Which cohort is currently reaching its life expectancy? Estimating and interpreting Lagged Cohort Life Expectancy (LCLE)

Michel Guillot
University of Pennsylvania

Collin F. Payne
University of Pennsylvania

Paper prepared for the 2013 PAA meetings in New Orleans, Session 122 "Mathematical and Computational Models and Methods"

Abstract

The life expectancy for the cohort currently reaching its life expectancy, or Lagged Cohort Life Expectancy (LCLE), is a useful mortality measure that provides information about levels of longevity currently being reached by actual cohorts of individuals. However, LCLE cannot be observed for the current year, because the cohort currently reaching its life expectancy is not yet extinct. Therefore the estimation of current LCLE must rely on assumptions about future mortality. In this paper, we examine various forecasting approaches and show that current LCLE can be estimated with precision using the most simple mortality forecast – one that applies current mortality to the remaining lifetime of cohorts currently alive. We estimate LCLE trajectories for three countries (France, Sweden, and the US) and discuss the usefulness of using LCLE as a summary measure of population health.

Introduction

Cohort summary indicators in demography, such as the cohort TFR or the cohort life expectancy at birth, have some inherent advantages over corresponding period indicators. Specifically, these indicators remain unbiased in the presence of heterogeneity, unlike period indicators which make the implicit assumption that the population is homogenous with respect to the risk of experiencing the demographic event of interest (Vaupel 2002). Similarly, the presence of cohort effects (i.e., the effect of past conditions on later-life outcomes) does not affect the interpretation of cohort indicators as indexes that summarize the unique set of conditions that a cohort has been experiencing (Guillot 2011). This contrasts with period indicators which are difficult to interpret in terms of current conditions in the presence of cohort effects (Preston and Wang 2006). Finally, period indicators, while seeking to summarize current conditions, have little relevance for the life course of actual individuals. These individuals do not spend their entire life course exposed to the conditions of only one period, but rather are exposed at each age to a sequence of periods with potentially changing conditions.

One inherent disadvantage of cohort indicators, however, is that by nature they represent an experience spread over many years. The time location of the events they summarize is thus very diffuse. One way to resolve this issue is to locate demographic cohort indicators in time at the mean year at which the relevant events occur. This is standard practice for fertility, where the cohort TFR is commonly plotted against the year at which the mean age at birth is reached (= birth year + mean age at childbearing) (Ryder 1980, Schoen 2004, Keilman 2006).

The equivalent solution for mortality is to plot cohort life expectancy against the cohort's mean year at death (= birth year + cohort life expectancy). This produces Lagged Cohort Life Expectancy (LCLE), an indicator that has been discussed in the literature on tempo effects in mortality (Bongaarts 2005, Bongaarts and Feeney 2006, Goldstein 2006, Rodriguez 2006).

One problem with this indicator, however, is that it is not possible to observe it for the current year (Guillot and Kim 2011). Indeed, by definition, the cohort currently reaching its life expectancy is not known, because that cohort is not yet extinct and will be exposed for its remaining life time to unknown, future mortality. The cohort currently reaching its life expectancy will only be identified many years later, once that cohort has become extinct. Yet, current LCLE is a useful indicator, for a number of reasons we discuss in the paper.

The purpose of this paper is threefold. We first discuss the usefulness of LCLE as an indicator summarizing a population's level of longevity. Second, we examine different strategies for estimating current LCLE. Third, we estimate current LCLE for three countries (France, Sweden, and the US) and interpret LCLE differences between them.

This paper builds on previous work showing that whenever mortality changes according to certain model patterns, current LCLE is equal to CAL, an indicator which can be observed for the current period as long as sufficient past mortality information is available (Bongaarts 2005, Wilmoth 2005, Bongaarts and Feeney 2006, Goldstein 2006, Rodriguez 2006). If these model patterns apply in the population, then current LCLE can be readily estimated using CAL, without resorting to projections. However it turns out that in practice, especially when considering life

expectancy at birth as opposed to life expectancy at age 30 or 60, the model's assumptions are not met and CAL cannot be used reliably to estimate current LCLE (Guillot and Kim 2011). In this paper, we contribute to this literature by explicitly building projection models for estimating the current value of LCLE. This approach has the advantage of treating current LCLE for what it really is: a cohort mortality indicator which takes past mortality into account but also involves some assumptions about future mortality.

Definition and interpretation of LCLE

Let $e_0^c(c)$ be the cohort life expectancy at birth for the cohort born during year c. The year at which the cohort born during year c reaches its life expectancy is $t(c) = c + e_0^c(c)$. $t(c)$ is an important year for cohort c, as it corresponds to the mean year at death for this cohort. Deaths in cohort c that take place before $t(c)$ occur below the cohort's mean age at death, while deaths that take place after $t(c)$ occur above the cohort's mean age at death. $t(c)$ can be considered as the central time location of deaths for cohort c. It divides cohort deaths into two parts: below average vs. above average.

Because of its interpretation as the central time location of deaths for cohort c, $t(c)$ provides a useful time location for $e_0^c(c)$. Indeed, $e_0^c(c)$ summarizes a mortality experience spread over many years, but centered around $t(c)$. If there was no variation in ages at death, all deaths in cohort c would take place at time $t(c)$.

LCLE examines levels and trends in cohort life expectancy with respects to $t(c)$. It is perhaps best understood graphically. Instead of plotting cohort life expectancy against the cohort's year

of birth, as typically done, cohort life expectancy is lagged by its own value and plotted against the cohort's mean year of death.

Viewed from another angle, *LCLE(t)* is the life expectancy for the cohort reaching its life expectancy during year *t*. When *t* refers to the current year, *LCLE(t)* is the life expectancy for the cohort currently reaching its life expectancy. Current LCLE can be considered as one possible answer to the question "How long do we live?". Period life expectancy, by resorting to synthetic cohorts, is a somewhat theoretical answer to this question, as it relies on the statement "if exposed to current mortality rates." Period life expectancy applies neither to the cohort currently becoming extinct nor to the cohort currently being born. In fact, unless mortality is constant, no cohort will be exposed to current mortality rates. Therefore period life expectancy can be considered as the result of a simulation rather than an observation anchored in reality.

Current LCLE provides a different answer. Because it relies on actual rather than synthetic cohorts, it is less theoretical than period life expectancy. (In fact, in populations that are closed to migration, cohort life expectancy is simply the cohort's actual mean age at death.) Current LCLE does not seek to reflect current conditions but provides information about levels of longevity currently being reached by actual individuals. As such it is perhaps a better indicator for evaluating the "earliness" of a given death occurring in a population. Suppose that in a population period life expectancy is currently 80 years while current LCLE is 70 years. According to current mortality rates, a death occurring at age 70 years is considered "early" as it is occurring below the mean age at death arising from these mortality rates. An alternative comparison is how long this individual lived compared to members of his or her own cohort, i.e.,

individuals who have been exposed to a similar set of epidemiological circumstances. Indeed, an individual currently dying at age 70 has not been exposed since birth to current mortality conditions but has been exposed to a particular set of past conditions. Thus this particular death is in part the product of these past conditions. Using this frame of reference, a death currently occurring at age 70 during time *t* is actually not "early" but "average" for that cohort.

Note that there can be more than one cohort reaching its life expectancy during a particular year. This occurs when cohort life expectancy decreases by at least one year between two successive annual birth cohorts. Such rapid declines in cohort life expectancy are rare. For most practical purposes, only one value of LCLE(t) is associated with each year *t*. (As long as $e_0^c(c)$ is a continuous function of *c*, there will be always at least one cohort reaching its life expectancy during year *t*.)

Projecting mortality for estimating current LCLE

As said earlier, current LCLE cannot be known with certainty, because the cohort currently reaching its life expectancy has not yet completed its full mortality trajectory. Cohort life expectancy can be observed only for cohorts that are now extinct, and current LCLE will only be known retrospectively, many years later, once that cohort will have completed its mortality trajectory. Nonetheless, current LCLE can be estimated by making assumptions about the future course of mortality.

Let LCLE(T) be the life expectancy for the cohort currently reaching its life expectancy (where T = current year). Although LCLE(T) cannot be observed, it can be estimated by forecasting

age-specific death rates, m(x, t), for years beyond T. The age-specific death rates that need to be projected are located in the Lexis triangle determined by the coordinates { (LCLE(T), T); (ω, T); (ω, T+ ω-LCLE(T) } need to be projected (where ω = maximum age at death). This Lexis triangle is illustrated in Figure 1, together with the LCLE trajectory for Swedish females. This is a rather small-scale projection exercise compared to more common types of projection exercises such as projections of period life expectancy. The fact that only ages above LCLE need to be projected implies that the task of estimating current LCLE will not need to take patterns of mortality at child or early adult ages into account. (Obviously, current LCLE is not known ahead of the projection exercise, so the exact size of the Lexis triangle is not known ahead of time, as indicated with the question mark in Figure 1. However, in the absence of long-term mortality deterioration, current LCLE will be at least as high as the cohort life expectancy for the most recent extinct cohort. Taking 100 years as the maximum age at death, that cohort was born in 1910 and, in the case of Swedish females illustrated in Figure 1, it reached a life expectancy at birth of about 67 years in 1977.)

