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Do Japanese and Italian Women Live Longer than Women in Scandinavia?

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Abstract Life expectancies at birth are routinely computed from period life tables. When mortality is falling, such period life expectancies will typically underestimate real life expectancies, that is, life expectancies for birth cohorts. Hence, it becomes problematic to compare period life expectancies between countries when they have different historical mortality developments. For instance, life expectancies for countries in which the longevity improved early (like Norway and Sweden) are difficult to compare with those in countries where it improved later (like Italy and Japan). To get a fair comparison between the countries, one should consider cohort data. Since cohort life expectancies can only be computed for cohorts that were born more than a hundred years ago, in this paper we suggest that for younger cohorts one may consider the expected number of years lost up to a given age. Contrary to the results based on period data, our cohort results then indicate that Italian women may expect to lose more years than women in Norway and Sweden, while there are no indications that Japanese women will lose fewer years than women in Scandinavia. The large differences seen for period data may just be an artefact due to the distortion that period life tables imply in times of changing mortality.

Keywords Cohort data · Expected number of years lost · Life expectancy · Life tables · Period data

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1 Introduction

Reliable mortality data starting in the early twentieth century exist for a number of countries in Western and Northern Europe. By the end of World War II, also data from other countries in the developed world become available. The Human Mortality Database (see list of references) is an important source of information. What emerges from these data is that life expectancy at birth, or briefly life expectancy, varied tremendously between countries and over time. In spite of the international differences, the general trend has been that mortality declined, resulting in improving life expectancies. During the early decades, controls for infectious diseases and new drugs were developed, resulting in large mortality reductions among infants and adults under age 50. Next, continuing medical developments brought child and young adult mortality to very low levels, and gains in survival at older ages were made at a steady pace. Within his framework of epidemiologic transition, Omran (1971) distinguishes three stages that all societies experience in the process of modernization. We will not deal with countries in the first stage of "pestilence and famine", when mortality is high and when it fluctuates strongly. The trends in developed countries during the early twentieth century described above are part of the second stage, during which pandemics recede and life expectancies rise from under 30 to over 50 years. The third stage occurs during the middle of the century in those countries, when degenerative and man-made diseases become more prominent and the pace of mortality decrease slackens. Life expectancies rise to 60 years or more. Omran did not foresee the cardiovascular revolution of the 1970s, which can be considered as a fourth stage of the epidemiologic transition (Frenk et al. 1991).

In this paper, we focus on the longevity for women in Italy, Japan, Norway and Sweden. We selected these four countries because they represent populations with different lifestyles and historical mortality developments; in two of the countries, the epidemiologic transitions to the second and the third stages happened early (Norway and Sweden), and in the other two, the transitions happened later (Italy and Japan). For instance, in the mid-1880s, female life expectancies at birth in Sweden and Norway were 45–50 years, and increasing by approximately 2 years per decade (Mamelund and Borgan 1996, p. 78; Meslé and Vallin 2011, p. 14; Vallin and Meslé 2004, p. 16). As noted by Vallin and Meslé (2004), Norway and Sweden had already entered the second phase, together with other countries in Northern and Western Europe. But Italy lagged behind by around 10–15 years. Mortality information for Japan is not available in the Human Mortality Database before 1947.

Figure 1 shows how life expectancy at birth for women in Italy, Japan, Norway and Sweden has increased from 1950 and until 2014. In 1950, women in Norway and Sweden had the longest life expectancy among the four countries with 73.3 years for Norway and 72.4 years for Sweden, while the expected life length was 67.4 years for Italian women and 60.9 years for Japanese women. In 2014, the situation was completely different. Now the life expectancy at birth for women in Japan and Italy was 86.9 and 85.2 years, respectively, clearly ahead of Norway (84.1 years) and Sweden (84.1 years). Based on these numbers, it seems as if

