Chapter 1
How Populations Age
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Introduction

In this chapter, I explain how changes in birth, death and migration act to change the age structure of populations. We will see how population aging is an inevitable part of the transition to lower rates of population growth that follow the demographic transition from high fertility and high mortality to low fertility and low mortality.

Contemporary populations vary tremendously in their age structure. In low fertility, low mortality populations like Japan there is 1 child under age ten for every person in their seventies. In a country like Pakistan, with a history of high fertility and where not so many survive to old ages, there are 10 children for every person in their seventies.

These numbers play out in everyday life. The classic street scene in either an historical or contemporary high fertility society is full of children, playing and working (Livi Bacci 2001). The elderly are few. The turnover of the population is rapid, with newcomers holding a large share of the slots in a society and with places of power opening relatively rapidly (Keyfitz 1973).

The age structure of a population also has important economic consequences (Lee 1994). Childhood is a time of learning, consumption and economic dependence. Much of adulthood is a time of production, savings and economic independence. In old age, adults often become net consumers once again, living off any accumulated savings as well as transfers from younger generations. Changes in age structure are an important force — although not the only one — that drives the shares of the population that are net consumers and net producers.

Both populations that are very young and very old have high “dependency” burdens, with a relatively small portion of the population in active working ages. Around the world, governments are concerned as they face the prospect of population aging and the challenges of supporting a population that is potentially more dependent. The challenges of aging also play out at a more personal level: the age structure of families will on average reflect the age composition of the population. As families age, more and more demands may be placed on the shoulders of fewer potential caregivers.

The goals of this chapter are first to give an overview of how demographers measure population age structure and aging and how such measures vary around the world. Secondly, the chapter shows how patterns of demographic rates — in births, deaths and migration — determine the age structure of a population. Finally, I discuss some ways that societies can adapt to population aging by shifting the definitions of who is elderly and who is young.

Measuring Population Aging

At any moment in time, a population’s age structure can be described by the numbers of people at each given age. Typical census tabulation groups the population into 5 (or 10) year age groups. These numbers are illustrated using a population pyramid, showing the numbers in each age group by sex, with females on the right and males on the left. Figure 1.1 shows some examples of such pyramids for Pakistan, New Zealand and Japan.
using estimates for the year 2000. Pakistan, a country with a long history of high fertility and population growth, has the youngest age structure. New Zealand, with a history of slow population growth and some ups-and-downs in fertility, has a considerably older age structure, which will age further as the baby-boomers move into retirement. Japan, with the highest longevity in the world and several decades of sub-replacement fertility, has an even older population age structure than New Zealand.

The visual comparison of the entire age distribution is a good way to see the full age distribution. For conciseness and to compare across populations easily, demographers use a set of single-numbers to summarize this age distribution. These include generic statistical measures like the mean, median and mode, as well as ratios of age groups. Also, the proportion of the population that is elderly (e.g., >65) is often used.1

The mean age is simply the average age of people in the population. The median age is the age that divides the population into two equal halves. The modal age is the age with the largest number of individuals. Each of these measures has advantages and disadvantages. The mean age is easy to understand but because age distributions are not symmetric — tends to differ considerably from the age of most individuals in the population. An advantage of the median is that exact ages of all of the individuals are not needed. In particular, an open oldest age interval (say 75+) poses no obstacle for calculating the median but forces assumptions to be made about the distribution of people in this oldest age group in order to calculate the mean. In growing populations the modal age tends to zero and so is not very useful for differentiation. However, the mode is a revealing measure for distinguishing different shrinking populations.

In addition to these summary measures, demographers are often interested in measures that capture the differing characteristic of people by age. "Dependency ratios" are the most popular way of doing this. "Active" and "dependent" ages are defined, with the young and old defined as "dependent" – the United Nations counts those under 15 as "young" and those over 65 as "old" – and those in the middle are the "active". The ratio of "old" to "active" population age groups is the old-age dependency ratio.

The old-age dependency ratios for Pakistan, New Zealand and Japan in 2000 were 7/100, 18/100 and 25/100 elderly per person of working age. Alternatively, we can look at the reciprocal, saying that there are 14 "workers" per "retiree" in Pakistan; compared to less than 6 in New Zealand and only 4 in Japan. These are the kinds of numbers that tend to scare fiscal planners. By 2050, it is forecast that there will only be 1.35 workers per retiree in Japan (an old-age dependency ratio of 74/100).

