Chapter 12

New Approaches to the Conceptualization and Measurement of Age and Ageing

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12.1 Introduction

People's views on population ageing are influenced by the statistics that they read about it. The statistical measures in common use today were first developed around a century ago, in a very different demographic environment. For around two decades, we have been studying population ageing and have been arguing that its conventional portrayal is misleading. In this chapter, we summarize some of that research, which provides an alternative picture of population ageing, one that is more appropriate for twenty-first century. More details about our new view of population ageing can be found in. (Sanderson and Scherbov 2019). Population ageing can be measured in different ways. An example of this can found in the UN's *Profiles in Ageing, 2017*. One way is to report on the forecasted increase in the number of people 60+ years old in the world.

According to data from World Population Prospects: the 2017 Revision, the number of older persons—those aged 60 years or over—is expected to more than double by 2050 and to more than triple by 2100, rising from 962 million globally in 2017 to 2.1 billion in 2050 and 3.1 billion in 2100. Globally, population aged 60 or over is growing faster than all younger age groups. (United Nations [n.d.](#))

A second way, also discussed in that report, is based on our research.

In this chapter we discuss the two ways of measuring population ageing. Conventional measures of population ageing consider people old at a fixed chronological age without regarding how healthy they are and how they function. Our measures of population ageing (Sanderson and Scherbov 2005, 2007, 2008, 2010, 2013,

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S. Mazzuco, N. Keilman (eds.), *Developments in Demographic Forecasting*,
The Springer Series on Demographic Methods and Population Analysis 49,
https://doi.org/10.1007/978-3-030-42472-5_12

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2014) consider people old based on their characteristics, which can differ over time, space, and across subgroups. We will show that the choice of measures to assess population ageing makes a substantial difference, one that could potentially affect the assessment of policies with respect to population ageing.

Before we begin a discussion of population ageing, we must first define what population ageing is. There are several definitions of ageing at the population level. In the *UN report on World Population Ageing: 1950–2050* (United Nations 2002) population ageing is defined as “the process by which older individuals become a proportionally larger share of the total population”. The *Encyclopedia of Population* (Demeny and McNicoll 2003) defines ageing of population as “a summary term for shifts in the age distribution (i.e., age structure) of a population toward older ages”. Population ageing is often measured “by increases in the percentage of elderly people of retirement ages” and “The median age – the age at which exactly half the population is older and another half is younger – is perhaps the most widely used indicator” (Demeny and McNicoll 2003). Since the study of population ageing is often driven by a concern over the sustainability of pension systems, the old age dependency ratio (the number of individuals of retirement ages compared to the number of those of working ages) is also frequently used as a measure of population ageing.

Our view of population ageing is broader than this. It is based not only the chronological ages of people, but on their characteristics as well. So the first step in specifying our new measures of population ageing is to define who is elderly based on population-level characteristics.

Conventionally, the elderly are defined as those above age 60- or 65-years-old. This boundary or *old-age threshold* is, then, kept fixed. In 1916 an American sociologist Isaac Rubinow (1913, 14) defined age 65 as an old age threshold

Age 65 is generally set as the threshold of old age since it is at this period of life that the rates for sickness and death begin to show a marked increase over those of the earlier years.

More than 100 years have passed since this definition of old-age threshold was introduced. People live much longer now and in many developed countries life expectancy at age 65 increased by around 10 years since Rubinow suggested his old-age threshold. Not only people live longer, but they are also healthier, stronger physically and cognitively perform better. However, in the conventional statistics of population ageing, people as old as age 65 and sometimes even 60 are classified as being old.

12.2 Characteristic Approach to the Measurement of Population Ageing

Conventional measures of ageing consider people being old at a fixed chronological age, usually at age 65. They do not distinguish where or when people lived. When conventional measures of ageing are applied, the old age threshold for a person

living in a region with low life expectancy, say Burkina Faso, is the same as for a person living in Japan or other places with high life expectancy. Moreover, a 65-year-old person living today will be considered as old as a person of the same age who was living 100 years ago or who will be living 100 years from now. Conventional measures of ageing recognize only one characteristic of people – chronological age. But ageing is a multidimensional phenomenon and chronological age is only one of its relevant dimensions. Other characteristics of people such as physical and mental health are ignored in conventional measures of ageing.

Sanderson and Scherbov (2013) developed what they called the *characteristics approach* to the measurement of population ageing. This approach considers people old depending not only on their chronological age, but on other characteristics, such as health, physical strength, and cognitive abilities. When those characteristics change in time and space, the threshold of old-age becomes dynamic.

