Measuring the relative progress of mortality improvement (RPM) to evaluate stagnation and sudden increase of life expectancy in the Netherlands 1970-2009

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Abstract:

Between 1970 and 2001 the Netherlands, formerly being a country with one of the highest life expectancy in the world, experienced a long period of stagnating or even increasing mortality levels followed by a sudden increase in life expectancy more recently. Using the two measures period life expectancy and cross-sectional average length of life (CAL) we compute a measure indicating the relative progress of mortality improvement (RPM), which we compare between the Dutch pattern with other countries and the record levels. Our analysis shows that the RPM is in particular a sensitive indicator of sudden period changes, and thereby seems to relate closely to public health policy. While smoking as a determinant of longevity operates more gradually over time, major reforms in health care seem to have a direct and large impact on period life expectancy. RPM thereby works as magnifier helping to identify effects and there relative size. We utilize this indicator for evaluating the trend in life expectancy in countries that experienced comparable patterns of stagnation and resumption, as Norway and Denmark. We conclude that health care policy has a direct and sustainable impact on longevity and need to be taken into account if variations in life expectancy are explored.

Introduction:

Being a former world leader in life expectancy the Netherlands showed stagnation in its improvement and even increasing mortality among the elderly females during the 1980s and 1990s (Nusselder & Mackenbach, 2000). Together with Denmark, Norway and the USA the Dutch experience has been a remarkable deviation form the universal and stable long-term decline of mortality rates in many of the western countries (Meslé & Vallin, 2006; Tuljapurkar, Li, & Boe, 2000). However, this situation changed dramatically with a trend reversal in 2001 characterized by a sharp increase in Dutch life expectancy (Mackenbach & Garssen, 2011). Against the background of a linear increase of record life expectancy in the world of about 3 month in every year during the last 160 years (Oeppen & Vaupel, 2002) the sudden increase of about 2 years between 2002 and 2007 (an average progress of 5 months a year) for both females and males in the Netherlands is even more surprising after the long lean period. It challenges in particular the theoretical reasoning that this country could be seen as a forerunner that approaches the upper limit of average life expectancy and all the other countries will sooner or later follow this trend (Janssen et al., 2003). In contrast to this interpretation the recent trend seems rather to confirm the hypothesis that aging is highly plastic which allows life expectancy in a population to respond quickly to better societal and health-related conditions (Vaupel, 2010). Although this would be an appealing and hopeful perspective for other countries that undergo a stagnation of life expectancy at the moment - the most prominent example is probably the USA - we have to back up such reasoning with empirical findings.

Therefore the goal of the present paper is to evaluate the progress in the Netherlands concerning life expectancy by taking into account alternative indicators and international comparisons. Our approach is motivated by a series of papers that critize the measure of period life expectancy, in particular its interpretation as hypothetical life expectancy of a newborn child if current conditions would remain stable for its whole life course (Bongaarts & Feeney, 2010). The three main factors influencing life expectancy in addition to period conditions described in the literature are cohort influences, heterogeneity and tempo effects (Guillot, 2011). Even though there is an ongoing debate about their importance and existance it has been argued that each of them could potentially lead to the incongruence between period life expectancy and period conditions and that demographers face serious problems to interpret the life table when mortality is changing (Vaupel, 2009). Although the debate in this field is dominated by theoretical arguments, its relevance for real populations is striking and calls for further empirical validation (Ní Bhrolcháin, 2011). For such an application the Netherlands are a prime example. Most fundamentally several remarkable trend changes of period life expectancy have been observed in the past century which potentially allow to test if they coincide with changing period conditions. Second, smoking patterns influence mortality in this country, hence cohort effects and population heterogeneity are present. Finally, an natural experiment-like situation is given by the budgeting of clinical health care in 1983 for several decades until the constraints were relaxed in 2001 (Casparie & Hoogendoorn, 1991; Mackenbach & Garssen, 2011). In this perspective the Netherlands represent the case group with the experimental treatment "fixation of budgets for hospitals" and the other developed countries without such policy measures serve as control group.

In this paper we will utilitze in particular the latter aspect since it has not been analyzed in detail in the discussion about the explanation of Dutch life expectancy. To analyse life expectancy during the period of regulation of health care budget we use complementary to the standard life table approach an alternative measure which characterizes the cross-sectional average length of life (CAL) of real living cohorts in contrast to the hypothetical population in the classic measure (Guillot, 2001). The specifications of both measures will be explained in the next section. In the subsequent results chapter, we focus on the difference between both measures and its interpretation as *relative progress of mortality* (RPM).

The findings of this study contribute to the so far mainly theoretical debate about problems of the period life expectancy measure e_0 to adequatly reflect current conditions and thereby representing one of the most important indicators of population health.

Data and Methods:

Data

To analyze life expectancy in the Netherlands in comparison to other developed countries we use high quality data based on the human mortality database[1]. This source contains 37 countries with a large number of period life tables mainly of the 20th and 21st century, but for several countries also much earlier data (e.g. for Sweden 1751-2010). We restriction our analysis up to 2009 since here only one country is available. In addition, Iceland is excluded due to its very small population size and exotic geographical characteristics. In addition to mortality data we use hospital admission rates and health care costs provided by Statistics Netherlands (CBS) via the portal Statline[2].

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1 Human Mortality Database. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at: www.mortality.org or www.humanmortality.de (data downloaded on 9/15/2011).