1 See Chu (1997) for a critical view of measures of aging involving the simple proportion over a given age.
One advantage of the dependency ratios is that they have an interpretation in terms of transfer rates and tax rates. While it is hard to have intuition about the implications of a year's difference in mean age, a change in the old age dependency ratio can sometimes be easier to understand. In a pay-as-you-go pension system, the tax rate is proportional to the ratio of pension receivers (the elderly) to tax payers (the workers). Thus, all other things being equal, the change in old-age dependency ratios in Japan from 25/100 in 2000 to 74/100 in 2050 implies a near tripling of the pension tax burden.

Despite their ease of calculation and interpretation, dependency ratios should be treated with some skepticism. While age and dependency are clearly related concepts, they are not the same thing. The young can be relatively more or less independent. Those of working age can be working or not. And the elderly can be more or less productive and more or less consuming. In fact, the definition of dependency ratios suggests a solution to problems associated with population aging. Changing the social and economic definitions of young and old and increasing the number working by increasing labor force participation of women, the old, and the under-employed — these are exactly the kind of solutions that aging societies are seeking (Vaupel and Loichinger 2006). In addition, increasing productivity can counterbalance rising dependency ratios, by increasing the output of each worker. We will return to these issues in the final section of this chapter.

An Overview of Population Aging

The world as a whole has not yet aged dramatically. From 1950 to 2000, the median age of the world population rose only from 23.9 to 26.7 years. But in the decades ahead, populations will age significantly: by 2050, the median age is forecast to be 38.1.

In the industrial world, the small number of births during the Great Depression followed by the rise in births after World War II created decades in which there were relatively few elderly and many workers. This is set to change quite quickly in the decade-or-so ahead as the large post-war cohorts are entering retirement. In the longer term, populations will age further as the small birth cohorts of the 1970s enter their working years.

In the developing world, the decline in fertility seen in almost every part of the world except Sub-Saharan Africa and parts of the Middle East will eventually lead to population aging. In addition, throughout the world — with the exception again of Sub-Saharan Africa — increasing longevity will further population aging. The dramatic change that is to be expected is well-illustrated in maps produced by the U.S. Census Bureau. The two panels in Fig. 1.2 show the percentage of the population over age 65 around the world. In 2000, the club of the oldest population is exclusively European and Japanese. But by 2030, this group will joined by Russia, China,
Canada, the United States, Brazil, Argentina, Chile and Australia, among others. The only countries of the world that will avoid significant aging in the next few decades are found in Sub-Saharan Africa and parts of the Middle East.

**Short-run Influences on Population Aging**

Populations change over time. Arrivals come in the form of births and immigrants. Departures go in the form of deaths and emigrants. Understanding how such changes influence population age structure in the short-term is straightforward. If the population has a mean age \( \bar{A} \), then any arrivals that occur before this mean age will make the population younger and any arrivals that occur after this mean age will make the population older. Departures do the same thing in reverse.

Additional births will always make a population younger. Since births arrive at age zero, they will always be less than the mean age of the population.

Additional deaths have an ambiguous effect, depending on the age at which they occur. Deaths of the young, for example infant mortality, make the population older. While deaths of the old make a population younger. Historical mortality decline has largely consisted in saving the lives of the young and so over the last century or two, mortality decline has – contrary to conventional wisdom – made populations younger. More recently, however, there have been substantial increases in adult survival, making mortality decline a contributor to population aging.

Migration occurs at all ages but is concentrated in the early adult years, usually less than the mean age of the population. Thus, in the short-term immigration tends to make populations younger.

Preston et al. (1989) formalized these ideas. They showed that the rate of change in the mean age of the population \( \bar{A} \) is

\[
\frac{d}{dt} \bar{A}(t) = 1 - b(\bar{A} - 0) - d(\bar{A} - \bar{A}) - i(\bar{A} - \bar{A}) - o(\bar{A} - \bar{A}),
\]

where \( b, d, i \) and \( o \) are respectively the crude rates of birth, death, in-migration and out-migration and the subscripts on \( \bar{A} \) refer to the respective mean ages.

The intuition of this expression is that a population with no births, no deaths and no migrants will simply age like an individual, at a rate of 1 year of age per year of time. Births will counteract this force, with the contribution of each birth being greater, the older the population is. Deaths can make the population older or younger, depending on whether the average age at death is greater than or less than the mean age of the population, and immigrants act in the same way.

The important lesson is that in the absence of entrances and exits, a population ages just like an individual, getting one year older for each year of time that passes. Entrances of the young rejuvenate a population, as do exits of the old. In this sense, population dynamics are like a group of people riding an escalator. If no one new steps on to the escalator, the group of passengers will rise higher. Increasing the rate of entrances will shift the group lower. Extending the length of the escalator will let the group rise higher.

