1 Introduction

Globally, people are living longer. Today, for the first time in history, most people have a life expectancy of over sixty years. By 2050, the world population aged sixty and over is expected to reach 2 billion, up from 900 million in 2015. Today, 125 million people are aged eighty and over. By 2050, 80 percent of older people will live in low- and middle-income countries. The aging of the global population is also accelerating sharply. For example, while France has had almost 150 years to adapt to the increase in the share of people aged sixty and over in the population (which has increased from 10 to 20 percent over this period), Brazil, China, and India have had a little over twenty years to do so. Longer life opens up possibilities, not only for older people and their families, but also for society as a whole. These extra years are an opportunity to embark on new activities, for example, further training, a new career, or a long-neglected passion. Seniors also make a wide variety of contributions to their families and communities. However, the magnitude of these opportunities and contributions depends largely on one factor: health. And it cannot be stated clearly enough that older people live their last years in better health than did their parents.

Although over the past thirty years, rates of severe disability have declined in high-income countries, there has been no significant change for mild or moderate disability. If people live those extra years in good health and in a supportive environment, their ability to do what they enjoy will be quite similar to that of young people. If, in contrast, these years are marked by a decrease in physical and mental capacities, the consequences for the elderly and for society will be more negative. Beyond biological changes, aging is also associated with other life transitions such as retirement, relocation to more suitable housing, and the death of friends or partners. Taking public health action in the face of aging requires approaches that not only reduce losses associated with aging, but also enhance recovery, adaptation, and psychosocial development. Old age is characterized by the onset of several complex health conditions that usually do not appear until later in life and do not constitute separate disease categories. These are commonly referred to as geriatric syndromes. All these elements explain why the concept of life expectancy in good health has been developed. As we will see, longevity in good health generally increases but not at the same pace as plain longevity.

The pervasive increase in longevity has lately attracted the attention of economists who are concerned by two facts. First, behind an apparent steady trend, there remains a lot of variability across individuals, or, rather, across groups of individuals segmented according to characteristics such as gender, occupation, location, and education. Hence, heterogeneity in individual characteristics affecting survival chances is a central dimension of the problem at stake. Second, a sizeable part of longevity changes is endogenous, that is, triggered by individual and collective decisions. As a consequence, longevity changes can hardly be treated as exogenous shocks affecting the economy, but, rather, can be better viewed as the output of a complex production process. In this Element, we plan to review some major effects that evolving longevity has on a number of public policies, which were initially designed for unchanged longevity. For that purpose, it is important to start by studying the challenges raised by varying longevity for the description of individual preferences and the social welfare criterion. On that basis, we will be able to analyze a number of questions pertaining to the design of optimal public intervention in the context of varying longevity. The questions are related to the areas of health care, pensions, disability, wealth distribution, education, poverty, and growth. Here is a sample of issues that are treated in this Element:

- Longevity is partially endogenous and this implies some free-riding. How should the state react to this source of inefficiency?
- Given that longevity genes or learning ability are private information, how should public policy be adjusted?
- Longevity increase has an impact on education decisions. Is there a role for the government?
- Longevity increase combined with social security has a definite effect on economic growth. Should the government intervene?
- Longevity changes have an impact on income inequality and poverty particularly given that mortality varies with income. How does that affect redistributive policies?

This Element is organized as follows. Section 2 presents basic definitions and key empirical facts on longevity and life expectancy. Section 3 discusses the challenges raised by unequal longevity for both individual and collective choices. Section 4 presents a number of public policy issues that have to be revisited in the context of risky and unequal lifetimes. It focuses on cases in which longevity is exogenous. Section 5 is concerned with the case of endogenous longevity. Concluding remarks are drawn in Section 6.

This Element draws on our previous work, in particular the surveys of Pestieau and Ponthière (2014a, b). We are grateful to our coauthors and especially Gregory Ponthière who over the years helped us to reflect on the various implications that declining mortality and age- and income-differentiated longevity may have on the design of public policy.

2 Concepts and Figures

2.1 Aging and Dependency

Aging can be understood in two different but related ways. One can indeed distinguish between individual and population aging. Individual aging means the process of one's becoming old or older. Aging is then measured by longevity or by life expectancy. This has been steadily increasing globally, as we show below. Population aging is a shift in the distribution of a country's population towards older ages. It is due to declining fertility and rising longevity. This is usually reflected in an increase in the population's mean and median ages, a decline in the proportion of the population composed of children, and a rise in the proportion of the population composed of the elderly. Population aging is widespread across the world. It is most advanced in the most highly developed countries, but it is now growing more quickly in less developed regions, too.