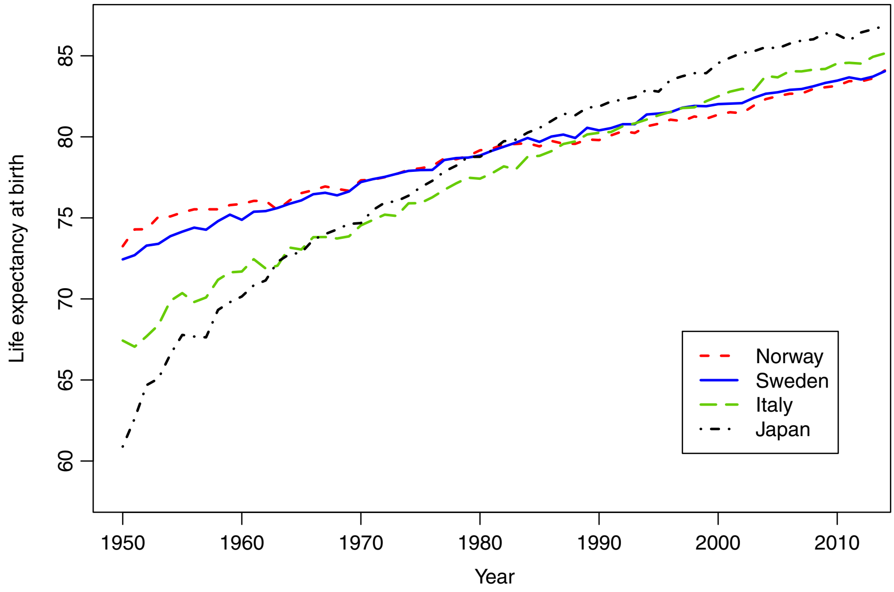

Fig. 1 Life expectancy at birth for females in Italy, Japan, Norway and Sweden for the periods from 1950 to 2014. *Source*: The Human Mortality Database

Japanese and Italian women may expect to live longer than women in Scandinavia, and this has, for example, been attributed to a healthy lifestyle and diet (e.g. Willett 1994).

But the situation is more complicated than it may seem at first look. The life expectancies shown in Fig. 1 are computed from period life tables, and they may be interpreted as the expected life length of a newborn girl if the age-specific period mortality rates would remain the same for many years into the future. But this is a hypothetical situation, and real women do not live in this way. They are members of a birth cohort in a given country and live their lives under the changing living conditions of that country.

Survival in real birth cohorts is different from survival in the hypothetical situation of unchanged period mortality rates, for various reasons. These will be discussed more extensively in Sect. 2, but here we name a few. First, in times of falling mortality, one ought to compare survival of a certain birth cohort with survival based on age-specific mortality rates for a particular year many decades later. This is what is generally known as a “tempo effect”. Second, there are cohort effects. Mortality decreased regularly for subsequent cohorts, but some cohorts display a typical pattern. An example is adult men born in the interwar period who adopted more healthy lifestyles during the 1980s, after their longevity had stagnated in the 1950s and 1960s. Third, there is selection. The frail members of a birth cohort tend to die earlier than those who are more robust. That leaves a selected population at the higher ages. When longevity improves, more of the frail cohort members will live longer. Thus, for a country where the living conditions improved earlier (like Norway and Sweden), the elderly population in our days will contain more frail persons than it does in countries where the living conditions improved later (like Japan and Italy).

To obtain a fair comparison of the longevity of women in different countries, we should therefore consider cohort data, not period data. But then we are faced with a new problem. In order to compute the cohort life expectancy, we need to know the complete mortality history of a cohort, and this is only possible for cohorts that were born more than 100 years ago. For younger cohorts, we are not able to compute the cohort life expectancies. In this paper, we suggest that one may instead consider the expected number of years lost for a cohort up to a given age (Andersen 2013). Then, by computing the expected number of years lost for a number of cohorts, one will obtain a picture of the longevity in a country that is only based on the available data for the cohorts. Moreover, as we demonstrate in Sect. 4, our approach reveals that the period life expectancy may be misleading when comparing the longevity in two countries where the epidemiologic transitions happened at different times.

