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This PhD thesis is written as part of a collaboration between the Institute for Social and Economic Change (ISEC) in Bangalore (India), the Population Research Centre (PRC) at the Faculty of Spatial Sciences of the University of Groningen (the Netherlands), and the Netherlands Interdisciplinary Demographic Institute (NIDI) in The Hague. This collaboration has been made possible through funding from the Ubbo Emmius Fund (sponsored by alumnus and friends of the University of Groningen) and through the ICSSR Institutional Doctoral Fellowship from ISEC. An Indian-European research networking grant: Ageing and well-being in a globalizing world, funded by NWO-ESRC-ICSSR (Project Number:465-11-009) led to this collaboration.

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PhD thesis

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the decision by the College of Deans.

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Chapter 1 Introduction

1.1 Problem statement

Population ageing, or the rise in the share of elderly in the population, is the central demographic phenomenon of the century, and is unprecedented in human history. The share of the global population aged 65 or older was 5.1% in 1950, had increased to 8.3% by 2015, and is projected to increase further to around 16% by 2050 and around 23% by 2100 (United Nations, 2019). This demographic change is the result of sustained low fertility combined with considerable gains in longevity across countries (Bloom and Luca, 2016). Population ageing has important societal consequences, including higher dependency ratios (Weil, 1999); rising health and long-term care expenditures (Muszyńska and Rau, 2012); increasing public pension expenditures and macro-economic effects (Börsch-Supan, 2003); and concerns about retirement policies and labour market participation (Falkenstein, Möller and Staudinger, 2011). Given its broad implications for societal and economic arrangements, population ageing is predicted to be the most important societal change of the 21st century (Lutz *et al.*, 2014).

Population ageing is more advanced in Europe than in Asia. However, while the share of elderly in the population is higher in Europe than in Asia, Asia is rapidly following the European trajectory. While the shares of elderly in the population are highest in the European countries, the absolute numbers of older people are highest in the Asian countries. In 2015, the share of the population aged 65 or older was 17.5% in Europe, compared to 7.5% in Asia. But in absolute numbers, these shares translate into the number of elderly people being around three times higher in Asia than in Europe (United Nations, 2019).

However, the existing understanding of (the differences in) population ageing are typically based on the traditional perspective of using fixed old-age thresholds, such as age 65. These traditional measures – such as the proportion of the population aged 65+ or aged 80+, or the old-age dependency ratio (OADR) – have several drawbacks. First, these measures are not ideal for international comparisons, as they do not consider the exceptionality of reaching a particular age across countries. For instance, the share of the population who survive to age of 65 is more exceptional in a country with lower mortality than in a country with higher mortality. The attitudes towards and the status of the elderly are determined by such exceptionalities (Angus and Reeve, 2006). Second, the existing measures do not fully capture the multidimensionality of population ageing. For instance, people aged 65 or older in the developed countries not only have a higher life expectancy, they are healthier and are less likely to have severe physical disabilities than their counterparts in rest of the world (Christensen *et al.*, 2009; Crimmins and Levine, 2016). Likewise, aspects related to their health and human capital, such as their cognition and ability to work productively, tend to be greater among elderly populations in advanced countries (Weber, Dekhtyar and Herlitz, 2017). Hence, the application of traditional measures cannot provide a holistic view of population ageing.

In addition, the considerable differences between countries, between men and women, and between people with different levels of socio-economic status are often ignored in population ageing studies, and particularly in the few studies on future population ageing. Within the Asian region, East Asia has been leading in terms of population ageing, and has patterns close to those of Europe. Similarly, Eastern Europe has lower levels of population ageing than other regions within Europe. In addition to this regional diversity, very large differences in levels of population ageing by sex and by educational attainment can be observed across these two continents (Luy and Minagawa, 2014; Robine *et al.*, 2020). Generally, older women in Europe and in Asia live longer than their male counterparts; and, consequently, the shares of older females in the population are higher than those of their male counterparts. However, levels of morbidity and disability are higher among older women, especially in the Asian countries (Saikia *et al.*, 2011; Crimmins *et al.*, 2019). Similarly, compared to their less educated counterparts, the higher educated generally live longer, have lower rates of physical disability, and higher levels of productivity (Ross and Wu, 1996; Mackenbach *et al.*, 1997; Leopold and Engelhartdt, 2013). To gain a comprehensive understanding of current and future population ageing in Europe and Asia, an outlook that is sensitive to these differences in population composition is essential.

1.2 Aim of the thesis

The aim of this PhD thesis is to compare current and future population ageing in Europe and Asia using new comparative ageing indicators that are able to take into account differences in life expectancy, health, and human capital across populations.

More specifically, the sub-objectives are:

1) To assess population ageing across Europe and Asia in a comparative manner;
2) To assess the sex and country differences in population ageing in Europe and Asia using a multi-dimensional perspective; and
3) To assess future population ageing in Europe and Asia, the educational differences therein, and their responsiveness to changes in education.

The study will provide a more comprehensive understanding of current and future population ageing in Europe and Asia, and will introduce novel tools that can be used to study population ageing in a comparative and multi-dimensional manner.

1.3 Background

1.3.1 Population ageing in Europe and Asia

The current level of population ageing is unprecedented in human history, and population ageing is expected to be the among the most important demographic and social changes of the 21st century (Lutz, Butz and Samir, 2014). The main reason for the rise in population ageing is that life expectancies at different ages are increasing while fertility is declining or remaining at low levels (Bongaarts, 2009). The transition from high to low mortality and fertility rates is often referred as the first demographic transition. The pace of the first demographic transition is associated with population growth and ageing. Generally, a decline in mortality precedes a decline in fertility, and the population grows during the intermediary phase. When a fertility decline occurs alongside a mortality decline, the population stagnates or decreases. Consequently, population ageing is characterised by an increase in the share of older people in the population. While shifts in mortality and fertility associated with the first demographic transition have common features across regions, the onset and the pace of the first demographic transition varies across regions due to differences in the socio-economic conditions that trigger the transition (Willekens, 2016). Thus, the demographic transition in each country or region is entangled with changes in its economy, culture, politics, and technology; and with events such as epidemics, natural or man-made disasters, and social revolutions.

While both European and Asian countries have undergone the first demographic transition, its timing was earlier in Europe than in Asia. Consequently, while the populations of both Europe and Asia are ageing, and are expected to age further in the coming decades, the ageing process is more advanced in Europe than it is in Asia (United Nations, 2017). However, Asia quickly followed Europe in moving through the first demographic transition. Population ageing is traditionally defined by the share of the population aged 65 or older, which was, as of 2015, 17.5% in Europe and 7.5% in Asia. This share is expected to rise further to 28.1% in Europe and 18% in Asia by 2050; and to 30.4% in Europe and 27.6% in Asia by 2100. Although the shares of the population aged 65+ are much higher Europe than in Asia, these shares translate into much higher absolute numbers in Asia. For instance, in absolute numbers, the population aged 65+ was three times higher in Asia than in Europe in 2015 (United Nations, 2019).

As their populations grow older, concerns about how these demographic changes will affect European and Asian societies and economies are also mounting. On the economic front, population ageing is associated with lower labour force participation levels, increasing health care and pension expenditures, and strains on savings rates and economic growth (Bloom and Luca, 2016). The dependence of the non-working elderly population on the younger population is expected to increase, which is reflected in the rise in the old-age dependency ratio (OADR) in Europe and Asia. The OADR is the ratio of the non-working elderly population (aged 65 or older) to the working-age population (aged 20-64). On the societal front, traditional living arrangements and family formation patterns are undergoing a transformation. Especially in Asian countries, the move away from traditional intergenerational family arrangements is expected to be costly for the elderly, many of whom will lose access to family care (James, 2011; Giridhar *et al.*, 2014). Moreover, epidemiological changes in the disease burden are associated with population ageing (Omran, 1998). An ageing population tends to be vulnerable to non-communicable diseases, and to suffer from co-morbidities (Shetty, 2012).

1.3.2 Diversity in population ageing in Europe and Asia

The vast diversity in the demographic characteristics of populations across and within Europe and Asia is accompanied by considerable heterogeneity in patterns of population ageing. Within Europe, Western and Northern European countries have higher shares of elderly in the population, whereas Eastern European countries have lower shares (Kluge, Goldstein and Vogt, 2018). In Asia, Eastern Asian countries have higher shares of older people in the population, while Central and South Asian countries have lower shares (Shetty, 2012; Beard *et al.*, 2016). At the same time, there is huge variation across regions in Europe and Asia in terms of the characteristics associated with ageing. For example, the older populations in some countries have higher levels of physical health, cognition, and productivity than in others. In general, the older populations in Western and Northern European countries and in Eastern Asian countries have better characteristics as measured by life expectancy at higher ages, physical health, cognition, productivity, and the ability to perform activities of daily living (Mackenbach *et al.*, 2003; Rechel *et al.*, 2013). The age-specific characteristics of populations have been shown to be worse in Central and South Asian countries (Lloyd-Sherlock *et al.*, 2012).

The life expectancies of all elderly populations in Europe and in Asia have been increasing over time (United Nations, 2019). For instance, life expectancy at age 65 rose from 13.34 years in Europe and 9.74 years in Asia in 1950-55 to 18.29 years in Europe and 15.78 years in Asia in 2010-15 (United Nations, 2019). Similarly, thanks to various improvements in medical technology, today's older adults are healthier and have less severe functional disabilities than their earlier counterparts (Christensen *et al.*, 2009). Other measures of physical health, as well as bio-marker indicators among the elderly, such as hand grip strength and walking speed, have also improved over successive cohorts (Al Saedi *et al.*, 2019; Robine *et al.*, 2020). Over time, average levels of education have increased (Lutz and Samir, 2011), intellectual abilities have improved (Philipov, Goujon & Di Giulio, 2014), productivity has grown (Skirbekk, Loichinger & Weber, 2012), and the likelihood of being able to perform activities of daily living has increased (Parker and Thorslund, 2007) among the elderly.

In addition to these geographical differentials, there is substantial variation across Europe and Asia in the characteristics of the elderly population by sex and level of education. While women have a mortality advantage, as their life expectancy levels are higher than those of men at different ages, they have disadvantages in terms of health and disability prevalence (Christensen *et al.*, 2009; Luy and Minagawa, 2014; Robine *et al.*, 2020). The gender gap in differentials in life expectancy, health, and disability among older adults is larger in Asia than in Europe (Saikia *et al.*, 2011; Jasilionis and Shkolnikov, 2016). Sex-specific changes over time in levels of mortality, morbidity, productivity, and cognition among older adults differ across regions in Europe and Asia (Mackenbach *et al.*, 2003; Skirbekk, Loichinger and Weber, 2012). In parts of Asia, such as in Central and Southern Asia, women did not start to exhibit a mortality advantage until the last three decades (Saikia *et al.*, 2011). Likewise, although the average levels of education across successive cohorts have been rising in Europe and in Asia, the trajectories of age-specific characteristics related to health and human capital differ across higher and lower educated groups (Leopold and Engelhartdt, 2013). Education tends to reproduce and magnify cumulative advantages or disadvantages in health-related resources over the life course. Therefore, there is a growing gap in health between people with higher and lower education from younger to older ages (Ross and Wu, 1996). Previous studies for Europe have shown that there are large differences in the trajectory of health depending on education: i.e., that people who are better educated tend to score better on health indicators than their less educated counterparts. Such differences have been growing across successive cohorts in Europe (Leopold, 2018). As Asia also has high levels of socio-economic inequality and relatively poor educational infrastructure, similar differences in health by educational level are likely to occur in Asia (Lutz and Samir, 2011).

At the same time, when we are comparing population ageing across diverse populations such as those of Europe and Asia, it is important to recognise the heterogeneity of these populations. While rising life expectancy and the compression of morbidity are observed in Europe and in Asia, these trends are not identical (Andrews, 2001). These patterns also vary by region, sex, and educational level within each continent (Picco *et al.*, 2016; Santosa *et al.*, 2016). The attitudes and levels of status and well-being of elderly people differ across countries depending on whether a minority or a minority of the population survives to higher ages (Dowd and Bengtson, 1978; Giles and Reid, 2005; Angus and Reeve, 2006). Similarly, the ideals of elderly well-being are heterogeneous across cultural contexts. For instance, whereas in Europe older people participating in the labour market may be viewed favourably (Walker, 2002), this is not necessarily the case in the Asian context (Singh and Das, 2015). Moreover, there are concerns that unlike in most European countries, many developing countries in Asia are seeing their populations start to age before they achieve economic prosperity (Shetty, 2012).

1.3.3 Multiple dimensions of ageing

Population ageing is a multidimensional phenomenon (World Health Organization, 2015). While it is associated with improvements in life expectancy, it is also associated with changes in different dimensions related to health and human capital. These dimensions include different aspects of health, such as physical and mental health; and other human capital dimensions, such as cognition and the ability to work productively (Timonen, 2016). Hence, population ageing can be characterised not only by changes in the number of years older people live, but by changes in their quality of life.

Numerous paradigms have developed in the literature as theoretical frameworks designed to capture the multidimensionality of population ageing (Walker, 2002; World Health Organization, 2015). Among the most prominent of these paradigms are ‘active ageing’, ‘healthy ageing’, and ‘successful ageing’. ‘Active ageing’ is a concept that encompasses multiple dimensions of the potentials of the elderly population, and that emphasises that the improved age-specific characteristics of the elderly enable them to continue to participate in the economic and the social life of their societies (Walker, 2002). Both ‘healthy ageing’ and ‘successful ageing’ are concepts that focus on the multidimensionality of the ageing process, and that stem from the theory of compression of morbidity (Rowe and Kahn, 1987; Karlin and Weil, 2017). The theory of compression of morbidity states that as life expectancy increases, the onset of morbidity is shifted to higher ages (Fries, 1989). All of these paradigms of population ageing reflect the improvements in both the quantum and the quality of life years among the elderly, and view population ageing from a multidimensional perspective.

Of the several dimensions of changes associated with population ageing, the increase in remaining life expectancy is a significant facet (Sanderson and Scherbov, 2005). Almost all countries in Europe and Asia have seen improvements in the remaining life expectancy of their elderly population in the last five decades (United Nations, 2019). The progress in remaining life expectancy in these countries is attributable to various social and economic developments, and to public health improvements. Similarly, other dimensions of health among older people, such as functional abilities, have changed over time. Improvements in life expectancy do not necessarily reflect improvements in functional abilities (Crimmins, Kim and Solé-Auró, 2011). Functional abilities among older people are indicative of their levels of independence or their vulnerabilities. Among the elderly, having better functional abilities is associated with having greater independence, and with being less vulnerable in terms of health care utilisation (Tsuji *et al.*, 1994; Luppa *et al.*, 2009). Similarly, the human capital composition of the older populations across countries in Europe and in Asia is changing (Lutz, Sanderson and Scherbov, 2001). Human capital is a rather broad concept, and generally refers to the set of skills, knowledge, habits, personality attributes, and abilities of a given population. Intellectual traits, like educational levels and cognition, or labour market characteristics, such as labour force participation levels or the productivity of labour, are the variables usually used to capture the latent concept of human capital (Becker, 1975; Angrist and Krueger, 1991). The average educational levels of populations in countries across Europe and Asia have increased over the last five decades (Lutz *et al.*, 2014). Similarly, other variables that proxy human capital, such as average levels of cognition and of productivity, have been improving among successive cohorts of elderly people (Skirbekk, Loichinger and Weber, 2012; Williams, 2014).

1.3.4 Existing measures of population ageing

Previous research on population ageing has mostly been based on the traditional measures of population ageing (World Health Organization, 2015). Of these traditional measures, the old-age dependency ratio (OADR) and the share of elderly in the population are the most common. While the OADR represents the ratio of the population aged 65 or older to the working-age population (usually defined as the population between the ages of 20 and 64), the share of elderly in the population represents the percentage of people aged 65 or older in the total population. These measures aim to quantify the changes in the age structures of populations. They use a chronological age such as age 60 or 65 to define the elderly population, and measure changes in this age group relative to changes in other age groups. These traditional measures have formed the basis of our understanding of population ageing across countries for more than half a century.

However, the traditional conceptualisation of population ageing fails to capture the changes in mortality and morbidity patterns across populations over time (Chang *et al.*, 2019). Such measures are also insensitive to changes in other characteristics related to health and human capital across populations (Bloom *et al.*, 2010). Furthermore, they do not recognise the heterogeneity of the elderly populations in different regions (Lutz, Butz and Samir, 2014).

Recently, efforts have been made to develop new measures of population ageing that account for the changing characteristics of the elderly. These recently developed measures can be broadly classified into three categories:

(i) Adjusted dependency ratios, such as the unhealthy old-age dependency ratio, the community-adjusted dependency ratio, or the cognition-adjusted dependency ratio (File and Kominski, 2012; Muszyńska and Rau, 2012; Skirbekk, Loichinger and Weber, 2012). The adjusted dependency ratios recalculate the burden of population ageing after subtracting the number of people aged 65 or older who perform well in any specific characteristics. For instance, the unhealthy old-age dependency ratio recalculates the share of the unhealthy population aged 65 or older relative to the share of the population aged 15-64.

(ii) Multi-dimensional ageing measures, such as the Active Ageing Index or the Global Age Watch Index (Zaidi *et al.*, 2013; HelpAge, 2015). These multi-dimensional measures recognise that there are many different variables associated with well-being among the elderly, and provide an index score based on several characteristics. For instance, the Active Ageing Index formulates a score using on 22 variables such as employment and independent and healthy living among the elderly, and ranks countries in Europe based on their overall index scores.

(iii) Measures that use recalculated old-age thresholds, such as old-age thresholds based on the average labour market retirement age or on changes in the population distribution (d'Albis and Collard, 2013; Loichinger *et al.*, 2017). Measures that use recalculated old-age thresholds formulate old-age thresholds based on specific population-level changes, such as the average retirement age in the population. The characteristics approach (Sanderson and Scherbov, 2013) provides a theoretical framework that recalculates the old-age threshold using different population characteristics, such as remaining life expectancy.

While these measures try to account for the changing characteristics of elderly populations, they are not simultaneously multi-dimensional and comparable across different regions. The adjusted dependency ratios merely account for specific changes in a population's characteristics, and are generally based on the adjustment of just one of the characteristics included in the traditional measures. The multi-dimensional measures are intended to reflect the well-being of elderly people in specific regions. A common limitation of both the adjusted dependency ratios and the multi-dimensional measures is that they are based on the traditional assumption that there is an abstract old-age threshold, such as age 65. Thus, they assume that people aged 65 or older are homogeneous across countries. Furthermore, an embedded feature of both of these sets of measures is that they fundamentally aim to 'solve' the 'problem' of population ageing, and therefore conceptualise old age based on a regressive framework, even as they acknowledge the changes that have occurred among the elderly (Timonen, 2016; de São José *et al.*, 2017). While the measures based on recalculated old-age thresholds recognise the need to redefine 'old age' as the times change, they do not simultaneously account for the multiple dimensions of the changes in the health outcomes, life expectancies, capabilities, and human capital levels among today's older people.

Moreover, most of these recently developed measures of population ageing come from developed countries, and are thus based on the ideals of well-being among the elderly in the Western world. Hence, these measures might not be effective in cross-country comparisons, especially in those that include both developed and developing countries. For instance, among the major concerns in developed countries are the potential losses associated with the changes in labour force participation alongside population ageing (Hammer, Prskawetz and Freund, 2015). Many of the recent measures are focused on accommodating the altered abilities of the elderly population that could enable them to remain in the labour market longer (Walker, 2002). The key idea underlying such measures is that staying in the labour market longer is associated with improved well-being. However, this may not be the case in the developing countries of Asia, where the elderly may be compelled to remain in the labour market out of economic need (Singh and Das, 2015).

1.3.5 Future population ageing in Europe and Asia

One of the most important concerns that have been raised about population ageing in Europe and Asia is that it is expected to rise continuously in the coming decades (United Nations, 2019). Future population ageing scenarios are based on specific combinations of assumed changes in life expectancy and fertility. As life expectancy at different ages is projected to increase continuously while fertility is projected to decrease or remain a low levels, it is generally anticipated that population ageing in Europe and Asia will be an important demographic phenomenon in the coming century (United Nations, 2019). While the European region is expected to have the highest shares of elderly in the population, these shares also projected to increase substantially in Asia, and Asia is expected to be home to the largest numbers of older people (United Nations, 2019). The rates of increase in the share of elderly in the population and in the speed of population ageing are projected to be higher in Asia than in Europe in the coming decades (Lutz, Sanderson and Scherbov, 2008). The United Nations project that in 2050, the share of elderly in the population will be 21% in Europe and 18% in Asia (United Nations, 2019). The shares of elderly in the population are projected to be highest in Western Europe, followed by in Eastern Asia and Northern Europe. Improvements in survival chances across birth cohorts are also associated with future increases in population ageing in Europe and Asia. This means that successive cohorts will have greater longevity. For instance, it is projected that even if health conditions do not improve, three-quarters of babies born in the developed countries of Japan, Germany, and Sweden will survive to celebrate their 75th birthdays. Moreover, it has been estimated that most babies born in the developed countries in Western Europe and Eastern Asia since 2000 will live to celebrate their 100th birthday (Christensen *et al.*, 2009).

Population ageing trends can differ across populations, not just because of differences in their age and sex structures, but because of differences in their educational achievement levels (Lutz *et al.*, 2014). The most fundamental causes of population ageing – i.e., decreasing fertility and increasing life expectancy – are driven by differences in educational levels. Higher educational attainment is associated with increased life expectancy at different ages, and with decreased fertility (Lloyd-Sherlock *et al.*, 2012; Lutz *et al.*, 2014). The educational achievement levels of a population are also indicative of latent socio-economic gradation variables in that population. In most parts of the world, better educated populations have higher incomes and better health (Lutz and Samir, 2011). The characteristics of populations, such as their morbidity and cognition levels, vary depending not only on their age and sex structures, but on their educational levels. Compared to their less educated counterparts, cohorts with higher education have significantly lower rates of physical disability, and higher levels of productivity (Lutz, Butz and Samir, 2014). Moreover, differences in mortality rates by educational level have been widening over time (Mackenbach *et al.*, 2003). The World Health Organization has recognised the significance of the relationship between education and health by incorporating an education component into its formulae for forecasting future health scenarios (Mathers and Loncar, 2006).