Population aging is traditionally measured by dependency ratios. The best-known dependency ratio is the age-population ratio, namely, the ratio of those typically not in the labor force (the dependent part, those aged 0 to fourteen and those over sixty-five) and those typically in the labor force (the productive part, those aged fifteen to sixty-four). It is used to measure the pressure on the productive population. One can also use the old age dependency ratio, that is, the ratio of those aged over sixty-five to those aged fifteen to sixty-four. This ratio is convenient to study the sustainability of social security and health care systems. In OECD member countries, the old age dependency ratio has increased from 13 to 26 percent over the past six decades. As appears from Table 1, in the OECD, Japan has the highest ratio and Mexico the lowest. As a widely accepted

Table 1 Old age dependency ratios in some OECD countries, 2020

Countries	Old age dependency ratio
France	33
Germany	33
Italy	36
Japan	47
Mexico	11
UK	29
USA	25

Source: OECD (2020)

convention, the threshold age for measuring dependency is sixty-five. If we consider that people may become healthier over time, this threshold should be adjusted upward, which would result in a less sharp increase in dependency.

2.2 Life Expectancy

Life expectancy is a statistical measure of the average time someone is expected to live for, based on the year of their birth, current age, and other demographic factors including their sex. It is used to assess and set a number of important policies that impact on everyday life, for example, setting retirement age and targeting health policy initiatives. To calculate life expectancy, one uses a life table that shows, for each age, what the probability is that a person will die before their next birthday. There are two different types of life table: cohort and period.

A cohort life table shows the probability of a person from a given cohort dying at each age over the course of lifetime. In this context, a cohort refers to a group of people with the same year of birth. The cohort life table is based on age-specific probabilities of death, which are calculated using observed mortality data from the cohort. A cohort life table takes into account observed and projected improvements in mortality for the cohort throughout its lifetime. Cohort figures are therefore regarded as the appropriate measure of how long a person of a given age would be expected to live on average.

An alternative way of looking at life expectancies is the use of period life expectancies, rather than cohort life expectancies. Period life expectancies use mortality rates from a single year (or group of years) and assume that those rates apply throughout the remainder of a person's life. This means that any future changes to mortality rates would not be taken into account. Period life expectancies are the traditional measure of mortality rates in international comparisons. Needless to say, period life expectancies tend to be lower than cohort life expectancies because they do not include any assumptions about future improvements in mortality rates. In other words, *published* life expectancies tend to understate *actual* longevity.

Let us look at some stylized facts on the evolution of human longevity. For that purpose, a natural starting point consists of considering the evolution of period life expectancy at birth during the last few centuries. As shown in Figure 1, period life expectancy at birth has grown strongly during the last three centuries. Whereas life expectancy was equal to about thirty-eight years in 1750 in Sweden, it is nowadays over eighty-two years. Figure 1 shows also that the extent of growth in life expectancy has not been constant over time: life expectancy growth was particularly strong in the first part of the twentieth century,

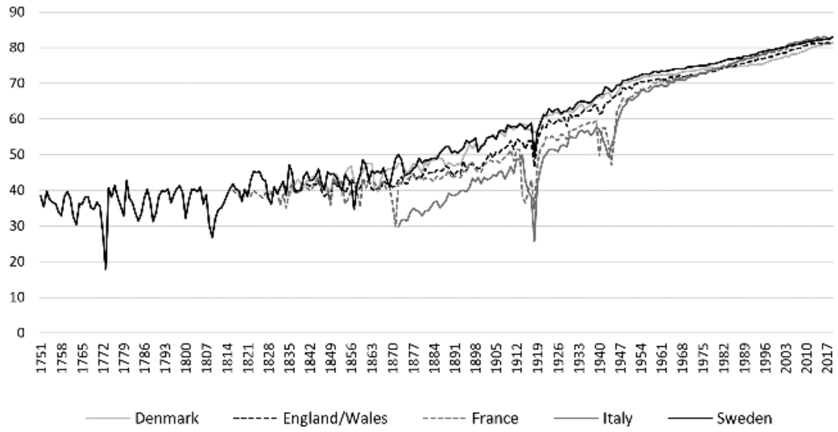

Figure 1 Life expectancy at birth (period) in several European countries, 1750–2019

Source: Human Mortality Database (2012)

but less so ince then. Another important thing that appears in Figure 1 is the convergence between countries: whereas significant inequalities existed in terms of life expectancy in the early twentieth century, those inequalities are, one century later, much smaller. The life expectancies of Italy and Sweden in 1875 were respectively equal to 33.78 and 46.20; in 2015, they were 82.82 and 82.51.