The outline of the paper is as follows. Section 2 contains a discussion of possible explanations why period data and cohort data may lead to different conclusions, taking mortality in developed countries after World War II as the reference. In Sect. 3, we describe the data we use in our investigation and give a formula for the expected number of years lost before age a for the cohort born in year c. In Sect. 4, we then compute the expected number of years lost for different cohorts c and ages a and show how this makes it possible to obtain a fair comparison, also for younger cohorts, of the longevity of women in Japan, Italy, Norway and Sweden. In the final Sect. 5, we conclude and discuss our findings.

2 A Discussion of Possible Explanations

There are several factors that make it difficult to interpret life expectancy differences based on period data. First, there is the obvious reason that mortality changes over time. Survival of a cohort born in a certain year takes place during a period of about 100 years. In times of falling mortality, cohort survival will typically be better than survival based on mortality data from the year when the cohort was born. Conventionally calculated period life expectancy at birth gives a distorted view of real life expectancy whenever mortality is changing. In the literature, this is called a “tempo effect” (Bongaarts and Feeney 2002; Guillot 2006). More precisely, a tempo effect in mortality is caused by an increase in the life expectancy for a certain birth cohort (or the mean age at death of its members, which is the same) as a consequence of falling mortality. Then, the following question arises: given a certain birth cohort, can we find a calendar year for which the period life expectancy is comparable with the cohort’s mean age at death? Or, to put it differently, when we have the period life expectancy for a certain year, does it reflect the life expectancy of some real cohort? A related question is: can we find an adjustment to the classical period life expectancy, which takes into account the changes in age-specific mortality in the past and which reflects the life expectancy in the situation that the age-specific mortality remains the same in future? Luy et al. (2011) present tempo-adjusted period life expectancy for 34 European countries that apply to the years 2001–2005. The authors focus on e(15), that is, the remaining life expectancy at age 15. They find that adjusted values of e(15) for women are typically 1–2 years lower than unadjusted ones. In other words, the fact that mortality fell during several decades before 2001 leads to a relatively high value for e(15) compared to a situation with unchanged mortality. This pattern applies to countries that witnessed a decrease in mortality. As expected, unadjusted life expectancies are lower than adjusted ones for countries such as Russia and Ukraine, where mortality increased during the last decades, and thus tempo distortions caused an opposite effect. Interestingly, the authors find that tempo adjustment is stronger for Italian than for Norwegian women: the unadjusted e(15) for Italian women is 2.22 years higher than the adjusted value (68.66 vs. 66.44 years). For Norwegian women, the difference is 1.30 years (67.35 vs. 66.05 years). After World War II, mortality fell more in Italy than it did in Norway. Therefore, Italian mortality is more distorted than mortality in Norway.

The technicalities of computing tempo-adjusted indicators are not undisputed; see the discussions by Guillot (2006) and Barbi et al. (2008). But demographers and epidemiologists agree that a period measure, such as the period life expectancy, gives a distorted picture in times of changing mortality.

Second, there are cohort effects. Several studies have documented the existence of early-life effects on later mortality and health outcomes at the individual level (e.g. Forsdahl 1977; Barker 1994; Davey Smith and Kuh 2001). Some of these studies investigate prenatal factors, for instance, a possible association between foetal growth and later life health outcomes such as blood pressure and cardiovascular mortality (Christensen 2007). Early-life effects were first proposed in 1934 by Kermack, McKendrick and McKinlay, who studied age-specific mortality in England, Wales, Scotland and Sweden (see Murphy 2010 for a summary and a critical discussion). They concluded that reductions in age-specific mortality depended primarily on the date of birth of the individuals and only secondarily on the actual year of death. In more recent times, cohort effects associated with patterns of smoking have been established (Doll et al. 1994, 2004). These cohort effects are thought to reflect living conditions and socio-economic conditions earlier in life that affect health in later life. They represent mechanisms that are different from those represented by period effects, for instance, the results of living conditions (e.g. living standards and diet, public health institutions and medicine, or other areas relevant for the physical well-being of the population) that improve from one period to the next.

