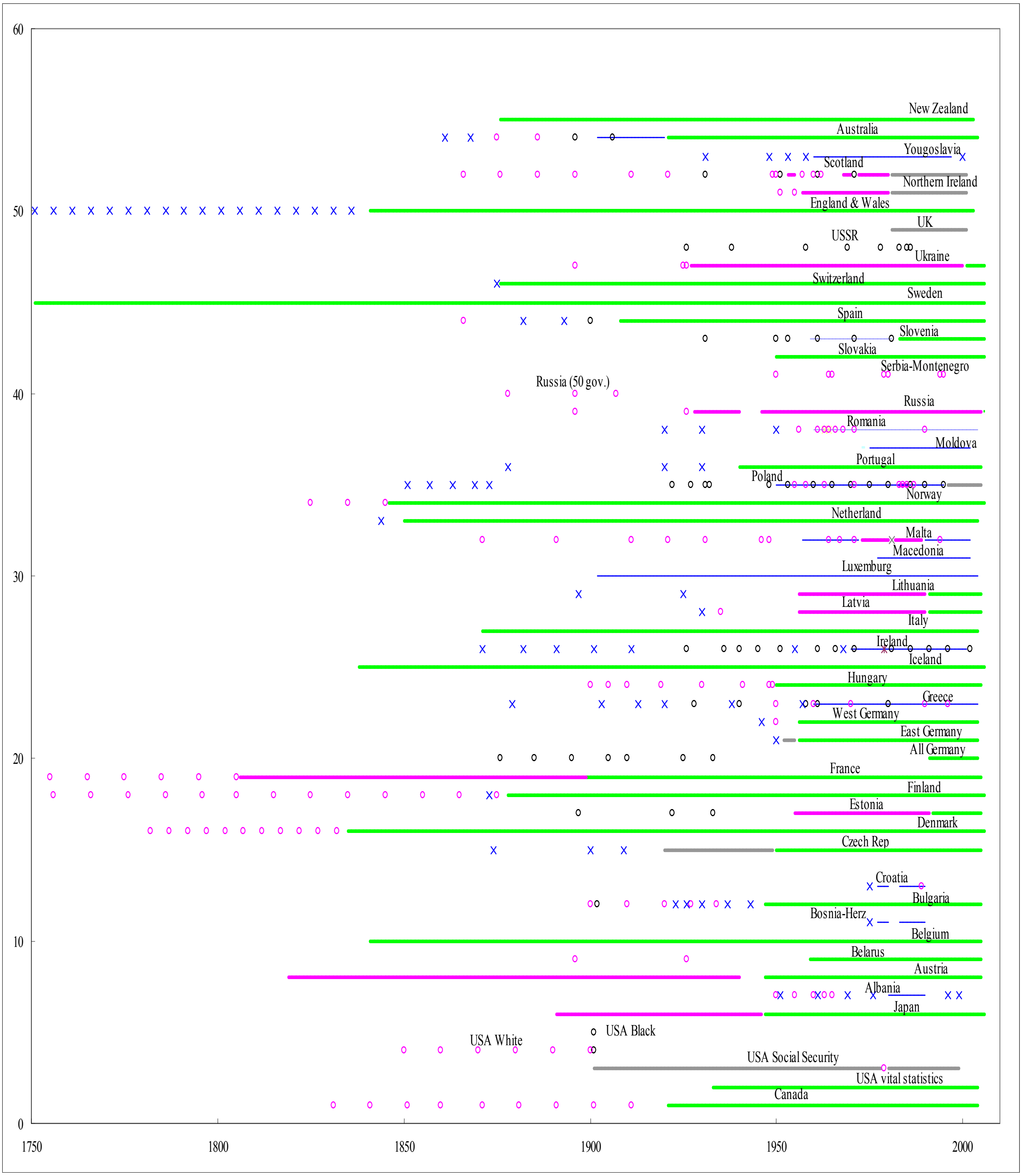
Five different sources were used for our analyses (Table 1 and Figure 1):

- the *Human Mortality Database* (*HMD*)[4], which gives all classical life table functions systematically computed annually on the basis of complete series of deaths and population by single year of age and single year of occurrence; this is the most reliable set of annual complete life table functions in the world and we used it her first and foremost; 2884 annual life tables where available from HMD;
- the *Human Life Table Database* (*HLTD*)[5] gathers original life tables published by statistical offices and other relevant institutions or in the framework of *ad hoc* research projects (it makes available not only *fac simile* of original tables but also reconstructed life table functions from the most appropriate originally produced, according to the same protocol; this is our second priority source that we systematically used when it covers a country for one year that is not provided by HMD; contrary to HMD life tables, most HLTD life tables cover several years (only few of them are strictly annual); 309 additional life tables were available from HLTD;
- right now, these two sources do no cover all existing reliable life tables and we gathered in an additional file here called *Meslé-Vallin Database* (*MVDB*) any other life tables (not included neither in HMD nor in HLTD) that we could get (or compute from age specific mortality rates) for the relevant countries; though the basic rule was to use here only those tables that do not double any HMD or HLTD tables, two exceptions were made here, considering that new estimations available for Russia (Meslé *et al.,* 2003) and Ukraine (Meslé and Vallin, 2003) are better than those given in HMD or HLTD; in the total, 750 additional life tables are available from MVDB;

Table 1: Sources of data used

Initials	Name	Type of content	Number of year-countries
HMD	Human Mortality Database	Complete annual life tables	2884
HLTD	Human Life Table Database	Published life tables, heterogeneous according to age group and period length	309
MVDB	Meslé-Vallin Database	Any other life tables covering period/countries not available in HMD nor HLTD	750
e_0	Life expectation file	Life expectancy at birth published without life table	679
KTDB	Kannisto-Thatcher Database	Mortality rates and life expectancies above age 80 computed with extinct generation method	***

[4] Jointly built in and regularly updated by the Department of Demography at the University of California, Berkeley, USA, and the Max Planck Institute for Demographic Research (MPIDR) in Rostock, Germany, Rostock) the HMD is accessible at: http://www.mortality.org (Shkolnikov *et al.,* 2005).
[5] Jointly developed by the MPIDR, the Berkeley Departement of Demography and the Institut national d'études démographiques (INED, Paris), it is available at: http://www.lifetable.de.



Legend:
Solid lines represents continuous series of yearly data: thick lines for life tables (green for HMD, grey for HLTD, or pink for MVDB) and thin (blue) lines when only e_0 is available.
Circles (grey for HLTD or pink for MVDB) represent punctual life tables while blue x represent punctually available e_0.

Figure 1. Synopsis of data used

- as a fourth source, we used any available life expectancy published alone for relevant countries for years not covered by the previous sources (including those already identified in James Oeppen's personal file); thus 679 life expectancies at birth do not overlap with the 4 previous sources; of course that source can only serve when discussing the Oeppen-Vaupel line, not at Section 2 devoted to age specific comparisons;
- the fifth source will also serve in a limited field but will be much more productive, since it is the *Kannisto-Thatcher Database*, which is the most accurate source of estimation of mortality at age 80 and over; it provides mortality rates and life expectancies above that age, computed on the basis of the *extinct generation* method.

While collected data include information for both sexes separately, only female data will be used here, since the Oepppen-Vaupel line was based on female life expectancy. This is quite justified by the fact that females enjoy nowadays longer length of live than males in all advanced countries.

B) Adding additional data

Not only HMD data are of high quality in most cases, but they offer continuous yearly series. Today, it also consists in a rather large sample of relevant countries, since at the beginning of the 2000s more than 30 countries of our selected universe are included. Figure 1 displays maximum life expectancy (MLE) yearly observed from that source since 1751 to 2005, and the number of countries involved each year as well. At the beginning, only one country (Sweden) is available and MLE is nothing else but Sweden life expectancy. From 1850 to 1870, however, 7 countries are included, and the number grows up to stay at 11-13 for about 40 years (1880-1918) then to 15-17 for two decades (1923-1946) and to 26-28 for three (1960-1990), to finally reach 32 in 1993. Of course, in the most recent years the number of countries goes down according to delays in updating[6].