**Long-term Influences on Population Aging**

The immediate effects of a new arrival or departure are easy to understand. Over time, however, each new arrival eventually gets older. Additionally, each new arrival has the potential to generate more new arrivals in the form of births. To understand the longer term effects we must think not only of stocks (the current age structure) and flows (new arrivals or departures) but also about the evolution of the population over time.

The main tool used by demographers to understand long-term population dynamics are models of “stable populations”. A stable population experiences unchanging age-schedules of fertility and mortality and has no in- or out-migration. The remarkable property of a population subject to fixed age-specific fertility and mortality rates is that its age structure will converge over time to a unique stable age structure. The stable population may change in absolute size but, eventually, the proportions of people at each age group do not change. We can describe the stable age structure in a mathematical formula for \( c(x) \) the proportion of the population aged \( x \).
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where \( r \) is the growth rate of the population, \( l(x) \) is the proportion surviving from birth to age \( x \) and \( b \) is the birth rate of the stable population.\(^3\) To understand this formula, take a simple example of a growing population in which everyone survives to some age. In this case, the number of people of a given age \( x \) will equal the number born \( x \) years ago. Thus, moving up the age pyramid will reduce the fraction of the population at the same rate \( r \) at which the birth cohorts have grown. The \( l(x) \) term generalizes this for an arbitrary pattern of survival by age. The \( b \) term simply converts the relative numbers to proportions.

Some mathematics is required to prove that the stable age structure is determined only by the rates of fertility and mortality and is uninfluenced by the historical age structure of a population (Sharpe and Lotka 1911). Intuitively, however, this property of forgetting past age structures is not hard to understand. What happens is that peaks and troughs in the history of a population are smoothed out with each successive generation, because births and deaths happen to different people at a range of ages (Arthur 1982). Thus, an unusual feature like the 1967 year of the “fire horse” in Japan in which fewer children were born, shows up at first as a notch in the age structure. When this notch is echoed a generation later, it is not so sharply defined, because the notch babies do not themselves decide to have children all at the same time. The “echo” of the notch is thus a more gentle dip. A generation later, the dip is even smoother and the age structure continues to smooth until all traces of the initial feature are lost.

Stable populations are fictions but convenient ones. They are easy to analyze mathematically and often bear a reasonable resemblance to real population age structures. The logic of the stable age structure applies to any population that has seen fairly steady growth or decline in the number of births and more-or-less constant mortality patterns.

There are three qualitatively different shapes of stable age pyramids (see Fig. 1.3). In a rapidly growing population, the age pyramid will be shaped rather like the silhouette of a pine tree, a wide base exponentially shrinking as one moves up the age pyramid to earlier birth cohorts. In a stationary population, the shape will be roughly like a hay stack, with relatively constant numbers up to age 50 or so, when mortality starts to have a large effect. In a shrinking population, the pyramid will have a bulging “barrel” or “cobra-head” shape, in which the size of age groups grow as we move back in time and up the age pyramid until about age 50 or so when mortality starts to shrink the age groups in size once again.

The three stylized shapes are shown in Fig. 1.3 and by flipping to the page back the reader can see that Pakistan, New Zealand and Japan have a rough correspondence with these three stylized shapes. The stable population model is also useful for what it reveals about departures from the stylized stable age structure. For example, we can see that the base of the age pyramid in Pakistan does not grow as quickly from below age 20 as it does from ages 20 to 40, corresponding to an observable decline in fertility in recent decades. In New Zealand we see the baby boom and its echo. In Japan we see the dramatic decline in fertility after World War II and the echo of this decline in recent decades.

The Influence of Mortality and Fertility on Stable Age Structures

One use of stable population theory is to provide an understanding of the role that mortality and fertility play in determining a stable age structure. Using mathematics, we can answer a question like what drives the

\[ c(x) = bl(x)e^{-rx} \]  

Fig. 1.3 Illustrative shapes of stable age pyramids in growing, stationary and shrinking stable populations. Compare with observed aged pyramids in Fig. 1.1. \( r \) is the growth rate of the stable population.

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\(^3\) This formula follows from a population experiencing exponentially growing (or shrinking) counts of births. Let \( N(x) \) denote the number of persons aged \( x \). If \( B \) people were born this year, then \( Be^{-rt} \) were born \( x \) years ago, of which a fraction \( l(x) \) survives. Thus \( N(x) = Be^{-rt}l(x) \). Dividing both sides by the total population gives the equation above.
differences in age structure seen between real populations: fertility or mortality?