When analysing age-specific mortality, cohort effects are difficult to separate from period effects. This is caused by the perfect relationship between the three variables cohort, period and age. Once two of these variables are known, the third one follows from the obvious fact that year of observation equals year of birth plus age. Hence, statistical models do not allow estimating independent contributions of cohort, period and age to mortality, unless one imposes special conditions. Another solution is to perform counterfactual simulations. For instance, Lindahl-Jacobsen et al. (2016) studied the temporary stagnation of Danish women's life expectancy in the period 1970–1986. The life expectancy of Swedish women increased steadily during those years. When the authors assumed that Danish women born in

1915–1945 would have survival probabilities equal to those of Swedish women born in 1915–1945, the stagnation disappeared. The temporary stagnation is driven by the high mortality of the interwar generations of Danish women. Smoking was more prevalent in these generations than in cohorts born before and after the two wars. As a result, period life expectancies rose quickly from the mid-1990s, because the survivors from the interwar generations were a selected group with relatively low death rates, compared to later generations at that age (see also below on selection).

A final problem associated with cohort effects is that linkages and pathways that connect prenatal and childhood conditions to adult mortality risks are manifold and complex. Therefore, there is no consensus regarding how and which early-life conditions imply strong or weak contributions to health and longevity differentials in the population (Smith and Hanson 2015).

Third, there is selection. Not all the members of a cohort are equally robust, and the frail ones tend to die first. That leaves a selected population of more robust persons at the higher ages (Vaupel et al. 1979). Moreover, when the living conditions in a country improve, the selection pressure becomes smaller and more of the frail cohort members will live longer. Thus, for a country where the living conditions improved earlier (as was the case in Norway and Sweden), one will expect the elderly population in our days to contain more frail persons than it does in countries where the living conditions improved later (as they did in Japan and Italy). Reasons for the differences in health and mortality risks are manifold, ranging from socio-economic status and the nature of social relationships to psychosocial factors, neighbourhood contexts and biological linkages (clinical factors—blood pressure, cholesterol levels or blood glucose levels, markers of inflammation and immune function, and neuroendocrine mechanisms). See Goldman (2015) for a review. In general, persons of higher socio-economic status (higher income, education, occupational class) and persons who are more socially integrated (e.g. those who are married) experience lower death rates than their respective counterparts. Two broad sets of possible mechanisms have been proposed to explain these patterns. First, causal mechanisms imply that socio-economic status and social relationships potentially affect health status and the risk of dying. Second, selection or reverse causation pertains to a set of pathways whereby unhealthy individuals may reduce their socio-economic status or become less socially connected as a consequence of their inferior health status.

The three broad sets of factors make it difficult to compare period life expectancies for different countries when their populations have had very different histories regarding social developments. For this reason, in this paper we suggest that a comparison of countries may be based on the expected number of years lost for different cohorts c and ages a. In the following sections, we describe how this may be done.

3 Data and Methods

We downloaded the period life tables with 1-year age and calendar time intervals for Italy, Japan, Norway and Sweden from the Human Mortality Database. From these life tables, we extracted the 1-year probabilities of death $q_{x,t}$, for all ages x and the periods $t = 1950, 1951, \ldots, 2014$, for each of the four countries. We restricted ourselves to women. One reason for this is that we wished to avoid possible reverse health selection effects caused by World War II, which may have affected men in Norway and Sweden differently than men in Japan or Italy (e.g. Dinkel 1984).

A woman born in year c will be x years old in calendar year $t = c + x$. From the one-year probabilities of death $q_{x,t}$ from the period life tables, we may therefore obtain the 1-year probabilities of death for the cohort born in year c by $q_x^{(c)} = q_{x,c+x}$. These 1-year probabilities of death may then be combined in the usual way to obtain the expression

$$l_x^{(c)} = \prod_{i=0}^{x-1}\left(1 - q_i^{(c)}\right), \quad x = 1, 2, \ldots$$