In this study, we explored three projection scenarios: (1) a scenario with mortality remaining constant at current levels; (2) a scenario using the logistic model; (3) a scenario using the Lee-Carter model. These three scenarios are applied to data from France, Sweden and the United States. Projections are made for males and females separately. Observed single-year age-specific death rates for these three countries are taken from the Human Mortality Database (www.mortality.org). Life expectancy at birth was calculated with the assumption that the force of mortality was constant within each single-year age group. Life table calculations were top truncated using a maximum age chosen such that the truncation produced less than .1 year of

error in period life expectancy at birth for the most recent available year (2010). Ages for this top truncation are shown in Table 1.

Constant mortality projection

This most simple mortality forecast assumes that old-age mortality will remain constant at current levels. Under this scenario, cohorts are exposed to their actual, observed mortality until the current year. Starting with the current year, their remaining life time is projected using current mortality. This is the baseline scenario against which other scenarios will be compared. In populations experiencing old-age mortality decline that is projected to continue in the future, this model provides a lower-bound estimate for current LCLE and an indication of which ages need to be extrapolated in the projection scenarios described below.

Logistic projection model

This model is based on the assumption that period mortality follows the following equation (Thatcher 1999; Thatcher, Kannisto and Vaupel 1998; Bongaarts 2005):

$$\mu(x) = \frac{\alpha e^{\beta x}}{1 + \alpha e^{\beta x}} + \gamma$$

For the purpose of this projection, we first fitted this model to observed data for each year starting in 1950. The age range for the model fit was chosen such that it includes LCLE under the constant scenario and such that it produces a consistent series of positive gamma values. The linear portion of the α, β and γ observed trajectories were then used as a basis for a linear

extrapolation for the needed future years. Extrapolated trajectories of α, β and γ were then used for estimating projected rates for the needed age-year combinations. The age ranges and years used for the model fit and extrapolation are shown in Table 1. (This projection approach is adapted from Bongaarts (2005). Unlike Bongaarts, however, we did not assume β to be constant, because in fact we observed systematic trajectories of increase in β in the studied populations.)

Lee-Carter projection model

As an alternative to the logistic projection method, we forecasted annual mortality rates using a simple Lee-Carter model (Lee and Carter 1992):

$$\ln [m(x,t)] = a(x) + b(x) \cdot k(t)$$

Values of a(x), b(x), and k(t) were estimated using annual mortality rate data from 1950-2010. We then extrapolated values of k(t) for our forecasts via OLS regression of the most recent linear portion of the k(t) trajectory. The linear portion of k(t) was judged to be 1985 onwards for Swedish males, 1975 onwards for Swedish females, 1980 onwards for French males, 1960 onwards for French females, 1975 onwards for US males, and 1960 onwards for US females. Our estimates corrected for jump-off using actual 2010 log-mortality rates in place of a(x) and resetting k(t) to 0, while keeping b(x) unchanged.

Results

Figures 2A-2C shows observed values of LCLE up to the point where the most recent extinct cohort is reaching its life expectancy (a date which varies depending on the level of cohort life expectancy for each population). Beyond that point, Figures 2A-2C shows LCLE values that were estimated using projected mortality rates according to the three projection scenarios described above (constant, logistic, Lee-Carter). (Note that for the US, no observed values of LCLE are shown, because in that country the earliest cohort for which a life table can be calculated was born in 1933 and is not extinct as of 2010.) Estimated values of LCLE for the most recent year (2010) are shown in Table 2.

These results show that for all studied populations (except French males – a special case we discuss later), there is very little discrepancy between the different projection scenarios. By introducing mortality decline beyond the current year, estimates of current LCLE increase by only .11-.48 years. This is due to several factors:

- In each of these scenarios, only rates for ages beyond LCLE are forecasted. Mortality rates for years prior to LCLE are observed and are identical in all projection scenarios. Thus discrepancies in age-specific death rates between projection scenarios can arise only during a rather limited portion of the cohorts' life time, which limits the amount of discrepancy in LCLE values between scenarios.
- The overall time frame for these mortality projections is rather short, as illustrated in Figure 1. This gives little room for discrepancies among scenarios to emerge.

- The projection time frame varies in an age-specific manner. Starting from zero year for the age group centered at the current LCLE value, the projection time frame increases by one year for each subsequent single-year age group (as illustrated in Figure 1). Therefore projected age-specific death rates are more likely to diverge across various scenarios at higher ages vs. younger ages, but beyond a certain age discrepancies in age-specific death rates have little impact on corresponding cohort life expectancy values due to the increasingly small number of survivors.
- In the logistic and Lee-Carter projections, mortality at older ages is not projected to decline by an amount that is sufficiently large to create important discrepancies when compared to a scenario that assumes no mortality decline.

French males are an outlier in these results. Indeed, for this population, scenarios with mortality decline generate a difference of .86 year for the logistic scenario and 1.20 years for the Lee-Carter scenario, by comparison with the constant mortality scenario. This is not explained by the fact that old-age mortality is projected to decline faster among French males as compared with the other populations. This is explained by the fact that among French males, the cohorts currently reaching their life expectancy are experiencing declines in life expectancy, due to higher mortality rates at the time of their birth. (These cohorts were born during WWII.) At the same time, discrepancies among mortality scenarios generate increasingly large differences in cohort life expectancy values, since more recent cohorts have a larger portion of their life time that is projected as opposed to observed. When these projected cohort life expectancies are lagged, an overall declining trajectory in cohort life expectancy will amplify differences among

current LCLE values. This contrasts with improving trajectories in cohort life expectancy which minimizes differences among current LCLE values.

This is illustrated in Figure 3. Figure 3-A shows a situation in which LCLE is following an overall trajectory of increase. The black line illustrates LCLE values estimated with constant future mortality, while the red line shows LCLE values estimated with declining future mortality. Discrepancies between the constant vs. declining mortality scenarios generate increasing large discrepancies in cohort life expectancy values, which can be visualized on Figure 3-A with the green lines along the diagonals representing cohorts. As the higher cohort life expectancy values are lagged further in time, the vertical distances between LCLE values are minimized (as illustrated with the red arrow). The reverse is true when LCLE is declining (Figure 3-B): a declining overall trajectory in LCLE will amplify vertical distances between scenarios. This is what is currently happening among French males. Declines in life expectancy for cohorts currently reaching their life expectancy explain why discrepancies between projection scenarios are larger than for the other 5 population groups. In fact, for years during which LCLE is increasing (i.e., up to 2006), the difference between scenarios is in a similar range as in the other population groups.

Overall, except in the unusual situation of a declining trajectory in cohort life expectancy, the most basic projection scenario assuming constant future mortality appears to produce results that are so close to more complex projection scenarios that these latter scenarios may not be worth the extra effort.

Sensitivity analysis of constant scenario

In this section of the study, in order to further justify the use of the constant mortality scenario, we examined how sensitive the constant mortality scenario is to departures from the projection's underlying assumption of future mortality remaining constant at current levels. The first test retrospectively evaluates how the constant scenario performs for years where observed values of LCLE are available. The second test simulates how the amount of error in estimated LCLE varies with various rates of decline in age-specific mortality.

Retrospective evaluation of the constant mortality scenario

In this first test, we retrospectively evaluated how the constant mortality scenario performs by comparing estimated vs. observed values of LCLE. For each year in the past at which a value of LCLE can be fully derived from the observed data, we estimated LCLE by ignoring actual mortality data beyond that specific year and instead making the assumption that mortality beyond that year remained constant at the levels observed during that year. In other words, we replicated the data availability that an analyst would have faced during that year. We then compared the estimated LCLE value for that year with the observed value that eventually emerged as the cohort, many years later, completed its life trajectory. This comparison was made for every year in the past in which a value of LCLE can be observed. Results are shown in Figure 4 for Sweden and France. (No comparison is possible in the US.) These results show that for these past years, the constant mortality scenario produces LCLE estimates that are very close to truth. There is a slight tendency for the estimated values to underestimate the true values

(which is expected given that the estimated values ignore the mortality declines that subsequently took place), but the amount of underestimation is not large.

Simulations of errors in current LCLE values estimated with constant mortality

Here we estimated the amount of error in current LCLE (estimated with the constant mortality scenario) that would arise if, instead of remaining constant, mortality had declined by a constant rate, applied to all ages starting with the current year. The amount of error is estimated for all six population groups studied in this paper.