Using the terminology in Sanderson and Scherbov (2014), we call the ages that correspond to different characteristics of people “ α -ages.” To define α -ages, we begin with $C_t(\alpha)$, a schedule of some characteristic relevant to the study of population ageing (such as mortality hazard or remaining life expectancy), that defines the values of the characteristic at each chronological age α at a time or place denoted by t . We call these relationships “characteristic schedules”. Generally, characteristic schedules change over time and are different from place to place. If $C_t(\alpha)$ is continuous and monotonic in α , it can be inverted to obtain the schedule of chronological ages associated with each value of the characteristic at time or place t .

α -ages can be calculated from the inverse of the characteristic schedules. For example, $\alpha_{\kappa, t} = C_t^{-1}(\kappa_t)$ is the α -age associated with the characteristic level κ_t in situation t .

In the simplest case the level of the characteristic does not change over time, so that κ has no t subscript. For example, if the time-invariant characteristic was a remaining life expectancy of 15 years, the α -age, the age at which that remaining life expectancy was attained for Germans (average of both sexes) in 2017 was 71 years. We call the α -ages based on invariant characteristics *constant characteristic ages*.

Different characteristics may be used to define thresholds reflecting different features of population ageing. To our knowledge, (Ryder 1975) was the first to do this. Ryder’s old-age threshold was based on remaining life expectancy. A health-based characteristic could be also used to mark the entrance to old age. Health is a complex quality, but a rough and readily accessible measure of it is the corresponding age-specific mortality rate. In this case, α -ages based on the life-table mortality rate m_x would provide ages of comparable population health across space and time (Cutler et al. 2007; Vaupel 2010; Fuchs 1984) and could also be used to define an old-age threshold.

When the characteristic under consideration is remaining life expectancy, we have a special term for α -ages. We call them *prospective ages* and measures derived from prospective ages are called prospective measures of ageing. For example, if we derive the old age threshold based on a constant remaining life expectancy, we call this the prospective old age threshold (POAT). Based on the prospective old age threshold, we have produced several prospective measures of population ageing.

Usually we define the prospective old age threshold as age that corresponds to a remaining life expectancy of 15 years (Sanderson and Scherbov 2010, 2013). In the 1970–1980s that was the level of the remaining life expectancy at age 65 in many countries with high life expectancies. Once the prospective old age threshold is defined, the prospective old age dependency ratio (POADR) and prospective proportion old (PPO) could be derived as well:

$$\text{POADR} = \frac{\text{Number of people older than the POAT}}{\text{Number of people ages 20 to the POAT}}$$

$$\text{PPO} = \frac{\text{Number of people older than the POAT}}{\text{Total number of people}}$$

The POADR appears on the UN website, *Profiles in Ageing, 2017*, for all UN countries and for the years 1980, 2015, 2030, and 2050. (<https://population.un.org/ProfilesOfAgeing2017/index.html>). The comparison between the conventional old-age dependency ratio and the prospective one on that website provides a simple way to assess the quantitative implications of the different approaches to the measurement of population ageing.

The prospective measure analogous to the median age is the prospective median age. In this case the population characteristic – remaining life expectancy – is not constant. To calculate prospective median age, we select a standard year. The prospective median age is the age in the standard year when the level of characteristic – remaining life expectancy at the median age – is the same as it is in the year of interest. Put differently, the prospective median age can be derived as $pma_{t,s} = C_s^{-1}(\kappa_t)$, where $pma_{t,s}$ is the prospective median age in year t , using the characteristic schedule of year s as a standard and κ_t is the median age of the population in year t .

We illustrate the notions introduced above with a country specific example. Figure 12.1 illustrates the concept of prospective age with data for Spanish females. Each line in this graph corresponds to constant remaining life expectancy and, therefore, a constant prospective age. For example, the line marked as 70, shows the age (y axis) when remaining life expectancy was the same as for a 70-year-old female in the year 2010. We read from this chart, that a 70-year-old person in 2010 had the same remaining life expectancy and prospective age as a 63-year-old woman in 1970. Or if we take a line that corresponds to the prospective age 40 in 2010, we can see that a woman at age 40 in 2010 had the same prospective age as a 30-year-old woman had around 1960. This provides a justification for the famous saying that 40 is the new 30.