for the probability that a woman who is born in year c will survive at least to age x. We compute the expected number of years alive up to age a as the area under the curve of the survivorship function $l_x^{(c)}$ (with $l_0^{(c)} = 1$) between ages 0 and a. We denote this expected value as $e_{0|a}^{(c)}$. It is the partial life expectancy between ages 0 and a [sometimes called "temporary life expectancy" or "truncated life expectancy"; see Arriaga (1984), Guillot and Canudas-Romo (2016)]. Each age interval $[x, x+1]$ (for $x \le a - 1$) contributes an amount $L_x^{(c)}$ to $e_{0|a}^{(c)}$. We approximate $L_x^{(c)}$ (the number of years lived between ages x and $x + 1$) by $(l_x^{(c)} + l_{x+1}^{(c)})/2$, $x = 1, 2, \ldots, a - 1$. For $x = 0$, we assume the usual approximation 0.3 $l_x^{(c)}$ + 0.7 $l_{x+1}^{(c)}$ (e.g. Rowland 2003, p. 280). Then, for the partial life expectancy, we obtain

$$e_{0|a}^{(c)} = \sum_{i=0}^{a-1} L_i^{(c)} = 0.3 + 1.2 \cdot l_1^{(c)} + \sum_{i=2}^{a-1} l_i^{(c)} + 0.5 \cdot l_a^{(c)}.$$

It follows that the expected number of years lost before age a for the cohort born in year c is given as $a - e_{0|a}^{(c)}$.

In our comparison between countries (cf. the next section), we focus on the expected number of years lost before age a for the cohorts born in year c for various values of a and c. Alternatively, we could have compared the partial life expectancies $e_{0|a}^{(c)}$. Guillot and Canudas-Romo (2016) took this approach when they constructed their "truncated cohort life expectancy". The interpretation of the latter as a function of age a is rather complicated (Guillot and Canudas-Romo 2016, pp. 54, 55), compared to our results. However, the two approaches are complementary, and the qualitative conclusions are the same.

4 Results

Figure 2 shows the expected number of years lost before age a as a function of a for the cohorts born in 1950, 1960, 1970 and 1980. For the cohorts born in 1950, we may compute the expected number of years lost before age a for ages up to $a = 64$ years. We see (Fig. 2a) that for the 1950 cohort, the expected number of years lost is highest for Japanese women, but Italian women could expect to lose almost the same number of years. Sweden has the lowest expected number of years lost, but the number of lost years for Norwegian women is not much higher. At age 64, the expected number of years lost for Swedish and Norwegian women is 2.56 and 2.86 years, respectively, while women in Japan and Italy could expect to lose more than twice as many years before age 64 (Japan: 6.28 years; Italy: 5.92 years). For the cohorts born in 1960 and 1970, we may compute the expected number of years lost before age a for ages up to $a = 54$ and $a = 44$ years, respectively. We