Hence, given that the ageing-related characteristics of populations differ significantly based on their educational levels, efforts to project population ageing into the future would benefit from distinctions being made between older people's educational levels. Among the elderly in

Europe and Asia, the educational distribution is highly varied. Previous studies of future population ageing have not accounted for the significant heterogeneity in the educational distribution across the regions. Moreover, scenarios of future population ageing based on different assumptions about the future educational distribution of the population could help to answer the question of whether greater educational investments would be an effective policy response to future population ageing.

1.4 This study

1.4.1 Approach

This PhD thesis adopts a comprehensive and holistic approach to understanding population ageing across Europe and Asia.

The comprehensive component of this approach refers its sensitivity to the diversity across the continents, which makes it appropriate for comparing levels of population ageing across Europe and Asia. Such an approach is rooted at both the conceptual and the methodological level.

The holistic element of this approach refers to its perspective on population ageing as a multidimensional process, and to its examination of the phenomenon from a multidimensional angle at both the methodological and the empirical level.

Moreover, this thesis takes a multidisciplinary approach, combining knowledge, methods, and data from demography, public health, and economics.

Quantification of current and future population ageing, which is the chief aim of the thesis, is often discussed in demography. The thesis draws parallels from economics on the conceptualisation of purchasing power differentials across currencies, while formulating a demographic population-level understanding of differentials in age. By comparing population ageing processes while accounting for changes in life expectancy, health, and human capital, the thesis has a high degree of public health relevance.
The thesis uses different demographic and health-related datasets, and applies to these data several state-of-the-art demographic techniques (see next section), as well as novel methodologies to measure ageing.

1.4.2 Data and methods

The thesis combines population-level mortality data, longitudinal data from international health surveys, and projected population and mortality data by educational levels.

The population-level demographic data on mortality include data from many countries over a long period of time. These data are based on life tables drawn from Human Mortality Database (Max Planck Institute for Demographic Research, 2015) for the Organisation for Economic Co-operation and Development (OECD) member countries. For the non-OECD countries, these data were drawn from the Population Division of the United Nations.

Longitudinal data from cross-country surveys at comparable time periods were used for data on different aspects related to health and human capital. Specifically, data from the Survey of Health, Ageing, and Retirement in Europe (SHARE) (Börsch-Supan, 2018) and the WHO Study on Global AGEing and Adult Health (WHOSAGE) (Kowal *et al.*, 2012) were used.
The projected population and mortality data were drawn from the Human Capital Database of the Wittgenstein Centre for Demography and Global Human Capital (Lutz *et al.*, 2014).

The main method used in the PhD thesis is a formulation of a novel methodology that stipulates a new old-age threshold based on differences across populations, including differences in remaining life expectancy, adult survival rates, disability, and cognition. This methodology stems from an innovative application of the characteristics approach that provides a theoretical framework for formulating old-age thresholds based on population characteristics. In addition, life table techniques, interpolation techniques, and standardisation techniques are employed.

1.5 Outline of the thesis

The thesis consists of six chapters. The current Chapter 1 introduces the key elements of this research and their significance based on the relevant literature. Chapter 2 analyses population ageing in Europe and Asia in a comparative manner (sub-objective 1). Chapter 3 and Chapter 4 assess the sex and the country differences in population ageing in Europe and Asia using a multi-dimensional perspective (sub-objective 2). In Chapter 3, a multi-dimensional measure of ageing is formulated and applied to examine population ageing in selected countries of Europe and Asia from a multi-dimensional perspective. In Chapter 4, sex differences in population ageing in the provinces of the most populated Asian countries of India and China are estimated from a multi-dimensional perspective. In Chapter 5, an assessment of future population ageing in Europe and Asia, the educational differences therein, and the responsiveness to changes in education, is provided (sub-objective 3).

The final chapter, Chapter 6, provides a summary and discussion of the main results; a discussion of the methodological strengths and limitations; and an overview of the implications of the methodology and the empirical results for future research, society, and policymaking.

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Chapter 2 Comparison of population ageing in Europe and Asia using a time-consistent and comparative ageing measure

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Abstract

Objective:
We compare population ageing in Europe and Asia using a measure that is both consistent over time and appropriate for cross-country comparison.
Methods:
Sanderson and Scherbov proposed to estimate the old-age threshold by the age at which the remaining life expectancy (RLE) equals 15 years. We propose an adjustment of this measure, taking into account cross-national differences in the exceptionality of reaching that age.
Results:
Our old-age threshold was lower than 65 in 2012 in Central Asia, Southern Asia, South-eastern Asia and many Eastern European countries. These populations also experienced a higher share of elderly compared to the RLE=15 method. Our method revealed more geographical diversity in the shares of elderly. Both methods exhibited similar time trends for the old-age thresholds and the shares of elderly.
Discussion:
Our prospective and comparative measure reveals higher population ageing estimates in most Asian and Eastern European countries and more diversity in ageing.

Keywords: population ageing, characteristics approach, adult survival, Europe, Asia

2.1 Introduction

In most countries, the numbers of elderly and their population shares have been increasing rapidly in recent decades, and these trends are expected to accelerate in the coming decades. Population ageing will likely to be the most important social change of the 21st century (Lutz, Sanderson, & Scherbov, 2008a). Ageing is occurring rather quickly in Europe and in Asia. The shares of elderly in the total population are the highest in European countries, whereas the absolute numbers of older people are the highest in Asian countries (United Nations 2016). However, these estimates on the alarming increase in the share of elderly are based on a fixed old-age threshold of 65.

An important drawback of the conventional measures of ageing—such as the proportion of people aged 65 or 80 and over, or the old-age dependency ratio (Lutz, Sanderson, & Scherbov, 2008b)—is that they do not take into account the large increases in life expectancy that have been observed in almost all parts of the world over the past five decades (Sanderson & Scherbov, 2015a). In many parts of the world, the elderly who are alive today are healthier and have less severe disabilities than their earlier counterparts (Christensen et al. 2009). The conventional measures do not account for such major improvements in health and life expectancy. Hence, there is a tendency to overestimate the impact of population ageing when these indicators are used (Spijker & MacInnes 2013).

Of the various alternative approaches to measure ageing (Skirbekk et al. 2012; d'Albis & Collard 2013; Kot & Kurkiewicz 2004; Chu 1997; Ryder 1975), the prospective age approach was a significant progress towards the measurement of population ageing (Sanderson & Scherbov, 2005, 2007, 2008, 2010). In the original prospective age approach, the size of the elderly population (i.e., the people who are older than the old-age threshold) is estimated based not on chronological (and thus on retrospective) age, but on a forward-looking approach that defines the old-age threshold based on a constant remaining life expectancy (RLE) of 15 years. By redefining ageing based on remaining life expectancy, this approach proposed a dynamic old-age threshold that changes over time by accommodating the improvements in the life expectancies of populations over time.

Later, the prospective age approach was further modified (Sanderson and Scherbov 2013, 2015b, 2015c; Scherbov and Sanderson, 2016), and generalized in the, so called, 'characteristic approach'. Instead of working with a constant remaining life expectancy of 15, other characteristics which have direct implications for ageing like mortality rate, grip strength, chair rise speed or normal pension age (defined by life course ratio) can also be used to redefine ageing. For example, if the average grip strength at age 70 in the year 2000 was equal to that at age 60 in the year 1950, the approach considered age 60 in 1950 the same as age 70 in 2000 (Sanderson et al. 2016). Within the generalized framework of the 'characteristic approach', the prospective age approach using RLE = 15 remains its most popular application (Sanderson and Scherbov, 2013).

Although the prospective age approach and the more general characteristics approach was successful in obtaining a time horizon constant ageing measure, it has limitations for comparisons across countries with varying mortality patterns. In a country with high mortality at young and adult ages, reaching the age at which the remaining life expectancy is 15 will be more exceptional than in a country with lower mortality. How exceptional it is to reach a particular old age in a country, will determine the attitudes towards and status of the elderly (Dowd & Bengtson 1978; Giles & Reid 2005; Angus & Reeve 2006). Someone who reaches the age at which the remaining life expectancy is 15 in a country where only a small percentage of the population reaches this age is likely to be considered older than a person who reaches this age in a country where this is quite common. This hampers the comparability of ageing across countries.

In this paper, we compare population ageing in Europe and Asia using a measure that is both consistent over time and appropriate for cross country comparison. More specifically, within the framework of the characteristic approach, we combine a country specific life-course characteristic (adult survival ratio) with a constant characteristic (RLE = 15) in benchmark country Japan. By doing so, we accommodate for differences in the chances of reaching the age at which RLE = 15 across countries. Using a selected set of countries from Europe and Asia, we demonstrate how our measure is more useful for the cross-country comparison of ageing in Europe and Asia as compared to the RLE = 15 method while maintaining comparability over time as well.

2.2 Data and Methods

2.2.1 Data

For our analysis, we used life table and population data by age and sex for Asian and European countries, for different years (1972, 1992, 2012). We used two sources. For the OECD member countries in Europe and for Japan, we used the available data from the Human Mortality Database (Human Mortality Database, 2015). For the remaining countries, and the regions (see below), data from the World Population Prospects Revision 2015 (United Nations, 2015) prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations (UN) are used.

Whereas the Human Mortality Database provides annual population and life table data by single year of age, the UN database provides data by five-year age groups for five-year time intervals. We used UN data for 1970-1975, 1990-1995 and 2010-2015 as an estimate for the year 1972, 1992 and 2012, respectively.

To obtain data by single year of age based on the UN data available by five-year age groups, we applied linear interpolation to the population and lifetable data (l_x, RLE) (Shryock et al. 1976). A sensitivity analysis in which we used a more advanced interpolation technique (e.g. TOPALS) (de Beer, 2012) revealed the same results.

2.2.2 Methodology

In the original prospective age approach, the prospective old-age threshold (= the age from which people can be considered older) is defined as the age at which the remaining life expectancy (RLE) is 15 years (Sanderson and Scherbov, 2007). The value of 15 was chosen because in Europe in 1980 the RLE at age 65 was indeed 15 years, and because the use of a RLE of 15 years was considered less sensitive to data issues than the use of other values such as the 10 years suggested by Ryder (1975) (Sanderson and Scherbov, 2008).

However, the original prospective age approach cannot sufficiently account for cross-country differences in ageing. That is, the chances of survival to the age at which RLE is 15 may be considerably different in countries with varied mortality experiences. In 2012, 81% of the Japanese population, 82% of the population of the Netherlands, and 70% of the population of India were still alive at the age at which RLE = 15 (Table 2.1). As people living in Japan or the Netherlands were more likely to reach the age at which RLE = 15 than people living in a developing country like India, the elderly in Japan and in the Netherlands constitute a less selected group than the elderly in India.

When examining ageing trends across countries, it is essential to take into account the exceptionality of reaching a RLE of 15 years in order to avoid comparing groups that are less or more selected.

Table 2.1: Age at which remaining life expectancy (RLE) is 15, and percentage of survivors to the age at which RLE = 15 for Japan, the Netherlands and India, 2012

Country	**Age at which RLE = 15**	**Percentage of survivors to the age at which RLE = 15**
Japan	73.29	81%
The Netherlands	70.73	82%
India	64.90	70%

Our new measure, which we call the comparative prospective old-age threshold (CPOAT), adapts the original prospective old-age threshold (POAT) by taking into consideration the differentials of reaching a RLE of 15 years due to variations in adult survival between countries and over time. Our method can be regarded an extended application of the overarching characteristic approach (Sanderson and Scherbov 2013, 2015b, 2015c; Scherbov and Sanderson, 2016) in that it also uses different characteristics to measure ageing, but does so in a way to enable optimal cross-county-comparison.

Our approach takes into account changes over time and differences across countries in the adult survival ratio (ASR) which is calculated as:

$$ASR_{x,i} = l_{x,i}/l_{15,i}$$

The ASR for an age x for a country i is the ratio of the population surviving to age x in country i ($l_{x,i,}$) to the population surviving to age 15 in country i in a life table population ($l_{15,i}$). The values of $l_{x,i}$ and $l_{15,i}$ are obtained from the life tables of the respective countries.

We considered the adult survival ratio and not the complete survival chances. In considering the survival of adults after age 15, we have excluded infant and child mortality which are not that relevant for determining whether a person can be considered ‘older’. If survival at young ages is low but survival changes from age 15 are quite high, then reaching a certain high age will very likely be considered not that exceptional. Also, if survival at young ages is high, but adult survival changes are low (like in Russia) then reaching a certain high age is very likely to be considered exceptional.

We multiply the remaining life expectancy at each age by the ASR, i.e. by the probability that a person aged 15 will survive to that age. As the benchmark country we selected Japan in the year 1972. The reason is that for Japan in 1972 the age at which RLE = 15 was 65 (Human Mortality Database, 2015). The ASR up to age 65 in Japan in 1972 was 82.9%. Multiplying the RLE and ASR yields 12.4 years. This can be interpreted as the number of years that someone in Japan aged 15 in 1972 could expect to live after age 65 taking into account the probability that the person will survive to age 65.

Our comparative prospective old-age threshold (CPOAT) for each country and each year is the age at which the value of ASR * RLE is closest to 12.4 years. Thus if in one country the value of ASR * RLE exceeds 12.4 years at age 65, the old-age threshold is higher than 65. This may be due to the fact that the ASR at age 65 is higher than 82.9% (in that country it is more common to reach age 65 than in Japan in 1972) or that RLE is higher than 15 (people aged 65 may expect to live longer than Japanese aged 65 in 1972).

In doing the calculations we rounded the threshold ages to whole ages. A sensitivity analysis revealed no substantial effect on the results obtained.

To calculate the share of elderly we divided the population size equal and higher than the old-age threshold with the total population size.

2.3 Empirical application

In our empirical application we will show the results of our new comparative prospective ageing measure in terms of both the old-age threshold in 1972, 1992 and 2012 and the share of elderly in 2012.

For a selection of countries, we will compare the results of our new method with the results using the prospective RLE = 15 method, and the traditional measure using chronological age 65 as old-age threshold, in table format. For this purpose, we selected ‘typical’ countries from the five Asian regions and four European regions that the UN distinguishes (United Nations, 2018). These were: China (East Asia), Thailand (South East Asia), India (South Asia), Azerbaijan (West Asia), Uzbekistan (Central Asia), Norway (Northern Europe), The

Netherlands (Western Europe), Spain (Southern Europe), Ukraine (Eastern Europe). We also show the results for the totals in Europe and Asia, based on the aggregate life table and population figures from the UN. Furthermore, we distinguish within Europe between Eastern Europe and the rest of Europe (non-Eastern Europe) and within Asia between Eastern Asia and the rest of Asia (non-Eastern Asia), because of the different results we observed for these regions. For Eastern Europe and Eastern Asia we used as well the aggregate life table and population figures from the UN. For the 'rest of Europe' and the 'rest of Asia', however, we applied unweighted averages to our results for the different sub-regions that it consists of.

In addition, we will map the share of elderly using our new measure for all European and Asian countries in 2012, using QGIS 2.14.3 and the world map provided by the QGIS website (QGIS Development Team, 2016). To match our data with the map, we had to exclude the Channel Islands when mapping the results. In Appendix Figure 2.3 we will show similar maps for the RLE15 method and using age 65 as old-age threshold.

2.4 Results

Table 2.2 shows the old-age threshold, i.e. the age at which people can be considered "older", for both our new method and the RLE = 15 method, for the different Asian and European countries, in 1972 and 2012.

In Japan in 1972, the age at which RLE = 15 was 65. The prospective old-age threshold (POAT) using the RLE = 15 method was therefore 65 in Japan in 1972. The ASR at age 65 in Japan in 1972 was 82.9%. Because we consider Japan as the benchmark country in our new comparative prospective old-age threshold (CPOAT), the CPOAT for Japan in 1972 equals the POAT for Japan in 1972. In the other years for Japan and in the other countries, however, the CPOAT resembles the age at which ASR * RLE = 0.829 * 15 = 12.4 years.

For Japan, the age at which RLE = 15 increased to 73 in 2012. Because, in Japan, the ASR up to age 73 in 2012 (0.832) largely resemble the ASR up to age 65 in Japan in 1972, the CPOAT is similar to the POAT in Japan in 2012 as well.

For the other countries however interesting differences exist between the POAT values and the CPOAT values. In general, the CPOAT values are smaller than the POAT values (see the negative values in the last two columns of Table 2.2). Differences are especially large for Thailand, India, Uzbekistan, and Ukraine. Figure 2.1 shows that the lower CPOAT values compared to POAT values can be most clearly observed for Eastern Europe, and the majority of Asian regions. Appendix Figure 2.2, which shows the results for all individual European and Asian countries illustrates this as well. This results in more diversity in old-age thresholds both within Europe and within Asia.

All in all, in 2012, our comparative and prospective old-age threshold was highest, among the selected countries, in Japan (73) and Spain (72), and lowest in Ukraine (63) and India (63). Our old-age threshold was higher than 65 in 2012 in most countries, except in South-eastern Asia, Southern Asia, Central Asia and many Eastern European countries. This in comparison to the

POAT in 2012 which is 65 or higher. For Europe as a whole the CPOAT in 2012 was three years higher compared to Asia, 69 and 66 respectively. Whereas Southern and Western Europe exhibited the highest average CPOAT (72), the lowest average CPOAT was observed for Southern Asia and Central Asia (63). (Table 2.1, Figure 2.1, Appendix Table 2.1)

Table 2.2 also gives information about the change in the old-age thresholds from 1972 to 2012. In all selected countries, and using either our new measure or the RLE = 15 measure, the old-age threshold has increased. Thus, in 2012 people are considered ‘old′ when they are older as compared to 1972. One exception is for Ukraine, which shows a decline in the old-age threshold, as a result of the health crisis (McKee and Shkolnikov 2001; Vallin and Meslé 2004; Leon 2011). For Central Asia the old-age thresholds have been stable. According to our new measure, and for the selected countries, the increase in old-age thresholds has been strongest for Japan and Thailand (+8), and stronger for Asia (+7) as compared to Europe (+5). Interestingly, the changes over time we observed for the CPOAT measure are almost similar to the changes over time in the POAT measure. That is, a maximum difference of 2 is observed, solely in Thailand and Western Asia.

Table 2.3 shows the share of elderly based on our new method for selected European and Asian countries in 2012. According to our method and among the countries considered, Ukraine has the highest share of elderly (17 %), whereas Uzbekistan has the lowest share of elderly (5 %). Europe has a share of elderly that is double from that of Asia, 13 and 6.5 per cent, respectively.

Table 2.3 also compares the share of elderly in 2012 obtained by our new method with the share of elderly using the RLE = 15 method, and the share of elderly using the traditional old-age threshold of 65. In addition, Figure 2 graphically shows the differences between the share of elderly in 1972 and 2012 for our new method and the RLE = 15 method. In line with our results on the old-age thresholds, we can see that the shares of elderly obtained for countries with low adult survival rates (most Asian countries, Ukraine) are slightly higher when our new method is used than when the RLE = 15 method is applied. The shares of elderly obtained for South-Eastern Asia, Southern Asia and Eastern Europe using the new method are also higher than the shares obtained using the traditional old-age threshold of 65. For Asia and Europe as a whole the shares of elderly are as well slightly higher when using our method compared to the RLE = 15 method, but lower as compared to using age 65 as old-age threshold. Examining the change in the share of elderly over time (Figure 2.2), we can observe both for our measure and the RLE = 15 method that the shares have been declining for most regions, except Southern Europe, Eastern Europe and Eastern Asia, where the shares have been increasing.

Figure 2.3 maps the shares of elderly for all European and Asian countries calculated using our method for the year 2012. Clear differences in the shares of elderly between and within the two continents exist. Within Asia, the United Arab Emirates and Qatar had the lowest shares of elderly (0.52% and 0.77%, respectively), whereas Japan and Georgia had the highest shares of elderly (13.86% and 13.48%, respectively). The resulting range (13.3) and variance (7.1) are substantially lower than when 65 is used as old-age threshold (22.9 and 15.8, respectively), and slightly higher (variance only) than when the RLE = 15 method was used (13.3 and 6.9, respectively) (see Table 2.4 and Appendix Figure 2.3). Within Europe, Ireland and Iceland had the lowest share of elderly (7.37% and 7.50%, respectively) using our method for the year 2012, and Latvia and Lithuania had the highest shares (18.56% and 18.08%, respectively). The resulting range (11.2) and variance (7.5) are slightly higher than when 65 is used as old-age threshold (10.8 and 6.5, respectively) but especially higher than when the RLE = 15 method was used (9.3 and 4.9, respectively). For all Asian and European countries combined our CPOAT resulted in more diversity compared to the POAT and less diversity compared to the use of 65 as old-age threshold.