Figure 5 shows that except for French males (which are an unusual case, as discussed above), the amount of error in LCLE increases only modestly with respect to the rate of decline in mortality. If all age-specific death rates declined at the rate of 3% per year in the future, LCLE estimated with constant mortality would underestimate true LCLE by only .58-1.00 year. This would be unprecedented mortality decline for the populations and age groups at stake. For the 6 population groups analyzed in this paper, mortality in the age range 70-99 years has declined at an average rate in the range of .4% - 1.2% since 1950 and .9% - 1.8% since 2000. Overall, LCLE estimated with the constant scenario appears resistant to likely departures from constant mortality.

In brief, we conclude from this section that even though we know that mortality is not likely to remain constant at old ages in the future, estimating current LCLE by applying current mortality to close the life table of cohorts that are not yet extinct provides excellent results as long as the

cohorts currently reaching their life expectancy are not experiencing declines in life expectancy. This provides a simple approach to estimating current LCLE without having to resort to actual mortality forecasts. The lack of knowledge about mortality beyond the current year does not represent a serious barrier to the estimation of current values LCLE. Only major departures from past trends (which in any case would be poorly predicted by existing projection methodologies) would generate substantial deviations from true values.

Interpreting LCLE differences among countries

Figure 6 represents life expectancy and LCLE estimates for 2010 for France, Sweden and the US, by sex. (In this section, we use LCLE estimates based on the constant mortality scenario.) The overall levels are quite different when looking at LCLE as opposed to the period life expectancy at birth (e_0^P). For females, e_0^P is between 81-85 years, while current LCLE is between 75-77 years. Taking the US as an example, a death at age 75 for a female in 2010 would seem relatively early when compared to the period life expectancy of 81, but in fact this value is right at the mean age at death when considering the mortality conditions to whom that individual has been actually exposed. Conversely, a death occurring at age 81 in 2010 would seem quite normal when compared to the period life expectancy, but in fact this age at death is substantially past the life expectancy for the cohort currently reaching its life expectancy. (Since an individual dying at age 81 belongs to a cohort born earlier than the one currently reaching its life expectancy, and given a trajectory of increase in cohort life expectancy, the number of years lived past the life expectancy for that individual's own cohort is even larger.) The loss of level when switching from period life expectancy to LCLE is particularly large for French females, who lose their top life expectancy ranking. Males in the three populations of interest also lose a

large amount (between 7 and 10 years of life), when examining LCLE instead of e_0^P. Here also, the loss of level is largest in France, placing this population below the US in terms of LCLE.

Differences in LCLE between countries for a given year do not reflect differences in age-specific mortality for an identical cohort in each country, since these different LCLE values refer to different cohorts. As illustrated in Figure 7, a lower LCLE value in country B vs. country A for a given year *t* reflects higher cohort mortality for at least two birth cohorts: (1) the birth cohort born at time $t\text{-}LCLE^A(t)$ and (2) the birth cohort born at time $t\text{-}LCLE^B(t)$. If mortality is changing gradually, a lower value of LCLE in country B reflects patterns of higher cohort mortality in country B for a series of cohorts reaching the age range $LCLE^B$ to $LCLE^A$ during year t.

Because of the impact of past mortality on current LCLE values, countries that have transitioned quickly from relatively high to relatively low period mortality will be particularly disadvantaged in rankings based on LCLE as opposed to e_0^P. This is illustrated in Figure 8, which shows trends e_0^P vs. LCLE in all three countries (by sex). In the case of females, we observe a cross-over in e_0^P between France and Sweden. Starting from a lower e_0^P value in 1950, French females surpass their Swedish counterparts around 1987. Such a cross-over does not appear in the LCLE data. This past history of higher mortality among French females is retained in current LCLE values. These current LCLE values also contain lower old-age mortality for future years in France vs. Sweden, but this is not enough to erase the mark of a past history of higher mortality in France vs. Sweden. While the e_0^P comparison indicates more potential in France for higher longevity in the future, the LCLE comparison indicates that actual cohorts of individuals in France have yet to see the benefits of this greater longevity potential. In other words, this greater

longevity potential has not lasted long enough to fully trickle down and generate higher longevity for actual cohorts of individuals.

Discussion

This study shows that the life expectancy for the cohort currently reaching its life expectancy can be easily estimated by making the assumption that future mortality will remain constant at current levels. More refined projection methodologies do not appear to make a difference that is large enough to justify the additional effort. This makes LCLE an indicator that is easy to calculate. One can note, however, that regardless of the chosen projection scenario, current LCLE can be estimated only in countries that have at least LCLE years of data. For current LCLE levels around 70 years, it is necessary to have 70 years of historical mortality data for its estimation. (In theory, mortality rates for earlier time periods could be estimated using back projection. Results, however, would likely be sensitive to the chosen approach, because the age-specific rates that would need to be back projected are for infant and child ages, which have a large impact on life expectancy at birth.)

Whenever mortality has been declining, LCLE values will be lower than e_0^P values. LCLE thus gives a more conservative picture of current longevity than when looking at period life expectancy, as we showed in the case of France, Sweden and the US.

It is clear that current LCLE does not reflect current conditions, since it involves observed age-specific mortality for past years as well as projected age-specific rates for future years. In spite

of the bias arising from heterogeneity and cohort effects, e_0^P is certainly a better reflection of current conditions. LCLE, by contrast, reflects longer term epidemiological trends and gives an indication of the levels of longevity currently reached by real cohorts of individuals, with no resort to synthetic cohorts or the assumption of homogeneity.

LCLE belongs to a family of mortality indicators that make use of cohort information but refer to one period. This family of indicators includes CAL, the size of the constant-birth population at time *t* (Brouard 1986; Guillot 2003), and MAD, the mean age at death at time t in the constant birth population (Bongaarts and Feeney 2003). Of all these measures, LCLE is perhaps the easiest to understand, because it uses the basic life table framework and does not rely on a population model. It also corresponds to the mean age at death for a real and well-defined group of individuals. This makes LCLE a particular attractive indicator for assessing current levels of longevity in populations.

References

Bongaarts, J. and Feeney, G. (2003). Estimating mean lifetime. Proceedings of the National Academy of Sciences 100(23):13127–13133.

Bongaarts, J. (2005). Five measures of period longevity. Demographic Research 13(21):547-558.

Bongaarts, J. (2005). Long-range trends in adult mortality: models and projection methods. Demography 42(1): 23-49.

Bongaarts, J. and Feeney, G. (2006). The quantum and tempo of life-cycle events. Vienna Yearbook of Population Research 2006:115–151.

Brouard, N. (1986). Structure et dynamique des populations. La pyramide des années à vivre, aspects nationaux et exemples régionaux. Espaces, Populations, Sociétés (2):157–168.

Goldstein, J. (2006). Found in translation. Demographic Research 14(5):71–84.

Goldstein, J. and Wachter, K. (2006). Relationships between period and cohort life expectancy: gaps and lags. Population Studies 60(3):257-69.

Guillot, M. (1999). The period average life (PAL). Paper presented at the PAA annual meeting, New York City, USA, March 25-27 1999.

Guillot, M. (2003). The cross-sectional average length of life (CAL): A cross-sectional mortality measure that reflects the experience of cohorts. Population Studies 57(1):41–54.

Guillot, M. (2005). The momentum of mortality decline. Population Studies 59(3):283–294.

Guillot, M. (2006). Tempo effects in mortality: An appraisal. Demographic Research 14(1):1-26.

Guillot, M. (2011). "Period Versus Cohort Life Expectancy," pp. 533-549 in International Handbook of Adult Mortality, Richard G. Rogers and Eileen M. Crimmins (eds). Springer. 2011.

Guillot, M. and H.S. Kim. 2011. "On the correspondence between CAL and lagged cohort life expectancy." M. Guillot and H. S. Kim. Demographic Research, 2011, Vol. 24(25):611-632.

Keilman, N. (2006). Demographic translation: From period to cohort perspective and back. In: Wunsch, G., Caselli, G. and Vallin, J. (eds.). Demography: Analysis and Synthesis. Elsevier:215-225.

Lee, R.D. and L.R. Carter. 1992. "Modeling and Forecasting U.S. Mortality." Journal of the American Statistical Association 87(419):659-71.

Preston, S.H. and H. Wang. 2006. “Sex Mortality Differences in the United States: The Role of Cohort Smoking Patterns.” Demography 43(4):631-46.

Rodriguez, G. (2006). Demographic translation and tempo effects: An accelerated failure time perspective. Demographic Research 14(6):85-110.

Ryder, N. (1980). Components of temporal variations in American fertility. In Hiorns, R.W. (ed.). Demographic Patterns in Developed Societies. London: Taylor & Francis:15-54.

Schoen, R. (2004). Timing effects and the interpretation of period fertility. Demography 41(4):801-819.

Thatcher, A.R. 1999. "The Long-Term Pattern of Adult Mortality and the Highest Attained Age." Journal of the Royal Statistical Society 162 Part 1:5-43.