2 Available at: http://statline.cbs.nl/statweb/ (data downloaded on 9/15/2011)

Alternative indicators of life expectancy: e_0 and CAL

For measuring life expectancy two measures will be used in the analysis.

First, period life expectancy at birth e_0, which utilizes age-specific central death rates μ_x^p, where *x* denotes age and *p* period, to calculate a hypothetical cohort with its survivors l_x^p in the following manner.

$$l_x^p(t) = e^{-\int_0^x \mu_a^p(t,a)da} \tag{1}$$

Starting this cohort with a population radix of 1, period life expectancy at birth e_0^p is the sum of all age specific survivors up to the highest age ω, which is 100 in our analysis.

$$e_0^p(t) = \int_0^{\omega} l_x^p(t)dx$$

Note that conditional life expectancy could also be computed by replacing the starting age of 0 by an arbitrary value x resulting in e_x^p. We will use e_{30}^p and e_{65}^p in our analysis.

Second, the cross-sectional average length of life (CAL) is computed as follows (Guillot, 2001). Instead of using mortality rates from one period, now cohort survivors l_x^c are calculated based on their respective mortality rates μ_x^c.

$$l_x^c(t) = e^{-\int_0^x \mu_a(a,t-a)da} \tag{2}$$

CAL is the sum of cohort survivors up to a specific period (t).

$$CAL_o(t) = \int_0^{\omega} l_x^c(t)dx \tag{3}$$

Measuring the progress of relative mortality

Several crucial features of CAL have been described, for which the following are important for the present paper. Due to its reference to the original birth cohorts, CAL provides a true description of underlying conditions these cohorts were exposed to (Guillot ,2011). An increasing CAL directly indicates on average improving conditions for the cohorts present in a given period as compared to previous cohorts. However, in comparison to period life expectancy the average conditions CAL refers to are located much more in the past than in the present. If the cohorts improve their death rates at a constant rate *r* over time, CAL exactly represents the life expectancy of the cohort born CAL years earlier (Goldstein, 2008). But also under less strict conditions CAL, when calculated for older ages only, in many empirical cases corresponds roughly to the cohort that reaches its life expectancy at the moment (Guillot & Kim, 2011). In the special case of *r*=0, CAL and e_0 will be equal, while for *r*>0

CAL will always be lower than e0 and for r<0 CAL will be higher the e_0. Based on these relations, the difference of CAL and e_0 could be interpreted as relative mortality improvement in a population, defined as:

$$RPM(t) = e(t) - CAL(t) \quad (4)$$

Thereby, RPM gives the amount of years, which the average level of the period is ahead or lags behind the average level of the cohort.

In most of the countries CAL is lower than e_0 meaning that mortality is decreasing and the average survival of the cohorts lags behind the most recent life table calculations. Increases of this difference in a country indicate an acceleration of mortality improvement while a decreasing difference could be viewed as deceleration. Due to its property as a relative indicator, the value of RPM is independent of the level of period life expectancy and could be compared over totally different countries. At the same time, its value allows a qualitative interpretation. If RPM is 3 we would say that the most recent estimate of period life expectancy is 3 years higher than the most recent estimate of cohort life expectancy or the period is 3 years ahead of the cohort.

CAL and tempo effects

A much more controversial aspect of CAL is that it could be used to adjust period life expectancy for so called "tempo effects" (Bongaarts J., 2005). Here, given a shift of deaths to higher or lower ages without any change in the shape of the death distribution and focusing on adult mortality only (age x>30 years), the differences between CAL and e_0 is interpreted as distortion in such a way that period life expectancy e_0 provides a misleading representation of current mortality conditions and changes in the underlying mortality regime (Bongaarts & Feeney, 2010). This holds true when mortality change is driven by a short-term delay of cohort deaths instead of an elimination of diseases, where avoided deaths are postponed many years in the future (Le Bras, 2008). It has been shown that the life table calculation of e_0 implicitly contains the assumption that deaths saved in one period at a certain age gain the full remaining life expectancy at that age (Vaupel, 2008). However, if deaths were only saved for several weeks or months during a change in the mortality regime, the life table would exaggerate period mortality in this case either in a negative or positive direction (Luy & Wegner, 2009). A general problem such reasoning suffers is that in empirical applications it is not possible to identify solely from the mortality rates on a population level if individual deaths have been postponed only a short amount of time or much longer. Hence, it is not possible to statistically estimate the degree of distortion in period rates, neither could the theory of tempo effects predict falsifiable outcomes. It is important to clearly state that the whole discourse on tempo adjustment is based on a pure theoretical reasoning about different assumptions on death delays (Inaba, 2007).

Proponents of tempo effects would interpret our measure RPM as amount period life expectancy is distorted due to short-term delays of deaths. In their view CAL represents the true level of period conditions and should be used instead of period life expectancy. As long as no empirical evidence for that interpretation is provided, we prefer to use RPM as valuable complement to classical indicators of life expectancy instead of replacement.

Results

Figure 1 displays the trends in life expectancy for both measures in the Netherlands from 1970-2009. Note that we have calculated conditional rates at survival up to age 30, since we are interested in adult mortality dynamics only, which is in line with comparable analyses (Bongaarts & Feeney, 2002). While life expectancy according to e_{30} strongly increases from 2001 onwards after a period of stagnation (females) or slower improvement, the curves of CAL_{30} both have a positive slope throughout the whole period of observation. This illustrates that in a cohort perspective, there is neither stagnation nor a sudden change of living conditions but rather a continuous gradual improvement. Also visible in figure 1 are the different properties of both indicators. While period life expectancy is a rather erratic and volatile measure, CAL works as kind of moving average producing a smooth trend independent of short-term fluctuations.