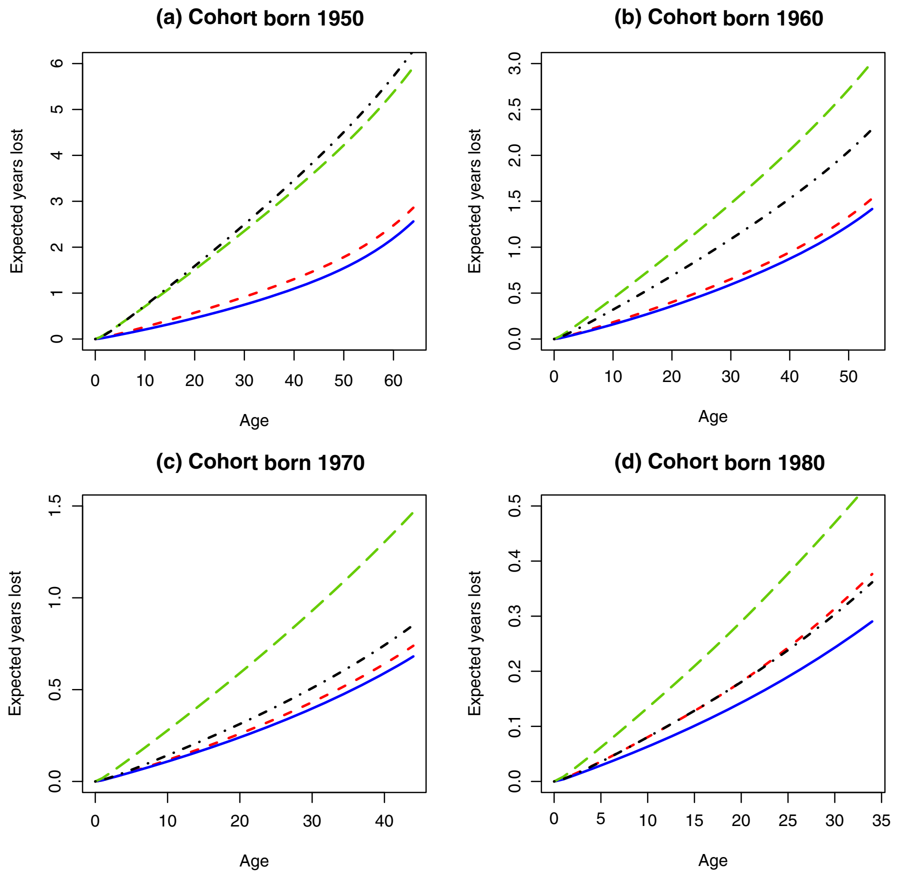

Fig. 2 Expected number of years lost before age a as a function of a for cohorts of women born in 1950, 1960, 1970 and 1980. Norway: dashed red lines, Sweden: drawn blue lines, Italy: long-dashed green lines and Japan: dash-dotted black lines. Note that the scales are not the same for panels **a**–**d**. (Color figure online)

see (Fig. 2b, c) that Sweden still has the lowest expected number of years lost, but the number of years lost for Norwegian women is only slightly higher. Also for the cohorts born in 1960 and 1970, Italian women could expect to lose more than twice as many years than the women from Sweden and Norway. But the situation for Japanese women is improved. For the cohort born in 1960, they are midway between the Scandinavian and Italian women, and for the 1970 cohort, the expected number of years lost for Japanese women is not much higher than for women from Sweden and Norway. Finally, we consider the cohorts born in 1980. We see (Fig. 2d) that also for these cohorts, Swedish women have the lowest expected number of years lost, while women in Italy may expect to lose about twice as many years. The number of years lost for Japanese and Norwegian women is almost indistinguishable and about 25% higher than for Swedish women.

Figure 3 supplements the results of Fig. 2. While Fig. 2 shows how the expected number of years lost before age *a* depends on *a* for four specified cohorts, Fig. 3