Thatcher A.R., V. Kannisto, and J.W. Vaupel. 1998. The Force of Mortality at Ages 80 to 120. Odense, Denmark: Odense University Press.

Vaupel, J.W. 2002. "Life Expectancy at Current Rates vs. Current Conditions: A Reflexion Stimulated by Bongaarts and Feeney's 'How Long Do We Live?'" Demographic Research 7(8):365-78.

Wachter, K. (2005). Tempo and its tribulation. Demographic Research 13(9):201–222.

Wilmoth, J. (2005). On the relationship between period and cohort mortality. Demographic Research 13(11):231-280.

Table 1
Projection parameters for the logistic model

Country	sex	Last age x at which observed ${}_1m_x$ is used for life table calculations (top truncation)	First age x at which observed ${}_1m_x$ is used for the estimation of logistic parameters	First year used for linear extrapolation of logistic parameters	jump-off adjustment
France	Females	99	63	1980	no
France	Males	96	60	1975	no
Sweden	Females	97	70	1986	no
Sweden	Males	95	60	1980	no
US	Females	98	65	1983	yes
US	Males	96	57	1982	yes

Table 2
Estimates of Lagged Cohort Life Expectancy for 2010 according to various projection scenarios

Country	Sex	Constant	Logistic	Lee-Carter	Difference Logistic vs. Constant	Difference Lee-Carter vs. Constant
France	Females	75.63	76.11	76.06	0.48	0.43
France	Males	67.58	68.44	68.78	0.86	1.20
Sweden	Females	77.36	77.55	77.58	0.19	0.22
Sweden	Males	72.61	72.74	72.92	0.13	0.31
US	Females	74.52	74.63	74.81	0.11	0.29
US	Males	69.90	70.20	70.24	0.30	0.34

Figure 1
Lexis diagram representing the area where age-specific death rates need to be projected for the estimation of current LCLE. Sweden, Females.

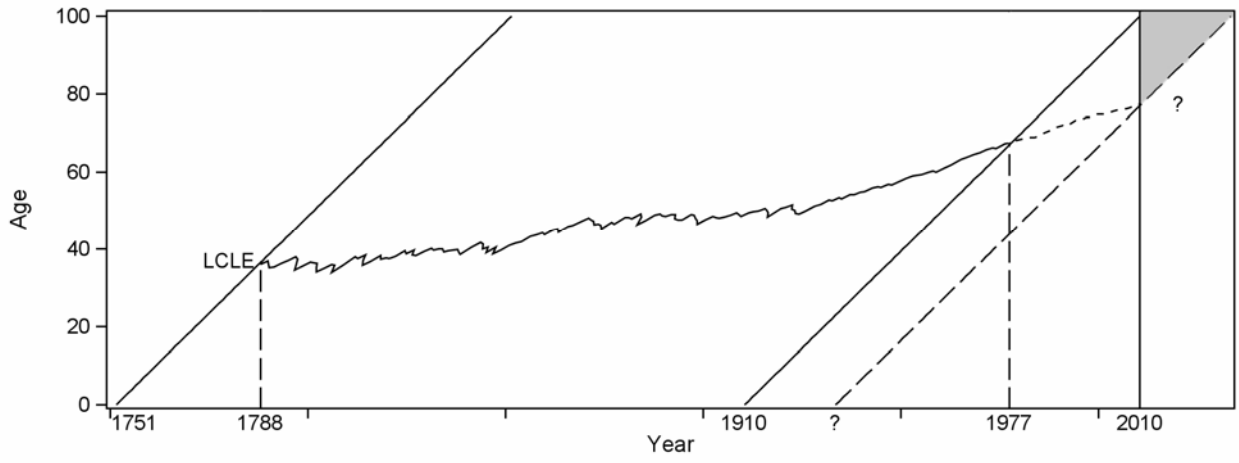
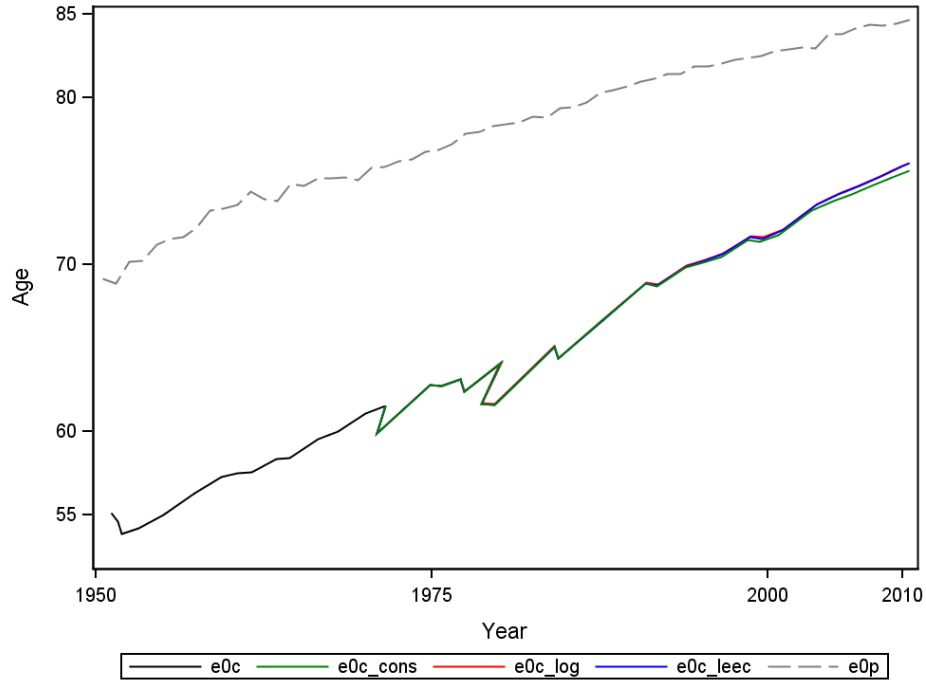
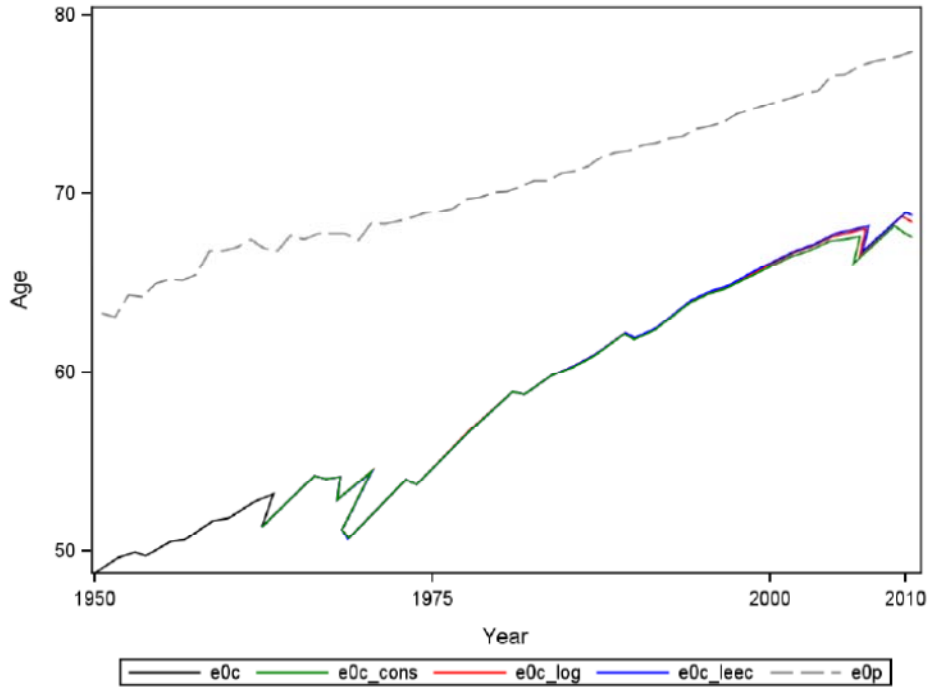


Figure 2
Life expectancy at birth and lagged cohort life expectancy observed and projected according to various scenarios.