To put the Dutch CAL and life expectancy into perspective, figure 2 and 3 compare its trend with all the other countries available in the HMD and the yearly world record levels respectively conditional on survival up to age 30 and 65. This analysis reveals two important points. While the record levels of both measures increase continuously at around the same rate over time, the Netherlands is lagging behind the general improvement rates starting in the 1980s. Thereby, the deviation is stronger for elderly females and by using the classical indicator period life expectancy. This may indicate that smoking as an explanation of the stagnation in Dutch life expectancy could be discarded, as this factor should work more strongly for middle-aged men and in a cohorts view, hence more visible in the CAL trend at age 30. In addition, the figures demonstrate that the sudden improvement in life expectancy in the Netherlands is rather a synchronization with the international trends than a catching up.

To analyze the relative progress of mortality improvement, its trend is displayed versus the values of the record level in figure 4 and 5. Here, we notice a close connection between the relative progress and the Dutch budgetary hospital constraints, that are additionally indicated in the graphs. Directly after the implementation of budget fixation the female RPM dropped from a very high level of 2 years up to almost 0 in 2001, while it suddenly accelerated after the relaxation and almost returned to the relative progress of the record level. Even though this is only a coincidence and not causal connection, the patter is remarkable. It seems that regulations of hospital care influence the progress of improvement remarkably.

To explain the observed particularities of the Dutch case, in figure 6 the health care costs as % of the GDP are displayed as well as admission rates per 10000 persons for the age groups "45-65" and "65+", both as inde. Figure 7 gives the admission rates separately for groups of diseases. The GDP trend in figure 6 shows that the money spent on hospital care increases before 1982 and after 2001 while it is almost constant in between. This gives some support to the hypothesis that part of life expectancy increase is "lost" or "gained" due to money. The admission rates show that after the fixation of costs mainly the younger age groups were affected as here the admissions declined about 50% up to 2001, while for the elderly the trend remained almost stable. However after the relaxation, the index for costs and admission of the two age groups shows an almost identical increase. Figure 7 confirms that the increase of admissions after 2001 is also indifferent for groups of diagnosis. Herein, a decline up to 2001 is followed by an increase of about 25% up to 2009. Although the particular mechanism is unknown, it seems that the expansion of the health care sector directly influences the progress in life expectancy in a country. To explore this hypothesis furthermore, we have added two other countries in our analysis that were also lagging behind the general improvement in life expectancy followed by a sudden improvement - Norway and Denmark.

The results of the comparison of RPM for age 30 and 65 for these two countries and the Netherland as well as the record levels and France as benchmark are shown in figure 8 and 9. Here, the vertical lines represent major health care reforms in the three countries. As especially visible in figure 9, there is a large increase in RPM immediately after the health care reforms. In Denmark and the Netherlands for females even a trend reversal occurred. Today, some years after the reforms took place the three countries are close to the record levels and France. The relative progress in record levels slowed down for females and sped up for male ranging between a level of 2 and 3 years.

Conclusions

To conclude the analysis of life expectancy at age 30 and 65, represented by two different measures and the difference between them (RPM), finally produced two main results.

I. The Netherlands shows about the same relative progress of mortality (RPM) as the respective world leader before and after the introduction of a fixation of budgets in the health care sector, while from 1982 until 2001 a poorer performance could be observed. Our results show that this pattern is quite independent from different age groups and sex, which leaves less room for explanations that rely on sex- and cohort specific differentials in behavior as for instances smoking patterns and/or heterogeneity among these groups.

II. The analyses indicate that in general mortality is able to respond quickly and with a high magnitude to health care budget reforms. A comparison of three countries that showed a stagnation of life expectancy in the past reveals that major health care reforms may explain their resumption to the record level progress in life expectancy.

Outlook

At the moment the results we have presented are only correlations and have no causal or explanatory property. However, there seem to be a strong connection between health care regulations and life expectancy that seem to have a high elasticity. The analysis of hospital admission rates suggests that the level of health care utilization plays on important role. Our explorative findings could be extended by analyzing RPM before and after adjusting the time series for smoking patterns that are the single largest influence on mortality. Recently, a series of methods to remove smoking related death from time series has been published.

In addition we need to take into account of health care regulation in all countries that are used to compare RPM with the Netherlands, also those that do not show any stagnation in life expectancy. If a relation at the aggregated level could be confirmed by such analysis, it appears necessary to use micro level longitudinal data for testing different hypotheses how health care reforms influence individual life spans.

In general RPM may help to identify problems in making progress against mortality in other countries and at the same time provides the goals which levels could be achieved if conditions change or were changed by policy makers.