Table 2.2 - Comparison of the comparative prospective old-age threshold (CPOAT) with the prospective old-age threshold (POAT), for selected countries 1972, 2012

	CPOAT			**POAT**			**Difference (CPOAT - POAT)**	
Country	**1972**	**2012**	**change**	**1972**	**2012**	**change**	**1972**	**2012**
Japan	65.00	73.31	8.31	65.00	73.29	8.29	0.00	0.02
China	59.74	66.92	7.18	61.26	67.13	5.86	-1.53	-0.21
Thailand	59.85	67.76	7.91	63.80	70.01	6.21	-3.95	-2.25
India	56.22	63.05	6.82	58.28	64.90	6.62	-2.06	-1.86
Azerbaijan	62.95	64.93	1.98	64.96	65.81	0.85	-2.00	-0.88
Uzbekistan	62.79	63.51	0.73	65.26	65.59	0.33	-2.47	-2.08
Norway	66.40	71.22	4.82	67.30	70.97	3.68	-0.89	0.25
Netherlands	65.78	70.90	5.12	67.03	70.73	3.70	-1.25	0.16
Spain	65.55	72.13	6.58	66.39	71.96	5.57	-0.84	0.17
Ukraine	64.16	62.86	-1.30	66.39	65.02	-1.38	-2.24	-2.16
Asia	58.72	65.93	7.21	60.77	67.27	6.50	-2.05	-1.34
Europe	64.09	69.01	4.92	65.46	70.65	5.19	-1.37	-1.64

Figure 2.1 - Comparison of the comparative prospective old-age threshold (CPOAT) with the prospective old-age threshold (POAT), for Asian and European regions, 2012

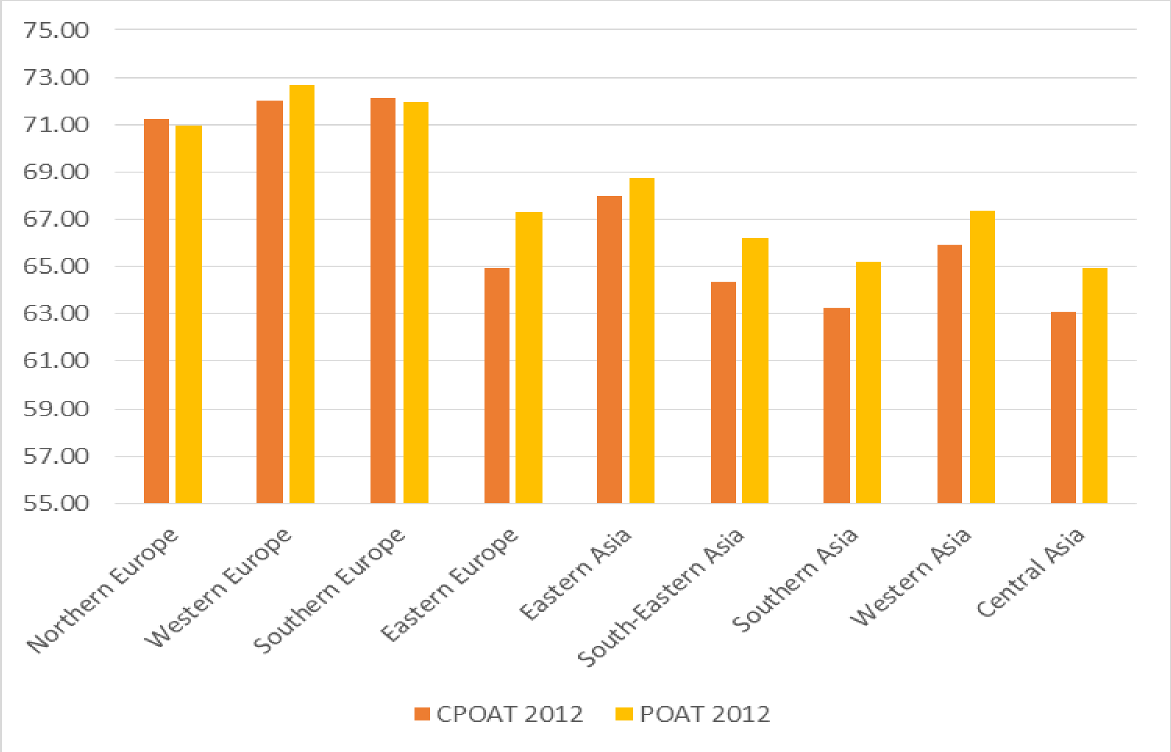

Table 2.3 - Share of elderly (%) with our new method, the RLE = 15 method, and 65 as old-age threshold, selected European and Asian countries plus average Asia and Europe, 2012

	Share of elderly 2012		
Country	**Our method**	**RLE = 15 method**	**Old-age threshold 65**
Japan	13.86	13.86	23.70
China	7.27	7.27	8.65
Thailand	7.38	6.22	9.44
India	6.31	5.29	5.29
Azerbaijan	5.77	5.50	5.77
Uzbekistan	4.98	4.30	4.62
Norway	9.71	9.71	15.40
Netherlands	10.19	10.19	16.24
Spain	11.04	11.04	17.36
Ukraine	17.26	15.23	15.23
Asia	6.47	5.93	7.03
Europe	12.98	11.35	16.77

Figure 2.2 Share of elderly in 1972 and 2012 according to POAT and CPOAT

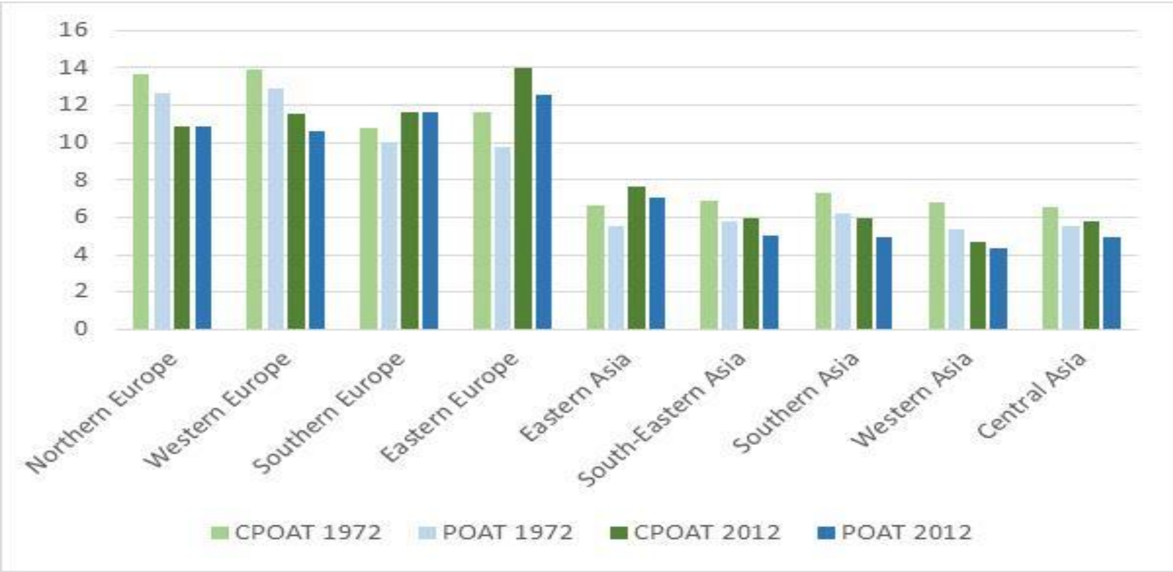

Figure 2.3: Share of elderly (%) in Europe and Asia using our new method, 2012

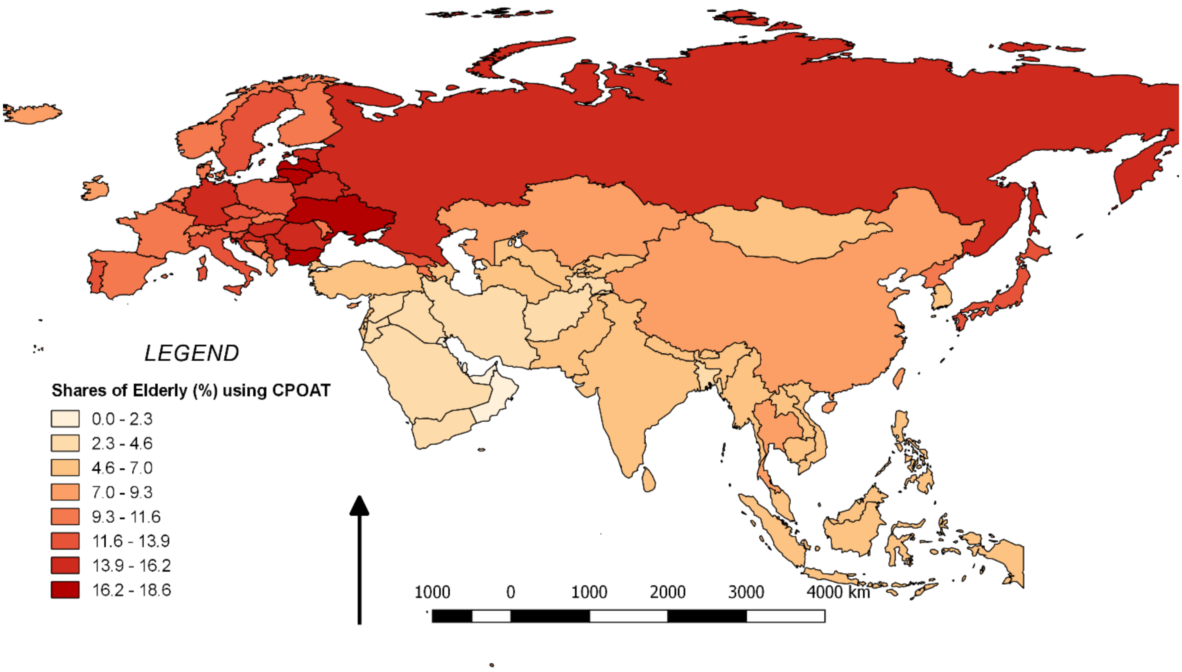

Table 2.4: Comparison of the range and variation in the share of elderly for CPOAT, POAT and 65 as old-age threshold, 2012

	Max value	Country with max	Min value	Country with min	Range	Variance
Asia						
- CPOAT	13.86	Japan	0.52	United Arab Emirates	13.34	7.08
- POAT	13.86	Japan	0.52	United Arab Emirates	13.34	6.87
- 65	23.70	Japan	0.85	United Arab Emirates	22.85	15.77
Europe						
- CPOAT	18.56	Latvia	7.37	Ireland	11.19	7.53
- POAT	16.70	Latvia	7.37	Ireland	9.32	4.89
- 65	20.84	Italy	10.08	Republic of Moldova	10.76	6.50
Asia and Europe						
- CPOAT	18.56	Latvia	0.52	United Arab Emirates	18.04	20.05
- POAT	16.70	Latvia	0.52	United Arab Emirates	16.18	18.11
- 65	23.70	Japan	0.85	United Arab Emirates	22.85	37.92

2.5 Discussion

2.5.1 Summary of results

We compared population ageing in Europe and Asia using a measure that is both consistent over time and appropriate for cross-country comparison.

Our prospective and comparative old-age threshold (CPOAT) was lower than 65 in 2012 in Central Asia, Southern Asia, South-eastern Asia and many Eastern European countries. This in comparison to the prospective old-age threshold (POAT) – as part of the RLE = 15 method - which showed values of either 65 and over. Consequently, the latter regions/countries experienced a higher share of elderly compared to both the use of 65 as old-age threshold and the RLE = 15 method.

Our method resulted as well in more geographical diversity in the old-age threshold and the shares of elderly compared to the RLE = 15 method. Within Europe, our method also resulted in more diversity compared to the use of 65 as old-age threshold.
Our CPOAT generally increased from 1972 to 2012 (Asia: from 59 to 66; Europe from 64 to 69), in a similar manner as the POAT. Changes over time in the shares of elderly were also roughly similar for the two methods, and were almost absent for Asia and Europe as a whole.

2.5.2 Explanation of the observed results

The lower CPOAT values compared to POAT values can be largely explained by differences in adult survival. Appendix Figure 2.1 illustrates this for Thailand in 1972, for which we observed a CPOAT value of 60 that was 4 years lower than the POAT value of 64. Whereas, in 1972, RLE = 15 occurs at age 64 in Thailand (=POAT value) compared to age 65 in Japan, the

ASR_{64} for Thailand (0.658) is much lower than the ASR_{65} for Japan in 1972 (0.829). In other words, in Thailand which exhibits relatively high mortality at adult ages, many people do not survive to the age at which RLE = 15, or the traditional old-age threshold of 65. Controlling for these cross-national differences in the exceptionality of reaching RLE = 15, therefore results in a lower old-age threshold as compared to the POAT for Thailand in 1972. By taking into account not only mortality in later life, as in the RLE method, but also differences between countries in survival rates across the life course, we clearly can account for differences in the exceptionality of reaching a certain old age.

Similarly, the other regions/countries for which we observe a lower CPOAT value compared to the POAT value (Eastern Europe, and the majority of Asian regions) exhibited relatively low adult survival, and consequently chances of reaching a certain old age were lower. For Eastern Europe the low adult survival can be largely linked to the health crisis that was experienced from 1975 onwards as a result of communist regimes' policies (McKee and Shkolnikov 2001; Vallin and Meslé 2004; Leon 2011). For Asia this can be linked to higher levels of adult mortality due to communicable diseases in the 1970s (Murray, Yang, & Qiao, 1992). Accounting for this low adult survival, and consequently, the exceptionality of reaching a certain old age as experienced in most Asian and Eastern European countries, as we do in our method, leads to a lower old-age threshold, and consequently a higher share of elderly, as compared to the RLE = 15 method.

For these regions our old-age threshold were lower and the shares of elderly were higher as compared to the traditional use of 65 as the beginning of 'old age' as well. Population ageing, thus, seems to have been underestimated, so far, in most Asian and Eastern European countries.

Using the RLE = 15 method not only the levels of population ageing have been underestimated, but also the differences between countries. That is, our method also resulted in more geographical diversity in the old-age threshold and the shares of elderly compared to the RLE = 15 method. Differences between methods proved especially strong within Europe when comparing Eastern European countries with the rest of Europe, and when comparing most Asian countries with non-Eastern European countries. In these comparisons, the RLE = 15 clearly underestimates the differences (Appendix Figure 2.2, Table 2.4) by not accommodating for the chance to reach RLE = 15. Within Europe, our method even resulted in more diversity in the shares of elderly compared to the use of 65 as old-age threshold. This has important policy implications (see recommendations).

2.5.3 Evaluation of our method

Within the general framework of the characteristics approach, we defined the prospective and comparative old-age threshold as the age at which the remaining life expectancy multiplied by the adult survival ratio (ASR) equals the value in a certain benchmark country in a given year.

The main argument for using the age at which RLE = 15 and the ASR together is that (1) the RLE takes into account that older people are likely to be healthier if their life expectancy is higher (and, thus, that people are considered old at an older age), and that (2) the ASR takes into account how common it is for people to reach a certain age (if many people survive to a certain age, that age is not considered old). One benefit of using CPOAT is that we only have to choose one benchmark country and the value for the RLE that we consider (RLE = 15 in our case). The year, and the value of the multiplication follow from that. Thus if we choose Japan as benchmark country, the year in which RLE = 15 at age 65 is 1972. In that year the ASR at age 65 in Japan was 82.9. Thus our criterion for each country is the age at which ASR * RLE = 12.4. Since both RLE and ASR decrease monotonously with age, for each country there is only one age at which ASR * RLE equals 12.4. This age is high in countries where survival in adult age is high (high value of ASR) and/or in countries in which health among elderly persons is good (high value of RLE).

Our new method is able to capture differences in the exceptionality of reaching 'old' age between countries. However, an important feature of the RLE = 15 method is that it is also able to take into account life expectancy developments over time in a specific country (Sanderson & Scherbov, 2007). Our observation that the changes over time in old-age thresholds and, consequently shares of elderly, are almost similar over time for our new approach in comparison to the RLE = 15 method indicates that our measure is capable of accommodating for the improvements in mortality in different countries across time as well. Our new method, thus, not only maintains the feature of time-consistency of the RLE = 15 method, but adds to it a way to better compare population ageing among countries with diverse mortality patterns and improvements in adult survival ratios.

In choosing our benchmark country our starting point was that we want to examine changes in population ageing over the last 40 years. Since we wanted to compare our measure with (1) a constant threshold age of 65 years and (2) a threshold age based on the RLE = 15 approach, we selected a country where the age at which RLE = 15 was 65 somewhere in the early 1970s. Another criterion was to select a country in which the value of ASR at that age was relatively high. The reason is that we wanted to select a country in which it was more common to reach that age compared with countries with a lower value of ASR. During the last 40 years Japan has been a country with both high values of RLE and ASR. Another reason to select Japan as benchmark country was that in Japan, the ASR up to age 73 in 2012 largely resembles the ASR up to age 65 in 1972. As a result the CPOAT is similar to the POAT in Japan in both 1972 and 2012.

Our new measure can better aid policy-making as compared to the RLE15 method. Using the RLE15 method, ageing will be diminished not only by improving the health of elderly (resulting in an increase in RLE15), but also by higher premature mortality. When less people reach the age at which RLE=15, this will result in less older people, and consequently less ageing. Increasing premature mortality can, however, not be a goal of policy makers, of course. Using the CPOAT measure, ageing will be diminished both by improving the health of elderly (increase in RLE) and by better survival to the age at which RLE=15 (increase in ASR). Which will be more in line of health policy.

2.6 Recommendations

Our observation that the old-age threshold in countries with low adult survival ratios, e.g. most Asian and Eastern European countries is lower—and that, as a result, the old-age dependency ratio is larger than was estimated using 65 as the old-age threshold and the RLE15 method—has important implications for policy-makers. These countries not only perform worse on health measures; they also appear to have larger shares of elderly people than previously estimated, which warrants attention.

We believe that our measure also has implications for other social science disciplines like economics, sociology, and political science and thus can be applied in these disciplines. For example, our measure can possibly substitute the current traditional measures of ageing in many cross-country comparisons of macro-economic models that study savings, expenditure, health care reforms, and fiscal burdens due to ageing.

Our measure advances the previous methods in that it takes into account not only improvements over time in health (life expectancy) at older ages, but also differences between countries in the commonality of reaching a particular remaining life expectancy threshold. However, to improve our estimates of the elderly population shares, future research should consider the human capital differences between countries as well (Skirbekk 2004; Day & Dowrick 2004; Engelhardt et al. 2010; Skirbekk et al. 2012). That is, in addition to differences in health, differences in productivity, skills, cognition, and labour force participation signal the age at which the elderly become dependent. These differences should be studied over time and across countries.

Moreover, given the differences in life expectancy between men and women (Rieker & Bird 2005; Luy & Minagawa 2014; Crimmins et al. 2011; Crimmins & Saito 2001), and the differences in human capital in general between the sexes (Blau & Kahn 2000; Becker 1985), it might be worthwhile for these and future measures of ageing to provide sex-specific estimates.

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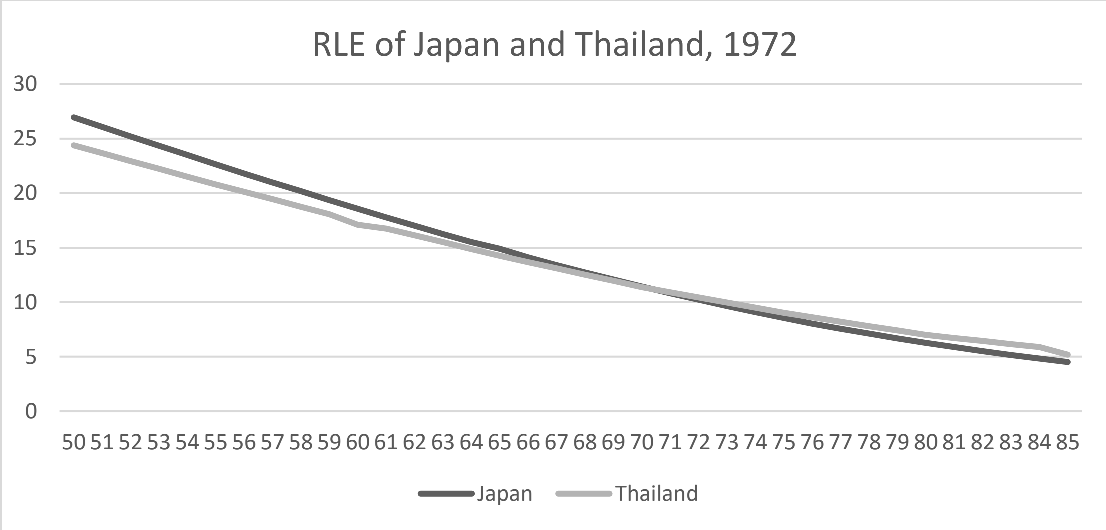
Appendix Table 2.1- Comparison of the comparative prospective old-age threshold (CPOAT) with the prospective old-age threshold (POAT), for selected countries and the different regions, Asia and Europe, 1972, 1992, 2012