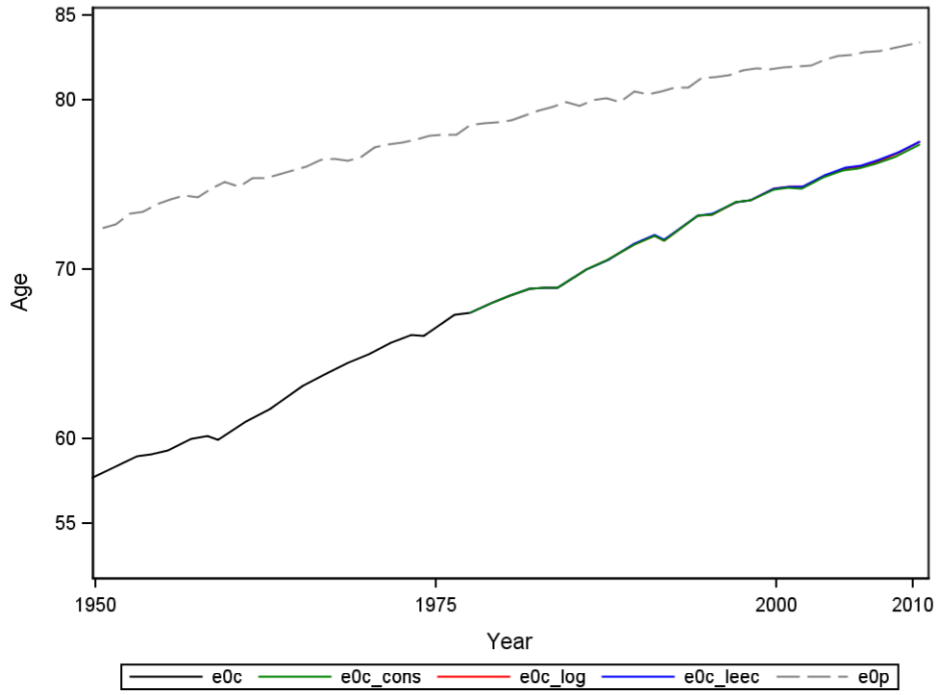
2-A. France, Females



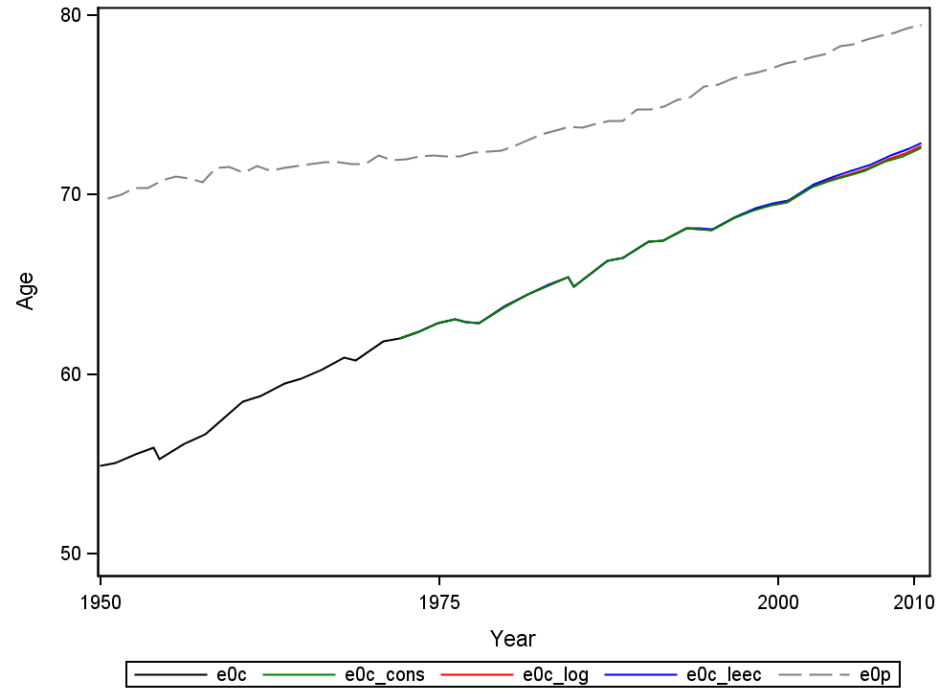
2-B. France, Males



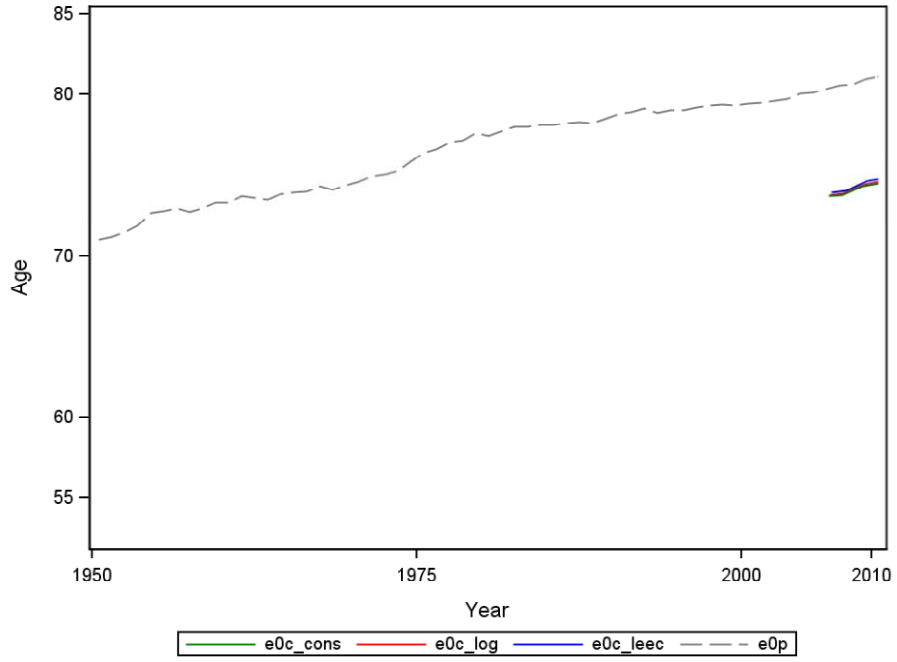
2-C. Sweden, Females



2-D. Sweden, Males



2-E. United States, Females



2-F. United States, Males

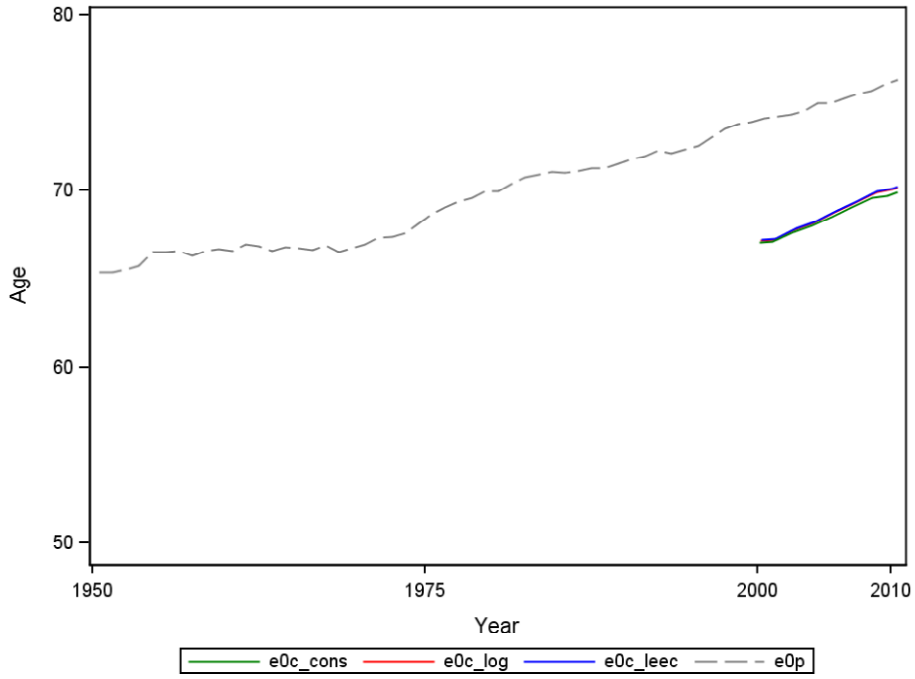
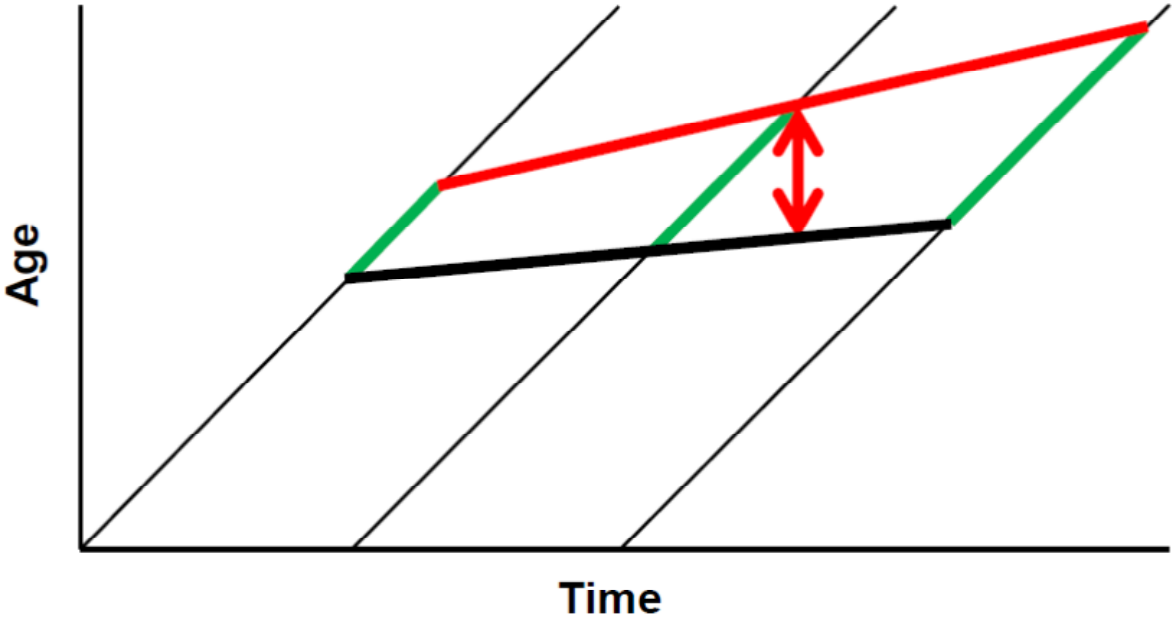