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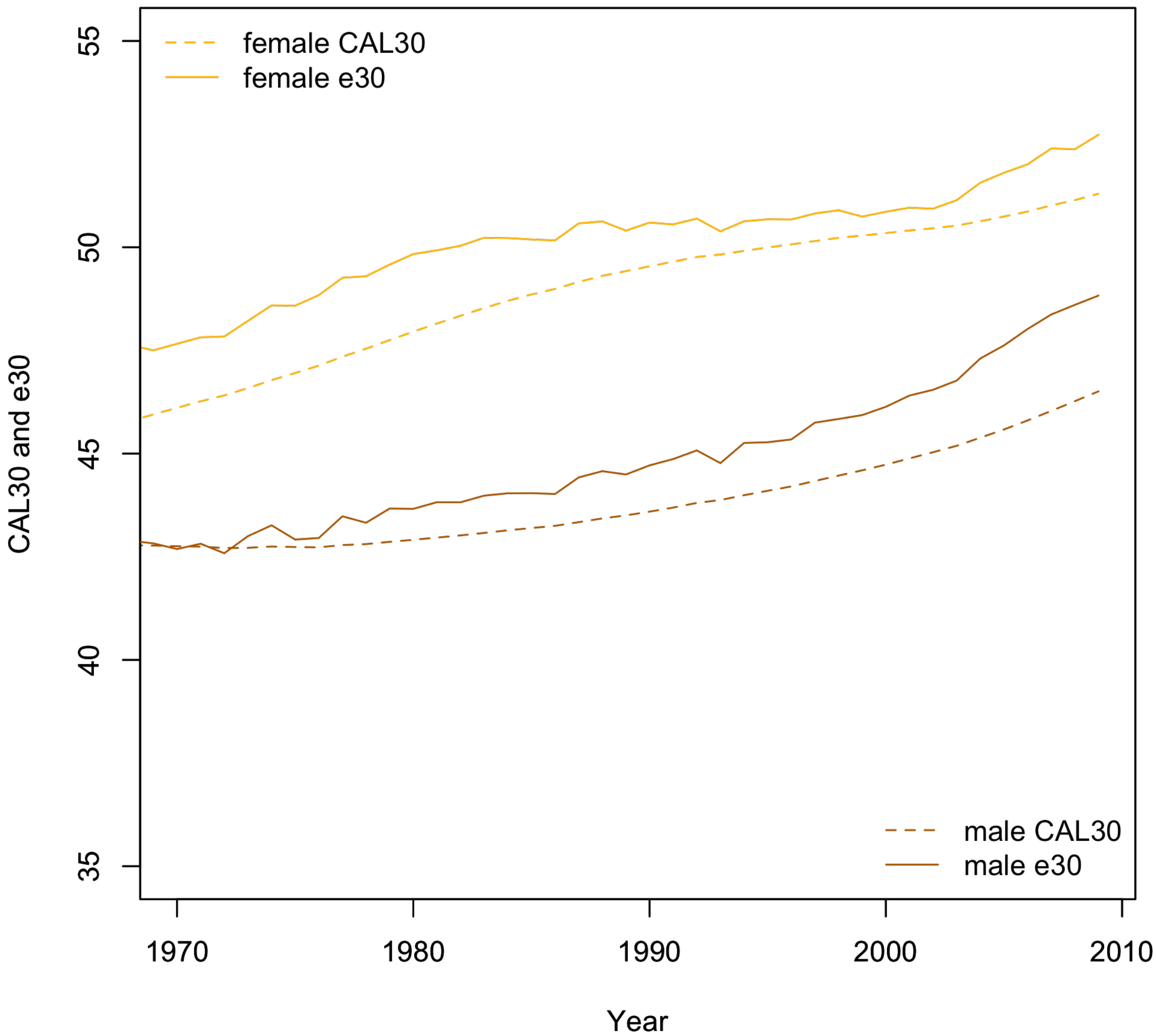
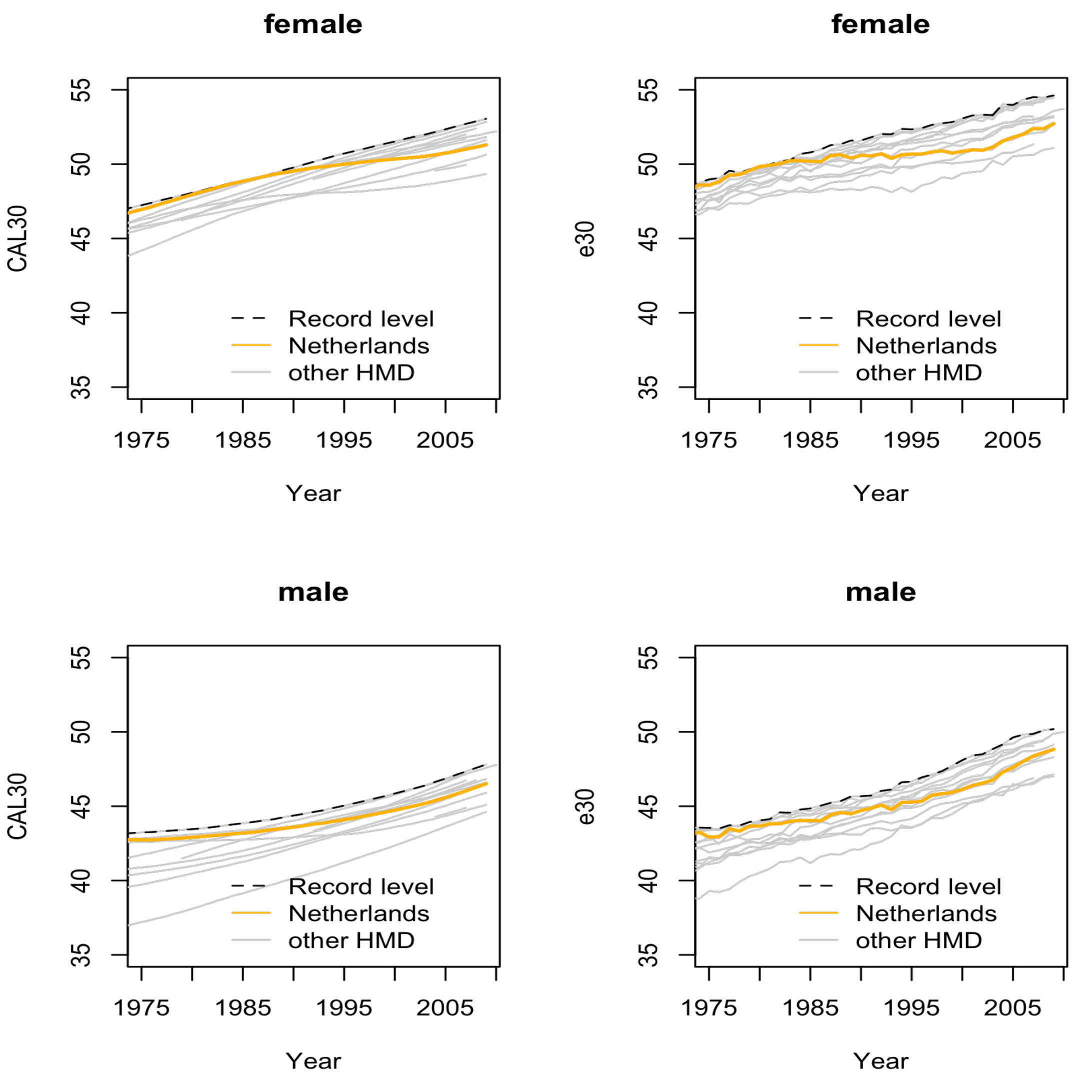
Tables and Figures