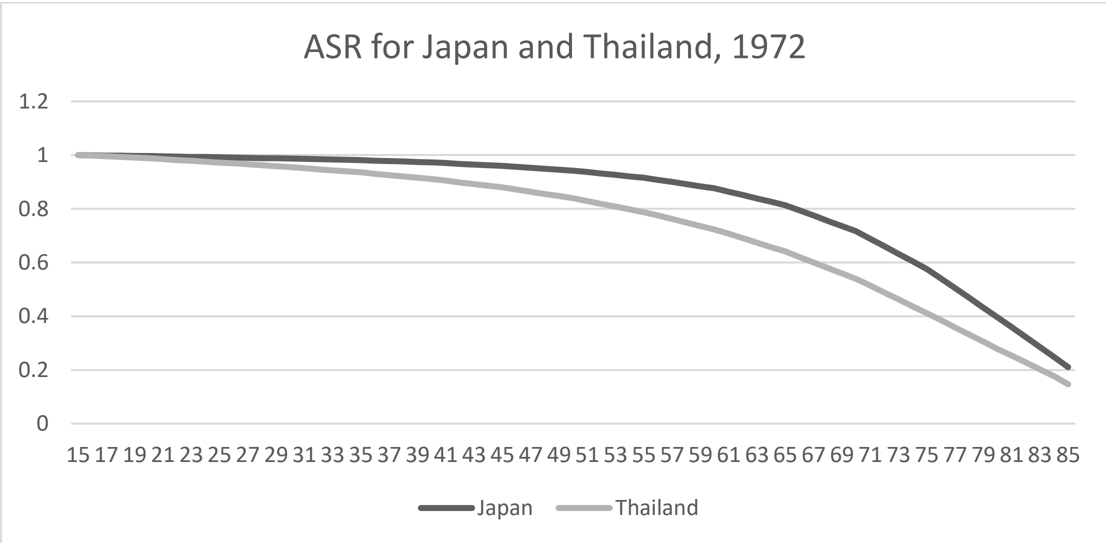
	1972			1992			2012		
Country	**CPOAT**	**POAT**	**CPOAT-POAT**	**CPOAT**	**POAT**	**CPOAT-POAT**	**CPOAT**	**POAT**	**CPOAT-POAT**
Japan	65.00	65.00	0.00	70.56	71.21	-0.64	73.31	73.29	0.02
China	59.74	61.26	-1.53	63.51	64.51	-1.01	66.92	67.13	-0.21
Thailand	59.85	63.80	-3.95	65.39	67.34	-1.95	67.76	70.01	-2.25
India	56.22	58.28	-2.06	59.28	61.39	-2.11	63.05	64.90	-1.86
Azerbaijan	62.95	64.96	-2.00	63.48	65.39	-1.92	64.93	65.81	-0.88
Uzbekistan	62.79	65.26	-2.47	62.77	65.49	-2.72	63.51	65.59	-2.08
Norway	66.40	67.30	-0.89	68.47	69.24	-0.77	71.22	70.97	0.25
Netherlands	65.78	67.03	-1.25	68.40	69.21	-0.81	70.90	70.73	0.16
Spain	65.55	66.39	-0.84	69.33	70.22	-0.90	72.13	71.96	0.17
Ukraine	64.16	66.39	-2.24	62.40	64.51	-2.10	62.86	65.02	-2.16
Asia	58.72	60.77	-2.05	63.35	64.18	-0.82	65.93	67.27	-1.34
Eastern Asia	61.47	62.57	-1.10	65.10	65.59	-0.50	67.99	68.75	-0.76
South-Eastern Asia	58.00	60.38	-2.38	62.55	63.83	-1.28	64.35	66.19	-1.83
Southern Asia	56.66	58.78	-2.12	59.78	61.53	-1.75	63.24	65.19	-1.95
Western Asia	59.93	62.68	-2.75	63.03	65.32	-2.29	65.94	67.35	-1.41
Central Asia	62.57	65.47	-2.89	62.43	65.31	-2.88	63.11	64.91	-1.80
Non-Eastern Asia	59.29	61.83	-2.54	61.95	64.00	-2.05	64.16	65.91	-1.75
Europe	64.09	65.46	-1.37	65.36	67.48	-2.12	69.01	70.65	-1.64
Northern Europe	65.00	66.04	-1.03	67.37	68.42	-1.05	71.22	70.97	0.25
Western Europe	65.00	65.79	-0.79	68.53	69.35	-0.83	72.02	72.69	-0.67
Southern Europe	64.69	65.89	-1.20	68.57	69.21	-0.65	72.13	71.96	0.17
Eastern Europe	63.22	64.87	-1.65	61.82	64.52	-2.69	64.93	67.33	-2.40
Non-Eastern Europe	64.90	65.90	-1.01	68.15	69.00	-0.84	71.79	71.87	-0.08

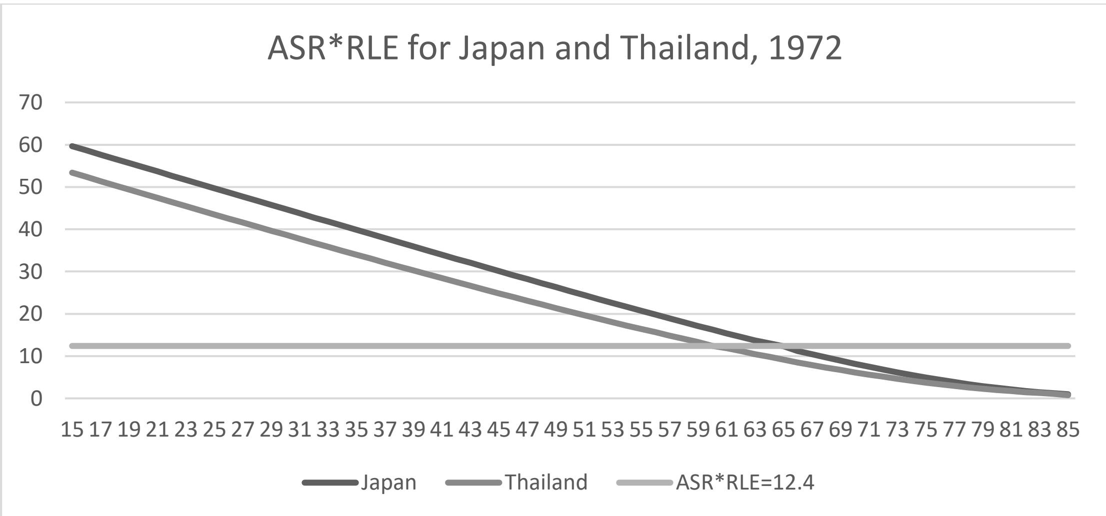
Appendix Table 2.2 - Comparison of the share of elderly calculated with the new measure, the RLE = 15 measure, and using 65 as old-age threshold, for selected countries and the different regions, Asia and Europe, 1972, 1992, 2012

Country	With our method	With RLE15 method	With 65 as old-age threshold	With our method	With RLE15 method	With 65 as old-age threshold	With our method	With RLE15 method	With 65 as old-age threshold
	1972			1992			2012		
Japan	7.70	7.70	7.70	8.33	8.33	14.10	13.86	13.86	23.70
China	6.75	6.22	4.11	6.79	6.16	6.16	7.27	7.27	8.65
Thailand	5.44	3.95	3.58	5.40	4.49	5.40	7.38	6.22	9.44
India	7.98	6.84	3.49	7.04	5.95	4.03	6.31	5.29	5.29
Azerbaijan	6.02	5.11	5.11	6.71	5.39	5.39	5.77	5.50	5.77
Uzbekistan	6.57	5.68	5.68	5.36	4.10	4.49	4.98	4.30	4.62
Norway	12.74	11.80	13.67	12.39	12.39	15.77	9.71	9.71	15.40
Netherlands	9.91	9.16	10.66	10.91	10.11	13.31	10.19	10.19	16.24
Spain	9.50	9.50	10.25	11.09	10.11	15.03	11.04	11.04	17.36
Ukraine	11.58	9.72	10.56	16.31	13.46	13.46	17.26	15.23	15.23
Asia	7.05	6.45	4.01	6.42	5.86	5.30	6.47	5.93	7.03
Eastern Asia	6.63	5.54	4.44	6.87	6.34	6.87	7.69	7.03	9.66
South-Eastern Asia	6.85	5.82	3.68	5.86	4.89	4.41	5.98	5.05	5.45
Southern Asia	7.31	6.18	3.45	6.38	5.45	4.06	6.00	4.97	4.97
Western Asia	6.80	5.38	4.44	5.08	4.60	4.60	4.70	4.35	5.05
Central Asia	6.53	5.53	5.53	6.56	5.13	5.13	5.77	4.95	4.95
Non-Eastern Asia	6.87	5.73	4.27	5.97	5.02	4.55	5.61	4.83	5.11
Europe	12.50	11.51	11.51	13.65	11.70	13.65	12.98	11.35	16.77
Northern Europe	13.63	12.65	13.63	13.40	12.49	15.21	10.88	10.88	16.51
Western Europe	13.92	12.92	13.92	12.02	11.07	14.86	11.53	10.58	18.37
Southern Europe	10.80	9.99	10.80	11.99	10.98	14.99	11.63	11.63	18.21
Eastern Europe	11.66	9.74	9.74	15.04	12.14	12.14	14.01	12.54	14.01
Non-Eastern Europe	12.78	11.85	12.78	12.47	11.51	15.02	10.88	10.88	16.51

Appendix Figure 2.1 - Comparison Thailand, Japan, 1972

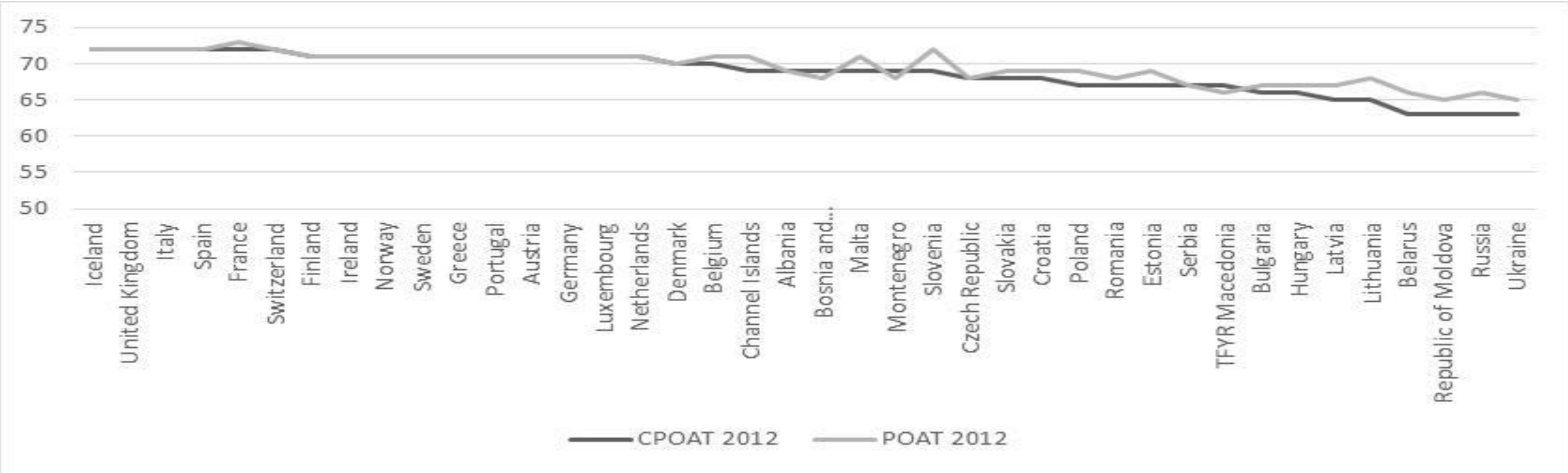




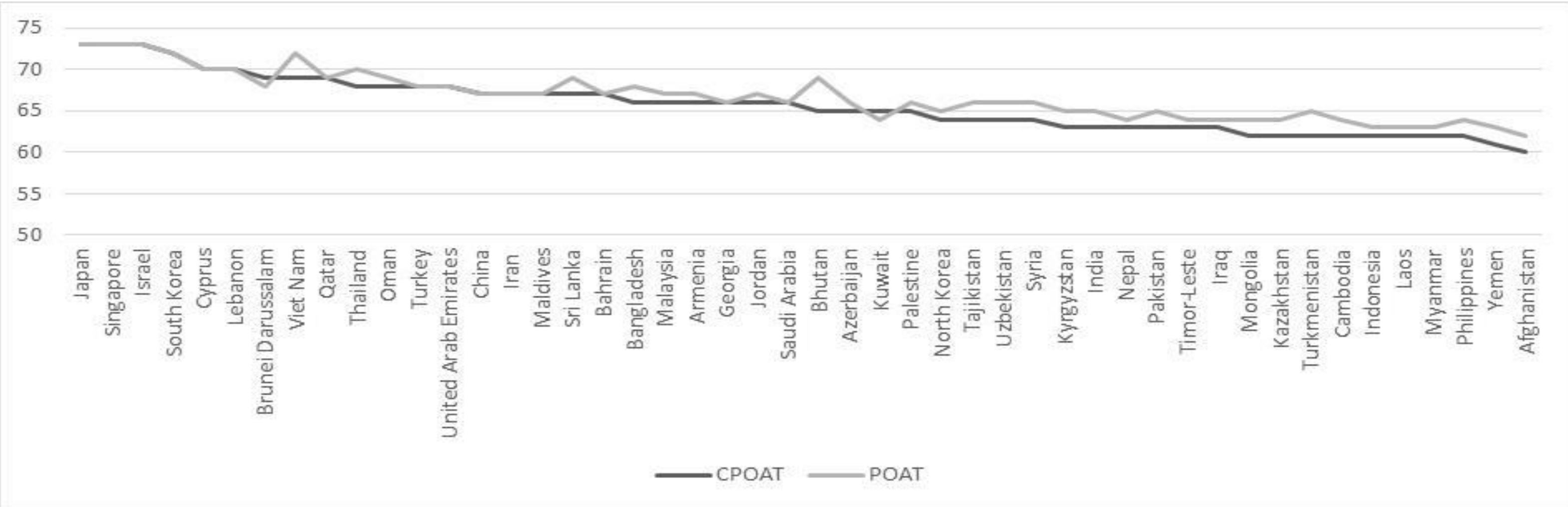


Appendix Figure 2.2 – Comparison CPOAT and POAT for the individual European and Asian countries, 2012

a) European countries

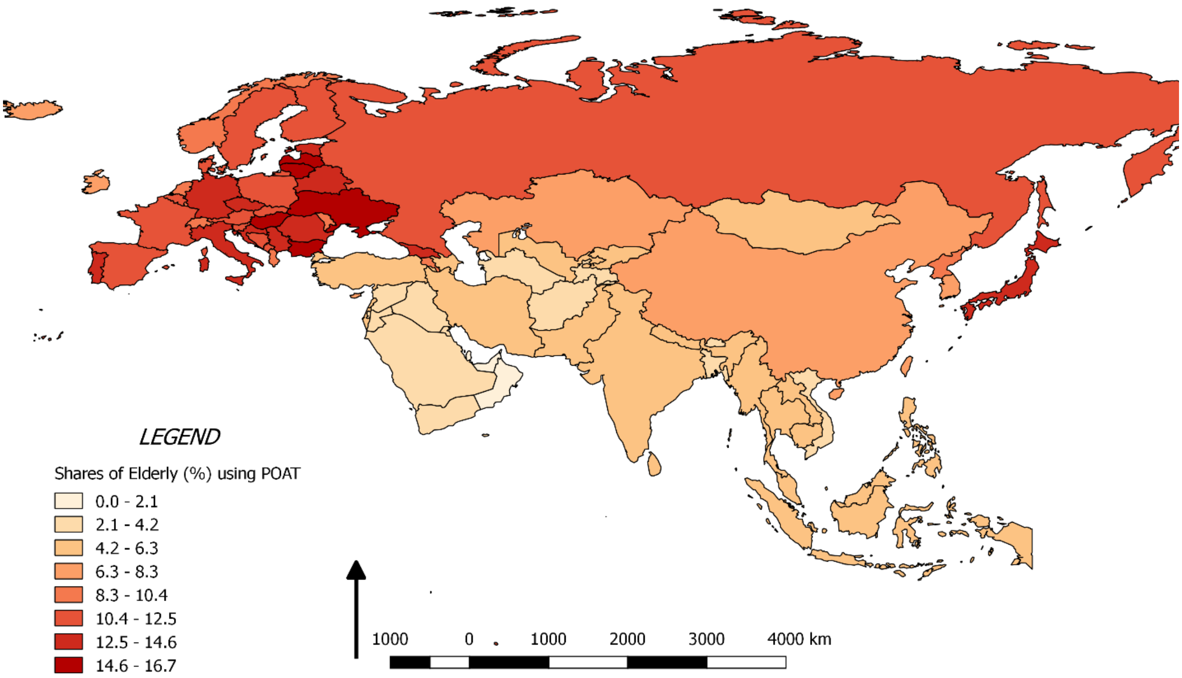


b) Asian countries

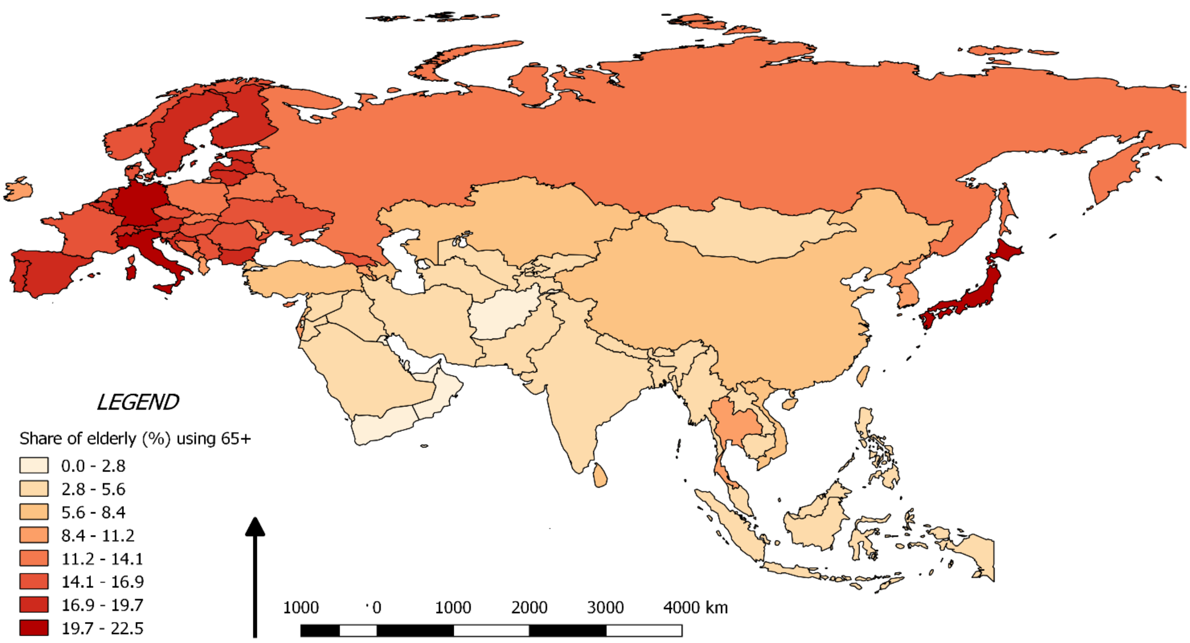


Appendix Figure 2.3 – Share of elderly (%) in Europe and Asia, in 2012, using the RLE = 15 method and the traditional old-age threshold of 65

a) Share of elderly (%) in Europe and Asia, using the RLE = 15 method, 2012



b) Share of elderly (%) in Europe and Asia, using old-age threshold of 65, 2012



Chapter 3 A multi-dimensional measure of population ageing accounting for Quantum and Quality in life years: An application of selected countries in Europe and Asia

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Abstract

Population ageing measured through a fixed old-age threshold like 60+ or 65+ ignores the other important dimensions of ageing. There has been changes among the older persons in multiple dimensions that corresponds to quantity of life years lived as well as the quality of life. The existing multi-dimensional measures also consider the characteristics within a fixed old-age threshold framework which does not account for significant improvements in life expectancy over the years.

We propose a new Multidimensional Old Age Threshold (MOAT) measure that accommodates different dimensions of quantity and quality of older persons. We achieve this through a modified framework of the Characteristic Approach. Our measure incorporates a forward-looking approach to measure ageing and specifies an old-age threshold for different countries after accounting for different dimensions of life expectancy, health and human capital. This method is more suitable for comparison across countries with distinct demographic and health achievements.

The empirical application of our method using selected countries from Europe and Asia shows that the relative performance of countries differs in terms of MOAT in comparison to estimates based on existing measures, primarily due to the inclusion of the quality dimensions. Countries that have better performance in life expectancy, health and human capital have higher values of MOAT and a lower ‘burden’ of older persons in a cross-country perspective in comparison to the existing measures.

Key words: Ageing, Multi-dimensional measure, Quality, Europe, Asia

3.1 Background

Merely depicting population ageing based on the proportion of older persons in a country disregard the large context of achieving quality ageing by these countries. Measurement of population ageing using traditional measures, like the proportion of people aged 65 or 80 and over, or the old-age dependency ratio overstates the 'burden' of ageing. This is because these traditional measures of ageing do not consider the enormous improvements among the older persons in multiple dimensions such as life expectancy, health and human capital (Spijker and MacInnes, 2013). Thanks to various improvements in medical technology, the present older adults are healthier and has less severe functional disabilties than their earlier counterparts (Christensen, Doblhammer, Rau, and Vaupel, 2009). Likewise, there have also been improvements in their intellectual capabilities (Philipov, Goujon, and Di Giulio, 2014; Skirbekk, Loichinger, and Weber, 2012). Since, such improvements in life expectancy, health and human capital among the present older persons are not captured by the traditional measures of population ageing, it fails to provide a holistic picture of the situation and exaggerates the challenges posed by population ageing. Moreover, such measures are particularly not useful for understanding population ageing across countries in Europe and Asia where the quality of life among the aged are significantly different. While Europe has moved to advanced levels of demographic transition and has highest share of older persons in the world, Asia is lagging Europe in the levels of demographic transition. However, Asia is fast approaching on the pathways of Europe and today accommodates the largest quantum of older persons in the world (United Nations, 2015).

Alternate indicators are developed to address the issue of overstating the quantum of population ageing (Chu, 1997; d'Albis and Collard, 2013; Kot, Kurkiewicz, 2004; Ryder, 1975; Skirbekk, Loichinger, and Weber, 2012). Among these, the prospective age approach by Sanderson and Scherbov (2005, 2007, 2008, 2010) has been extensively used for the conceptual and methodological novelty it grants. In this approach, the old-age threshold is not based on an absolute fixed cut-off like age 65, but instead is based on the remaining life expectancy of 15 (RLE=15). By re-defining the old-age threshold using RLE=15, the approach supplements the measures of population ageing using chronological age. While defining ageing through chronological age is retrospective, the RLE measure uses a prospective or forward-looking approach. For instance, as the life-expectancies at higher ages improve, the old-age threshold becomes correspondingly greater. Balachandran et al. (2017) has further adjusted this measure for better cross-country comparison by arguing that the selection of fixed value of RLE as 15 is based on the conditions in the developed countries and it needs to be adjusted when comparison involves both developed and developing countries. It prescribes that all countries be compared against a standard population for a better cross-country comparison. The method is known as comparative prospective old-age threshold. While the prospective age approach and the comparative prospective old-age threshold served towards accommodating differential improvements in life expectancies in different populations many other important features remain overlooked. An improvement in life expectancy does not necessarily qualify improvements in health, ability to work and intellectual capabilities (Nusselder and Peeters, 2006; J. M. Robine, Saito, and Jagger, 2009). There has been changes among older persons in other aspects such as improvements in health, decrease in disabilities, improvements in intellectual abilities and ability to contribute productively (Lutz, Sanderson, and Scherbov, 2008; Manton, Gu, & Lowrimore, 2008; Muszyńska & Rau, 2012; Philipov et al., 2014; Skirbekk et al., 2012; Spijker & MacInnes, 2013; Williams, 2014). Hence, the differences among the older persons has not only been with regards to changes in the dimension of life expectancy, but also in terms of multiple other dimensions as well. In other words, the changes among the older persons has not only been in terms of quantum of life years, but also been in terms of the quality of the life.