Figure 3
Diagonal (cohort) vs. Vertical (period) Difference in LCLE estimates according in situations of increase vs. decrease in LCLE

3-A: LCLE is increasing



3-B: LCLE is decreasing

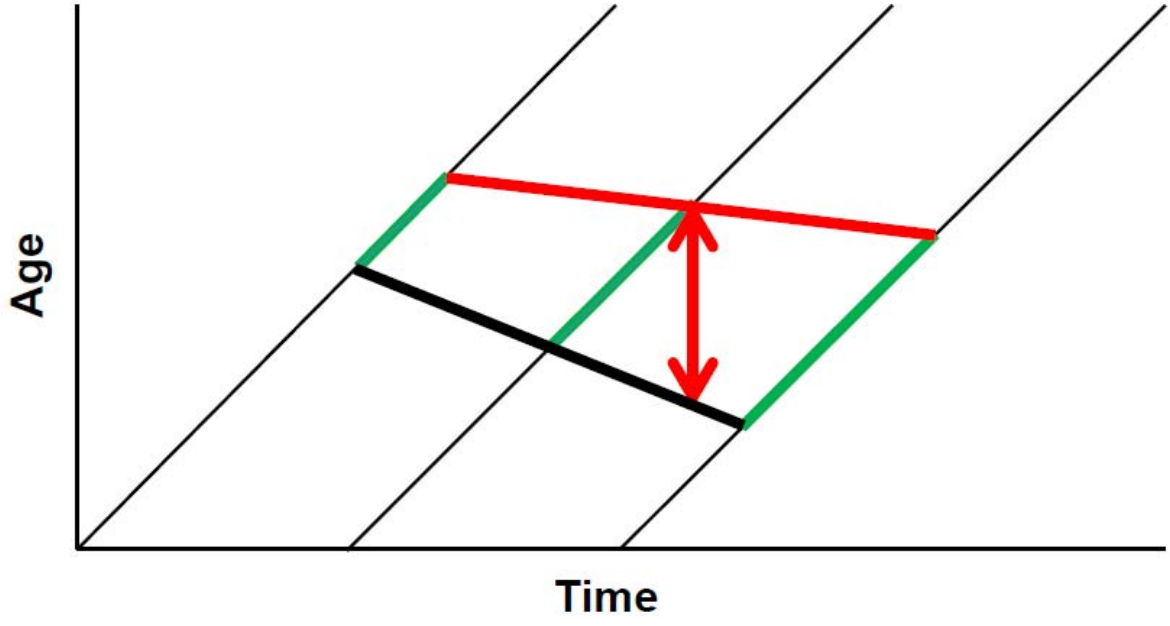
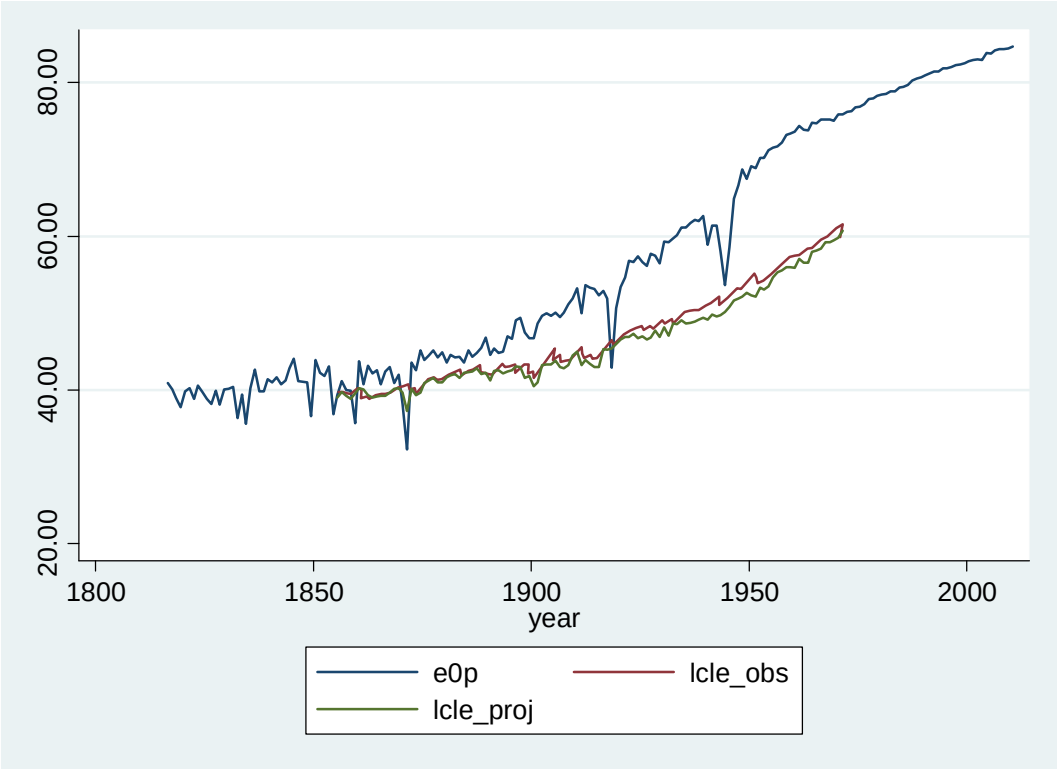
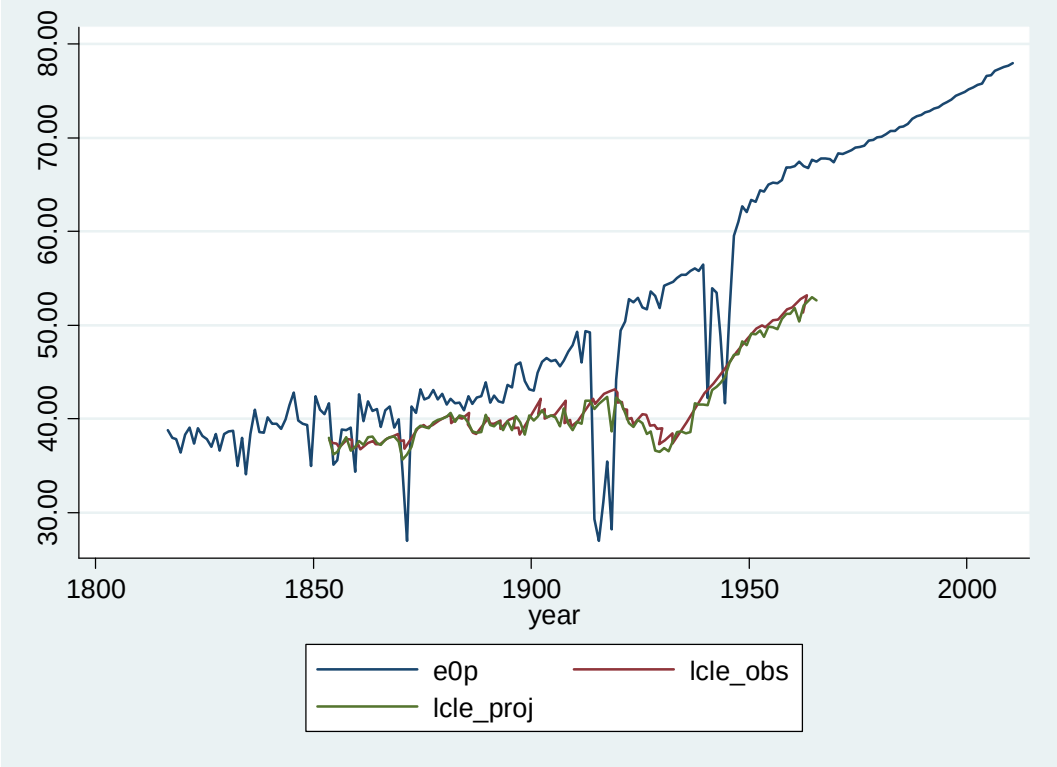