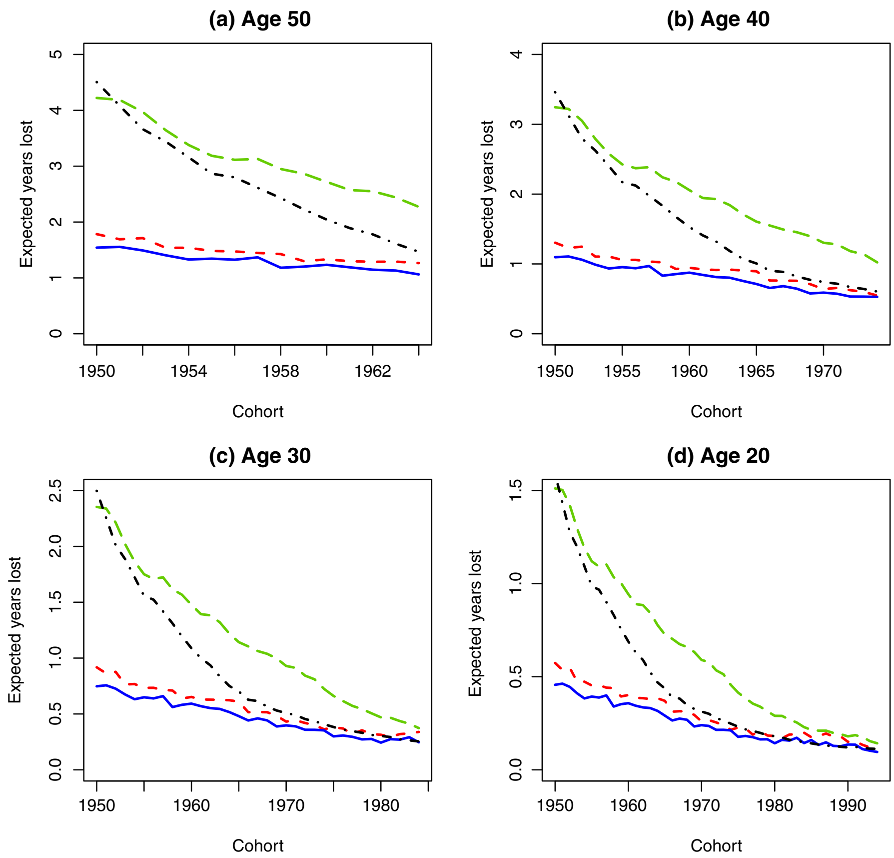

Fig. 3 Expected number of years lost before age 50, 40, 30 and 20 years as a function of birth cohort. Norway: dashed red lines, Sweden: drawn blue lines, Italy: long-dashed green lines and Japan: dash-dotted black lines. Note that the scales are not the same for panels **a**–**d**. (Color figure online)

illustrates how the expected number of years lost before ages 50, 40, 30 and 20 years depends on the birth cohort. The figure shows that the expected number of years lost is reduced for the younger cohorts and that the reduction is larger for women in Japan and Italy than for Scandinavian women (who already in 1950 could expect to lose quite few years). Further, for all the four ages considered and all cohorts (except the oldest ones), Italian women could expect to lose more years than women in Japan and Scandinavia. For the oldest cohorts, the expected number of years lost for Japanese women is close to the number of years lost for women in Italy. But the number of years lost is reduced more quickly for Japanese women than for Italian women, and for the cohorts born in 1980 and later there are only minor differences between women in Japan and Scandinavia.

Our findings agree very well with those in Guillot and Canudas-Romo (2016) based on the partial life expectancy $e_{0|a}$ for cohorts and periods. They find that Italy is ranked third on a list with partial *period* life expectancies for 17 countries, but only as number 16 on a list with partial *cohort* life expectancies. Sweden moves up from number 7 (period) to number 4 or 5 (cohort), while Norway improves its ranking from 10th to 2nd place. Japan is not included in the study by Guillot and Canudas-Romo (2016).

5 Conclusions and Discussion

If we consider life expectancy at birth based on period life tables (Fig. 1), we get the impression that Italian women may expect to live longer than women in Scandinavia. However, for all cohorts, the expected number of years lost for Italian women is higher than that for Swedish and Norwegian women (Figs. 2 and 3). This shows that the period life expectancies give a distorted view when they falsely give the impression that women in Italy may expect to live longer than Scandinavian women.

Japanese women have the longest life expectancy at birth in the world when computed from period data. Based on data from 2014, their expected life length was almost 3 years longer than that of Swedish and Norwegian women. But when we consider cohort data, we find that Japanese women born before 1980 may expect to lose more years than women in Scandinavia and that there are only minor differences after 1980. Thus, the cohort results provide no indication that Japanese women may expect to live longer than women in Scandinavia, so the large differences seen for period data seem to be an artefact due to the distortion that period life tables imply in times of changing mortality.

We have also computed the expected number of years lost based on period data for 2014, and the result is shown in Fig. 4. We notice that for period data, starting from about age 50 to 60, the loss is smaller for Italian and Japanese women than for women in Scandinavia, thus confirming the distorted picture created by the period mortality.

Cohorts live their lives during a period of about 100 years. In countries such as the ones for which results were presented here, death rates are very low until ages around 60, and mortality starts to become important beyond that age. This means