To recognize the multi-dimensionality in the population ageing, and also to account for the quality, several multi-dimensional indicators have come up recently such as the Active Ageing Index (AAI, 2015), the Global Age Watch Index (HelpAge, 2015), and the Index of well-being in older population by Stanford Center on Longevity and Population Reference Bureau (Kaneda, Lee, and Pollard, 2011), among others. These measures try to capture the differences in health, capabilities, and human capital among the present older persons in varied contexts. For instance, Global Age Watch Index is a measure that combines the levels of health, levels of income, level of capabilities such as education, and enabling environment of the 60+ population to understand the well-being of the older adults across different countries. Similarly, AAI, which was specifically formulated to understand the situation among the older persons in Europe, combines the employment levels, levels of social participation, level of capabilities, and enabling environment for the older persons (that includes variables like physical and mental well-being) of the population above age 60. Index of well-being in older population is a measure that combines that different aspects of well-being such as material, physical, social and emotional well-being of the population above age 60 in 12 developed countries.

Undoubtedly, these multi-dimensional measures have been successful in highlighting the multiple dimensions of changes in the health, life expectancies, capabilities and human capital among the present older persons, these measures have some serious drawbacks. First of all, these measures abstractly consider population above a traditionally based abstract cut-off old age threshold of 60 or 65 as older persons. It, therefore, assumes that the different characteristics with regards to population above age 60 or 65 remain same across countries. Moreover, it also assumes that there are no changes in different characteristics among the age-group above 60 or 65 over the years. However, both these assumptions do not hold well among the present older persons. For instance, for the period of 2010-15, the remaining years of life at age 65 in Netherlands is around 20 years, whereas it is only around 14 years for India. It may be also noted that the levels of disabilities at age 65 in an advanced county like the Netherlands is much lower than the levels of disabilities at age 65 in India. Therefore, the assumption of an abstract cut-off age of 65 does not hold well for cross country comparisons and comparisons across time.

Second issue with the existing multi-dimensional index is that it conceptualizes old-age from a regressive framework and the issue of population ageing is seen from a direction of ‘turning the problem into solution’ (de São José, Timonen, Amado, and Santos, 2017; Timonen, 2016). There are several examples to show in this direction. For instance, the older population is expected to stay longer in the labor market so as to reduce the potential losses for the labor market and the economy due to old-age. However, staying longer in the labor market may not be the idea of well-being in several countries, such as those in the Asian context (Singh and Das, 2011). Therefore, the conceptualization of older persons is regressive rather than being portrayed as progressive.

Sanderson and Scherbov (2013) propounded a relatively newer and broader methodological framework namely the ‘characteristic approach’ to measure ageing using any particular dimension. According to this approach, cross-country comparison of ageing can be made using any life expectancy, human capital or health by equating the chronological ages at which the values across the characteristics are same. Sanderson and Scherbov (2016, 2015) illustrates different applications of characteristics approach and showed that the results differ across countries when ageing is redefined using different characteristics. However, though these studies establish that there have been improvements among the present older persons in terms of life expectancy and different aspects of health and human capital, the applications of the approach has been restricted to only one specific dimension of health or human capital individually and do not simultaneously accommodate for the multi-dimensionality. Thus, the multi-dimensionality which is inherent in the improvements among the older persons in various dimensions are ignored in the existing applications of the method. The quality of ageing population cannot be captured by merely considering single characteristics but necessitates a multidimensional approach. The challenge would be to locate indicators that are relevant for examining the changes in the quality of ageing in a multidimensional framework.

In this paper, we compare population ageing in Europe and Asia using a multi-dimensional measure of population ageing that accommodates for the quantity and quality of life years among the population. The measure considers changes in life expectancy, health and human capital, three important dimensions of older persons’ well-being. In order to overcome the demerits of current multi-dimensional measures that abstractly consider cut-off age of 60 or 65, we apply a modified framework of characteristic approach that incorporates a forward-looking approach to measure ageing. In this way, our proposed measure looks into the multi-dimensionality in the improvements among the present older persons by simultaneously incorporating the changes in dimensions of life expectancy, health and human capital and also by providing a forward-looking approach to quantify ageing.

3.2 Data and Method

3.2.1 Selection of variables

As noted, there have been multi-dimensional changes in the present older persons in terms of life expectancy, human capital and health. To capture these changes, we have used one variable each to represent these three dimensions. To represent life expectancy, an adjusted version of the remaining life expectancy of 15 (RLE=15) method is used. The RLE=15 method redefines the conventional old age threshold value by successfully accommodating the improvements in life expectancy in different populations overtime (Sanderson and Scherbov, 2005,2010, 2007). However, the selection of the value 15 was based on the fact that the RLE of the European population in 1970 was indeed 15. Such a selection of the old-age threshold does not accommodate for the exceptionality of reaching the age at which RLE=15, which is different across countries with varied mortality experiences, especially while considering the Asian countries. Balachandran et al. (2017) tried to accommodate the exceptionality of adult population reaching advanced ages through a refined measure called comparative prospective old-age threshold (CPOAT). According to this adjusted measure, the old age threshold value of all the countries were adjusted with an adult survival value derived from a standard population. Based on the same principle, remaining life expectancy variable with a value that accounts for the mortality differences across the countries is used for deriving the multidimensional measure.

Human capital is rather wide in its conceptualization and measurement in literature. Broadly, it refers to the set of skills, knowledge, habits, personality attributes and abilities of an individual. Literature used different variables to describe human capital. For instance, some authors argue that labor market characteristics like wage rate represents the level of human capital (Angrist and Krueger, 1991; Mincer, 1958), as against others opining that the intellectual traits like educational levels would provide a better understanding of the levels of human capital (Becker, 1975; Schultz, 1961). While comparing older persons in Europe and Asia, it is perhaps not conducive to account for labor market characteristics. This is primarily because the labor market for the older persons is not well developed in many developing countries in Asia and sometimes it is poverty among older persons that compels them to continue in the labor market (Bloom and Eggleston, 2014; A. Singh and Das, 2015). Hence, it may not be appropriate to consider the characteristics that are not comparable across the regions of our interest. On the other hand, level of cognition has been identified as a good proxy for intellectual traits among the older persons (Skirbekk et al., 2012; Weber, Dekhtyar, & Herlitz, 2017). Rather than using traditional measures of intellectual traits like levels of education and years of schooling, the aspect of level of cognition offers comparability across older persons in these regions as it is more dynamic in nature. Further, the traditional measures of intellectual traits like years of schooling remain static over the life-course after attainment of a particular level at younger ages; however, the level of cognition is a variable that accounts for an individual's life-course developments. Another limitation of considering levels of education for the developing countries in Asia could be the very low educational opportunities and infrastructure prior to1960s due to historic reasons like struggle for independence and lags in development. Consequently, the level of education among the present older persons is rather low as they spend their childhood and youth in an environment of meagre development and educational opportunities. However, there were improvements in the skill sets in these populations over the life-course as their countries changed in terms of economic growth and social opportunities. Cognition captures better the intellectual traits in such conditions. To capture the levels of cognition, we look into the number of words recalled immediately out of 10 words from standardized surveys across countries. This is a widely used measure of cognition (Skirbekk et al., 2012; Weber et al., 2017). A higher number of words recalled represent better levels of cognition.

In order to capture the health dimension, we use a health variable that describes the functional abilities among the older persons. This variable is particularly useful for the assessment of older persons population in developing countries where the prevalence rate of disability is relatively high (Klimczuk, 2016; Wiener, Hanley, Clark, and Van Nostrand, 1990). Life expectancy need not necessarily reflect an improvement in functional abilities (Crimmins, Kim, and Solé-Auró, 2011; J. Robine and Michel, 2004). The variable also reflects other vulnerabilities among older persons like admission to retirement homes and weak health care utilization (Luppa et al., 2009; Scott, Macera, Cornman, and Sharpe, 1997; Tsuji et al., 1994). Due to aforesaid reasons, a variable proxying functional abilities- the percent of population able to perform the activities of daily living (ADL) - to reflect health dimension among the older persons is used. In order to capture the level of abilities with ADL, we look into an individual's ability to perform six activities: walking, eating, bathing or showering, using the toilet, dressing and getting in and out of the bed. If an individual is having disabilities in any one of these activities, she/he is identified as having physical disability (coded 0), or else not (coded 1).

3.2.2 Data Source

To obtain data on remaining life expectancy, we used data from the UN population division (United Nations, 2010). The data on cognition and ADL were obtained from the Survey of Health, Ageing, and Retirement in Europe (SHARE), Wave 4 (2010-11)(A Börsch-Supan, 2018; Axel Börsch-Supan et al., 2013; Malter and Börsch-Supan, 2013) for European countries and WHO Study on Global AGEing and Adult Health (WHO-SAGE), Wave 1 (2007-10) (Kowal et al., 2012) for India and China. The indicators in the two surveys are comparable and measured with similar questions.

We select representative countries from Europe and Asia for our analysis. We select India and China as WHO-SAGE data is available only for these two countries in Asia. However, India and China together constitute majority (around 62 percent) of the older persons over age 65 in Asia (United Nations, 2015). We also use representative countries from Europe: The Netherlands and France from Western Europe, Poland and Hungary from Eastern Europe, Denmark and Sweden from Northern Europe, and Spain and Italy from Southern Europe. All these countries have greater share of older persons (more than 15%) by conventional measure of simple proportion. A further overview of the dataset including the sample size is given in Table 3.1.

Table 3.1: Summary of datasets

	Asia		**Western Europe**		**Eastern Europe**		**Southern Europe**		**Northern Europe**	
Data Source	WHO- SAGE		SHARE, Wave 4							
Year	2007-2010		2010-2011							
Countries	India	China	Netherlands	France	Hungary	Poland	Spain	Italy	Denmark	Sweden
Sample size	12198	13857	2762	5857	3076	1724	3570	3583	2276	1951

3.2.3 Methodology

We use the principles of Characteristic Approach to execute the multi-dimensional measure. The characteristics approach provides a framework for re-assessing population ageing based on different characteristics of the population (Sanderson and Scherbov, 2013; 2016). For instance, if population A has a particular level of cognition at age 65 and population B has the same level of cognition at age 75, the framework stipulates that the age of 65 in population A is same as age 75 in the population B, when the characteristic of cognition is considered. Hence, the framework provides an opportunity to compare population ageing across countries using different characteristics.

Mathematically, it can be written as follows:

$$\propto_{A,k} = E_{k,t}$$

Where $\propto_{A,k}$ refers to old-age threshold value of country A using the characteristic 'k' (Sanderson and Scherbov, 2013). 'k' can be any characteristics that we take into account: RLE, level of cognition or abilities with ADL. The different characteristics here refers to the different variables considered. E refers to the age at which the old-age value is equal to the threshold value. As mentioned earlier, there are different threshold values for different characteristics considered.

We use the characteristic approach into the multi-dimensional framework to enable a cross-country comparison. We adopt 4 steps for the computation of the same:

Step 1: Selection of standard population

We select a standard population to formulate an old-age threshold based on three dimensions considered for the multi-dimensional measure. This is based on the principle propounded in Balachandran et al. (2017) which improves the RLE=15 method for a better cross-country comparison by using a standard population. The selection of 15 as the RLE value to re-define older persons was a pragmatic compromise to make an empirical comparison across countries (Sanderson and Scherbov, 2010). However, such an abstract selection of the value of 15 was in line with the European conditions and may not be apt for comparison across countries with varied mortality experiences. Instead, a more apt way to execute the cross-country comparison as formulated by Balachandran et al. (2017) prescribes to modify the RLE=15 method and to subsequently estimate the old-age threshold across counties using the selected standard country. It thereby offers a tool for better cross-country comparison.

Based on the principle, we choose different standard populations for different dimensions we considered for the multi-dimensional measure. Since our analysis consists of countries with varied mortality, human capital and health experiences at different ages, it is not advisable to select a country based on its overall performance neglecting the age-specific achievements in each dimension. While making a selection of standard population, we have two options. One is to choose the country with the best performance across different dimensions as the standard. Such a principle is followed in measures such as Human Development Index (United Nations Development Programme, 2016). However, an empirical investigation of the data found that a selection of the best performing country as the standard does not allow for appropriate comparability with lower performing developing countries, as there are substantial differences in absolute value across dimensions in these countries. Moreover, there are differences among the countries in terms of best and worst performers across the age-groups in the different dimensions considered for the analysis, and thus do not allow us to select one best performing country. Hence, we go for the second option for the selection of the standard population, which is to choose a standard population based on the highest age-specific performance as well as the lowest age-specific performance. Such a selection allows us to make cross-country comparison across developing and developed countries across Europe and Asia. Thus, we do not choose a specific country as the standard population, but instead resort to a hypothetically formulated standard population based on the age-specific performance. The standard population consists of the average of the values of the highest and lowest achievements in each of the age group considered. Mathematically, this can be expressed as:

$$V_{S,T,i} = \frac{V_{min_{T_k,i}} + V_{max_{T_k,i}}}{2}$$

Where $V_{min_{T_k,i}}$ refers to the value of the standard population S of the dimension T_k at age *i*. k can take value between 1 and 3, as three dimensions- remaining life expectancy, cognition or abilities with ADL. $V_{max_{T_k,i}}$ is the minimum value of dimension T_k at age *i* across the countries considered and $V_{max_{T_k,i}}$ is the maximum value of the dimension T_k at age *i* across the countries.

Hence, the remaining life expectancy at different ages of the standard population, which is hypothetically generated, is the average of the highest and lowest values of remaining life expectancies of the countries that are considered in our analysis. Similarly, the age-specific values of the standard population with regards to the dimension of cognition consists of the average of the highest and lowest values of the age-specific values of the number of words recalled across the countries considered. The standard population of the dimension on ADL is also obtained similarly.

Step 2: Selection of optimal value in each dimension

Once the standard population is obtained for different dimensions, we choose the optimal value for the different dimensions from the standard population. Since the data we use is representative of the population above age 50, we use age 50 as the lower bound for the standard population. Also, though there is no upper age limit in the datasets, an empirical investigation points that the comparable samples across countries considered are minimal above age of 85. Hence, we use age 85 as the upper bound of the standard population. In order to smoothen the fluctuations occurring in the data, we categorize the data into seven age groups of 5-year intervals. We then obtain the optimal value in each dimension from the standard population by averaging the values across the seven age groups between the ages of 50 and 85. In doing so, we make a choice of optimal value that is comparable across the varied countries in our analysis and thereby allows us to make an apt comparison of cross-country situation of population ageing across these countries. Mathematically, it can be expressed as:

$$OV_{T_k} = \sum_{i=50}^{85} \frac{V_{S,T_k,I}}{N}$$

Where OV_T is the optimal value using the dimension T_k; $V_{S,T_k,i}$ refers to the value of the standard population S of the dimension T_k at age group *I.* N is the number of age-groups. Since, there are seven age groups in our analysis, the value of N is 7.

Step 3: Identification of old-age threshold across countries

After identifying the optimal values, the next step is to identify the old-age threshold value for each of the three dimensions for different countries. Old-age threshold is the age at which a country reaches the optimal value. For instance, if the optimal value of the dimension of cognition is 4.5 and a country A reaches this value at age 70, then age 70 is considered as the old-age threshold for that particular dimension. In case a country continue to be at the same level of cognition at age 75, or if it returns back to the same level of cognition at age 75, then 75 is considered as the old-age threshold for the country. It can be expressed as:

$$OT_{C,T} : lC_{C,T} = OV_T$$

Where $OT_{C,T}$ refers to the old-age threshold of country C with regards to dimension T. This value is given by the last chronological age of country C at which the value the dimension T (given by lC_C) is same as the optimal value of dimension T (given byOV_T). Since we have 5-year age groups used in the analysis, a linear interpolation technique is used to find the exact old-age threshold.

Step 4: Combining different dimensions

After identifying different old-age thresholds based on the different dimensions for each country, we combine the old-age thresholds to obtain a multi-dimensional measure. We do this by averaging the values of old-age thresholds using the dimensions of life expectancy, cognition and abilities with ADL for each country. Such an averaging is in line with many other multi-dimensional measures such as Human Development Index. The resultant average old-age threshold is multi-dimensional one. We call this value as the Multi-dimensional old-age threshold (MOAT). Mathematically it can be expressed as:

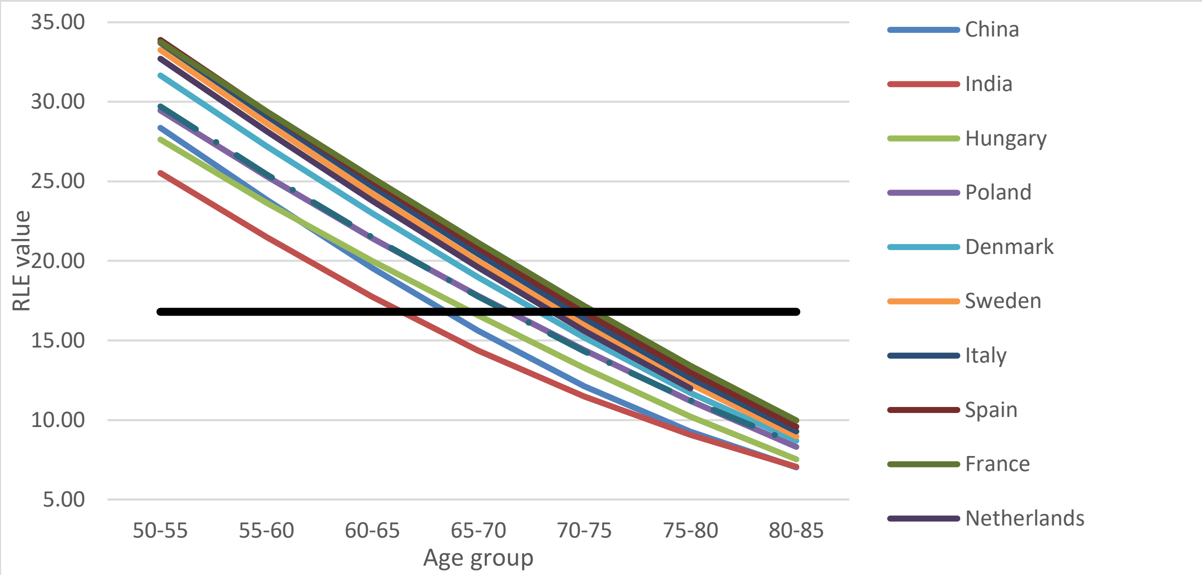
$$MOAT_C = \sum_{T=1}^{3} \frac{OT_{C,T}}{3}$$

Where $MOAT_C$ refers to MOAT of country C. It is given by the average of old-age threshold across characteristic T for country C (given by$OT_{C,T}$).

3.3 Results

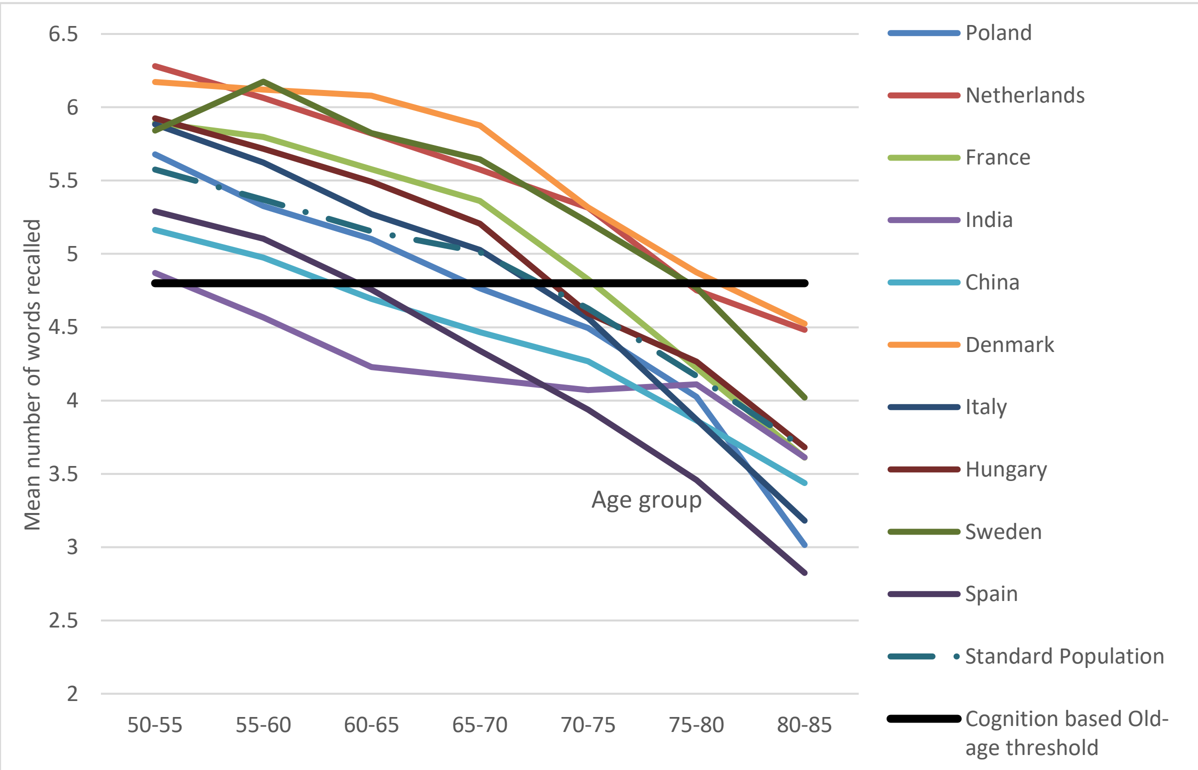
We have computed the age-specific values of RLE, cognition and the percentage of population with abilities to perform ADL for the 10 selected countries which is plotted in Figure 3.1 (a-c).