Figure 2 shows that, at least since the late 1870s, MLE follows rather well a straight line, in spite of the fact that important fluctuations are observed until the 1920s. This main difference with the Oeppen-Vaupel line is that Oeppen-Vaupel does not show such fluctuations, since it relies more on life expectancies produced for periods of more than 1 year, while we systematically used yearly data.

Before 1870, not only fluctuations are even larger, but the general shape of the MLE series is not quite in agreement with the straight line that could adjust the 1870-2005 series. Let us see if adding other data could improve the results.

In a second step, we add to HMD data those from HLTD and MVDB. Indeed, data from these last two files are of exactly the same nature (published life tables for periods not covered by HMD). The only difference is that MVDB life tables did not enter the HLTD yet, for practical reasons.

[6] The reader will probably note too that, for some specific years, the number of countries falls down by one (like in 1852, 1864, 1877, 1886). This is because HMD data were somewhat erroneous and the affected country had to be dropped from the set of data for a couple of years, until appropriate corrections are made in HMD. Also, the number of countries falls down during World War 2, because HMD does not include incomplete data.

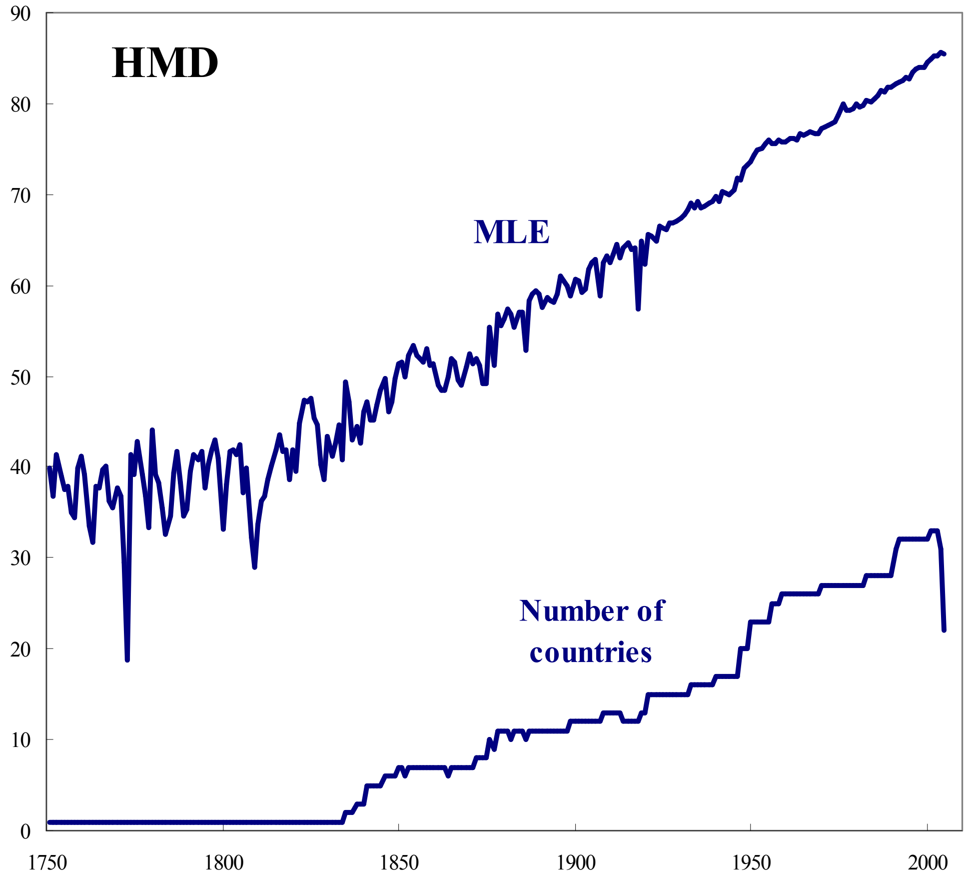


Figure 2. Yearly maximum life expectancy according to life tables available from the *Human Mortality Database* (HMD)

The main difficulty when adding these data to HMD ones is due to the fact that most of them cover more than one single year and that when the reference period consists in an even number of years it cannot be allotted to a full central year, but to a date moved by half a year. More precisely, whereas, for single year life table (for example 1951), we conventionally affected the result to the point corresponding to the year number (i.e. 1951), for several-year life tables, we had to attribute the result to the central year for an odd period (i.e. 1951 for the period 1950-1952) and in-between the two central years for even periods (i.e. 1951.5 for 1950-1953).

It resulted in the rather strange series showed in the first graph of Figure 3 that includes one point for each year and mid-year position. The unexpectedly numerous and sharp fluctuations are due to the fact that pluri-annual life tables are more often the only source in higher mortality countries than in lower mortality countries. Consequently, in most cases, the highest mid-year life expectancy is far less than the MLE of the two surrounding exact-years.

To solve the problem, data were interpolated to get exact-year and mid-year points for every country, as shown in the second graph of Figure 3. The new series demonstrate a clear improvement when compared to the results previously obtained on the only HMD basis. Fluctuations have reduced all along the time and the general shape of the series shows a better continuity. This is clearly related to the larger number of countries involved. Sweden is no more ever alone, since France starts in the same time and Finland arrives soon after (1755) and then Denmark (1783) and later on Austria, Norway and Canada in early nineteenth century (1819, 1821, 1831 respectively). Furthermore, the number of countries increases a lot in the first part of twentieth century reaching 36 in 1941. Maximum number is reached in 1981 with 45 countries. However, the number starts to decrease sooner (1990) than when HMD alone is used and at the very end, only 3 countries are taken into account in addition to HMD.

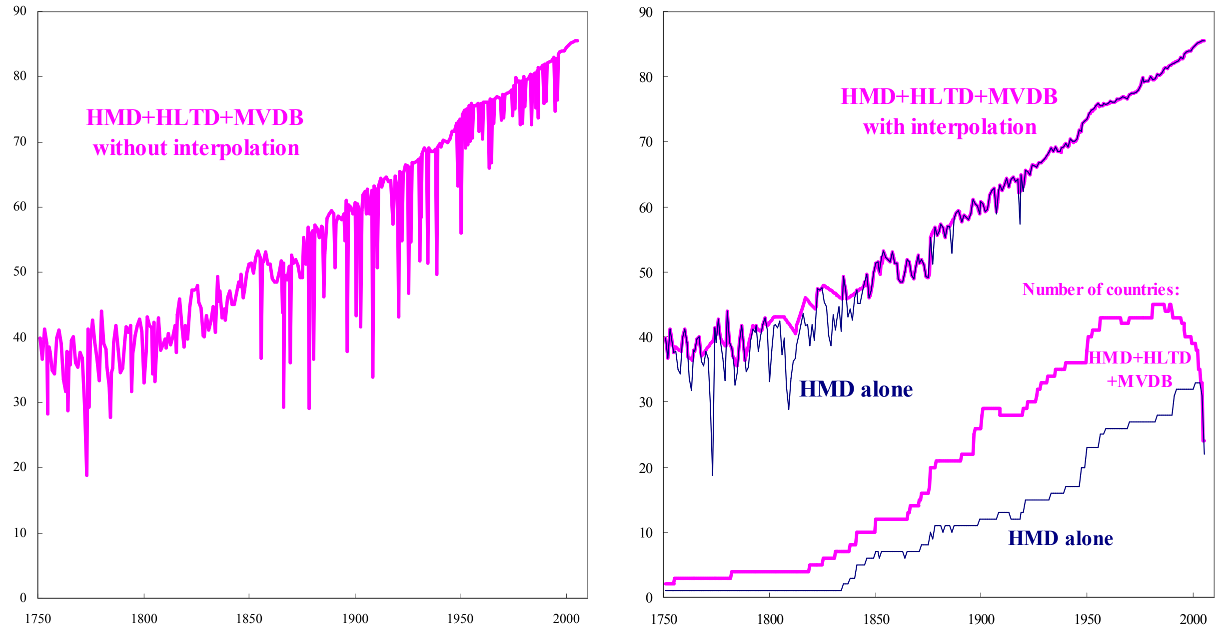


Figure 3. Yearly maximum life expectancy according to life tables available from the *Human Mortality Database* (HMD) the *Human Life Table Database* (HLTD) and the *Meslé-Vallin Database* (MVDB)

In fact, since 1846 these additional data do not change the general shape on the MLE series at all. It only moderates or even suppresses some quite questionable falls down in 1877, around 1888 and in 1918. On the contrary, the years before, not only fluctuations are strongly lessened but the general shape of the trends changes, especially from the late eighteenth century to the mid nineteenth.