Three features of Fig. 12.1 stand out. First, in 2010, the vertical distance between the lines is constant. This occurs because of the way in which the Figure is constructed. In 2010, the value along each line is assumed to be at the age indicated for that line. The second noteworthy feature is that the lines are roughly parallel. If no one died at ages below 80, then the lines would be perfectly parallel. The lines are roughly parallel because after age 30 most deaths do occur at advanced

Fig. 12.1 Prospective ages for Spanish females. Each line indicates prospective age that corresponds to remaining life expectancy in 2000 for a particular age. Remaining life expectancy is constant along each line. (Source: United Nations 2017)

ages. Finally, the lines are also roughly linear. This arises because improvements in mortality conditions in Spain were quite regular. Had there been a morality crisis in the period covered by the Figure, the lines would not have been so linear.

Prospective ages have an analog in economics. They are like the use of constant dollars to compare values from one period to another by taking inflation into account, Prospective age serves an analogous purpose by comparing ages taking the increase in life expectancy into account. Any kind of financial data that can be represented in dollar terms can be converted into constant dollars by using an appropriate price index. Similarly, chronological ages can be converted into prospective ages using appropriate life tables.

Figure 12.2 illustrates the dynamics of the prospective old age threshold for several selected Western European countries. The same selection of countries is applied for Figs. 12.3, 12.4, 12.5, 12.6, 12.7, 12.8 and 12.9. The countries that we have chosen are the Western European countries with the largest population, plus Sweden, which represents the Scandinavian countries. Later in the chapter (see Fig. 12.10), we present data for Western Europe as a whole.

As we can observe from this figure, the prospective old age threshold has increased by about 6–8 years. In 1955 it was around age 63–64 while in 2015 it reached the level of 71–73 years. The increase in the prospective old age threshold is about 0.13 years per calendar year. This is similar to increases in remaining life expectancy around the same ages. This is a relatively recent phenomenon that occurs because most of the increase in life expectancy in low mortality countries comes at the older ages.

In the left panels of Figs. 12.3 and 12.4, we present conventional measures of ageing applying the old age threshold fixed at age 65 for the same countries. In the right pane we present prospective measures that use the prospective old age

Fig. 12.2 Prospective old-age threshold (age when remaining life expectancy = 15 years) for several selected countries of Western Europe for both genders combined, 1955–2015. (Source: authors’ calculations based on United Nations 2017)

Fig. 12.3 Proportion of people 65+ and proportion of people with the remaining life expectancy 15 years or less (selected European countries), 1955–2015. (Source: authors’ calculations based on United Nations 2017)

threshold presented in Fig. 12.2. While conventional measures indicate that there was a considerable population ageing in the past 60 years, prospective measures, in contrast, show that there was little or none.

Fig. 12.4 Old-age dependency ratio and prospective old-age dependency ratio (selected European countries), 1955–2015. (Source: authors’ calculations based on United Nations 2017)

Fig. 12.5 Median age and prospective median age (selected European countries), 1955–2015. (Source: authors’ calculations based on United Nations 2017)

In Fig. 12.5 we observe that while traditional median age increased by about 10 years in the recent 60 years in our group of Western European countries, its prospective analog virtually stayed constant.

As we have shown above it makes a substantial difference what type of measure we use to assess past population ageing. If we use conventional measures of

ageing where only fixed chronological age defines the old age threshold then we observe that in the recent 60 years considerable population ageing occurred. Using examples of several Western European countries we showed that the proportion of old people and old age dependency ratios almost doubled during that time. Also, during the same period the median ages increased by almost 10 years. However, using measures of ageing that incorporate characteristics of people a very different picture of ageing is observed. According to all three prospective measures there was virtually no population ageing in our selected Western European countries. Moreover, in some cases we can even observe that populations as a whole became somewhat younger.

12.3 Future Ageing

Using forecasts in the 2017 Revision of World Population Prospects (UN 2017) it is possible to study how population ageing may develop in the future. Here we again consider two types of ageing measures – conventional and prospective ones. As was described above, to calculate prospective measures of ageing we need first to compute the POAT, the age at which forecasted remaining life expectancy is 15 years.

Figure 12.6 shows the dynamic of the POAT for the 6 selected Western European countries. By the end of the century the POAT in the 6 Western European approaches age 80.

Fig. 12.6 Prospective old age threshold (age when remaining life expectancy = 15 years) for several selected countries of Western Europe for both genders combined, 2015–2100. (Source: authors' calculations based on United Nations 2017)

Fig. 12.7 Proportion of people 65+ and proportion of people with the remaining life expectancy 15 years or less (selected European countries), projections, 2015–2100. (Source: authors’ calculations based on United Nations 2017)

Fig. 12.8 Old-age dependency ratio and prospective old-age dependency ratio (selected European countries), projections, 2015–2100. (Source: authors’ calculations based on United Nations 2017)

In Figs. 12.7 and 12.8 we present conventional and prospective measures of ageing projected up to 2100. We see there that both conventional and prospective measures are forecast to increase through the remainder of the century with a bump

Fig. 12.9 Median age and prospective median age ratio (selected European countries), projections, 2015–2100. (Source: authors' calculations based on United Nations 2017)

around the middle of the century for Italy and Spain that reflects specifics of the age composition caused by a rapid fertility decline in the 1980s. However, the share of people above age 65 by the end of the century is forecasted to be about 30%. The prospective proportion old, though reaches only around half that.