Figure 3.1 (a): Remaining life expectancy across age groups in selected countries of Europe and Asia, 2010



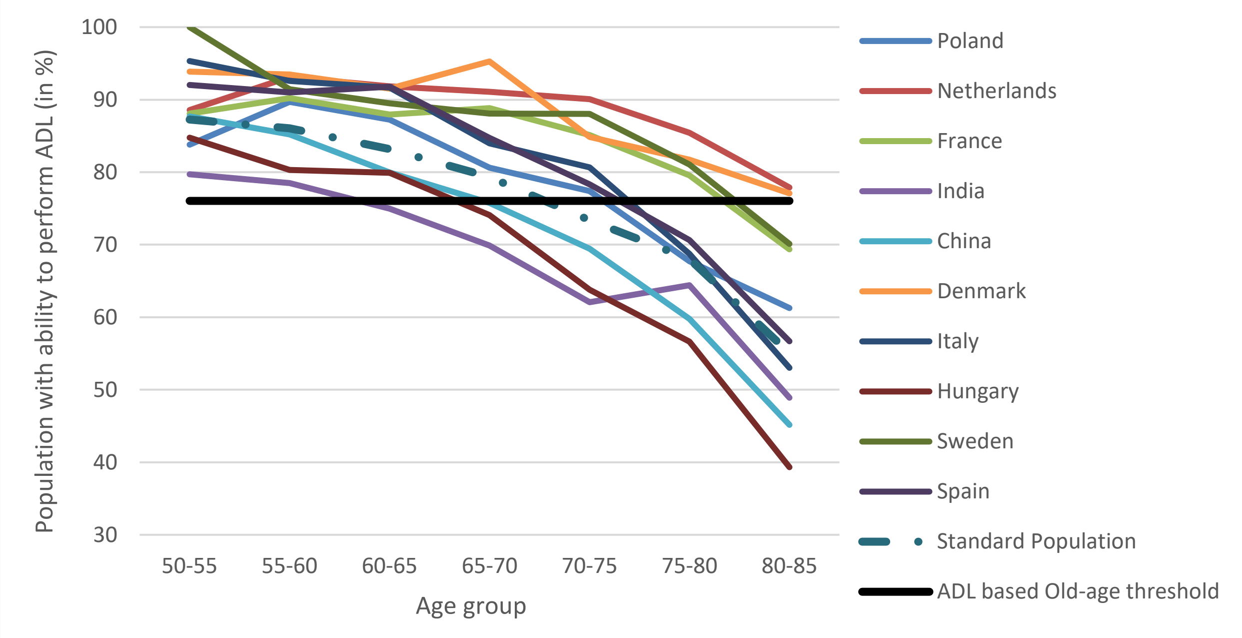
Source: Authors' calculation from UN population database (United Nations, 2010)

Figure 3.1 (b): Mean of number of words recalled across age groups in selected countries of Europe and Asia, 2010



Source: Authors' calculation based on SHARE, Wave 4, 2010-11 (Malter and Börsch-Supan, 2013) and WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

Figure 3.1 (c): Percentage of population able to perform ADL across age groups in selected countries of Europe and Asia, 2010



Source: Same as in Figure 3.1(b)

Figure 3.1 (a) shows how the remaining life expectancy decreases with increasing age in selected countries of Europe and Asia. The pattern shows a monotonic decrease in remaining life expectancy with increasing age. However, the levels of RLE are different across these countries. While Asian countries of India and China along with the Eastern European country of Hungary shows lower RLE at different ages, Western European countries like France and Netherlands have better RLE across all age groups. Similarly, it can be observed from Figure 3.1 (b) that the average mean number of words recalled goes down with age, though the pattern of decrease is different across the selected countries. Countries of Denmark and Netherlands have higher levels of means words recalled across life-course, whereas countries like India and Spain have lower levels of mean words recalled at different ages. Figure 3.1 (c) represents the percentage of population with abilities to perform ADL. It also decreases in general across countries with rise in age. However, there are country specific variations. Countries like India and Hungary have lower ADL abilities across different ages as against countries like Sweden and Netherlands with better abilities in ADL across age groups.

Figure 3.1 (a-c) also provide values of the standard population with regard to different dimensions. The standard population values of a dimension are estimated by averaging the age-specific average values of the dimension among the countries considered. The values of the standard population also decrease with age for the different dimensions considered. The plot of the standard population in the different dimensions of RLE, cognition and ADL abilities are also depicted in figure 3.1 (a-c) respectively and its values decreases with age as well. From the standard population, the optimal values of different dimensions were calculated. The optimal values are estimated as the average of the standard population values across the age groups- 50 to 85. The RLE based optimal value was identified as 16.8. This value is based on the conditions among the countries considered and is not an abstractly chosen value as in RLE=15 method.

The optimal values for the dimensions of cognition and ADL abilities were estimated as 4.8 and 76.04 respectively.

3.3.1 Estimation of dimension based old-age threshold and MOAT

Based on the optimal values identified, we estimate the old-age threshold for different dimensions and the also estimate the multi-dimensional old-age threshold (MOAT). These estimates are shown in Table 3.2.

Table 3.2: Estimates of old-age threshold values for different dimensions and MOAT in selected European and Asian countries, 2010

Region	**Country**	**Remaining Life expectancy based old-age threshold**	**Cognition based old-age threshold**	**Functional abilities based old-age threshold**	**Multidimensional old-age threshold (MOAT)**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Asia	China	63.6	60.5	67.0	63.7
	India	61.2	52.5	61.0	58.2
Western Europe	Netherlands	68.5	77.0	83.3	76.3
	France	70.3	72.0	79.0	73.8
Northern Europe	Denmark	67.9	78.0	83.5	76.5
	Sweden	68.9	77.1	79.7	75.2
Southern Europe	Italy	69.1	69.8	74.3	71.1
	Spain	69.9	61.9	74.0	68.6
Eastern Europe	Poland	66.6	66.9	73.0	68.8
	Hungary	64.5	70.7	65.6	66.9

Source: Authors' calculation from UN population database (United Nations, 2010), SHARE, Wave 4, 2010-11 (Malter and Börsch-Supan, 2013) and WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

Columns 3, 4 and 5 in Table 2 show the old-age thresholds based on the dimensions of RLE, cognition and functional abilities (ADL) respectively. For instance, age 63.6 is the RLE based old-age threshold for China. It means that 63.6 is the age at which China has a value of RLE of 16.8, which is the estimated optimal value. Similarly, the cognition based old-age threshold for China is 60.5 and functional abilities based old-age threshold for China is 67. This means that China attains the cognition based optimal value of 4.8 words at age 60.5 and ADL based optimal value of 76.04% at age 67. It may be noted that the cognition based old-age threshold in India is 52.5 and is very low in comparison to the other countries. This can be attributed to lower levels of educational opportunities for older persons cohort in India, who spend most of their childhood in the newly independent India with lower educational infrastructure (Singh, P et al., 2017). Lower levels of education leads to lower cognitive abilities (Mavrodaris, Powell, and Thorogood, 2013).

The divergences in the old-age threshold values in terms of different dimensions can also be observed from the Table 2. For instance, the RLE based old-age threshold of Netherlands is 68.5, as compared to its functional abilities based old-age threshold of 83.3. It can also be observed that the Northern and Western European countries of Denmark, Netherlands, and Sweden have relatively higher old-age thresholds using the characteristics of cognition and abilities with ADL. It indicates towards the relatively higher level of achievements in terms of health and human capital dimensions in these countries. Achievements of MOAT values in countries like Netherlands and Denmark due to their better performance in health and human capital than old-age threshold based on RLE. At the same time, the Asian countries of India and China, has lower values of MOAT showing relatively lower levels of life expectancy, health and human capital attainments in these countries. Column 6 in Table 2 shows the estimates of MOAT, which is obtained by averaging the values in columns 3, 4 and 5. A higher value of old-age threshold signifies that optimal value is reached at later ages and signifies the better performance by a country.

In general, the estimates also point towards the relative advantage/disadvantage for each country across different dimensions. For instance, the performance of the Southern European country of Spain in terms of the dimension of cognition is lower than its own performances with regard to dimensions of remaining life expectancy and functional ability. Likewise, Hungary's performance in the dimension of cognition is better than its own performance in dimensions of life expectancy and functional ability. Performances in the dimensions of cognition and functional ability is better for Netherlands and Denmark in comparison to its own achievements in remaining life expectancy. The results thus show that a higher quality among the older persons in a country helps the country to increase the age at which it reaches 'old-age' in a multi-dimensional sense.

3.3.2 Rankings of countries

Table 3.3 shows the relative ranks of countries using MOAT and also with regard to dimensions of remaining life expectancy, cognition and functional ability. Here, a value of 1 refers to best performance and 10 refers to the poorest. Two countries depict the same rank if they have the same old-age threshold values.

Table 3.3: Relative Ranks of the countries across different dimensions and MOAT, 2010

Region	**Country**	**Remaining Life expectancy based old-age threshold**	**Cognition based old-age threshold**	**Functional abilities based old-age threshold**	**Multidimensional old-age threshold (MOAT)**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Asia	China	9	9	8	9
	India	10	10	10	10
Western Europe	Netherlands	5	3	2	2
	France	1	4	4	4
Northern Europe	Denmark	6	1	1	1
	Sweden	4	2	3	3
Southern Europe	Italy	3	6	5	5
	Spain	2	8	6	7
Eastern Europe	Poland	7	7	7	6
	Hungary	8	5	9	8

Source: Computed based on Table 3.2

Columns 3, 4, and 5 in the Table 3 shows the ranks of selected countries with different dimensions. Column 6 shows the ranks of countries using MOAT. Denmark has the best rank using MOAT. It is also ranked best with the dimensions of cognition and functional ability. However, it is ranked only 6th in the dimension of RLE. The countries of Netherlands and Sweden follows Denmark in terms of better ranks with MOAT. However, these countries are ranked only 4th and 5th, respectively, in terms of the dimension of RLE. The Asian countries of China and India have the lowest ranks with MOAT. Similarly, Spain ranks 2nd in terms of RLE, but has lower ranks of 8th and 6th in the dimensions of cognition and functional abilities respectively. This results in Spain having only a rank of 7th using MOAT. Similarly, the Eastern European country of Hungary has better ranks in the dimension of cognition in comparison with the dimensions of RLE and functional abilities. Overall, using MOAT, the Western and Northern European countries as expected perform better among its counterparts from other parts in Europe as well as from Asia.

3.3.3 Shares of older persons

To understand the ‘burden’ of ageing across countries after accounting for their differentials in life expectancy, health and human capital, we estimate the share of older persons across countries using MOAT. We also compare it with the shares of older persons calculated using the prospective old-age threshold (that uses RLE=15), which only accounts for improvements in life expectancy. In addition, we also compare these values with the traditional measure of ageing (that uses 65 as the old-age threshold). The results of these comparisons are shown in Table 3.5.

Table 3.5: Shares of older persons (in percentage) in total population using different methods of population ageing for selected countries, 2010

		Shares of older persons (in percentage)		
Region	**Country**	**Using MOAT**	**Using RLE=15 method**	**Using traditional method (65+)**
Asia	China	10.06	7.94	8.65
	India	9.51	6.31	5.29
Western Europe	Netherlands	6.28	11.00	16.23
	France	9.95	11.28	17.29
Northern Europe	Denmark	5.92	12.29	17.34
	Sweden	8.31	12.71	18.81
Southern Europe	Italy	14.46	14.54	20.82
	Spain	13.85	11.93	17.35
Eastern Europe	Poland	10.80	11.36	13.81
	Hungary	14.88	14.80	16.87

Source: Computed from UN population database (United Nations Population Division, 2010)

The estimation shows that Hungary and Italy have the highest shares of older persons using MOAT. For the European countries considered, the shares of older persons calculated using the multi-dimensional measure of MOAT is lower than illustrated using the traditional measure of abstractly using age 65 as the old-age threshold. However, for the Asian countries, the share of older persons is higher using MOAT than both the traditional measure and the RLE=15 method. For countries that has made substantial improvements in human capital- Denmark, Netherlands and Sweden- the share of older persons using MOAT is substantially lower than that using the old-age threshold with RLE=15 method.

The differences in the share of older persons among European and Asian countries considered is lower using MOAT than the traditional measure of 65+; whereas it is slightly higher in comparison with the RLE=15 method. The difference in the percentage share of older persons between the countries which have the highest and lowest share of older persons among the selected countries is seen as 8.96% using MOAT, whereas this difference is 15.53% using the traditional measure and 8.49% using the RLE=15 method.

However, it may also be noted that the data on share of older persons needs to be cautiously interpreted with the case of MOAT. This is because the MOAT values are obtained using a standard population derived from the countries selected, rather than choosing the best performing country. Therefore, while the results are best for a comparative purpose across countries, interpretation of an absolute value may not be very meaningful. However, the important point here is that the picture with respect to the 'burden' of older persons changes when multi-dimensional improvements are considered, in comparison to the picture illustrated by uni-dimensional measures or traditional measure of 65+.

3.4 Discussion

This paper contributes to the literature both on methodological and empirical counts. Methodologically, it provides a framework for understanding population ageing from a multi-dimensional framework accounting for both quantity and quality in life. Not only that our framework conceptualizes ageing from a multi-dimensional perspective, but the method is also more suitable for comparison across countries with distinct demographic achievements like in Europe and Asia.

Empirically, the paper shows that 'burden' of older persons measured through the new method (MOAT) differs from the picture illustrated by traditional and uni-dimensional measures. These differences are the result of the inclusion of quality dimensions of older persons such as health and human capital indicators into the method of computation. The MOAT values are higher for countries and regions with greater advances in terms of health and human capital. Broadly, Western and Northern European countries have higher values of MOAT, indicating their better achievements in health and human capital. Conversely, Asian and Eastern European countries have relatively lower MOAT values. The share of population ageing in countries with greater improvements across quality dimensions are lower by MOAT than that illustrated by the traditional measures of ageing or a uni-dimensional measure like RLE=15 method. Conversely, countries that have lower levels of achievements across quality dimensions have a higher 'burden' of older persons than depicted by the existing measures. A country with better quality of older persons, that is, a country with better health and human capital achievements among its older persons reduces the absolute 'burden' of ageing in terms of quantity.

The paper also shows that the relative ranks of countries differ when comparison is made between the multi-dimensional measure-MOAT, with the three dimensions separately. Whereas some countries ranked better in terms of their performance in the dimension of life expectancy, they lagged in their performances in the quality dimensions of health and human capital. A country is ranked higher in MOAT performance if it performs consistently across all three dimensions. Hence, MOAT gives a more holistic view on population ageing than elucidated by individual dimensions. The approach elucidated in the paper is a further step towards multi-dimensional assessment of population ageing. While a uni-dimensional approach might offer a simple and easily quantifiable measure, it may not sufficiently capture the differential quality aspect among the aged. More importantly, a measure which is comparative, and which accommodates the quality dimension of the older persons are more suited for cross country studies. Our approach also provides a framework to make useful comparisons across diverse spaces of Europe and Asia. Our analysis makes it clear that once the multi-dimensionality in ageing is accounted for, estimates of population ageing differs from that of the RLE=15 method or of the traditional methods. There has been some recent efforts to bring out multi-dimensional measures for population ageing in specific contexts and interests, such as the Active Ageing Index and Global Age Watch Index (AAI, 2015; HelpAge, 2015). However, unlike the other existing multi-dimensional measures, our method provides a tool for measurement that can be used for comparison across countries or regions rather than merely indexing the different improvements in characteristics of older persons and their environments based on an already existing abstract definition of age 65 to define older persons.

An important choice for the execution of our method is the selection of the variables relating to the improvements in relation to life expectancy, health and human capital. We chose these variables in consideration of the literature, the suitability for the region considered in the study and in consideration with the data availability. However, alternative variables may also be chosen to represent differentials in life expectancy, health and human capital improvements based on the suitability for the regions of interest. For instance, variables relating to labor wages or labor force participation rates can also be considered into human capital calculations if the regions of interest have a well-developed labor market for the older persons. Similarly, if the regions of interest have paucity of data, appropriate variables that are suitable to define human capital in a particular area can be chosen based on data availability.

Another important choice in the execution of our methodology is the optimal values of the indicators in different dimensions to define the old-age thresholds. We chose the old-age threshold from the standard population that was obtained within the context of the specific countries that we considered. However, if the interest is in another area, different value of old-age thresholds can be used for the different dimensions considered. Selection of different countries into the analysis may change values of MOAT in absolute sense, however, the relative ranks of the countries may not substantially alter.

An important assumption in the construction of MOAT was the choice of weights given to different dimensions. We chose an approach of providing equal weights for different dimensions as performed in our analysis to avoid any kind of normative positions on the relative importance of different dimensions considered. This has been the norm in the case of many other measures of well-being aimed at international comparisons. However, in further applications of the method in future, if the interest is in a more uniform area or in understanding the importance of specific variables in more detail, our methodology can also be executed with differential weights.

Our methodology acknowledges the contribution of the characteristic approach (Sanderson et al., 2016; Sanderson and Scherbov, 2013) and is an application of it. However, our method is an addition to the literature in the sense that it applies the characteristic approach to understand ageing in a multi-dimensional sense rather than using a uni-dimensional character to redefine population ageing. Our method makes it more suitable for comparison across countries in diverse spaces of Europe and Asia by modifying in the characteristic approach to a standard population. Such comparisons of ageing using the characteristic approach specific for cross-country analysis are only scarce in the literature.

3.5 Recommendations

Our observation that the MOAT is lower and consequently the burden of older persons are higher for countries with lower levels of improvements in life expectancy, health and human capital has direct implications to the policy makers of these countries. The advent of 'old-age' will be earlier in the life course in such countries and life-course approach to improve quality of life years should be emphasized. It has considerable implications of this to the allotment of funds towards healthcare and pensions in these countries. Such information on the performance of countries in each individual dimension and quality of ageing will help to evolve better methodology of projection of gross domestic product, savings and fiscal expenditure in these countries. For countries that have a higher MOAT but performing lower in certain individual dimension can concentrate on dimensions where there is need for improvement in achieving highest levels of old-age wellbeing. Given that there are also large gender differential across countries in different dimensions- with females lagging in quality dimension in most countries, though advanced in terms of improvements in life expectancy, policy makers need to allocate substantial importance to women to achieve better quality of life in old-age.

We believe that the new measure has its relevance for other social science disciplines like economics, sociology and political science. It can very well serve as an alternative to the existing traditional measures of old-age dependency in economic modelling related to savings pattern, healthcare expenditure and fiscal burden due to population ageing.

This approach goes beyond the count of older persons to accommodate the quality dimension wherein the count is differentiated between good quality and bad quality. This also offers the scope to accommodating as many dimensions as possible provided they have least inter-dependence between them. We also acknowledge that there are significant differences across gender, ethnicity etc. in terms of the improvements in life expectancy, health and human capital (Crimmins et al., 2011; Crimmins and Saito, 2001; Luy and Minagawa, 2014; Rieker and Bird, 2005; Weber et al., 2017). It might be worthwhile that future applications of the method and also other new measures of ageing take these variations as well into consideration.

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Chapter 4 A multidimensional perspective on Gender Gap in health among older adults in India and China: Application of a new ageing measure

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Abstract

A continuous rise of female life expectancy above that of males among older adults in India and China may give the impression that the relative gender gap in health in these countries is decreasing. However, given the systemic gender bias against older females in these countries across multiple dimensions of health, a fuller understanding of gender gap in health calls for a multidimensional perspective. We estimate a Multidimensional Old Age Threshold (MOAT) that specifies different old-age thresholds for female and male populations which accommodates multiple dimensions related to physical, intellectual and general health. We use the MOAT to evaluate the multidimensional gender gap in India and China by differencing MOAT for females with that of males. Females in both countries have a lower MOAT than their male counterparts, indicating at an earlier advent of 'old-age' for females. The multidimensional estimates of the gender gap are also higher than the estimates based on only one dimension of health. A considerable level of variation is also observed in the gender gap across provinces. The study illustrates the need to understand the gender gap in health in India and China from a multidimensional perspective and provides an innovative way to quantify such a gap. Province-specific as well as health dimension-specific interventions are vital in reducing gender gap among older adults in these countries.

Keywords: Gender-gap, Multidimensional health, India, China, Ageing

4.1 Introduction

While female life expectancy is higher than that of their male counterparts in the developed countries, this was not the case in developing countries such as India and China during most of the last century. A systemic bias against females in both the family and society at large, such as female infanticide and higher levels of adult female mortality, resulted in lower levels of female life expectancy (Das Gupta and Mari Bhat, 1997; Meara, Richards, and Cutler, 2008). However, in the past few decades, female life expectancy in a number of developing countries has increased and surpassed male life expectancy (Le, Ren, Shen, Li, and Zhang, 2015; Saikia, Jasilionis, Ram, and Shkolnikov, 2011). India and China saw a rapid increase in female life expectancies and a widening of gender differences in life expectancies at higher ages in favour of females. For instance, the difference between female and male life expectancies at age 60 in India was only 0.7 years in 1950-55. This difference had increased to 1.5 years by 2010-15. Similarly, life expectancy at age 60 was higher by 1.8 years for Chinese females in 1950-55 and this difference increased to 2.3 in 2010-15 (United Nations, 2015).