In a third step, country-years where only life expectancy at birth was available were added (Figure 4). The number of countries is slightly increased, especially after 1880, but the results differ very few. The series of MLE is only changed for a few specific years around 1752, 1757, 1785, 1788, 1868 and 1875. Eighteenth century new points are due to the sooner arrival of England and Wales. Nineteenth century ones are due to Australia then Ireland. The output of this final addition of data is rather small but it results in moderating a couple of fluctuations significantly.

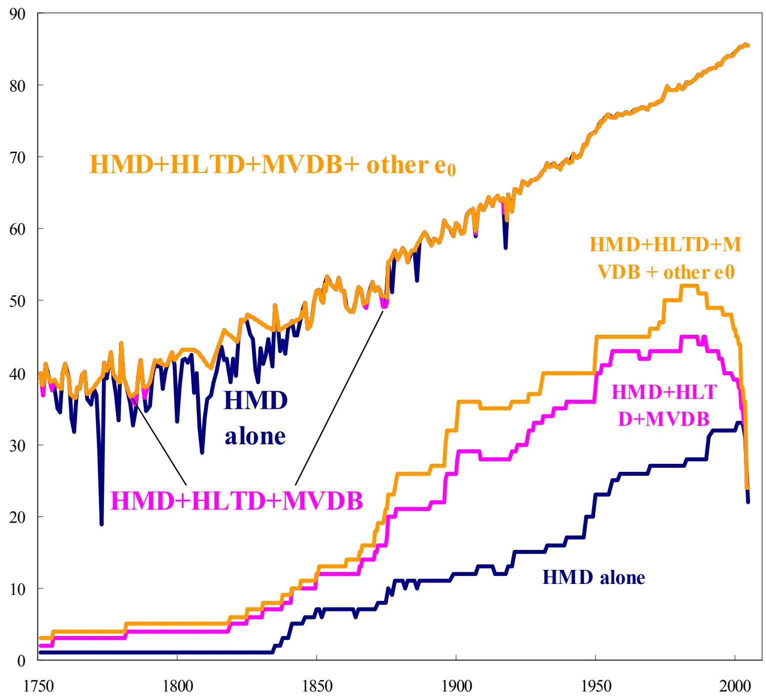


Figure 4. Yearly maximum life expectancy according to life tables according to the four sources of data cumulated

To better appreciate the reliability of these results, let us have a glance at the whole universe studied. Left graph of Figure 5 compares the MLE to the mean life expectancy and to the minimum life expectancy.

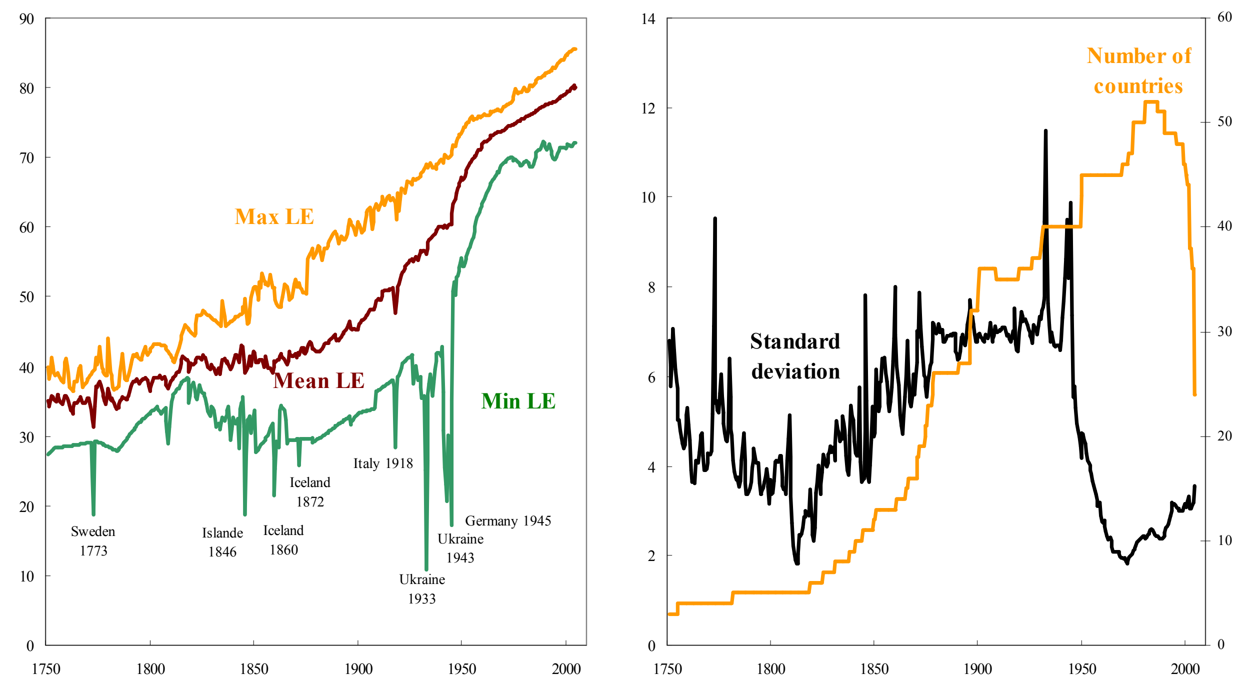


Figure 5. Maximum life expectancy as compared to average and minimum life expectancy, and standard deviation as compared to number of countries involved

At the beginning, the gap between maximum and minimum life expectancies is rather narrow while it is very large from about 1850 to 1950, narrows in the 1950s and 1960s and finally widens again since the 1970s. However, the first step of divergence took certainly place earlier than it appears, because for more than half a century, the number of countries involved is too small and too homogeneous to let see the real divergence that very likely started at the end of the eighteenth century, when life expectancy started to increase in a lot in countries like Sweden or England. The phase of divergence between highest and lowest life expectancy probably lasted until the end of the nineteenth century, when countries like Russia got into the large European movement of reducing infectious mortality.

Also minimum life expectancy is subject to very acute fluctuations, due to the fact that from time to time, certain countries are affected by specific mortality crisis, even in the twentieth century like the great Ukrainian famine of 1933.

Standard deviation varies also a lot according to the number of countries but that effect is combined with that of divergence and convergence movements observed within the group of countries involved. For example, at the beginning standard deviation goes down because the few countries involved converge. Then standard deviation increases a lot when the number of countries increases in a phase of general divergence. After World War 2, it falls down dramatically because of the general convergence produced by generalized success against infectious diseases. And again it rises since the 1970s under the new divergence movement caused by cardiovascular revolution. Finally standard deviation rise is also pushed up by the reducing number of countries involved.

Obviously, all these observations are an incentive to be prudent when interpreting results, but it seems to us that maximum life expectancy is much less affected than the other indicators by the number of countries involved because high levels of life expectancy are very likely correlated with the early availability of data.

C) Contributing countries to the MLE

Countries contributing to MLE are mostly Sweden for the second part of eighteenth century, Denmark then Norway for the three first three quarters of the nineteenth century, New-Zealand from 1875 to 1940, Iceland and Norway alternately from the early 1940s to the late 1970s, and finally Japan from the 1980s to now (Figure 6). A few other countries contribute too but much less: Finland and England & Wales in the eighteenth century, Ireland for a couple of years around 1875, Australia in 1907 and 1918, and even Belarus in 1964. In the last case, however, the fact results from an underestimation of mortality levels very likely[7]. For the period covered by Oeppen and Vaupel analysis (1840-2000) the main contributors are exactly the same, even if some differences appear, specially because our work is systematically based on yearly estimates of life expectancy. However, dealing with a much longer period of observation, it is possible to discuss further how our results confirm the Oeppen-Vaupel lime or open new perspectives, even at that first level of expectation of life at birth.