The dynamics of the old age dependency ratio is very similar to the dynamics of the proportion old except that by the end of the century the prospective old-age dependency ratios are only around a third of the conventional ones.

Forecasts of conventional and prospective median ages shown in Fig. 12.10. The two measures of population ageing exhibit opposite trends. While the median age increases by the end of the century by about 5–7 years its prospective analog decreases by 3–5 years. These observations indicate that although median-aged people in the 6 populations will be older in 2100 than today, they will also have longer remaining life expectancies than today's median-age people.

12.4 Probabilistic Ageing

In this section we employ probabilistic population projections, that were developed by the UN using Bayesian hierarchical models (Raftery et al. 2012; Sevcikova et al. 2015). There are several different approaches to probabilistic population projections that were developed in recent decades. However, we will not discuss this issue here since there is a substantial literature on the subject (Alho 1990; Lee 1998; Lutz et al. 1999, 2001; Keilman et al. 2002; Booth 2006).

Fig. 12.10 Probabilistic forecasts for three measures of population ageing based on chronological ages and three based on prospective ages, Western Europe 2015–2100. (Source: authors’ calculations based on United Nations 2015)

In this section we follow Sanderson et al. (2017, 2019) and merge two methodologies, prospective measures of population ageing and probabilistic population forecasts. Using this we compare the speed of change and variability in forecasts

of the conventional proportion old and prospective proportion old, the old age dependency ratio and the prospective old age dependency ratio, and the median age and the prospective median age.

Future distributions of conventional and prospective measures of ageing were computed from 1000 stochastic trajectories of population age structures and associated life tables over the 2015–2100 period for Western Europe. These trajectories were provided by the UN's Population Division (UN 2015).

Results of this analysis are presented in Fig. 12.10 which has 3 panels, upper, middle and bottom. The left side of each panel presents conventional measure and the right side prospective measures.

The upper panel of Fig. 12.10 shows the change over time of the probability distributions of the proportion of the population who are 65+ years old and its prospective analog.

In 2015, the proportion of the population 65+ years-old in Western European countries was 19.7%. The median forecast of this proportion rises to 29.0% in 2050, with a 90% prediction interval of 27.8–30.4%. The forecasts indicate that the increase in the conventional proportion of old people in the population will slow down between 2040 and 2080 and will then speed up again. By 2100, the median forecast of the proportion of the population categorized 65+ years-old is 31.7%, with a 90% prediction interval of 28.5–35.4. The median forecast of the prospective proportion of the population counted as old (those with remaining life expectancy of 15 years or less) is around 12.7% in 2015. This proportion increases to around 17.2% in 2045 where it reaches the maximum, with a 90% prediction interval of 16.5–18.0, and gradually decreases in the following decades. The median forecast of this proportion is 14.1 in 2100, with a 90% prediction interval of 12.9–16.8%.

The middle panel, which compares the forecasted distributions of conventional and prospective old-age dependency ratios looks similar to the upper panel except for the levels of the measures. In the bottom pane we show the probability distributions of the conventional and the prospective median ages. We compute the prospective median ages as the ages in the life table of 2015, in which people have the same remaining life expectancy as at the median age in specific years. Since the UN publishes life tables for 5 year age intervals, the 2015 life table was interpolated on the basis of the UN life tables for 2010–15 and 2015–20.

In Western Europe in 2015, the conventional and the prospective median ages were both 43.5 years. The median forecast of the conventional median age is 47.3 for 2050, with a 90% prediction interval of 45.9–48.7, and is 48.6 in 2100, with a 90% prediction interval of 45.1–52.0. The median probabilistic forecast of the conventional median age increases rapidly from 2015 to 2040, and there is virtually no chance that it will be ever lower than its 2015 value at any time during this century. The median forecast of the prospective median age is also expected to increase between 2015 and 2040. In 2040, the median forecast of the prospective median age is 42.0, and the 90% prediction interval between 40.5 and 43.7. By 2100, the median forecast of the prospective median age is 37.9, and the 90% prediction interval is between 33.8 and 41.4. Based on the UN's probabilistic forecasts, it is

highly unlikely that the prospective median age of the population in Western Europe region will be higher in 2100 than it was in 2015.