Figure 1: CAL_{30} and e_{30}, Netherlands 1970-2009



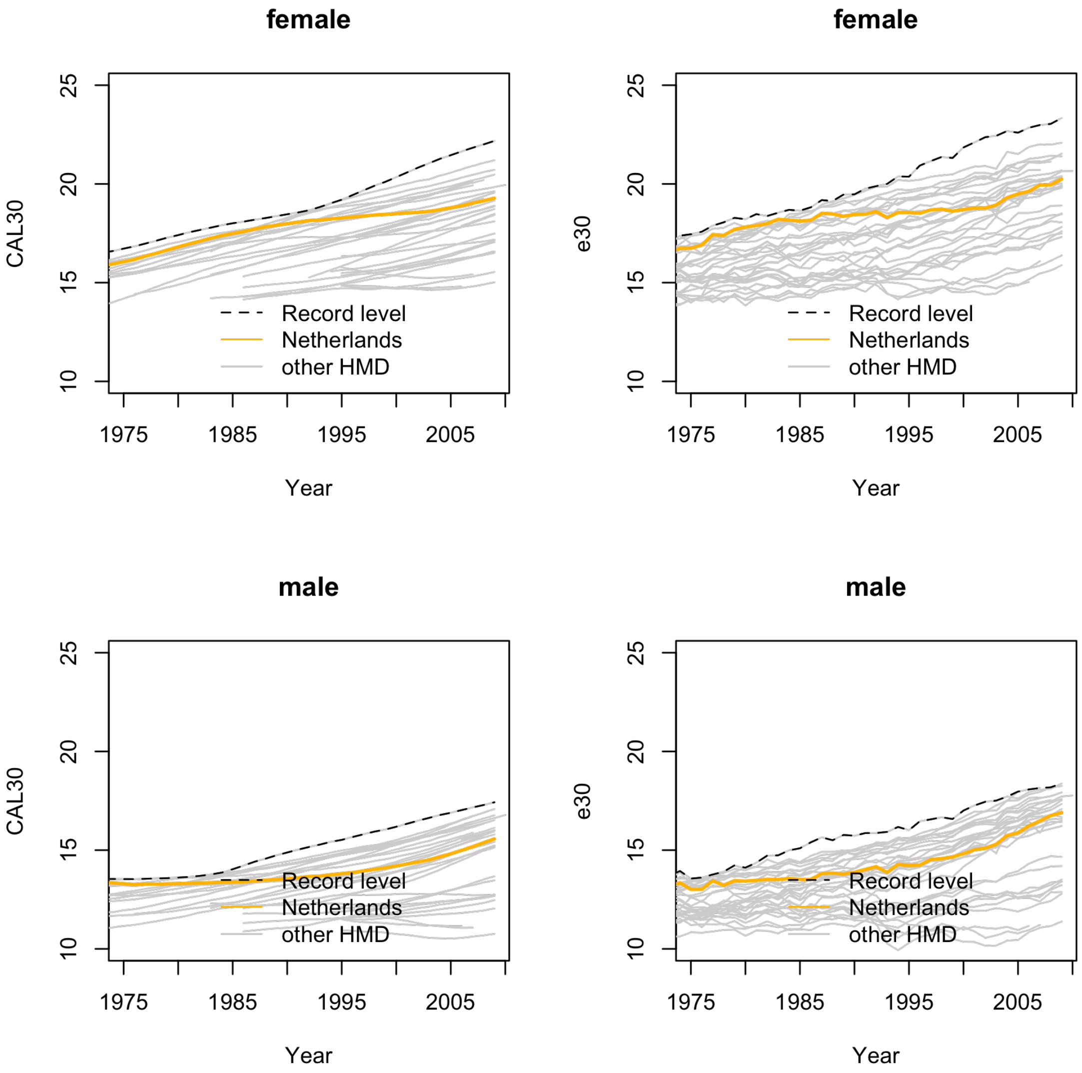
Source: Human Mortality Database

Figure 2: Comparison of record levels, the Netherlands and available other HMD countries for CAL_{30} and e_{30}, 1970-2010