[7] It has been shown that for other European countries of the former USSR, especially Russia (Meslé *et al.*, 2003) and Ukraine (Meslé and Vallin, 2003) mortality was significantly underestimated that time.

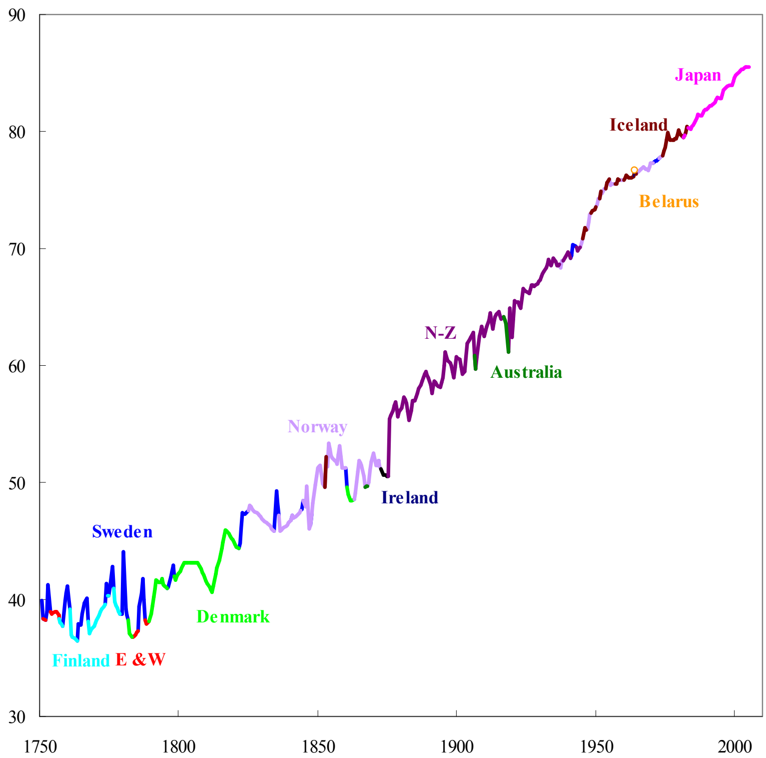


Figure 6. Countries contributing to maximum life expectancy

D) Comparing with Oeppen-Vaupel straight line.

Clearly, our set of results does not fit well with a linear adjustment (left graph of Figure 7). Indeed, it appears that the years before the late 1780s are not at all concerned by any increase in MLE. Only fluctuations are observed. It seems to us that the Oeppen-Vaupel principle comes up against an obvious limit for the past. Naturally, it is not a surprise, since a retropolation of the Oeppen-Vaupel line would necessary leads to absurdity (zero, or even worse, negative life expectancies) but we did not expect a so clear cut at exact time of the French Revolution!

Furthermore, things appear to be more complex. Considering the 1789 cut, it is possible to adjust quite perfectly our set of data by two different straight lines. The first one is perfectly horizontal while the second seems to look like Oeppen-Vaupel straight line very much (green lines of the left graph of Figure 7). In fact the second graph of Figure 7 shows that our green line differs significantly from the Oeppen-Vaupel line with a less steep slope. The pace of progress indicated by our set of results is less rapid that that of Oeppen-Vaupel line (the red one).

However, when starting our adjustment to the same period as that of Oeppen and Vaupel work exactly (1940) the two lines are perfectly superposed, with exactly the same slope.

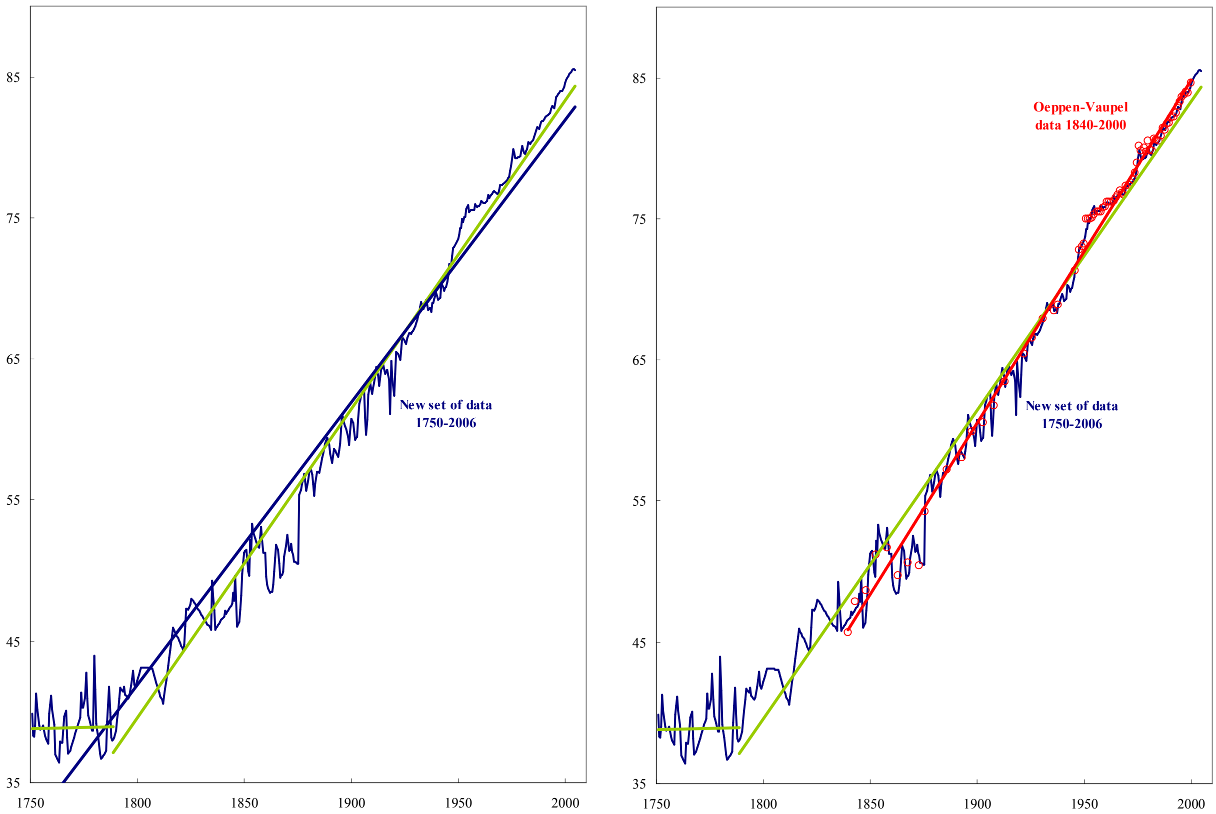


Figure 7. Adjustment of the new results as compared to the Oeppen-Vaupel line

Taking in account such a result, one can finally obtain (Figure 8) a better adjustment of our set of results by three different straight lines. As previously, the first one summarises the stagnation of the past until 1789, the second one seems to take in account a first range of progress at a rather moderate pace, from 1789 to 1840, and the third suggests that the 1840s start a new phase of accelerated progress that continue until now. Let us see if a study of age specific survival rates can confirm or modify such a vision.