Such improvements in female life expectancy in India and China could lead one to conclude that the relative gender gap in health in these countries is swiftly decreasing. However, making such conclusions based solely on improvements in life expectancy may not capture the gender differences in health. Improvements in life expectancy do not necessarily mean improvements in other aspects of health (Kassebaum et al., 2016). With an increase in life expectancy, morbidity and disability may decline and get compressed to shorter duration of life, or alternatively, they may increase and expand to occupy a longer period of life (Olshansky et al., 1991; Omran, 2005; Omran,1971). Developing countries such as India and China are experiencing a rapid demographic transition along with nutritional as well as economic transitions. Consequently, their morbidity and disability patterns vary substantially across the life-course (George et al.,2018; Jagger, 2006). Hence, in situations where there is an expansion of morbidity, increased life expectancy could lead to widening inequalities in health if all groups are not able to benefit equally from reductions in morbidity and mortality at later ages. In particular, functional and intellectual disability free life expectancy is considerably lower than actual life expectancy in both India and China (He et al.,2012). The absence of good functional and intellectual abilities severely impairs health and well-being among older adults, even when they have a higher life expectancy (Hay et al., 2017). Poorer functional and intellectual abilities not only lead to a greater burden of ill-health, but also result in lower levels of well-being among the older population (Engelhardt et al., 2010; Skirbekk and James, 2014). Hence, a narrow focus just on gender differences in life expectancy does not tell us the whole story about gender inequalities in health in later life in these countries. Studies have shown that the female disadvantage in health is not same across different dimensions of health and that this pattern differs between India and China (Santosa et al., 2016; Wheaton and Crimmins, 2016). For instance, although female disadvantage exists in both physical and cognitive health in India and China, the gender gap is higher in cognitive health compared to physical health; and the gap is higher in India than in China. Moreover, the gender gap in different dimensions of health varies across regions within these countries (Oksuzyan et al., 2018; Santosa et al., 2016; Singh et al., 2018). Thus, a comprehensive understanding of the gender gap in health among older adults in India and China requires a multidimensional perspective of health that captures physical and intellectual abilities, rather than a unidimensional approach which tends to focus on differences in life expectancy alone.

While a systematic disadvantage in multiple dimensions of health among older women in India and China is recognised, the current indicators used to understand this have a number of drawbacks: (i) these measures abstractly consider the population above an abstract cut-off age, such as 60 or 65 that is traditionally used to define the older population. Thus, these measures assume that there is no change in characteristics of the population above this age threshold either over time or across countries; (ii) existing multidimensional measures are not sensitive to cultural differences across countries and generalize the constituents of ideal well-being in later life. Most of the existing multi-dimensional measures have their origin in the developed countries and assume that the constituents of well-being for older people can be directly translated onto older people living in developing countries, such as India and China, as well. This may not be necessarily true. For instance, the Active Ageing Index (AAI, 2015), the Global Age Watch Index (HelpAge, 2015) and the Index of Well-being in the Older Population (Kaneda, Lee, and Pollard, 2011) are, among others, examples of multidimensional indicators that have been recently developed. All of these measures have their origins in the developed world, and aim at capturing the differences in health, capabilities and market participation among the older population in different countries around the world. A chief feature of all these indices is that they consider a higher level of labour force participation among population above a certain age threshold, such as 60 or 65, as an important component of well-being in later life. However, these multi-dimensional measures are not directly applicable to developing countries where staying longer in the labour market may not be an ideal situation for well-being for older people (Singh and Das, 2015). With regard to India and China, continued participation in the labour market in later life is generally the result of (economic) compulsion rather than individual choice (Pang et al., 2004; Singh and Das, 2015). Hence, the existing multi-dimensional indicators wrongly assume that the ideals related to well-being in later life do not differ across cultures and between the developed and the developing countries.

Of particular relevance for this study is the ‘prospective age approach’ (Sanderson and Scherbov, 2005; Scherbov and Sanderson, 2016). However, this has similar drawbacks. This is a measure of ageing based on remaining life expectancy rather than time from birth. As such it assumes that people with the same prospective age have the same remaining life expectancy The ‘prospective age’ approach was based on the assumption that capturing changes in life expectancy represents the multiple changes in health and well-being of older people. It proposed to measure population ageing using an old-age threshold with a remaining life expectancy of 15 years. Hence, if average life expectancy was 65 in country A then a person would be considered as an older person at age 50, e.g. 15 years before the end of life. However, if average life expectancy was 75 in country B then a person in that country would be considered an older person at age 60. While the measure was successful in capturing the improvements in life expectancy across populations, it has limitations: (i) it wrongly assumes that the changes in life expectancy capture the changes in multiple dimensions of health and (ii) it is based on the conditions in developed countries of the world. Setting the old-age threshold with a remaining life expectancy of 15 years was based on the experience of Europe, where the remaining life expectancy at age 65 in 1980 was indeed 15 years (Balachandran at al., 2019). From this we can see that the existing measures of population ageing that try to capture multi-dimensional changes among older adults are either based on an abstract definitions of old-age as the population above age 60 or 65, or are based on the ideals from the developed world on what constitutes well-being, or sometimes both. These existing multi-dimensional measures are not appropriate for the cross-country comparison, especially when the developing countries are involved.

Balachandran and James (2019) have proposed a novel multidimensional methodology to identify parity of ages across populations after accounting for different dimensions of health or other aspects of well-being in the population. This measure also takes a 'progressive' approach to measuring ageing as proposed by Sanderson and Scherbov (2005; 2013). But it represents an improvement over the existing applications (Balachandran et al., 2019; Balachandran et al., 2017; Sanderson et al.,2016) as it is sensitive to the conditions in developing countries. The methodology generates a multidimensional old-age threshold (MOAT). This is the value of the old-age threshold that is obtained after accounting for changes in the different dimensions of health and well-being of a population. Hence, if the MOAT of a particular population, say population A is 60 and of another population B is 65, it means that being of age 65 in population B is same as being age 60 if the differences in the multiple dimensions related to health and well-being are accounted for. Hence, while the methodology accommodates multiple dimensions of health and well-being among the older adults, it does not assume population above an abstract threshold age such as 60 or 65 as 'elderly'.

In this paper, we make use of the MOAT technique (Balachandran and James, 2019) to explore the gender gap in health in India and China from a multidimensional perspective. In this way, this paper presents an innovative application of the MOAT technique for understanding the multidimensionality of the gender gap in health in later life that is pertinent in these Asian countries. Moreover, given the regional heterogeneity within both India and China, it is crucial that we understand the extent of gender differences in health at the provincial levels not simply at the national level. To do this we apply the MOAT technique to analyse the multidimensional gender gap of major provinces in India and China.

4.2 Data and Methods

4.2.1 Selection of variables

As mentioned above there are multidimensional gender differentials in health among the older population in India and China. A change in general health alone cannot capture the multidimensionality in health, given that there are gender differences in physical and intellectual abilities. In order to capture these varied dimensions, it is necessary to choose variables to represent the different dimensions of health. While making this choice, we need to ensure that these variables are appropriate to the context of the population and the region that is being studied.

To represent the different dimensions of health, we used a combination of three variables: i) one representing the general health, ii) one capturing functional abilities and iii) a third capturing intellectual abilities. We used self-rated health (SRH) to capture the general health of the different populations considered. Self-rated health has been identified as a good proxy for actual health status and found to be correlated with mortality and morbidity patterns (Jylhä, 2009; Miilunpalo, Vuori, Oja, Pasanen, and Urponen, 1997). In addition, it is commonly used to measure health in developing countries such as India and China, and hence the data for this variable are readily available for gender and at the provincial levels. To understand age-specific levels of self-rated health at a population level, we used the percentage of the population with good or very good self-rated health (coded 1).

In order to capture functional capabilities of the populations considered, we used the percentage of the population which has problems performing activities of daily living (ADL). This variable is particularly useful in countries like India and China where the prevalence of functional disabilities is generally high (Dsouza et al., 2014; Yi et al.,2002). Moreover, SRH may not completely represent functional abilities (Tsuji et al., 1994). In developing countries, functional abilities among older people may indicate other vulnerabilities associated with ageing, such as higher levels of admission to retirement homes and low levels of healthcare utilization (Bloom and Eggleston, 2014; Chatterji et al., 2008; Picco et al., 2016). For these reasons, we used ADL to reflect the functional health of the older population in these countries. In order to capture the level of difficulty with performing ADL, we measured an individual's ability to perform six activities: walking, eating, bathing or showering, using the toilet, dressing and getting in and out of the bed. If an individual has difficulty in any one of these activities they are identified as having functional limitation (coded 0), or else not (coded 1).

To capture intellectual abilities, we measured the level of cognition among the population. A widely used measure of cognitive ability is the number of words recalled out of 10 words from a pre-set list (Skirbekk, Loichinger, and Weber, 2012; Weber, Dekhtyar, and Herlitz, 2017). A higher number of words recalled indicates better levels of cognition. Cognitive ability has been increasingly recognized as a more dynamic measure of intellectual ability for use with older populations, than traditional variables such as years of schooling which tend not change over the life-course after a certain level of attainment earlier in life (Skirbekk et al., 2012; Weber et al., 2017). Hence, although the level cognitive ability tends to be correlated with the levels of education, it is sensitive to changes over the life-course. This is particularly important in the context of countries such as India and China because there were very few educational opportunities and infrastructure in these countries prior to the 1960s, due to historical reasons such as the struggle for independence and subsequent lags in development. As a result of this, the present older population in these countries spent their childhood and youth with comparatively fewer educational opportunities. However, as these countries grew economically and socially over time and there were subsequent improvements among these populations over the life-course.

4.2.2 Data Source

We use the data for India and China from the WHO Study on Global AGEing and Adult Health (WHO-SAGE), Wave 1 (2007-10) (Kowal et al., 2012) for our analysis. The data are nationally representative data of population aged 50 and over in these countries. An overview of the dataset is given in Table 4.1.

Table 4.1: Summary of the representative dataset, by country and gender

Country	**Gender**	**Observations**	**Mean age**	**Minimum age**	**Maximum age**
India	Male	3623	62.33	50	105
	Females	3527	61.35	50	106
	Total	7150	61.84	50	106
China	Male	6397	63.27	50	99
	Females	6821	63.15	50	102
	Total	13218	63.21	50	102

4.2.3 Methodology

We use the methodology provided by Balachandran and James (2019) to capture the multiple dimensions of health in later life. Their approach is an extension of the characteristics approach by Sanderson and Scherbov (2013; 2016), which stipulates an old-age threshold across populations based on differentials in any dimension of health over the life-course. However, Balachandran and James (2019) have improved the characteristics approach by using a multidimensional framework. We make use of this multidimensional framework to understand the gender gap in health in India and China. This is the first attempt to use such a multidimensional framework to understand the gender gap in health in later life in developing countries. Their approach stipulates an old-age threshold for a population that accommodates for multiple dimensions of health. The resultant old-age threshold is called as the Multidimensional Old Age Threshold (MOAT). The higher the value of MOAT, the better is the achievements of the particular population in terms of different dimensions of health. The methodology for producing the MOAT consists of 4 steps:

Step 1: Selection of the standard population

To produce the values of MOAT, first, a standard population is chosen so as to compare the different dimensions against the standard population. A standard population is a hypothetically formulated population based on the age-specific values for each of the three dimensions of the different populations considered in the analysis. The age-specific value of the standard population is obtained by averaging the highest and lowest values for the corresponding age among the different populations considered. In choosing such an age-specific value for the standard population, it is ensured that the standard population chosen is comparable for the different populations considered. Mathematically, this can be expressed as follows:

$$V_{S,T,i} = \frac{V_{min_{T_k,i}} + V_{max_{T_k,i}}}{2}$$

Where $V_{min_{T_k,i}}$ refers to the value of the standard population S of the dimension T_k at age *i*. k can take value between 1 and 3, as three dimensions- self-rated health, cognition or abilities with ADL. $V_{max_{T_k,i}}$is the minimum value of dimension T_k at age i across the populations considered and $V_{max_{T_k,i}}$ is the maximum value of the dimension $T_k$at age i across the populations. Since, our interest is in analysing the gender gap in India and China, there are essentially four different populations under the purview of our analysis. These are the male and female populations in each of the two countries.

Hence, the value of the self-rated health at different ages is the average of the highest and lowest values among the male and female populations in India and China. Similarly, the age-specific value for cognition is based on the average of the highest and lowest age-specific number of words recalled across the different populations. Likewise, the standard population of the dimension of abilities with ADL is obtained.

Step 2: Selection of frontier value in each dimension

After formulating the standard population for each dimension considered, we obtain a 'frontier value' from the standard population. In the process of obtaining the frontier value, we set a lower and upper bound for the standard population, due to empirical reasons. Since the data we use is representative of the population above age 50, we use age 50 as the lower bound for the standard population. Although there is no upper age limit in the datasets, an empirical investigation points that the comparable samples across the populations considered are much reduced above age of 85. Hence, we use age 85 as the upper bound of the standard population. In order to smooth the fluctuations occurring in the data, we categorize the data into seven age groups of 5-year intervals. We then obtain the frontier value in each dimension from the standard population by averaging the values across the seven age groups between the ages of 50 and 85. Mathematically, this can be expressed as follows:

$$OV_{T_k} = \sum_{i=50}^{85} \frac{V_{S,T_k,I}}{N}$$

Where OV_T is the frontier value using the dimension T_k; $V_{S,T_k,i}$ refers to the value of the standard population S of the dimension T_k at age group *I*. N is the number of age-groups. Since, there are seven age groups in our analysis, the value of N is 7.

Step 3: Identification of old-age threshold across countries

Once the frontier values for different dimensions are estimated, the next step is to identify the each of the dimensions for the different populations under consideration. The old-age threshold is the age at which a population reaches the frontier value. For instance, if the frontier value of the dimension of cognition is 4 words and the male population in China reaches this value at age 55, then age 55 is considered as the old-age threshold for that particular dimension. In case the population continues to be at the same level of cognition at age 55, or if it returns back to the same level of cognition at age 55, then age 55 is considered as the old-age threshold for the population. Mathematically, it can be expressed as follows:

$$OT_{P,T} : lC_{P,T} = OV_T$$

Where $OT_{P,T}$ refers to the old-age threshold of the population P with regards to dimension T. This value is given by the last chronological age of the population P at which the value the dimension T (given by lC_P) is the same as the frontier value of dimension T (given byOV_T). Since we have 5 year age groups used in the analysis, a linear interpolation technique is used to find the exact old-age threshold.

Step 4: Combining different dimensions

After identifying the different old-age thresholds based on the different dimensions for each population, the different old-age thresholds need to be combined to attain the multidimensional measure called as Multidimensional Old-Age Threshold (MOAT). We combine the different dimensions by averaging the values of the old-age thresholds using the different variables of SRH, cognition and ADL. Such an averaging is in line with many other multidimensional measures such as Human Development Index. The resultant average old-age threshold is multidimensional one that accommodates for the changes in different dimensions of health. This averaged old-age threshold is called the MOAT. Mathematically it can be expressed as follows:

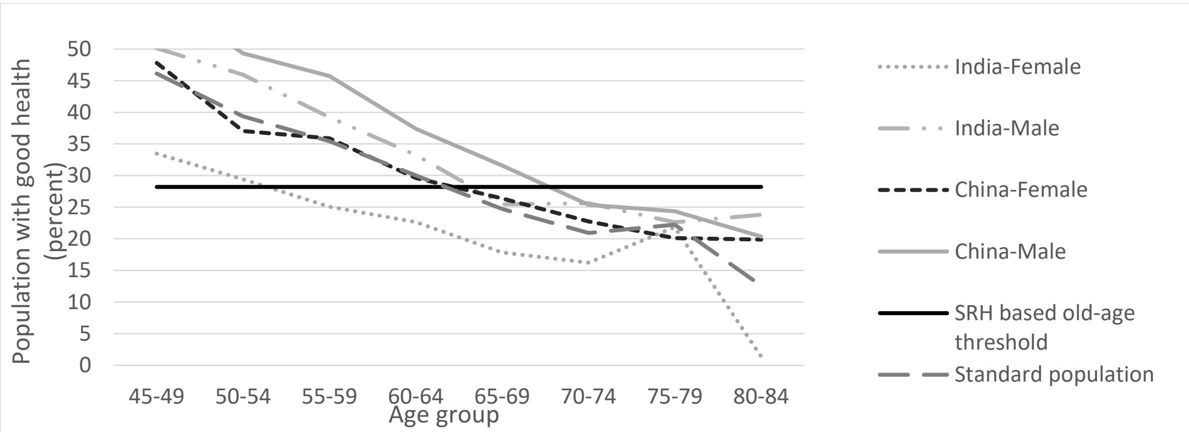
$$MOAT_P = \sum_{T=1}^{3} \frac{OT_{P,T}}{3}$$

Where $MOAT_P$ refers to MOAT of country C. It is given by the average of old-age threshold across characteristic T for the population P (given by$OT_{P,T}$).

4.3 Results

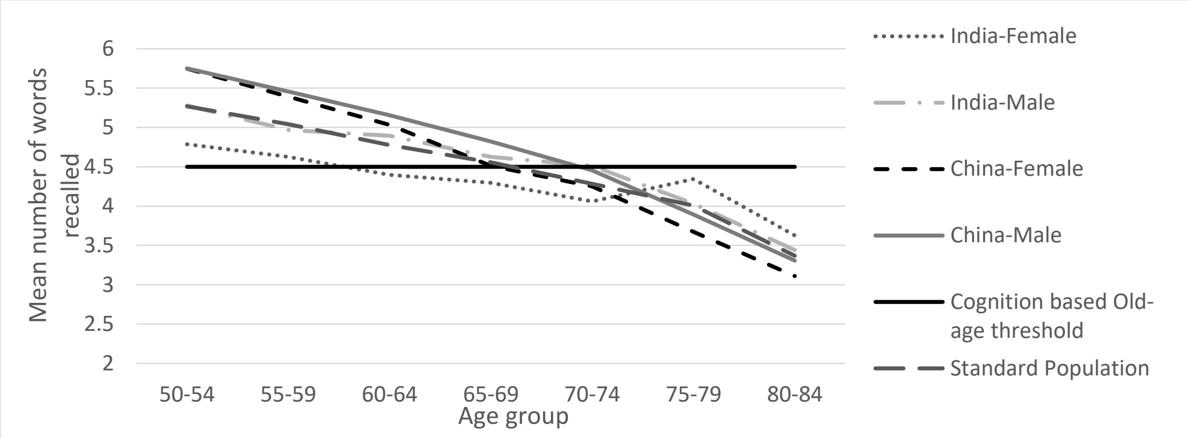
We computed the age-specific values of SRH, cognition and percentage of population with abilities to perform ADL for the 4 populations; i) Male population in India, ii) Female population in India, iii) Male population in China and iv) Female population in China. We also found the age-specific values of the standard population in different dimensions. The results of these computations are plotted in Figure 4.1 (a-c).

Figure 4.1 (a): Percentage of population with good self-rated health across different age groups for the selected populations, 2010



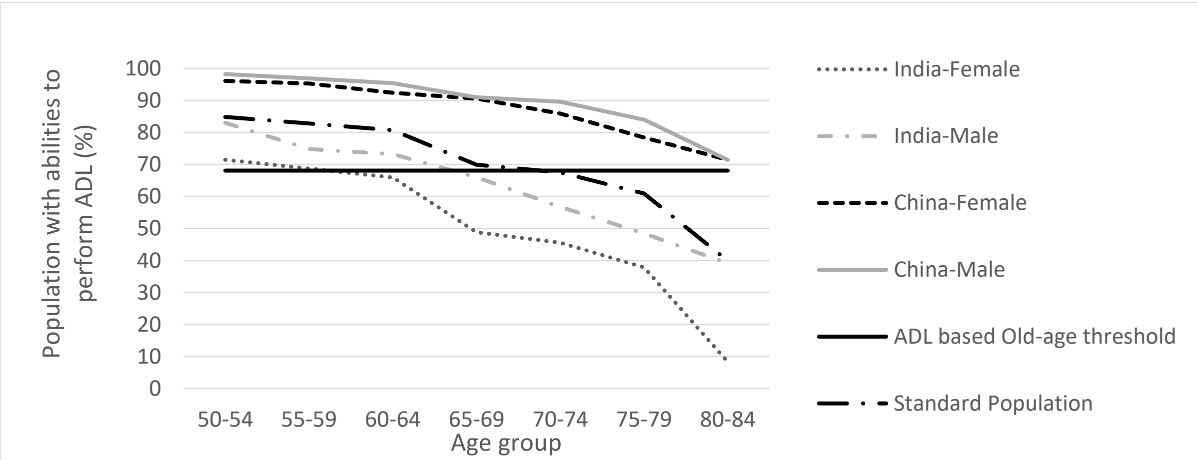
Source: Authors' calculation based on WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

Figure 4.1 (b): Age-specific values of mean of number of words recalled in selected populations, 2010



Source: Same as in figure 4.1 (a)

Figure 4.1 (c): Percentage of population able to perform ADL in different age groups among selected populations, 2010



Source: Same as in figure 4.1 (a)

Figure 4.1(a) shows a decline in self-rated good health of the population among the male and female populations in India and China. However, the levels and rate of decline across are different across the populations. While the Indian female population has the lowest levels of SRH across most parts of the life-course, Chinese males have the highest levels of SRH. Figure 4.1(b) shows that the average mean number of words recalled goes down with age. However, the patterns of decline are different across the populations. A similar pattern can be observed in figure 4.1(c) where the percentage of the population who are able to perform ADL is depicted. In general, this also shows a pattern of decline with increasing age though there are variations in the rate of decline across different populations. In general, it can be seen that the female population of India has lowest absolute values for the different dimensions, whereas the male population of China generally has better levels of performance.

Figure 4.1 (a-c) also provide values for the standard population with regard to different dimensions. From the standard population, the frontier values of the different dimensions were calculated. The SRH based frontier value was 28.2, for cognitive function it was 4.5 and for ADL it was 68.1. This means that the population has good SRH until it reaches the age where 28.2% of the population has good SRH. Similarly, the population good cognitive ability until it reaches the age where the frontier value of cognitive function-4.5 words. Likewise, the age where 68.1% of the population are still able to perform all the ADL is the age at which the population has good functional capabilities. Based on the frontier values identified, we estimate the old-age threshold for different dimensions and the also estimate the multidimensional old-age threshold (MOAT). These estimates are shown in Table 4.2.