Figure 4: Observed vs. Estimated values of LCLE (constant mortality scenario)

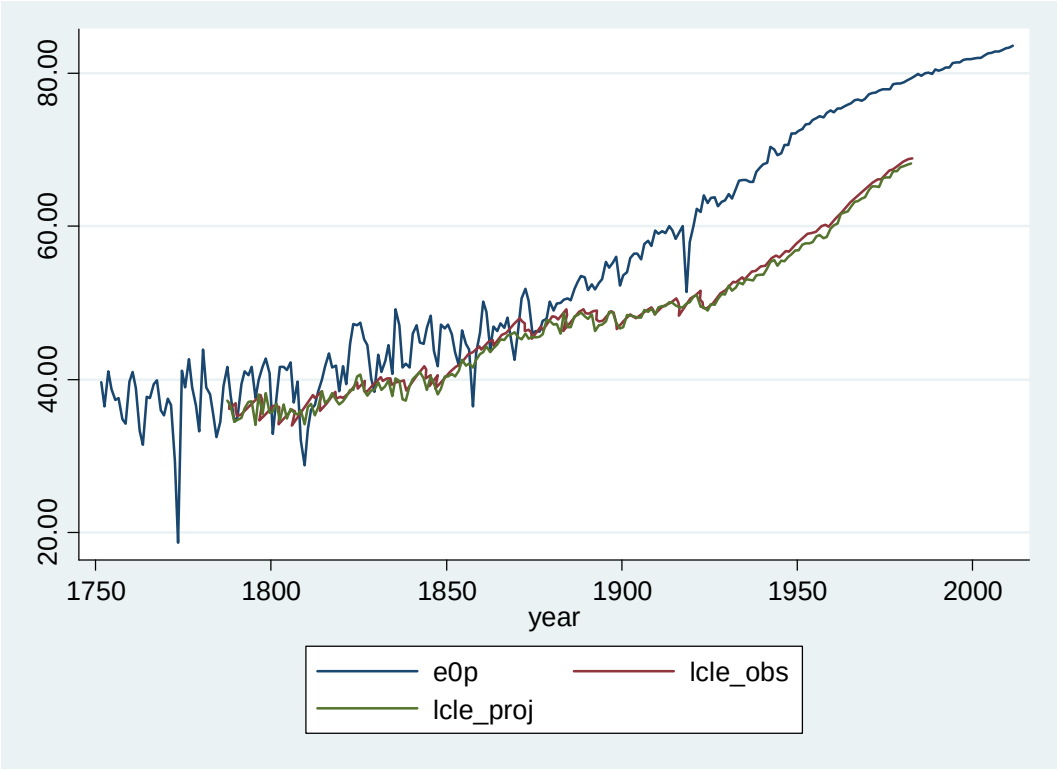
4-A: France, Females



4-B: France, Males



4-C: Sweden, Females



4-D: Sweden, Males

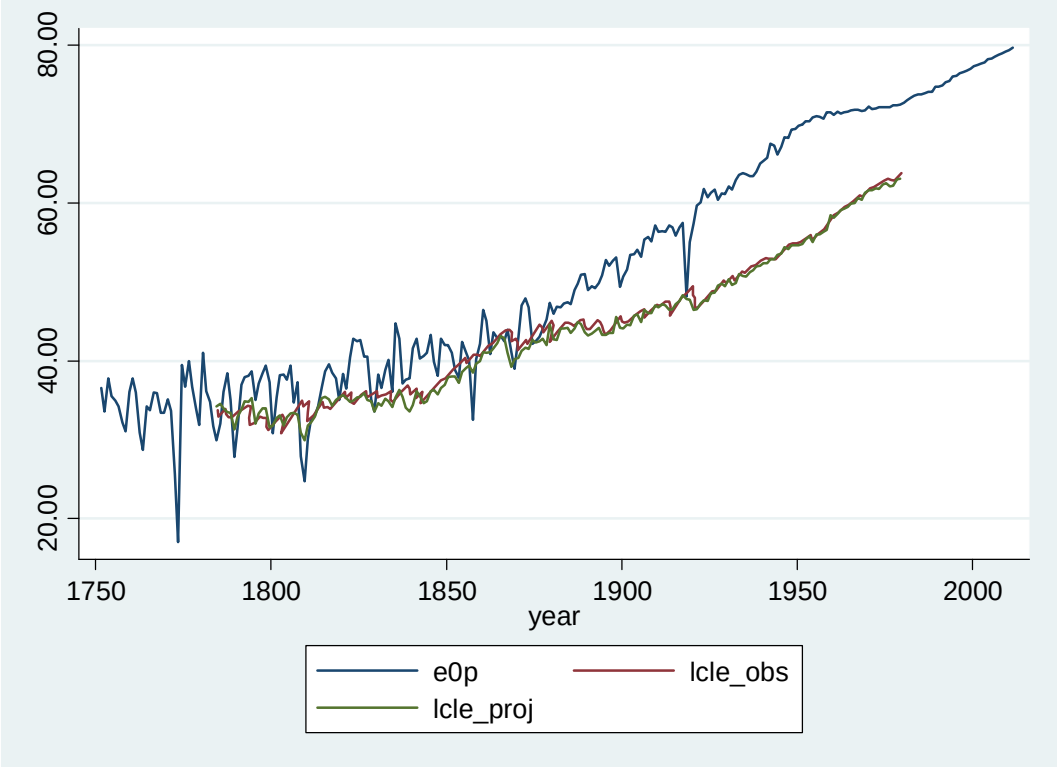


Figure 5
Error in current LCLE (estimated with constant mortality scenario) when in fact mortality will decline, by annual rate of change in ${}_1m_x$

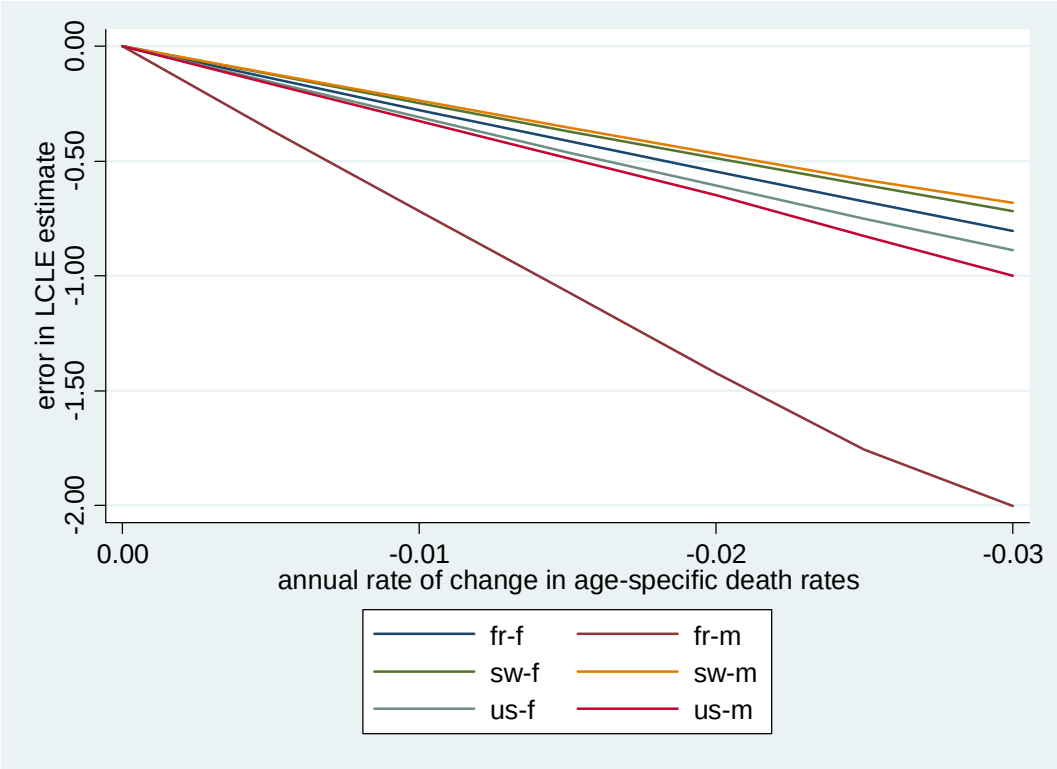


Figure 6
Period life expectancy vs. lagged cohort life expectancy in 2010 in France, Sweden and the US, by sex