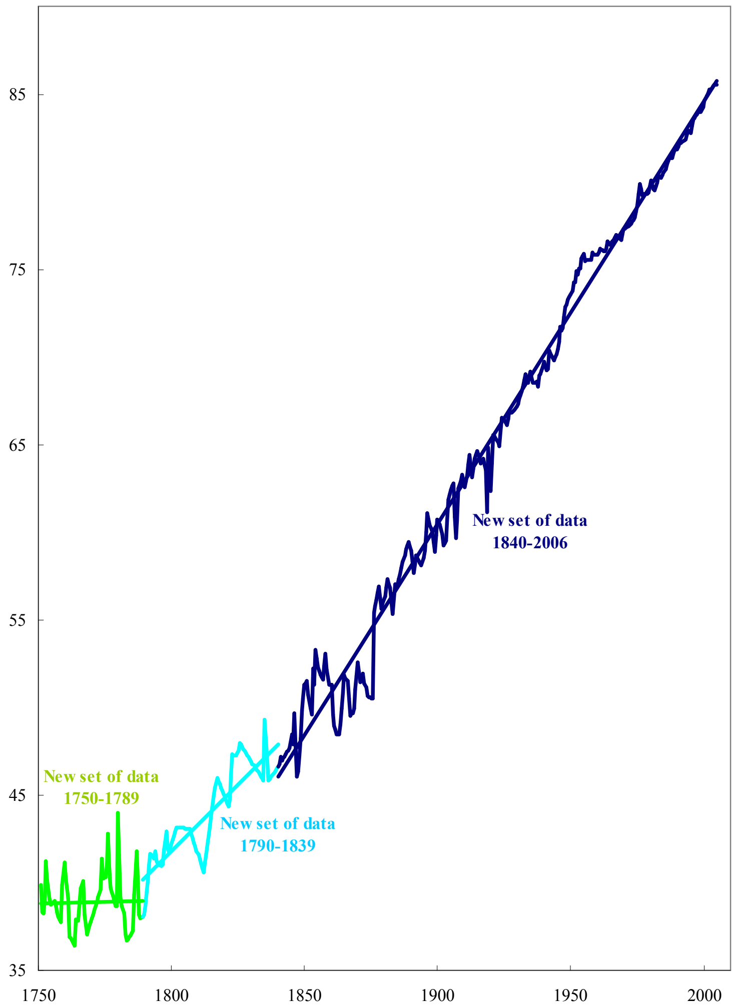


Figure 8. Adjustment of the new results divided into three successive periods

2. What about age specific survivals

The weight of the different age-specific mortality rates on progresses in life expectancy varies a lot with time. This well known phenomenon can be seen here from a particular point of view by analysing the difference between maximum and average life expectancies observed at various points in time. Of course, this approach is not relevant for periods where the number of countries is too small, and to be short, one can limit the analysis to four points: 1850, 1900, 1950, and 2000. Components of life expectancy differences have been computed with Andreev method (Andreev, 1982; Shkolnikov *et al.,* 2001).

From 1850 to 2000, age-group weights changed radically (Figure 9). In 1850, among the 8.9-year difference between the best e_0 and the mean, 4 years (45% of the total gap) were due to the only difference in infant mortality (Table 2), and 1 year and half (17%) was related to 1-5 mortality rate, while the whole range of mortality from age 15 to 60 contributed for only 1.9 year (21%). In 1900, for a much larger gap of 13.3 years, infant mortality still accounted for a big amount (3.8 years) but a less important part (28%) because an almost equal amount (3.6 years, 27%) was due to 1-5 mortality, while the contribution of 15-60 mortality was of secondary order.

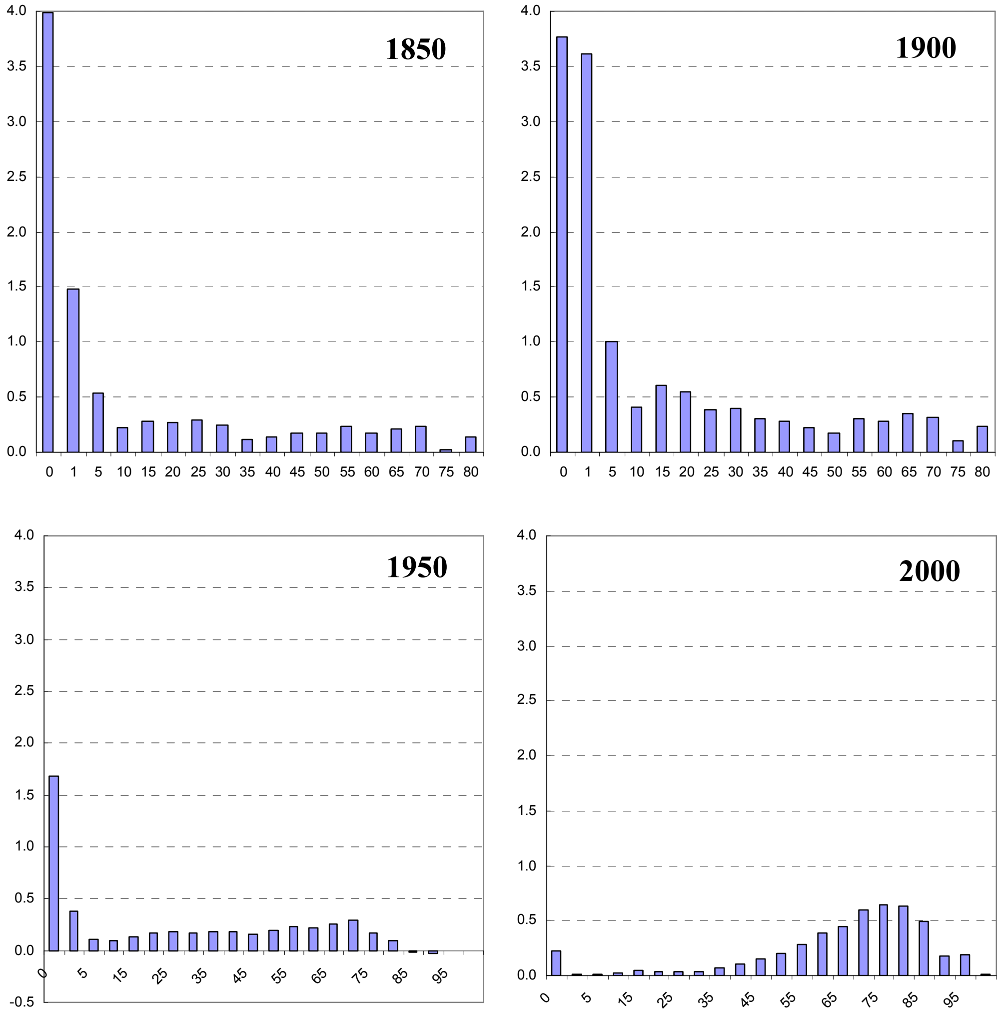


Figure 9. Age components of the life expectancy difference between the MLE and the average life expectancy, in 1850, 1900, 1950 and 2000

Table 2. Age components of the life expectancy difference between the MLE and the average life expectancy, in 1850, 1900, 1950 and 2000

Age	1850		1900		1950		2000	
	Years	%	Years	%	Years	%	Years	%
0-1	3.99	44.7	3.77	28.4	1.68	34.5	0.22	4.6
1-5	1.48	16.6	3.61	27.2	0.38	7.8	0.01	0.2
5-15	0.75	8.5	1.41	10.6	0.20	4.2	0.04	0.8
15-60	1.90	21.4	3.21	24.1	1.60	32.9	0.97	20.2
60+	0.78	8.8	1.29	9.7	1.00	20.6	3.56	74.2
Total	8.90	100.0	13.30	100.0	4.87	100.0	4.80	100.0

In 1950, the total contribution of young age mortality (ages 0-1 and 1-5) is much less than in the past (42% instead of 60% in 1850 and 56% in 1900) while that of older ages (5+) is much higher (57% instead of 36% in 1850 and 46% in 1900). And, finally, in 2000 the change in the pattern of the difference components is even more changed since less than 5% of the difference only is explained by mortality under 5 years against more than 95 %

explained by mortality above age 5. Even more, most of the total gap (74 %) is related to mortality above age 60!

How to show in what extent age specific survival rates contribute to the trends in life expectancy at birth? In a first step, survival rates within three age ranges (0-1, 1-15 and 15-60) as well as life expectancy at 60 have been examined (Figure 10). Obviously, no curve among these four follows a straight line during the last 150 years. The progression of 0-1 and 1-15 survival rates has been blocked close to 1 as soon as the 1950s, and the progression of 15-60 survival rates was suddenly broken in the late 1950s, while, on the contrary, the progression of life expectancy at 60 has been sharply accelerating during the whole twentieth century.