The impact of fertility level on age structure can be seen by comparing two populations with the same survival schedule \( l(x) \) but different growth rates \( r \) and \( r^* \). A simple way to do this is to look at the proportional change in the fractions at each age per unit change in \( r \) (Lotka 1939; Keyfitz 1985). Differentiating \( \log c(x) \) with respect to \( r \), one obtains

\[
\frac{d \log c(x)}{dr} = A_p - x
\]  

This tells us that an increase in the growth rate will cause young age groups to increase in relative size and old age groups to shrink in relative size, pivoting around the mean age (Preston et al. 2001).

We can also use stable population theory to assess the change in the mean age caused by a change in the growth rate. By differentiating the mean with respect to the growth rate we obtain

\[
\frac{dA_p}{dr} = -\sigma^2
\]

where \( \sigma^2 \) is the variance in the stable age distribution.\(^4\)

Typical values of the variance range from about 300 in rapidly growing populations to about 500 in roughly stationary populations (Keyfitz and Flieger 1968). Thus, older populations are themselves more susceptible to aging.

To illustrate, we take the case of a rapidly growing population, Honduras circa 1965, when the implied stable population had a mean age of 21.6 years. We can ask how much older this mean age would be in the stationary population with the same mortality — that is, if the stable growth rate were zero rather than the observed value of 3.4 per cent. The variance of the population is about 400.\(^5\) This implies a change of

\[
(0.034)(400) = 13.6 \text{ years}, \text{ from a mean age of 21.6 to a mean age of 35.2 years, close to the exact value of 35.9 years.}
\]

The analysis of mortality changes can be more complicated than changes in fertility, depending on the ages at which deaths occur. Take a simple case, with the same number of births every year and everyone dying at the same age. Here, the mean age of the population will be equal to half the length of life. Increasing longevity by 1 year will increase the mean age of the population by half a year. In more realistic examples, mortality changes occur across many ages. In general, mortality declines at older ages will make the population older but by less than the simple case above. Declines at younger ages will make the population younger.

Figure 1.4 summarizes the relationships between fertility, mortality and the mean age of the stable population. The contour lines show the combinations of fertility and mortality that produce the same mean ages. To see the effect of mortality change, holding fertility constant, move horizontally. To see the effect of fertility change, holding mortality constant, move vertically. The effect of lowering fertility is always to make the population older, no matter what the level of mortality. The tendency for improvements in survival to make populations younger, when mortality is high, can be seen. For example, at a TFR of 4, the mean age falls from 28 to about 26 as life expectancy increases from 40 to 65. Once life expectancy reaches about 65, however, further mortality decline makes populations older. Finally, we see that at lower fertility levels, the contours are spaced much more closely together, showing that a small change in fertility or mortality can have large effects on the population age structure.

The paths of India from 1900 to 2050 and Sweden from 1800 to 2050 are shown on the contour plot. We see in both cases a demographic transition making the population younger in its early stages but then followed by considerable aging. Developing countries making the transition in recent decades have considerably younger populations than populations in the historical transitions. However, the age structure at the end of the transition is similar, because the forecasts expect there to be similar demographic rates and all traces of the past age structure are lost as the population evolves over time.

\(^4\) For a related result, see Keyfitz (1985). To derive, differentiate the expression for the mean age of the stable population, recognizing that the variance is the difference between the mean square and square of the mean.

\(^5\) This is the average of the variances of the stable and stationary populations.
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Population Aging Over the Course of a Demographic Transition

Having considered how demographic rates influence age structure in the short- and long-term, we are now ready to look at the dynamics of populations that undergo changing demographic rates. Specifically, we look at the demographic transition from high to low mortality and from high to low fertility.

To motivate our discussion we will consider the case of Vietnam, a country that is going through a rapid demographic transition. We see in the accompanying Fig. 1.5, which shows the female population of Vietnam plotted for the years 1950–2075. In the first panel from 1950 we see the age structure created by the near zero growth history of Vietnam of the first half of the 20th century, when high mortality offset high fertility. Only in the unusually large youngest age group can we see the signs of impending demographic change – in this case, likely to be an increase in infant survival.

A generation later in 1975 we see that Vietnam had entered a time of rapid population growth. The number of surviving infants has more than doubled in only a generations time and the age pyramid has a mixed form: above age 25 or so, the population has the form of a stationary population and below age 25 it has the form of a rapidly growing population. The result is an extremely young population.