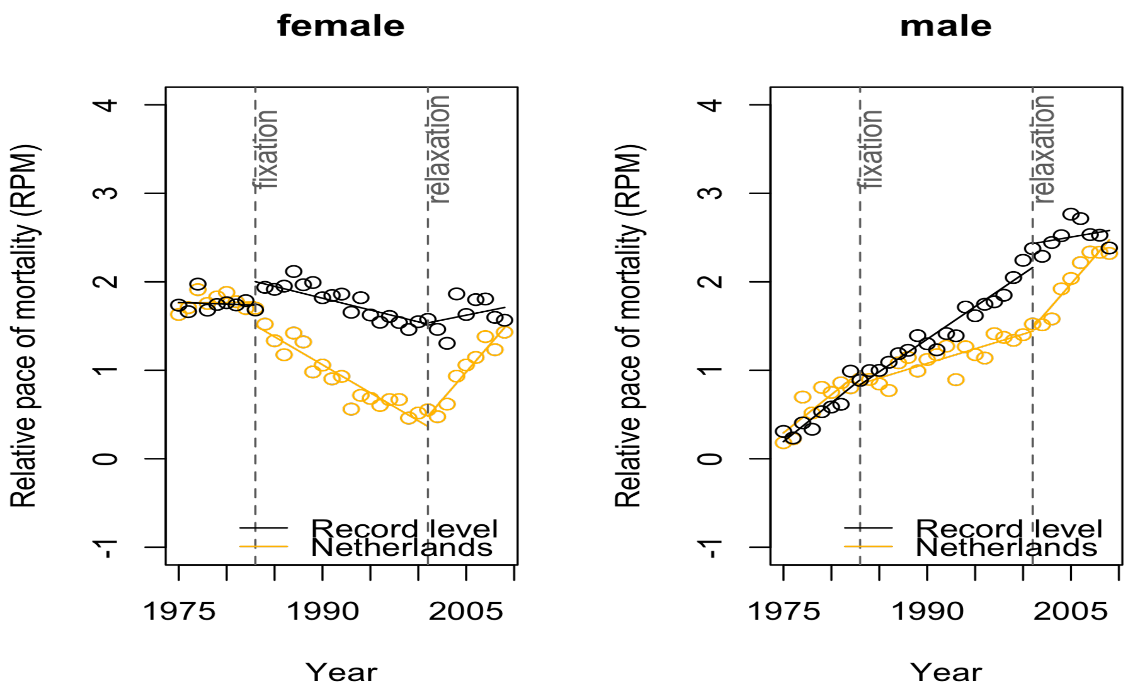
Source: Human Mortality Database

Figure 3: Comparison of record levels, the Netherlands and available other HMD countries for CAL_{65}, e_{65}, 1970-2010



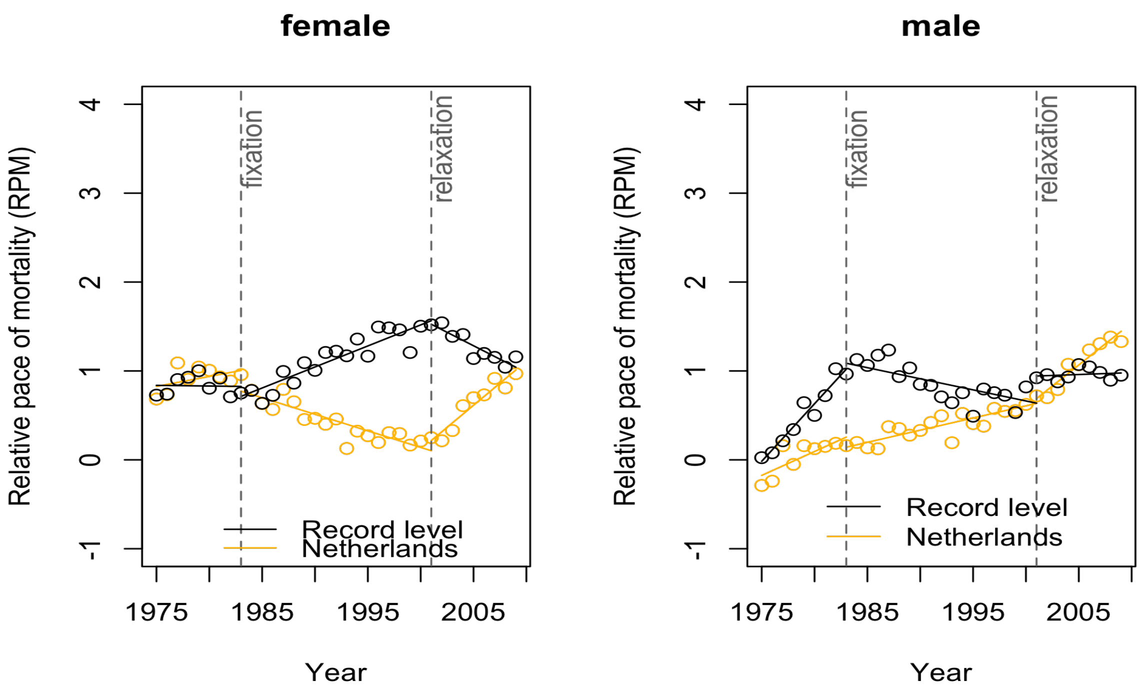
Source: Human Mortality Database

Figure 4: Relative progress of mortality (RPM) for the Netherlands and record levels as difference between e_{30}. and CAL_{30} 1970-2009