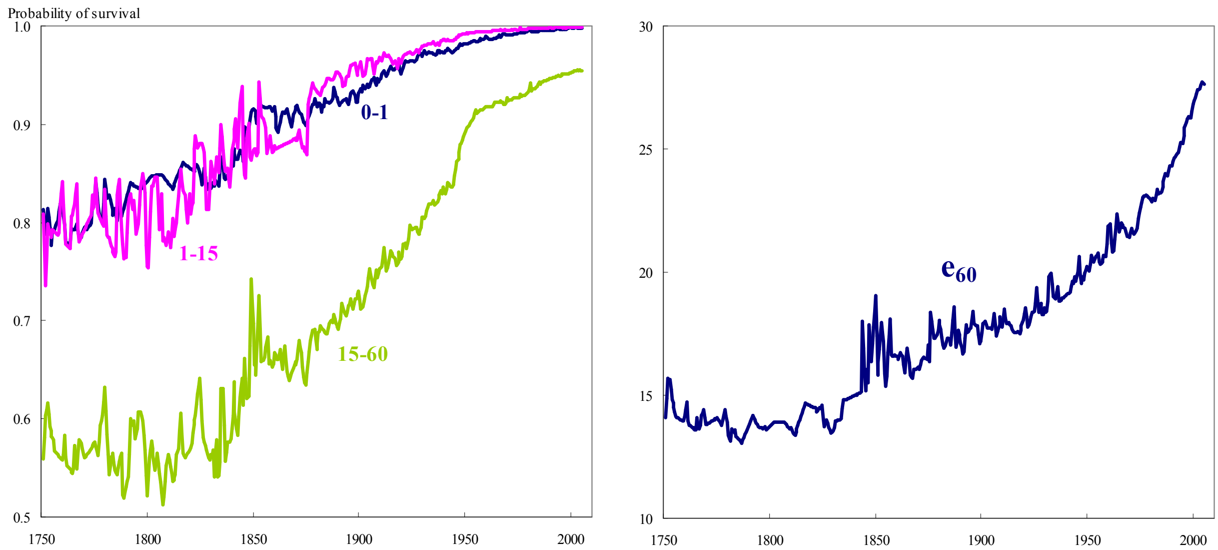


Figure 10. Trends in maximum survival probabilities between ages 0 and 1, 1 and 15 and 15 and 60, and maximum life expectancy at 60

Indeed, comparing survival rates within first age ranges with life expectancy at 60 is somewhat artificial, since indicators are not of the same nature. The view on first age-range survival can be improved by using logit (Figure 11), which shows that the relative progression lasts longer than it appears at Figure 10. Indeed, infant and 1-15 survivals appear to progress steadily along the whole twentieth century without interruption while, after the 1950s acceleration, the recent pace of progress in 15-60 survival rates is quite comparable to the rhythm observed in the first half of the twentieth century. But such a presentation does not improve the comparability between first closed age groups and the open group 60+.

The less bad solution is probably to compare only open groups by considering life expectancy at various ages (Figure 12).

While trends in life expectancy at birth fits almost perfectly with a linear adjustment since 1840 as shown above, as soon as one looks at life expectancy at age 1, a slight discrepancy appears: most recent maximum life expectancies are significantly above the adjustment line. And the phenomenon is growing when looking to upper ages successively. Finally, at age 60 the most recent maximum life expectancies are very far above the adjustment line, while the maxima observed during the first half of the twentieth century are significantly below.

Furthermore, when trying to adjust the 1840-2000 data exponentially, only life expectancy at 1 fits quite well with the exponential line. At all ages above recent increases in life expectancy are more than exponential. This is especially acute at age 60 but it is also very well marked at ages 50 and 40.

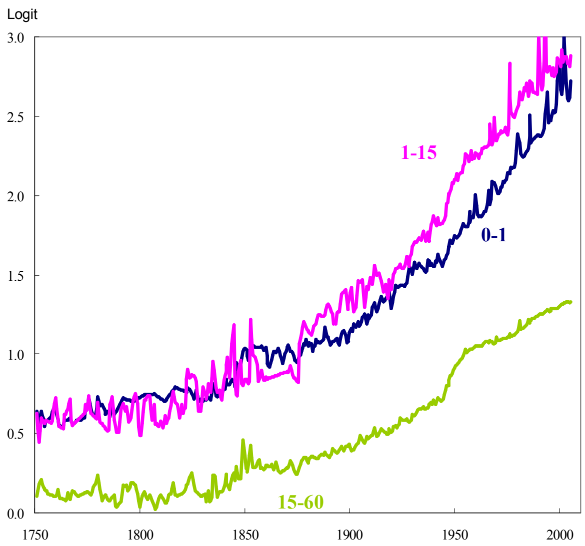


Figure 11. Trends in the logit of maximum survival probabilities between ages 0 and 1, 1 and 15 and 15 and 60

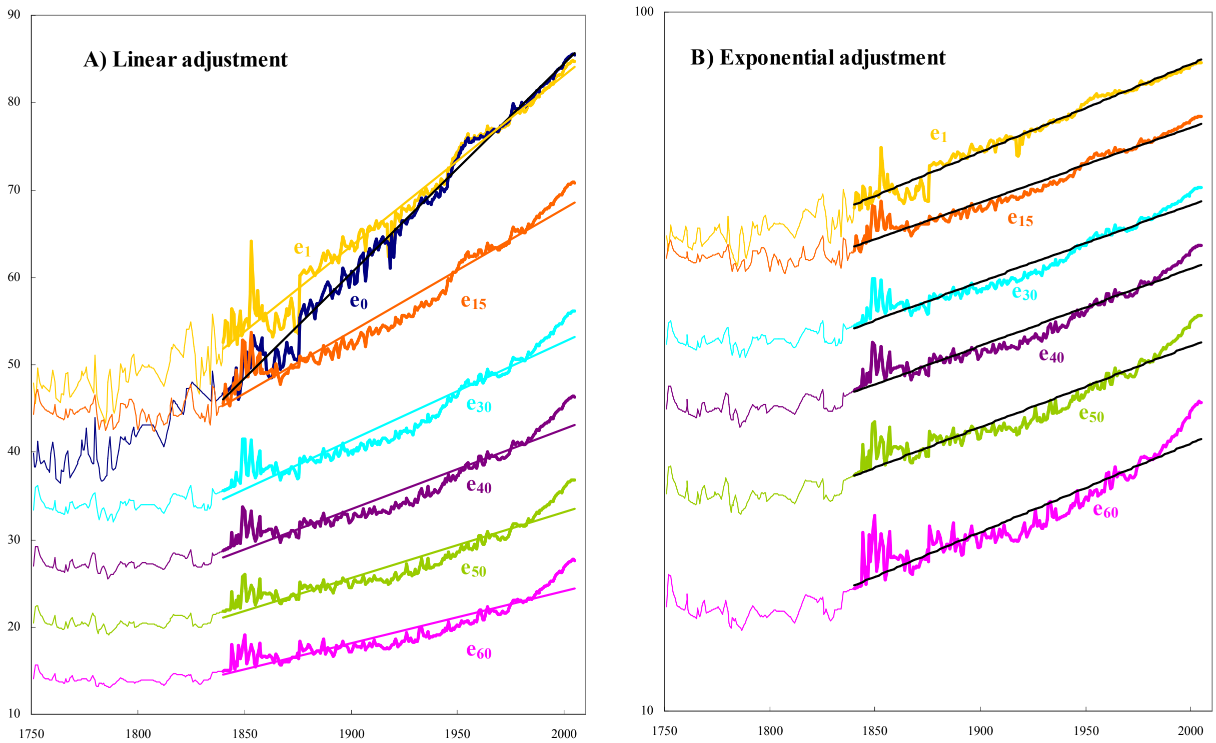


Figure 12. Trends in maximum life expectancies at various ages: linear and exponential adjustments

To go further and look at life expectancy at older ages, however, it is quite dubious that our full universe of reference can lead to reliable results, since mortality rates for the elderly are very questionable in many countries. Fortunately, it is possible to confront such results to those resulting from the Kannisto-Thatcher database which is much more accurate at oldest ages, even if it includes fewer countries for a shorter reference period.