By 2000, the population is still young but fertility decline has begun in earnest, apparently around 1990. The population is still growing, especially in the adult ages but aging has begun.

By 2025 the age structure looks like the stationary form we saw for New Zealand.

The UN forecasts assume that fertility will continue to fall to below – replacement levels. The result can be seen in 2050, where each new birth cohort is smaller than the last. The only trace of the high growth years is the large numbers over age 55, the last cohorts born before fertility decline began in earnest. Finally, by 2075, the age pyramid has assumed a
Fig. 1.5  The changing age structure of Vietnam over the course of the demographic transition, females only
Source: United Nations (2006) and author's projection. (Females only)
nearly stable profile. The Vietnamese population has completed the demographic transition and has aged. (The forecasts here assume constant rates after 2050. Most would predict continued change, with further increases in longevity.)

From the point of view of age structure, we see that the population is at its youngest around 1975 and its oldest after about 2050. The dependency ratio (including children) is most advantageous from about 2010 to about 2030, the so-called demographic dividend that provides a period in which a large number of workers need only support a small number of young and old dependents, allowing increased savings and investment (Bloom et al. 2003). All of this change will occur within the lifetime of Vietnamese born today.

The total dependency ratio, the sum of old-age and youth-dependency ratios, is about the same before and after the demographic transition. But whereas in 1950 the young made up virtually all dependents, by 2050 the old outnumber the young. The total dependency ratio can be misleading in terms of monetary costs, since the elderly can consume much, much more than the young, particularly if health costs are high.

What is notable about the changing demography of Vietnam is that after about 2000 there will be a time of relatively low dependency but that this will last only a few decades before aging raises new challenges. Furthermore, because of the bulge created by the quick shift from high to low fertility, the demographic dividend and the elderly bulge are both larger than they will be in slower transitioning countries (Li and Tuljapurkar 2005).

The transition seen by Vietnam is similar to many but not all, developing countries. As we saw, most of the world’s national populations will age in the next several decades. An exception is Sub-Saharan Africa, where fertility is not yet falling quickly and the impact of AIDS creates mortality-driven population dynamics. AIDS mortality can create a “chimney”-like age structure, in which the population from 0 to age 30 or so resembles the barrel-shape age structure of stationary populations but then a long narrow column of survivors continues to older ages. In such populations the mean ages can be very young but since young adult ages are no guarantee of independence in AIDS-stricken populations, the age structure is less important than the proportion of the population that is burdened with disease.

**Migration and Population Aging**

Countries facing population aging often consider increases in immigration. In the short-term, migration can make a population younger or older, depending on the age of new arrivals relative to the average resident. (A migrant aged “zero” has the same effect as a new birth.) But immigrants themselves age. Thus a migrant who joins a population at age 20 and exits a population (either through death or out-migration) at age 80 is, on average, 50 years-old during the time he or she is in the receiving population. This effective age of 50 is likely to be considerably older than the average age of the population, even though the age of entrance is likely to be considerably less than the average age of the population. This is the reason that a steady stream of immigrants almost always makes a population younger in the short-term but older in the long-term, as compared to the age structure in the absence of migrants. See Espenshade et al. (1982) and Schmertmann (1992).

There are several possible exceptions to this: the first is if the average age of the population is so old, perhaps because of low fertility, that its mean age is actually higher than the effective mean age of the migrants (Schmertmann 1992). The second case is if ever-increasing numbers of migrants are added (United Nations 2001; Blanchet 1989). In this case, the effective age of the migrant stream is made younger by weighting the ages soon after arrival, where there are more people. Finally, migration could make a population younger by raising the birth rate of the receiving population. This has historically not been a major factor, since the birth rates of migrants have tended to converge to that of natives after a generation or so but it could happen in the future.

In contrast to the long-term, the short-term effects of migration can be quite rejuvenatory. A classic example of this is Vienna toward the end of the 20th century (Lutz et al. 2003). Vienna had extremely low fertility prior to World War II and relatively few in-migrants after the war. This led to one of the oldest urban populations in the world in the 1970s. By 2000, however, the fall of the Iron Curtain and the influx of young from the Austrian countryside actually made Vienna younger than it was a generation earlier – despite not a single year of fertility in which the TFR was above replacement. Forecasts of Vienna’s population predict that aging will return in the future but new influxes of migrants could postpone this.
Adapting to Population Aging

When rapid population growth comes to an end, populations age. This is an inescapable consequence of population arithmetic. The social and economic consequences of aging, however, are open. As people live longer and have fewer children later in life, their own life cycle changes in many ways. Some of these changes counteract the economic effects of population aging.