When interpreting Figure 1, it is important to bear in mind that each point represents the expected duration of life conditional on the survival likelihood prevailing during that year. This explains why period life expectancy data vary strongly at the time of the First World War and the Second World War. Another key feature of periodic data lies in the fact that those life expectancies only predict the effective average duration of life provided age-specific probabilities of death remain constant over time. In light of this, it may well be the case that the large period life expectancy levels measured in the early twenty-first century underestimate the average duration of life for the people born in the early twenty-first century.

In order to give an idea of potential bias, let us compare, for the eighteenth and nineteenth centuries, the period life expectancy at birth with the cohort life expectancy at birth, that is, the average effective duration of life among a group of people born at the same point in time. As shown in Figure 2 for Sweden, the gap between the period and the cohort life expectancies at birth remained relatively small during the eighteenth century, but, after that, the cohort life expectancy remained permanently above the period life expectancy. The gap between, on the one hand, the duration of life that could be expected on

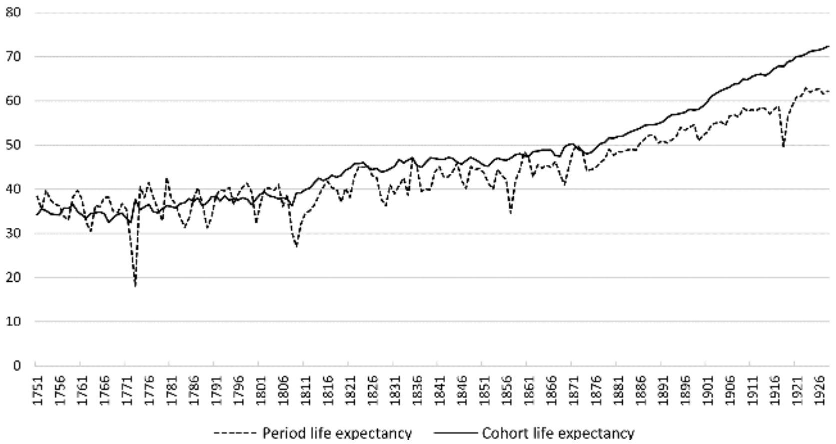

Figure 2 Period life expectancy at birth and cohort life expectancy at birth, Sweden, 1751–1928

Source: Human Mortality Database (2012)

the basis of observed age-specific probabilities of death, and, on the other hand, the average realized duration of life, is growing over time. In 1751, cohort and period life expectancy were respectively equal to 34.81 and 37.72, whereas, in 1928, they were equal to 71.78 and 62.25. This suggests that the accuracy of period life expectancy figures as proxies for actual average durations of life – which is perfect in periods of stationary survival conditions – should not be overestimated. Actually, the observed trend in period life expectancy gives us a qualitative clue regarding the future patterns of the average duration of life, rather than an exact magnitude of the lengthening of life that will take place in the twenty-first century.

2.3 Survival Curves and Rectangularization

In addition to the use of life expectancy statistics, another way to measure the fall of mortality consists of using survival curves. Period survival curves give us the proportion of a cohort that reaches each age of life, conditional on the age-specific probabilities of death prevailing during that year. Such a focus on the probabilities to reach the different ages of life allows us to go beyond the mere analysis of the average duration of life.

As shown in Figure 3 with the example of England and Wales, survival curves have moved substantially during the last two centuries. Two distinct movements have taken place. First, survival curves tended to shift upwards, implying that an increasingly large proportion of the population can reach a high age. This movement is known as the rectangularization of the survival

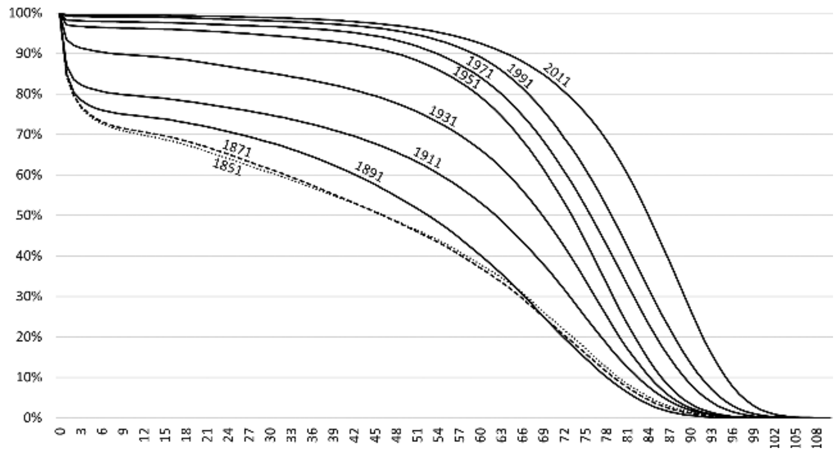

Figure 3 Survival curves (period), total population, England and Wales (1851–2011)

Source: OurWorldinData.org

curve. In the hypothetical case of a perfectly rectangular survival curve, there would be no risk about the duration of life, since all individuals would die at the same age.