3. The interest of Kannisto-Thatcher Database

Kannisto-Thatcher database (KTD) has been built on the basis of developed countries able to afford with detailed and accurate counts of death par single year of age after 80 and until the age where deaths occur no more[8] (Kannisto, 1994; Kannisrto *et al.,* 1994). Deaths are then computed by birth cohort to estimate age specific reference populations by single year of age according to the extinct generation method (Vincent, 1951). Thus age-specific mortality rates can be computed, by cohort and by period as well, by using reliable and coherent denominators. Naturally, the number of countries is smaller than in our data set of data (30 in 1995 instead of 49) and the covered period is shorter (starting in 1859 instead of 1750).

A) Comparing our new data set to KTD

Figure 13 compares trends in maximum life expectancy at age 80 according to our data and to KTD. The first graph (upper left) of this figure shows a huge discrepancy for about 100 years (from 1873 to 1977). It corresponds to the time when many new countries enter our set, among which some give probably unreliable data for the elderly.

We can first think of small countries where numbers of deaths at very old ages are so small that random errors are quite big. Consequently, small countries (i.e. Iceland, Luxemburg, and Malta) have been dropped. The result, however, is hardly changed (second graph of Figure 13). Another series of countries were then suspected: those which, like in the case of Belarus already mentioned, are very likely suffering of underestimation of mortality at oldest ages. Consequently, Eastern European countries (countries of the former Soviet Union, Bulgaria, Romania, countries of the former Yugoslavia and Albania) and US black population were also dropped. This time, results have much more improved since they coincide almost perfectly with the KTD since World War 2 and still rather well since the beginning of the twentieth century. But a remarkable discordance persists from 1876 to the end of the nineteenth century, starting with an important gap in 1876, vanishing then rapidly thanks to a steady decrease till the early 1900s.

The year 1876 is the one when New Zealand[9] enters our set of data. Why not trying to drop that country? Results are quite impressive (fourth graph of Figure 13): results from our data set perfectly correspond to those from KTD as soon as the latter are available! It is not quite a surprise to have to take away New Zealand. By 1840 this country was populated by about 100,000 Maoris and hardly 2000 Europeans, but in 1896, Maoris were only 42,000 while the number of European had grown until 700,000[10]. The rapid growth of the "non-Maori" population here involved has obviously mostly relied on relatively enormous immigration flows, which imported new settlers strongly selected by the difficulties of gathering the means to emigrate from Europe and to face so long a trip. Health conditions of the initial population were exceptionally favoured by such a selection. Then while population rises to several hundred of thousands, it became more "normal" and life expectancy became more similar to other "best countries".

From there, interesting additional comments can be done to precise the conclusion of the previous section, but, furthermore, a major question must be asked about the linear adjustment of maximum life expectancies at birth.

---

[8] The KTD includes 35 countries, of which we here excluded Chile (not in our universe), Luxemburg (too small), and Lithuania, Poland and Slovenia (starting after 1970).

[9] N.B. Only life tables for non-Maori population have been included in our set of data.

[10] (Wikipedia, http://en.wikipedia.org/wiki, consulted March, 31, 2008).

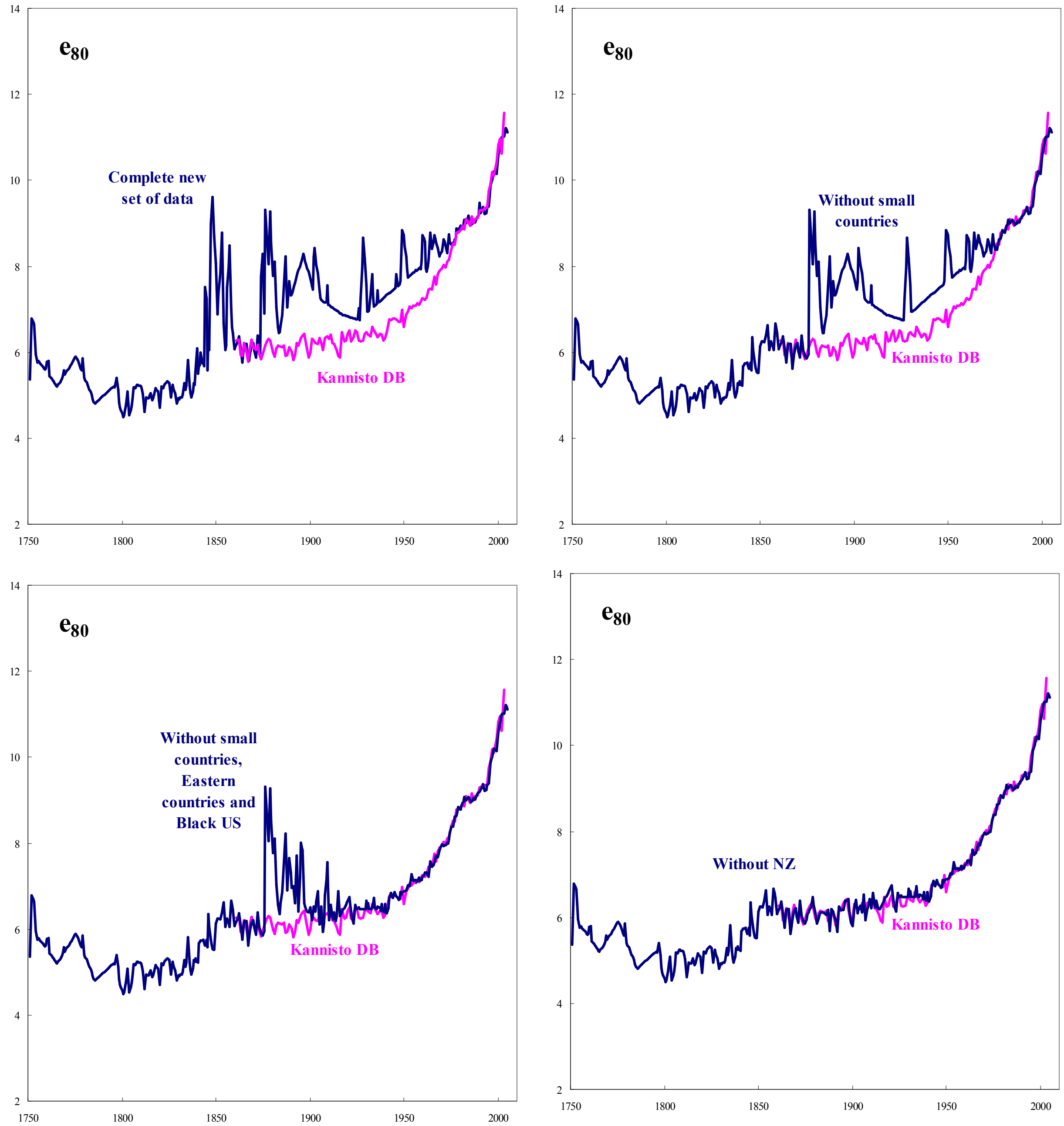


Figure 13. Trends in maximum life expectancies at age 80 according to our new set of data and to Kannisto-Thatcher database

B) The accelerated rise of elderly survival

Results from our full set of data must be interpreted differently for the years before the mid-nineteenth century and the years after. Very likely, the concave curve of the first 100 years of observation is largely artificial, due to new entering countries that underestimate old age mortality more than the pioneers, and then to general improvement of data among countries included in the database. On the contrary, especially when compared to KTB, trends shown by our reduced data set from the second part of the nineteenth century seems quite reliable. If it is the case, maximum life expectancy at 80 appears to have been stagnating until the 1940s and then increasing very rapidly, but in three different phases. First, from the early

1940s to the early 1980s increase strongly accelerated. Then, for ten years about, it has been slowing down, and finally from the mid 1990s, it is faster than ever. Firstly, it seems that, at these old ages, progress is much more recent than for any younger age. Secondly, this progress has probably been largely initiated by the diffusion of the last major tools of fight against infectious diseases (antibiotics) after WW2 jointly with significant improvement in living standard, and accelerated by both anti influenza immunization and the cardiovascular revolution since the late 1960s until the effects of these two major impacts became less productive at the end of the 1980s. Finally a new acceleration occurred when some very advanced countries adopt (from the mid 1990s) new positive health behaviour towards the elderly (Meslé and Vallin, 2006).