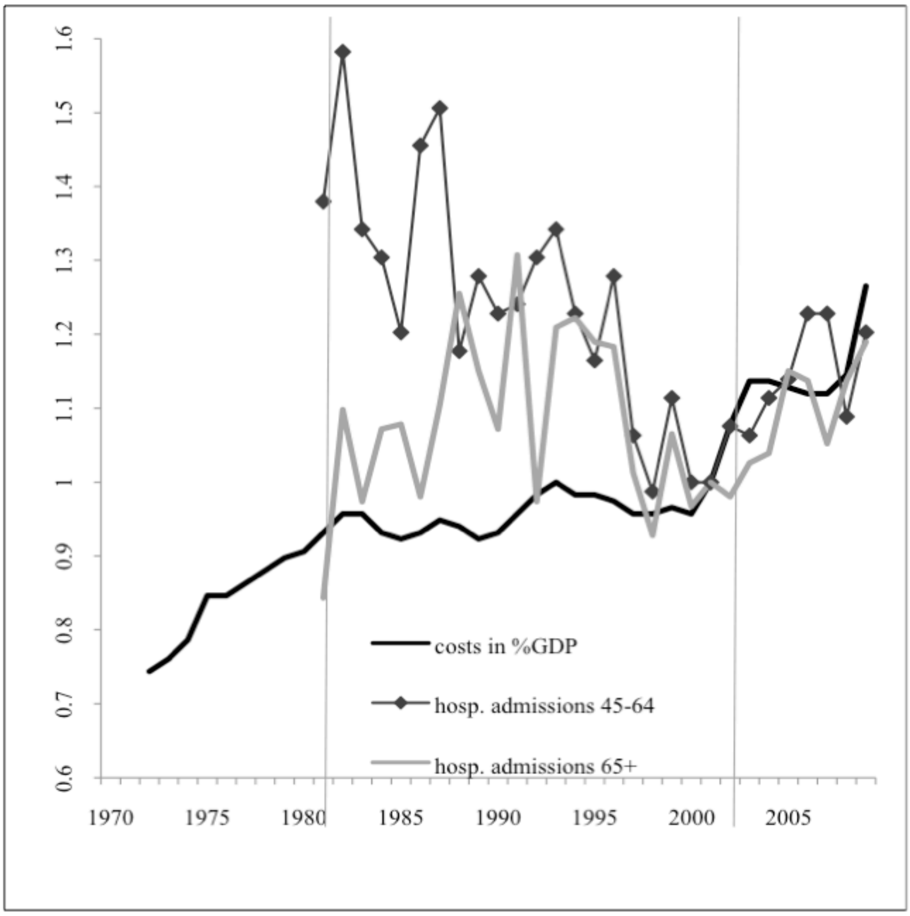
Source: Human Mortality Database

Figure 5: Relative progress of mortality (RPM) for the Netherlands and record levels as difference between e_{30}. and CAL_{30} 1970-2009



Source: Human Mortality Database

Figure 6: Index of Health care expenditures and age-specific hospital admission rates. 1970-2009, 2001=1



Source: Statistics Netherlands, Statline

Figure 7: Index of hospital admission rates for groups of diagnosis. 1970-2009, 1970=1