Accordingly, in that hypothetical case, there would be no inequality in terms of realized longevity. The second movement of the survival curve consists of a shift to the right, implying that the duration of life lived by the long-lived is increasing over time. This second movement can be regarded as a kind of increase in the limit longevity. That second movement has also been at work in the last few centuries. Note that this shift to the right is distinct from the shift upwards, since this does not necessarily imply a reduction in longevity risk. Although the two movements have been at work during the last two centuries, the rectangularization has been the dominant movement during the nineteenth century, and during the largest part of the twentieth century, whereas the rise in the limit longevity has been dominant in the last thirty years.

One important thing that we learn from Figure 3 concerns the size and extent of longevity inequalities. The survival curves for 1851–1911 show that child mortality was a widespread phenomenon in those times, whose size has strongly decreased during the twentieth century. But even if we concentrate on the survival curves for 1951–2011, we see that the proportion of individuals reaching, let us say, the age of sixty has reatgly increased. That decreasing trend in inequality is unambiguously good news. Note, however, that those figures can be interpreted in a less optimistic way. The 2011 survival curve tells us that, on the basis of the survival conditions prevailing in 2011, there is still

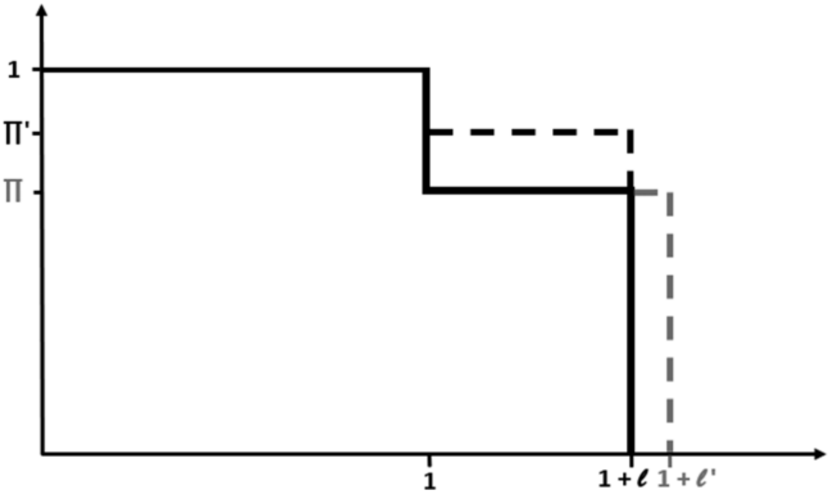

Figure 4 Survival curve in a two-period model

a not negligible proportion of individuals who will be dead before reaching the age of sixty, suggesting that longevity inequalities remain substantial even now.

In the following sections, we will use a simple representation of the survival curve. The setting we adopt is one of a two-period life cycle. The first (active) period has a unitary length and the second (retirement) period has a length of $l < 1$. This second period is uncertain with a survival probability π. In such a setting life expectancy is equal to $1 + \pi l$. Life expectancy can be increased through an increase of either the lifetime horizon $1+l$ or the survival probability π. An increase in π leads to a more rectangular survival curve. Rectangularization would be complete with $\pi = 1$. In Figure 4, the increase in l and that in π lead to the same longevity but to a different shape of the survival curve. In other words: $1 + \pi l' = 1 + \pi' l$.