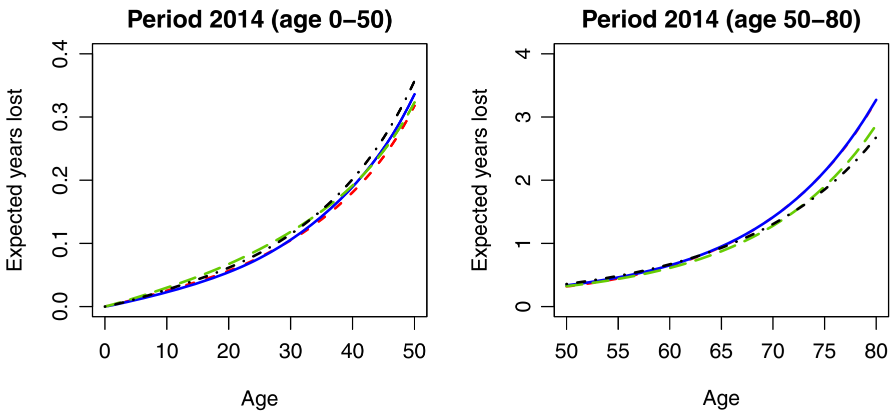

Fig. 4 Expected number of years lost before age a as a function of a for the period 2014. The left-hand panel is for ages 0–50 years, and right-hand panel is for ages 50–80 years. Norway: dashed red lines, Sweden: drawn blue lines, Italy: long-dashed green lines and Japan: dash-dotted black lines. Note that the scales are not the same for panels **a**, **b**. (Color figure online)

that it could also be of interest to present findings for expected numbers of years lost up to ages 80 or 90. That requires data for cohorts born in the 1920s and 1930s. For Italian, Norwegian and Swedish women, such data are available. Not surprisingly, these data show that for the cohorts born between the two world wars, Italian women could expect to lose many more years than Scandinavian women (Fig. 5). For Japanese women, no data are available in the Human Mortality Database for the period between the two world wars. However, a visual inspection of Figs. 2 and 3 clearly suggests that our conclusions regarding birth cohorts from 1950 onwards and regarding ages up to 64 also hold for older cohorts and higher ages.

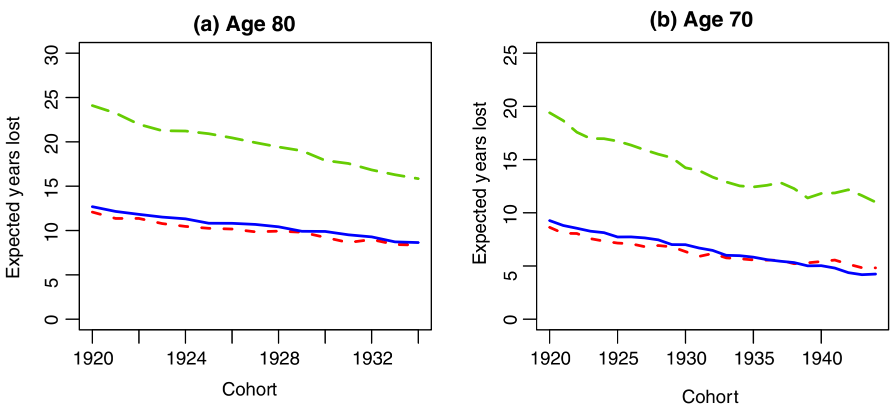

Fig. 5 Expected number of years lost before age 80 and 70 years as a function of birth cohort. Norway: dashed red lines, Sweden: drawn blue lines and Italy: long-dashed green lines. Note that the scales are not the same for panels **a**, **b**. (Color figure online)

In this paper, we have focused on women in Italy, Japan, Norway and Sweden. The four countries may be classified into two vaguely defined groups: (1) countries where the epidemiologic transitions took place relatively early (Norway and Sweden) and (2) countries where the epidemiologic transitions occurred later (Italy and Japan). The results for Norway, Sweden, Italy and Japan are typical for what one may find when comparing one country from each of the two groups, and in the supplementary material, we provide examples of other countries that show a similar pattern. The pattern is as follows: if we consider life expectancies at birth based on period life tables, the country in group (1) will have the longest life expectancy back in time. But the life expectancy for the country in group (2) will increase more rapidly and may eventually become longer than the expected life length for the country in group (1). However, if we consider the expected number of years lost for different cohorts c and ages a, it may be the case that people from the country in group (2) may expect to lose more years than people from the country in group (1) for all cohorts c and ages a. In such a situation, the period life expectancies give a distorted view when they give the impression that people in the country in group (2) may expect to live longer than people in the country in group (1). This highlights that differences in life expectancies based on period life tables may be artificial and not reflect real differences for the cohorts.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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