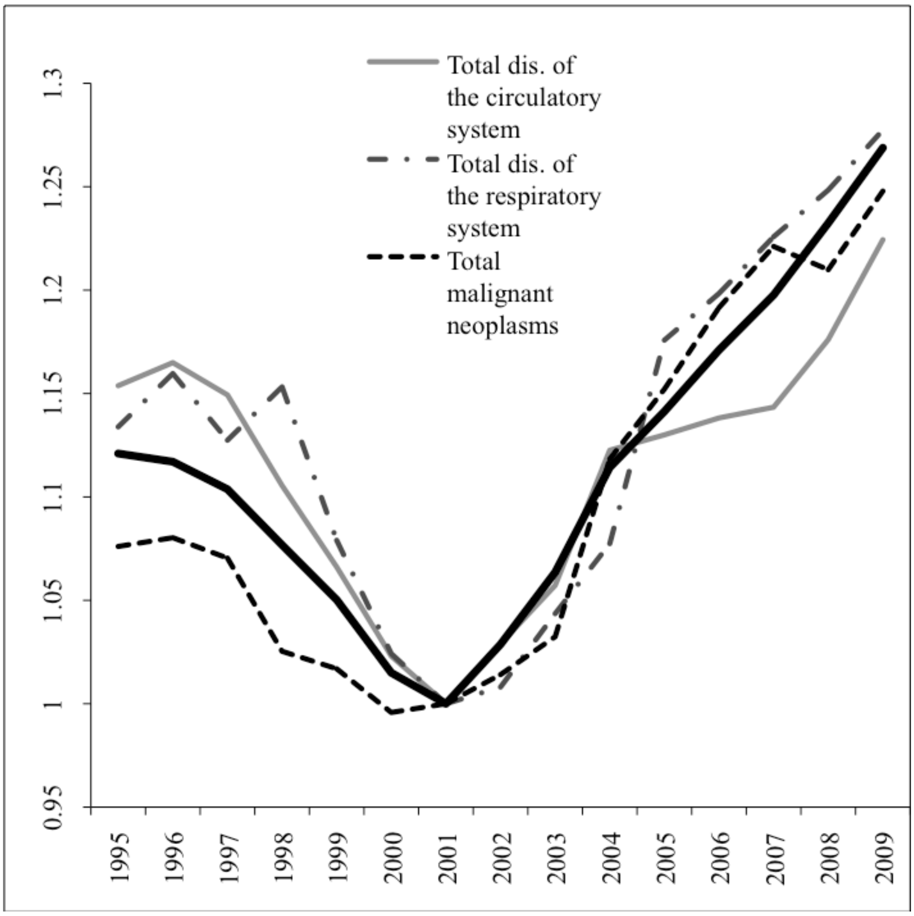


Figure 8: The relative progress in mortality decline at age 30+ for different European countries and record values and important policy reforms (vertical lines)

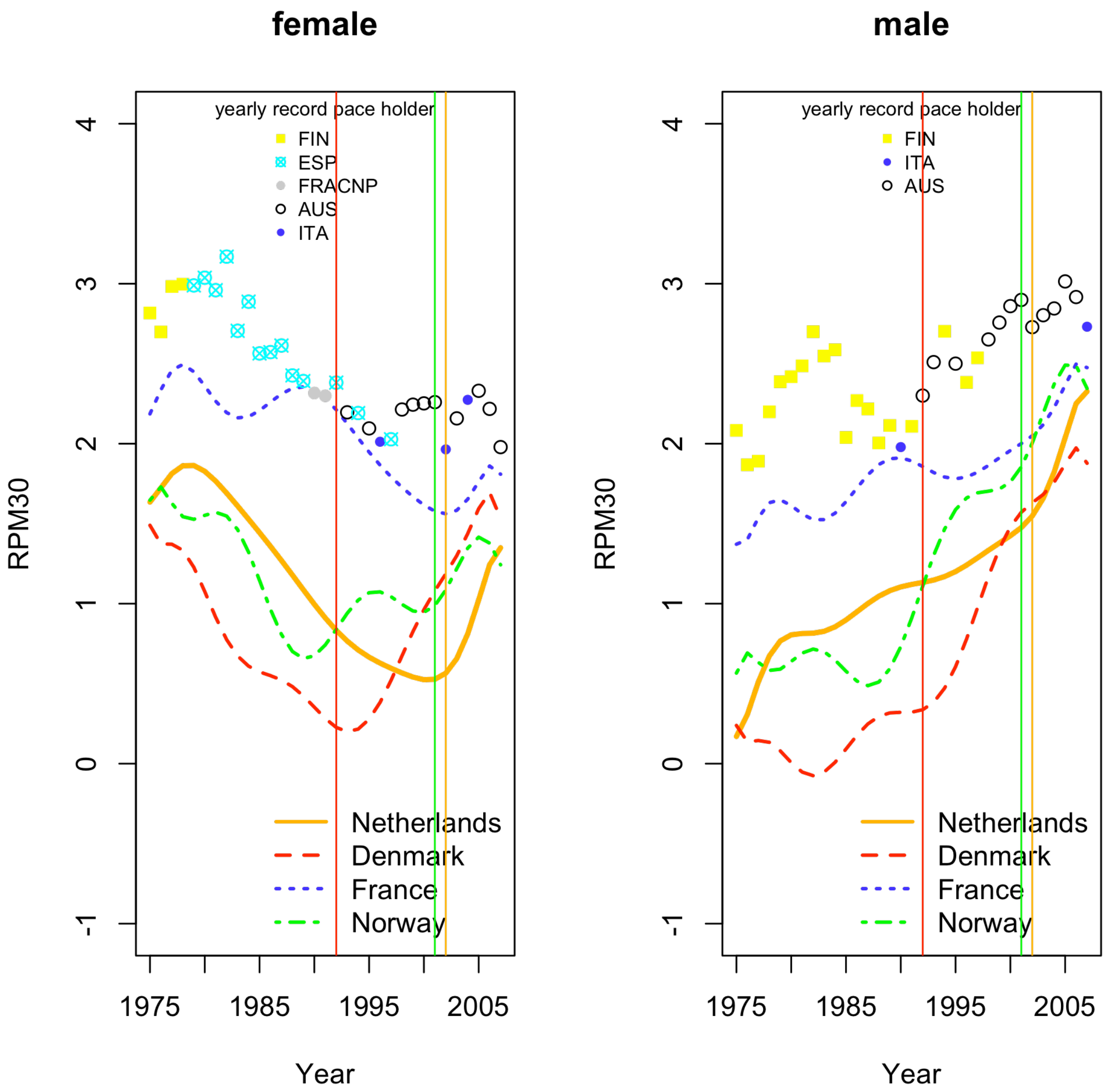


Figure 9: The relative progress in mortality decline at age 65+ for different European countries and record values and important policy reforms (vertical lines)