2.4 Longevity Differentials Across Individuals

Although longevity disparities across countries have been falling over time, there remain, nonetheless, significant longevity differentials across individuals. Longevity differs across persons because of differences in a range of characteristics, including gender, ethnicity, and educational background. To illustrate this, let us first look at the evolution of life expectancy at birth for males and females in Sweden. As shown in Figure 5, over the three centuries under consideration, women exhibited a higher life expectancy than did men. The gender

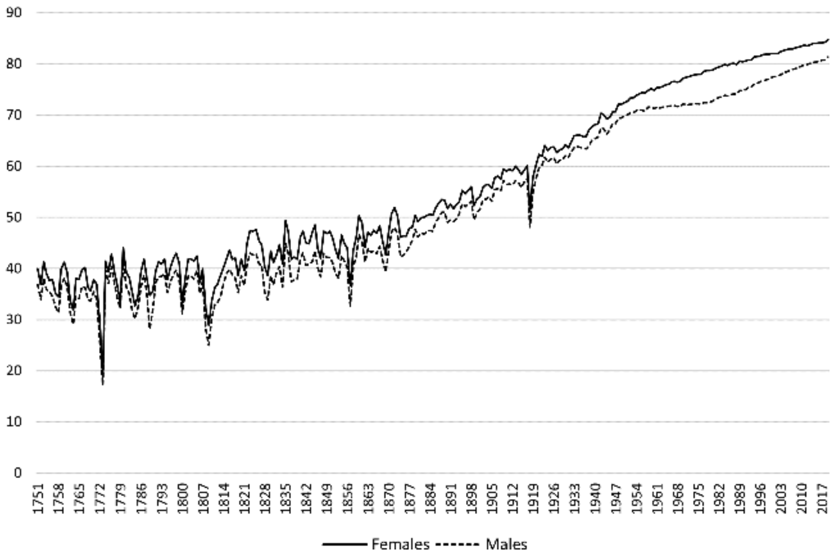

Figure 5 Life expectancy at birth (period) for females and males, Sweden (1751–2019)

Source: Human Mortality Database (2012)

gap increased between 1950 and 1980. Then it decreased during the last thirty years. It was equal to six years in 1980 and dropped below four years in 2019.

Besides gender, another important characteristic that is correlated with longevity inequalities is ethnicity. This point was highlighted by Sen (1998), who argued that the life expectancy of black males in poor US neighborhoods was in some cases lower than the one prevailing in developing countries. A recent study by Arias (2014) shows that, for the USA, the white/black gap in life expectancy at birth is equal to 3.5 years for women and to 5.3 years for men. When considering life expectancy at age sixty-five, longevity differentials remain, although their sizes are smaller. Black females' life expectancy at age sixty-five remains one year smaller than that of white females, whereas for males the gap is about two years.

Another important source of longevity inequality lies in educational background. In a study using US data, Hendi (2017) shows that among non-Hispanic whites, the life expectancy at age twenty-five was, in 2009, twelve years lower for men with low educational background than for men with a bachelor's degree. For females, the education gap is barely smaller: it is equal to 11.7 years. Among non-Hispanic blacks, these gaps are even larger. They are, respectively, equal to 13 and 12.5 years. Education-based inequalities in longevity are growing over time. Life expectancy at age twenty-five has increased quite significantly for highly educated men and women between 1990 and 2009, while it has remained almost stable for low educated men and women with the exception of non-Hispanic black men.

Combining education and ethnicity has led to some somewhat surprising findings over the last decade. Case and Deaton (2020) observe marked differences in mortality by race and education, with mortality among white non-Hispanics (males and females) rising for those without a college degree, and falling for those with a college degree. In contrast, mortality rates among blacks and Hispanics have continued to fall, irrespective of educational attainment.

In sum, these few figures illustrate that, inspite of a substantial improvement in survival conditions on average, there remain significant inequalities in longevity achievements. Those demographic facts raise deep challenges to policy-makers: how can public policy adapt to the increase in average longevity, while providing more redistribution towards those unlucky short-lived people?

2.5 Healthy Life Expectancy

Life expectancy at birth is still increasing in most countries, thanks mainly to lower mortality at advanced ages. But are the years gained spent in good health, or with disabilities and in a state of dependence? This question is important not only for the organization of healthcare and long-term care services, but also for social and economic reasons: raising the retirement age unless those concerned are healthy and self-sufficient is questionable. Estimating the number of healthy years that people can expect to live for provides crucial information for policy-makers. In 2004–5, life expectancy without activity limitation was added to the European Union's list of social indicators.

The European Union Statistics on Income and Living Conditions surveys, coordinated by Eurostat, collect health data on the populations of European Union countries via three questions that concern "perceived health," "chronic morbidity," and "activity limitations." Those three types of health expectancy are obtained by matching the frequencies of persons reporting health problems against the life table. Of course, these data are partially driven by the respondents' subjectivity and health may be perceived differently from one country to another; this is an other important factor to be considered in studies of this kind.

Table 2 provides some data for healthy and gross life expectancy for a number of countries. While European women have a much longer life expectancy than men, their healthy life expectancy is very similar. One exception is Iceland where healthy life expectancy of women is lower than that of men.