More generally, the first conclusion of this age-specific analysis is the one we could expect from the beginning. Trends in maximum life expectancy, as well as historical trends in individual country life expectancies, result from a combination of different trends in mortality at various ages. Basically, at the beginning, increase in life expectancy relies mostly on infant an child mortality reduction, which depends itself on the major weapons that have successively taken the lead in the fight against infectious diseases (agriculture and food, then hygiene and social progress and spread of education, and finally, vaccines, social security, and antibiotics). Then adult mortality decrease took the lead with successful policies in terms of man made diseases (alcohol, tobacco, accidents) and the arrival of new means against cardiovascular diseases (new technologies and changes in way of life). Finally, mortality at very old ages starts to decline faster and faster when the elderly itself benefits from all what already contributed to improve adult heath and even of new approaches towards gerontological specific health problems. We can then think that the perfect linearity that characterizes trends in maximum life expectancy is simply the result of a happy timing of the various technological and societal progresses that have increased the survival at different ages.

Actually, escaping from the disorder caused by the New Zealand case can allow seeing more on the topic.

C) The broken adjustment line

Since it has been mentioned above that New Zealand contributed to the maximum life expectancy at birth as soon as it enters our set and that its contribution lasted for a quite long period after, it is very important to check in what extent trends in maximum life expectancy at birth could be changed without New Zealand.

The first graph of Figure 14 compares both series. Remarkably, the impact of the New Zealand withdrawal is quite important, much more than expected after dealing with the case of old age mortality. The new series does not fit anymore with the previous linear adjustment and it would be hard to think of a satisfying linear adjustment of this new series all along the period 1840-2005. On the contrary, it gives sense to the striking bump already noticed (but neglected until now) around the years 1960s.

Quite obviously, the new series can be properly adjusted by two different straight lines instead of one for the years 1840-2005, with a change in the pace of increase in the late 1950s. Thus, the complete series 1750-2005 can be adjusted by four successive straight lines, characterized by different slopes (second graph of Figure 14).

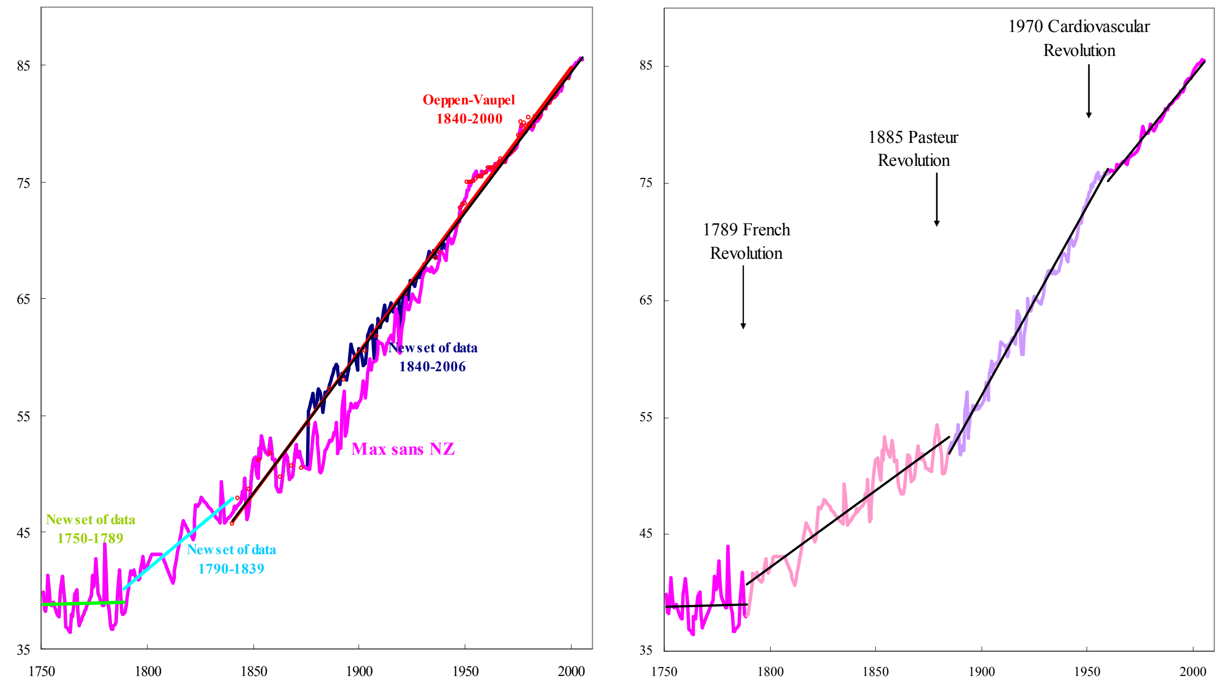


Figure 14. Maximum life expectancy at birth when New Zealand is taken away

It is certainly not by random that the former global straight line is now broken into four segments after three ruptures that occurred first at the time of the French Revolution, second at that of the Pasteur Revolution and finally when arrives the cardio-vascular revolution. French revolution is more an historical symbol than a precise cause of rupture in health trends, but it coincides with both a period of great agricultural and food production and circulation progresses and the time when Jenner invented the vaccination. Not only Pasteur discoveries but also, in the same time, spread of education and implementation of the first social insurance systems gave a dramatic acceleration to the first gains on infectious mortality. Finally the cardiovascular revolution of the early 1970s opened a new era of life expectancy increase after the break of the 1960s that ended the era of infectious diseases receding. The new step mentioned above about the elderly did not yet produce visible effect at the level of life expectancy at birth, however.

References

ANDREEV Evgueni, 1982. – Metod komponent v analize prodolzhitelnosti zhizni, *Vestnik Statistiki*, n° 3, p. 42-47.

KANNISTO Väinö, 1994. – *Development of oldest-old mortality, 1950-1990 : evidence from 28 developed countries.* – Odense (Danemark), Odense University Press, 108 p. (Odense Monographs on Population Aging n° 1).

KANNISTÖ Väinö, LAURITSEN Jens, THATCHER Roger and VAUPEL James, 1994. – Reductions in mortality at advanced ages : several decades of evidence from 27 countries , *Population and Development Review*, vol. 20, n° 4, p. 793-810.

MESLE France and VALLIN Jacques, 2003. – *Mortalité et causes de décès en Ukraine au XXe siècle.* – Paris, INED, XVI + 396 p. (Les cahiers de l'INED, cahier n° 152, with contibutions from Vladimir Shkolnikov, Serhii Pyrozhkov and Serguei Adamets).

MESLÉ France and VALLIN Jacques, 2006. – Diverging trends in female old-age mortality: the United States and the Netherlands versus France and Japan, *Population and Development Review*, vol. 32, n° 1, p. 123-145.

MESLÉ France, VALLIN Jacques, HERTRICH Véronique, ANDREEV Evgueni, and SHKOLNIKOV Vladimir, 2003. – Causes of death in Russia: assessing trends since the 50s, *in :* Irena E. Kotowska et Janina Józwiak (éd.), *Population of Central and Eastern Europe : challenges and opportunities,* p. 389-414. – Warsaw, Statistical

Publishing Establishment, 724 + CD-Rom p. (Published on the occasion of the European Population Conference 2003, Warsaw, Poland, 26-30 August, 2003).
OEPPEN Jim and VAUPEL James W., 2002. – Broken limits to life expectancy, *Science*, vol. 296, n° 10 May 2002, p. 1029-1031.
SHKOLNIKOV Vladimir M., VALKONEN Tapani, BEGUN, Alexander Z., ANDREEV Evgueni .M., 2001.– Measuring inter-group inequalities in length of life, *Genus*, vol. LVII, ,°3-4, p. 33-62.
SHKOLNIKOV Vladimir M., WILMOTH John R. and GLEI Dana A., 2005. – Introduction to the Special Collection "Human Mortality over Age, Time, Sex, and Place: The 1st HMD Symposium", *Demographic Research*, vol. 13, n° 10, p. 223-230.
VINCENT Paul, 1951. – La mortalité des vieillards, *Population*, vol. 6, n° 6, p. 181-204.