Take for example, declines in fertility, which free up years of life spent raising children, enabling more women to enter the market workforce. In the United States, for example, the per cent of women over age 16 in the labor force increased from 43 per cent in 1970 to 60 per cent in 1999. (U.S. Department of Labor 2005).

On the other hand, lower fertility and longer life also encourage longer periods of economic youth dependency, mostly because the pay-offs to education increase. In the short-term this is a dilemma, as societies must increase schooling even as the number of tax payers may not increase. But in the longer term, higher education could increase productivity across the life cycle and counteract the effects of a later start to working life.

Increased longevity can also, at least in theory, lead to a greater pool of savings available for capital investment. Because workers expect to be retired for more years, they need larger stocks of capital at the time of retirement (Lee and Goldstein 2003). Increased capital can also be a source of higher productivity.

Longer life in and of itself is not a source of concern as long as the age of elderly inactivity moves together with the length of life. Take a hypothetical stationary population in which everyone starts work at 15, retires at 65 and lives to be 75. Compare that to another population in which work begins at the same age but everyone lives to 85. In the first population, the OADR = 10/50 and in the second, if retirement is still at age 65, it has doubled to 20/50. Adjusting the age at retirement, this can easily be remedied. Increasing retirement proportionally – by 8 years – would keep the dependency ratio unchanged. Increasing the age at retirement by an amount equal to the increase in longevity – 10 years – would actually reduce the Old Age Dependency Ratio to 10/60.

If, on the other hand, longer life is accompanied by longer periods of frailty and disability, population aging will be a considerably larger challenge. Retirement ages would not be able to be increased enough to counterbalance demographic aging. What matters in the long-term is not the ratio of people of different particular ages but rather the ratio of those who are in good health and who are able to be productive and those who are in poorer health and who need assistance. So far, research suggests that healthy life expectancy is keeping pace with increases in longevity (Mathers et al. 2001). But, so far, extensions in work life have not matched the increase in healthy life expectancy.

The intertwined nature of fertility, longevity, human capital accumulation and productive economic work mean again that simple metrics like population age structure are not going to capture the full social and economic effects of demographic change. One approach for reassessing population aging is to measure the relative age of a population not by how far its members are from birth but rather how many years separate them from death (Ryder 1975). According to this way of thinking, a population that, on average, has many years to live is for all practical purposes “younger” than a population that has fewer years to live. Sanderson and Scherbov (2005) showed that some “aging” populations will actually become younger in the coming decades – if the years until death are a measure of youthfulness.

Figure 1.6 shows a contour plot of average remaining life expectancy (E) of stable populations by different levels of fertility and mortality. The contours show that higher fertility and higher longevity both make populations younger in the sense that the average remaining life expectancy increases. Over the course of the demographic transition, E increases from the mid-20s to about 40 but this rise is not steady. Most of this change occurs as mortality falls early in the transition, because the population age structure gets younger at the same time that longevity is increasing. In the middle of the transition – when fertility is falling – the average remaining life expectancy falls again, because the age structure shifts to older ages faster than life expectancy at these ages rises. As fertility declines slow, then mortality decline again dominates and E begins to increase once more.

The trade-offs between fertility and mortality that keep the average remaining life expectancy constant can be seen in the slope of the contour lines at any given point. For example, the contour line in a stable
population with a TFR of 2 and life expectancy at birth of 80 has a slope of about 1/20. This means that a one-tenth of a child fall in the TFR can be offset by a 2-year increase in life expectancy at birth. The lower the fertility, the bigger the increase in life expectancy is needed to offset further fertility declines.

As an economic problem, aging from mortality decline is fundamentally different from aging due to fertility decline (Lee 2003). Both increase the proportion of the elderly and the average age of the population but mortality decline is accompanied by the improving health and functional status of the elderly, whereas fertility decline ages the population without a corresponding increase in the ability of individuals to work longer. The kinds of increases in late-life activity that can enable a population to adapt to population aging are possible when mortality declines but a hardship if fertility declines.

Nearly all populations around the world will age in the coming century. The largest and most challenging cause of population aging is due to the fact that the demographic transition is expected to complete its course throughout the developing world, and a new regime of near or sub-replacement fertility will become the norm. Aging will also occur because of increased longevity but this can be adapted to, in large part by increasing the length of economically active lives.

References