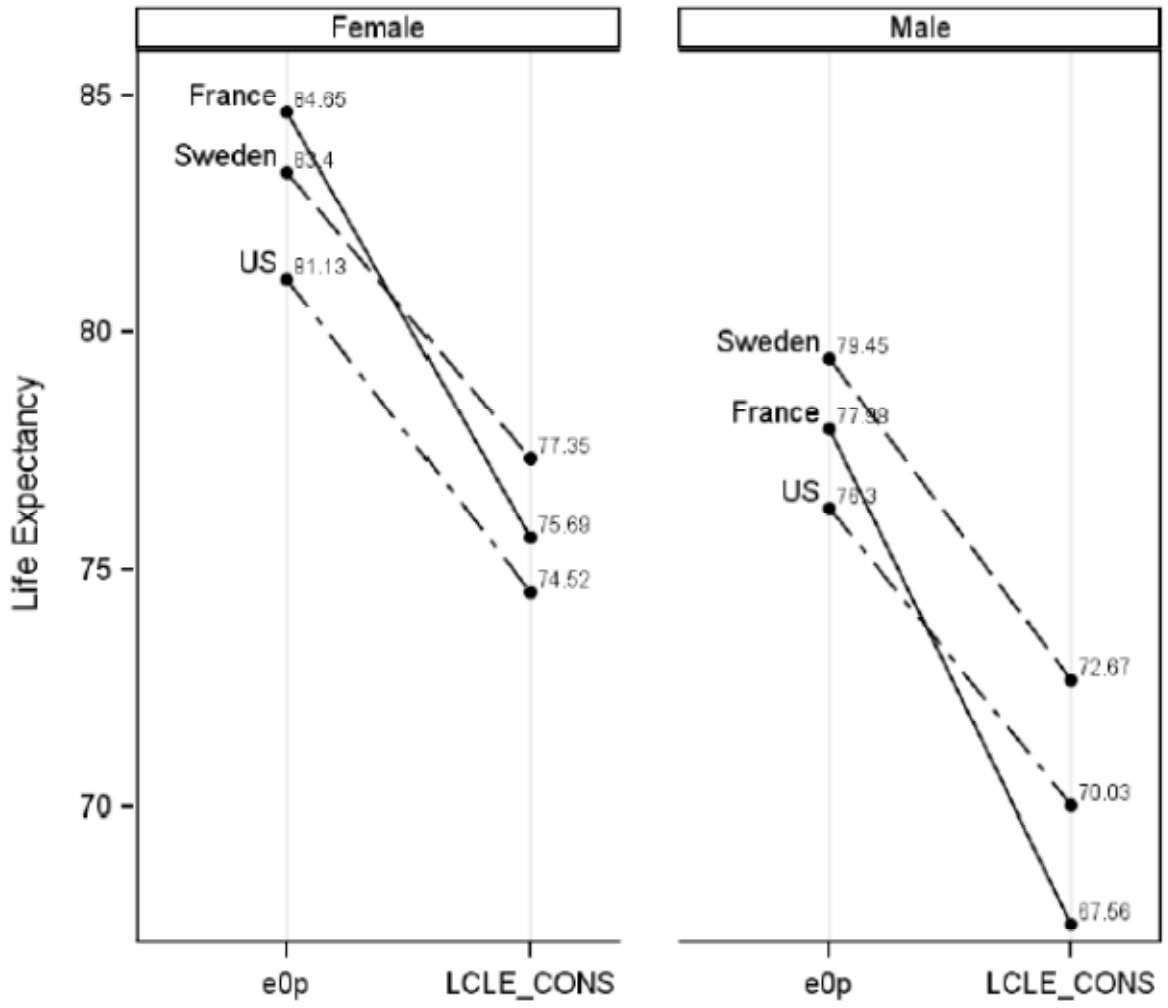


Figure 7
Illustration of the cohorts involved when comparing LCLE values between countries

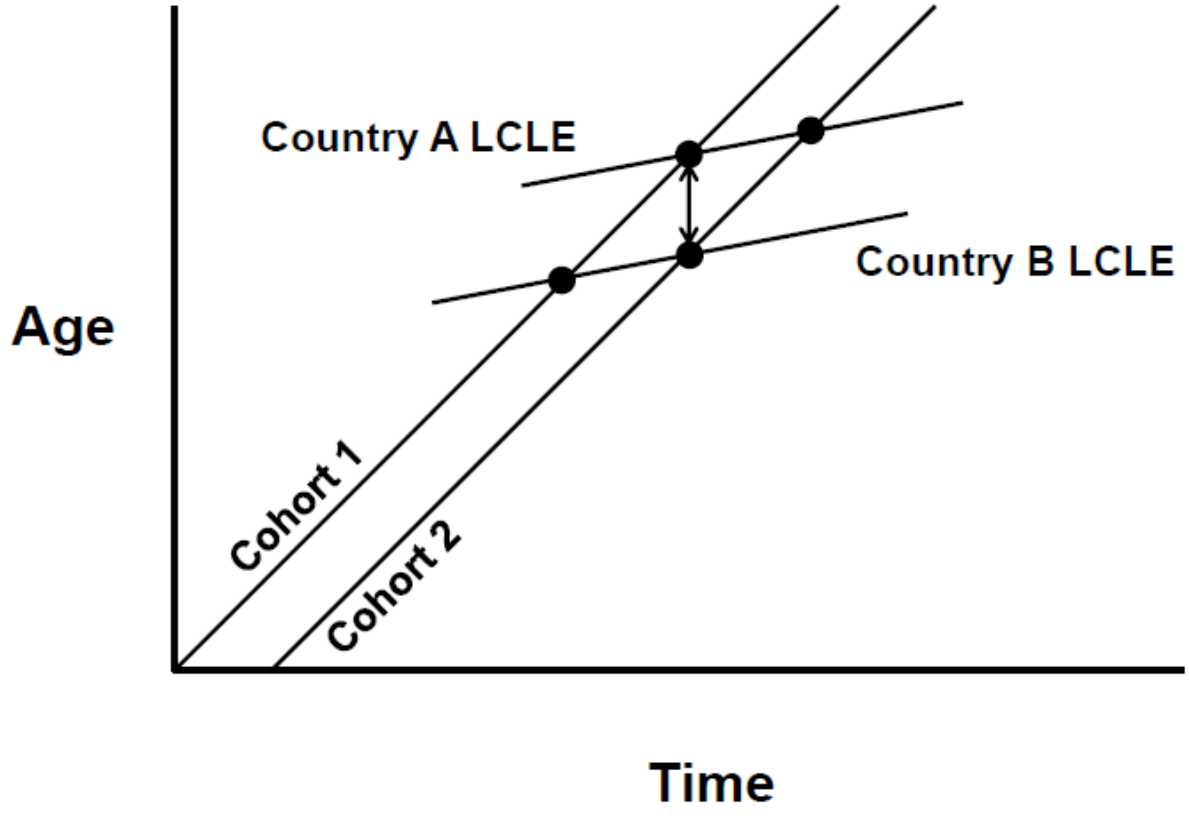
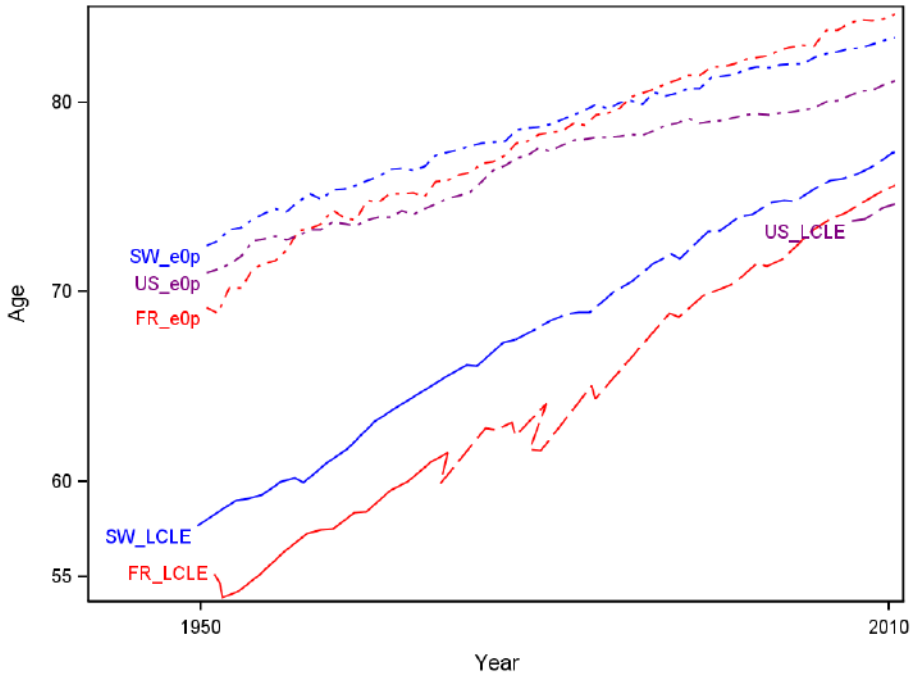


Figure 8
Period life expectancy vs. LCLE trajectories in France, Sweden and the US

8-A: Females



8-B: Males