As we see the use of prospective measures not only produces different levels of ageing compared to their conventional analogs, but it may also produce different trends.

It is also important to note that the standard deviations of the forecasts of the prospective proportion of the population who are old and the prospective old age dependency ratios are less than their counterparts that do not use prospective ages. As was discussed in detail in Sanderson and Scherbov (2015b), the major reason for that is that in conventional measures the trajectories with higher life expectancy will have more people above age 65. In case of prospective measures, higher life expectancy leads to a higher old age threshold. Higher old age thresholds decrease both the prospective proportion old and the prospective old age dependency ratio. Thus, higher life expectancies produce two offsetting effects on the prospective measures. However, in case of median age and its prospective analog the situation is different because prospective median age uses the median age as an input, while the prospective old age dependency ratio does not use the conventional old age dependency ratio as an input. Thus, the distribution of median ages affects the distribution of prospective median ages.

12.5 Discussion

Population ageing is a multidimensional phenomenon, but chronological age is the only dimension that is traditionally used in its measurement. Assuming the people are old at a fixed chronological age, say 65, means that we consider people's characteristics invariant at this age. But this is very far from reality. Consider Italian men. In 1910, their life expectancy at birth was 46.32 year and 100 years later in 2010 it was 79.56 or more than 30 years higher. Of course, a very strong impact on the changes to life expectancy at birth occurred due to a drop in mortality at younger ages. Still, their life expectancy at age 65 in 1910 was 11.16 years and 100 years later it was 18.35 years, or more than 7 years higher. The age when the remaining life expectancy reached 15 years or less in 1910 was about 59. In 2010 it was above 69. If we select another characteristic that might serve as a proxy for morbidity, which is mortality rate, then the mortality rate of Italian males at age, 65 in 2010 was the same as the mortality rate of a male at age 49 in 1910. On the other hand, the mortality rate at age 65 in 1910 corresponds to the mortality rate at age 76 in 2010.

People's characteristics are very different, but conventional methods ignore them and do not distinguish people living today and 100 years ago. But this is not the end of the story. Country or regional differences in longevity are also enormous. Russian men in 2010 at age 65 had the same mortality rates as Italian men had at age 77 in the same year. In measuring ageing conventional methods ignore regional differences in characteristics of people of the same age as well.

As we learned in this chapter accounting for characteristics of people makes a very big difference regarding conclusions that are made with respect to the past and the future of ageing. Prospective measures paint a much less gloomy picture. In this chapter, we touched only prospective measures, which uses remaining life expectancy as a characteristic of choice. If instead of life expectancy we would have selected mortality rates as a characteristic of interest, the picture of future ageing would be painted even more optimistic.

The use of the characteristic approach has an additional advantage; it converts characteristics of people to the metric of age. This is very useful because it allows us to construct aggregate indicators of ageing based simultaneously on different characteristics of people.

Population ageing will certainly be the source of many challenges in twenty-first century. But there is no reason to exaggerate those challenges through mismeasurement. The approach presented in this chapter reconceptualizes age based on the characteristics of people and allows the construction of new multidimensional measures of ageing.

The discussion of our approach to the study of population ageing has been based on period life table measures. This was necessary to present our core concepts simply, but it is far to limiting. First, cohort life table could also be used, but much more importantly, many characteristics of people can be used to study population ageing using the methods described above. More detailed descriptions of how our methods can be applied can be found in (Sanderson and Scherbov 2017, 2019). An analytic discussion of the differences between results based on period and cohort life tables can be found in (Sanderson and Scherbov 2007).

We have not discussed the connections between health and ageing in this chapter. This is a complex and controversial topic (Christensen et al. 2008; Angel et al. 2015). We address it in (Sanderson and Scherbov 2019) where we investigate years of healthy life expectancy following the prospective old-age threshold using data from the SHARE survey (Munich Center for the Economics of Aging 2013). We show there that in the European countries for which data were available, years of healthy life expectancy from the prospective old-age threshold onward have been roughly constant from 2004 to 2012. In other words, we did not find evidence to suggest that health during the period of old-age was either improving or deteriorating.

We have used the methodology described in this chapter in a number of related contexts. In (Sanderson and Scherbov 2015b; Ediev et al. 2019), we showed that faster increases in life expectancy lead to slower population ageing when prospective measures are used. In (Sanderson and Scherbov 2015a, 2019), we showed how our methodology can be used to compute an intergenerationally equitable public pension age.

Acknowledgements This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 635316 (Project Name: Ageing Trajectories of Health: Longitudinal Opportunities and Synergies, ATHLOS).

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