Table 4.2: Estimates of old-age threshold values for different dimensions and MOAT across gender in India and China, 2010

Population	**Self-rated health based old-age threshold (Threshold value=28.2)**	**Cognition based old-age threshold (Threshold value=4.5)**	**Functional abilities based old-age threshold (Threshold value=68.1)**	**Multidimensional old-age threshold (MOAT)**
(1)	**(2)**	**(3)**	**(4)**	**(5)**
India-Female	54	61	57	57.3
India- Male	65	73	65	67.7
China-Female	64	68	83	71.7
China-Male	65	72	83	73.3

Source: Authors' calculation based on WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

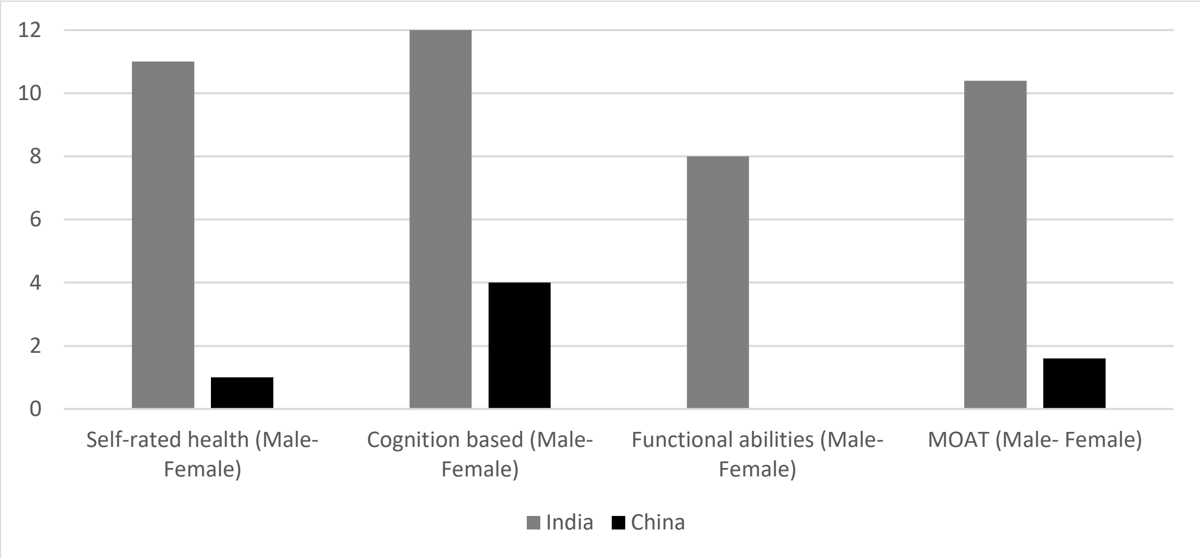
Columns 2, 3 and 4 in table 4.2 show the old-age thresholds based on the dimensions of self-rated health, cognition and functional abilities (ADL) respectively for the selected populations. For instance, the self-rated health based old-age threshold for the Chinese male population is 65. This means that at age 65, the percentage of population in the Chinese male population with good self-rated health is same as the frontier value of 28.2 percent. Similarly, the cognition based old-age threshold for the Chinese male population is 72 and functional abilities based old-age threshold for China is 83. This means that the Chinese male population attains the cognition based frontier value of 4.5 words at age 72 and ADL based frontier value of 68.2 percent at age 83. It may also be noted that the female population in India has lower values of old-age thresholds in different dimensions as well as in terms of MOAT. The male populations in India and China have higher values of old-age thresholds across the different dimensions in comparison to their female counterparts. The only exception here is for the dimension of ADL abilities in China, where the male and female populations have the same old-age threshold value.

The estimates highlight the relative advantage/disadvantage for each of the populations in terms of different dimensions. For instance, the Indian female population has higher old-age threshold values in cognition based old-age threshold in comparison with self-rated health, functional abilities and also based on MOAT. This means that the relative performance of Indian female population in terms of cognition is better than their performance in other dimensions. Contrary to this, the cognition based old-age threshold of the Chinese female population is lower than their performance in the dimensions of self-rated health and functional abilities.

3.3.1 Gender Gap across India and China

A higher old-age threshold depicts better performance of the population in a particular dimension or in terms of multiple dimensions (if MOAT is considered). Likewise, a lower old-age threshold indicates a lower level of performance. Thus, a difference between the old-age thresholds of the male and female populations of a country illustrates the gender gap in the country. In figure 4.2, we illustrate the gender gap in India and China for different dimensions and also for MOAT. The higher the value of the gender gap, the higher is the level of disadvantage among females in comparison with males in the particular dimension.

Figure 4.2: Gender gap in India and China across different dimensions and MOAT, 2010



Source: Authors' calculation based on WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

The difference, which represents the gender gap in a country, is clearly higher in India in comparison to that of China across the different dimensions. However, there are differences across the dimensions. The cognition based gender gap is higher in India, than in the other dimensions. This is followed by gender gap in SRH and then by functional abilities. A similar pattern is also observed in China. The cognition based gender gap is higher in China as well, in comparison to the gender gap in other dimensions. This is followed by the gender gap in the dimension of self-rated health and functional abilities. In fact, the gender gap in China in terms of functional abilities is zero. Both India and China have a significant gender gap in cognition in later life.

The gender gap estimation with MOAT shows the multiple levels of deprivation faced by older women in these countries. The estimates show that the multidimensional gender gap in India is much higher than that in China. The values of the gender gap are 10.4 in India and 1.6 in China. This means that the multidimensional gender gap is 6.5 times higher in India than in China. The results based on MOAT clearly add to our understanding of gender gap as MOAT captures the complexity of this gender gap. A uni-dimensional understanding of the gender gap can, by definition, only identify the gender gap in one specific dimension of health. On the other hand, the MOAT based analysis of the gender gap is comprehensive and accounts for the gender gap along multiple dimensions. For instance, the MOAT based gender gap in both India and China is lower than the cognition based gender gap in the particular countries. However, in both the countries, the MOAT based gender gap is higher than gender gap in the dimension for functional abilities. Similarly, the MOAT based gender gap is lower than the self-rated health based gender gap in India, whereas in the case of China, the MOAT based gender gap is higher than that for self-rated health.

3.3.2 Gender gap in India and China at provincial level

Both India and China are known for having high levels of regional inequalities in health (Yip and Mahal, 2008). The socio-economic inequalities at the provincial levels in these countries are believed to be responsible for this (Dummer and Cook, 2008). Given these regional inequalities it is important not just to understand the extent of the gender gap in health at the national level. We must also drill down to the regional level to get a more holistic picture of the patterns of gender inequalities in health in these countries. The WHO-SAGE dataset provides information on six Indian provinces and eight Chinese provinces. Among the provinces considered in India, Karnataka and Maharashtra have better levels of Human Development Index (HDI) values, while Rajasthan and Uttar Pradesh have lower levels of HDI values (Global Data lab, 2017). Among the Chinese provinces considered, Shanghai has the highest levels of HDI values while Yunnan has the lowest levels. It is probable that the gender inequality is lower in provinces with higher levels of HDI values, and this needs to be explored. We illustrate the MOAT and old-age thresholds based on different dimensions for the provinces of India and China in Table 4.3 and Table 4.4 respectively.

Table 4.3: Estimates of old-age threshold values for different dimensions and MOAT across gender in different provinces of India, 2010

Province	**Self-rated health based old-age threshold**		**Cognition based old-age threshold**		**Functional abilities based old-age threshold**		**Multidimensional old-age threshold (MOAT)**	
	Female	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*
Assam	79	82	46	48	77	79	67.33	69.67
Karnataka	77	78	79	75	58	55	71.33	69.33
Maharashtra	52	64	73	67	62	64	62.33	65.00
Rajasthan	50	59	59	75	63	64	57.33	66.00
Uttar Pradesh	62	73	69	73	68	66	66.33	70.67
West Bengal	51	60	72	68	63	67	62.00	65.00

Source: Authors' calculation based on WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

Table 4.4: Estimates of old-age threshold values for different dimensions and MOAT across gender in different provinces of China, 2010

Province	**Self-rated health based old-age threshold**		**Cognition based old-age threshold**		**Functional abilities based old-age threshold**		**Multidimensional old-age threshold (MOAT)**	
	Female	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*
Guangdong	70	69	66	70	79	81	71.67	73.33
Hubei	58	55	64	67	85	83	69.00	68.33
Jilin	60	64	64	66	78	81	67.33	70.33
Shaanxi	51	62	58	60	84	82	64.33	68.00
Shangdong	61	70	75	78	81	82	72.33	76.67
Shanghai	75	79	69	75	84	85	76.00	79.67
Yunnan	63	74	69	72	75	80	69.00	75.33
Zhejiang	78	77	67	72	84	85	76.33	78.00

Source: Authors' calculation based on WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

Table 4.3 shows the MOAT and old-age thresholds based on different dimensions for six different provinces in India. The province of Karnataka has the highest MOAT for females and Assam has the highest MOAT for males. At the same time, the province of Rajasthan has the lowest MOAT value for females, the provinces Maharashtra and West Bengal have the lowest values of MOAT for males. Interestingly, the province of Karnataka has a MOAT value for females higher than that of the males. This pattern in Karnataka, the South Indian province included in the analysis, is in accordance with the general patterns of health in India, where the South Indian provinces shows a comparatively higher gender equality (Balarajan, Selvaraj, and Subramanian, 2011). Studies shows that the general health among the older adults in the South Indian provinces of Kerala, Tamilnadu and Karnataka is significantly better than their counterparts in rest of India (Giridhar et al., 2014; Rajan, Mishra, and Sarma, 2001). There are also provincial level patterns for individual dimensions. Some provinces with better performance in MOAT lags in performance in certain dimensions. For instance, Assam has higher values of old-age thresholds based on the dimensions of self-rated health and functional abilities, but has lower old-age threshold based on the dimension of cognition.

Similarly, Table 4.4 shows the MOAT and old-age thresholds based on different dimensions for eight provinces of China. Shanghai has the highest MOAT among the Chinese male population and Zhejiang has the highest MOAT for the Chinese female population. Shaanxi has the lowest MOAT values for the Chinese male and female populations. Patterns in individual dimensions also differ across provinces. The old-age thresholds based on the dimensions of self-rated health and functional abilities are higher in Zhejiang than the old-age thresholds based on cognition. Likewise, the old-age thresholds based on the dimensions of cognition and functional abilities are higher for Hubei than its old-age thresholds based on self-rated health.

We use the MOAT and dimension specific old-age thresholds across male and female populations to analyse the gender gap in the different provinces in both the countries. As executed in the case of estimation of the national comparisons of the gender gap, we find the difference between the MOAT of the male and female population across the different provinces considered to obtain the results multidimensional gender gap at the provincial level. Table 5 and Table 6 shows the results of the estimation of gender gap in the provinces of India and China respectively.

Table 4.5: Estimates of multidimensional gender gap and gender gap based on different dimensions in different provinces of India, 2010

Province	**Self-rated health (Male- Female)**	**Cognition (Male-Female)**	**Functional abilities (Male- Female)**	**MOAT(Male-Female)**
Assam	3	2	2	2.33
Karnataka	1	-4	-3	-2.00
Maharashtra	12	-6	2	2.67
Rajasthan	9	16	1	8.67
Uttar Pradesh	11	4	-2	4.33
West Bengal	9	-4	4	3.00

Source: Authors' calculation based on WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

Table 4.6: Estimates of multidimensional gender gap and gender gap based on different dimensions in different provinces of China, 2010

Province	**Self-rated health (Male- Female)**	**Cognition based (Male- Female)**	**Functional abilities (Male- Female)**	**MOAT (Male-Female)**
Guangdong	-1	4	2	1.67
Hubei	-3	3	-2	-0.67
Jilin	4	2	3	3.00
Shaanxi	11	2	-2	3.67
Shangdong	9	3	1	4.33
Shanghai	4	6	1	3.67
Yunnan	11	3	5	6.33
Zhejiang	-1	5	1	1.67

Source: Authors' calculation based on WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012)

Table 4.5 shows the estimation of gender gap in the six Indian provinces. Except for the province of Karnataka, all the provinces have a positive value of difference in MOAT across gender, indicating that the multidimensional gender gap is biased against females in these provinces. The province of Rajasthan has the highest gender gap using MOAT. That is, the female disadvantage is highest in Rajasthan in comparison to other provinces. After Rajasthan, the gender gap using MOAT is highest in Uttar Pradesh. This is followed by West Bengal, Maharashtra and Assam in that order. There are also provincial level patterns in individual dimensions as well. Maharashtra has the highest gender gap in the dimension of self-rated health, followed by Uttar Pradesh. Rajasthan has the highest gender gap in the dimension of cognition. The low level of access to education and cultural bias against female literacy can be endorsed with the responsibility of this pattern in the dimension of cognition in the province of Rajasthan (Thomas et al., 1999). The province of West Bengal has the highest gender gap in the dimension of functional abilities.

Table 4.6 shows the results of estimation of gender gap in eight provinces of China. The values of the difference in MOAT is positive in most provinces of China as well, indicating the gender gap in multidimensional health that is biased against females in the Chinese provinces. The only exception to this is the province of Hubei, where the difference of MOAT values across gender is negative and less than one. This indicates, the slight female advantage in multidimensional health in the province. The province of Yunnan has the highest gender gap followed by Shangdong. There are also variations in the gender gap across the dimensions. While Yunnan and Shaanxi has the highest gender gap in the dimension of self-rated health, Shanghai has the highest gender gap in the dimension of cognition. Again, Yunnan has the highest gender gap in the dimension of functional abilities.

4.4 Discussion

The paper contributes to the literature in multiple ways. Firstly, it provides an innovative way to use a population ageing measure to understand gender inequalities in health across countries. Secondly, it highlights the need to take a multidimensional approach to understanding gender inequalities in health in developing countries. Thirdly, it provides empirical insights into the multidimensional gender gap in health in India and China, at the national and provincial levels.

Empirically, the paper illustrates the existence of the multidimensional nature of the gender gap in health both in India and China and that this is higher in India than in China. An effort at quantifying the intensity of multidimensional gender gap among the older population shows that the gender gap in India is around 6.5 times higher than in China. The estimations of multidimensional gender gap in both the countries is different from the estimations based merely on one-dimension. For instance, the gender gap using the dimension of functional abilities alone is lower in both India and China in comparison with the multidimensional estimate of gender gap in these countries. Similarly, the gender gap using the dimension of cognition is higher than the multidimensional gender gap in both the countries. It also needs to be noted that the picture presented by multidimensional perspective of gender gap is also different from that presented by the differences in the life expectancies. While the life expectancies among older females has been continuously increasing in these countries and is higher than those of males, the relative position of females is actually disadvantaged and vulnerable once the multiple dimensions of health are taken into consideration. For instance, for the period of 2005-2010, the difference in life expectancies at age 50 across gender was 2.2 years in India and 2.5 years in China, with a relative advantage for females (United Nations, 2015). Thus, a conclusion based on merely life expectancy may presume female advantage in these countries at older ages. However, our analysis depicts a clear female disadvantage in both the countries once multiple dimensions of health are taken into consideration. Hence, when a multidimensional lens is used to understand the gender gap among older population, a country has better levels of gender equality in health when it simultaneously improve gender equality in multiple dimensions related to health.

The paper also highlights how the multidimensional gender gap among the older population is heterogeneous across the provinces of India and China. The province of Karnataka in India and Hubei in China have lower levels of gender inequality compared to other provinces in their respective countries. Likewise, the province of Rajasthan in India and Yunnan in China have the highest levels of gender inequality. These patterns are in accordance with the wider patterns of health at provincial levels in the countries (Balarajan et al., 2011; Evandrou et al.,2014). Rajasthan and Yunnan are also provinces with relatively lower levels of HDI values, while Karnataka has higher levels of HDI values. However, it may also be noted that our analysis illustrates that the gender gap need not necessarily have a direct association with the levels of HDI values. For instance, the provinces of Shanghai and Maharashtra in China and India respectively have relatively higher levels of HDI values, but also have relatively higher levels gender gap.

Our application also shows that the multidimensional gender gap estimations at the provincial level are significantly different from uni-dimensional estimates, and thereby underlining the importance of a multidimensional perspective to derive a more holistic picture. There has been some recent efforts to bring out multidimensional measures for population ageing in specific contexts and interests, such as the Active Ageing Index and Global Age Watch Index (AAI, 2015; HelpAge, 2015). However, unlike the other existing multidimensional measures, our application is progressive as it provides a measurement for comparison of the intensity of the gender gap across populations. The existing multidimensional measures, on the other hand, merely index the different improvements in characteristics of older persons and their environments based on an already existing abstract definition of age 60 or 65 to define older persons.

However, it should be noted that the old-age thresholds need to be cautiously interpreted. The old-age thresholds are estimated on the basis of the standard population, which is derived from the populations considered. The resultant old-age thresholds are useful for comparisons across the considered populations, but the interpretation of the absolute value of the old-age threshold may not be very useful. However, the important point here is that the old-age thresholds are extremely useful for understanding the gender gap across the countries. A difference between the old-age thresholds derived across the gender in both the countries indicates a difference in the relative achievements of the male and female populations in the respective countries.

An important choice in the analysis is the choice of the variables that corresponds to the multiple dimensions relating to different aspects of health. We chose the variables in consideration of the suitability of the region considered for the study, literature and availability of data in the region. However, it would be possible to use different variables that represent different dimensions of health in the region of interest and based on data availability.

Another important assumption in the execution of the methodology is the choice of the weights given to different dimensions. We chose an approach of giving equal weights to different dimensions during the creation of the MOAT. Such an approach is in line with other international multidimensional indices for well-being, such as the Human Development Index. The provision of giving equal weights to different dimensions avoids any kind of normative positions on the relative importance of different dimensions considered. However, in future, the methodology to understand the gender gap used in our analysis can also be executed with differential weights if the interest is in understanding the relative importance of certain dimensions.

4.5 Recommendations

Our findings have direct implications for policy makers. The start of 'old-age' for women is earlier than their male counterparts in these countries and thus a life-course approach to improve different aspects of health of women should be underscored. Policy makers should concentrate on giving equal educational opportunities to women, given the connection between education at younger ages and cognitive abilities across life-course. The educational opportunities for women in these countries are presently very low. The burden of functional disability is also higher among women than among men, pushing them to 'old-age' sooner than males. With a continuous rise in the older population in these countries, the study suggests the need for a comprehensive and holistic gender sensitive health agenda in India and China. Such a health agenda should recognize the multi-dimensionality of deprivation among different aspects of health among women.

The provincial level differentials of gender gap in health directs policy makers to the need to concentrate on older women in regions with higher gender gap. A cumulative disadvantage for women across life-course in many socio-economic-cultural aspects maybe responsible for the multi-dimensional disadvantage in health. A targeted approach for elimination of gender gap in these regions is called for.

Our results point towards the serious need to increase not only the health budget, but also budgetary provisions related to education and other quality dimensions for females in India and China. Given the vastness and heterogeneity in these countries, we acknowledge that there would be a multiplicity of factors that are country and region specific that would be determining the gender gap in the countries and its provinces. It might be worthwhile in future studies to understand the determinants of the differentials in gender gap as well. Also, efforts aimed at gathering the heterogeneity in these countries through better data documentation initiatives is needed.

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Chapter 5 Can changes in education alter future population ageing in Asia and Europe?

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Abstract

While population ageing is rising, the educational composition of elderly is rather heterogeneous. We assess educational differences in future population ageing in Asia and Europe and how future population ageing in Asia and Europe would change if the educational composition of its populations would change.

We do so using a comparative population ageing measure that recalculates old-age thresholds after accounting for differences in life expectancy, and the likelihood of adults surviving to higher ages. We combine data from projected age- and sex-specific life tables (from the United Nations) with projected age- and sex-specific survival ratios by different levels of education (from the Wittgenstein Centre for Demography and Global Human Capital) to construct projected life tables (2015-2020, …, 2045-2050) by educational level and sex for different regions of Asia and Europe. Based on these life tables we calculated the future comparative prospective old-age thresholds by educational level and sex.

We find that in both Asia and Europe and among both men and women, the projected old-age thresholds are higher for higher educated people than for less educated people. While Europe has a larger projected share of elderly in the population than Asia, Europe's older population is better educated. In alternate future scenarios in which populations hypothetically have higher levels of education, the projected shares of elderly in the population decrease across all regions of Asia and Europe, but more so in Asia.

Our results highlight the effectiveness of investing in education as a policy response to the challenges associated with population ageing in Asia and Europe. Such investments are more effective in the Asian regions, where the educational infrastructure is less developed.

Keywords: population ageing projection, education, adult survival, Europe, Asia

5.1 Introduction

In most countries, the elderly population is growing, both numerically and as a share of the overall population. With these trends expected to accelerate in the coming decades, population ageing is poised to become the most important social change of the 21st century. Population ageing is occurring especially rapidly in Europe and Asia. Europe has the largest share of elderly in the population, and Asia has the highest number of elderly people (United Nations, 2017). However, population ageing patterns are rather heterogeneous. Population ageing trends can differ across populations not just because of differences in their age and sex structures, but because of differences in their educational achievement levels(Lutz et al., 2008). The most fundamental causes of population ageing – i.e., decreasing fertility and increasing life expectancy – are driven by differences in educational levels. Higher educational attainment is associated with increased life expectancy at different ages, and with decreased fertility.

The characteristics of populations vary starkly across educational levels. The educational achievement levels of a population are also indicative of latent socioeconomic gradation variables in that population. In most parts of the world, better educated populations have higher incomes and better health (Lutz et al., 2014a). The characteristics of populations, such as their morbidity and cognition levels, vary depending not only on their age and sex structures, but on their educational levels. Compared to their less educated counterparts, cohorts with higher education have significantly higher life expectancy,(Olshansky et al., 2012) lower rates of physical disability, and higher levels of productivity (Leopold & Engelhartdt, 2013; Mazzonna & Peracchi, 2012). Moreover, differences in mortality rates based on educational level have been widening over time (Mackenbach et al., 2003). The World Health Organization has recognized the significance of the relationship between education and health by incorporating an education component into its formulae for forecasting future health scenarios(Mathers & Loncar, 2006). Given that the characteristics of populations differ significantly based on their educational levels, efforts to project population ageing into the future must account for changes in the educational distributions of populations. Among the elderly in Europe and Asia, the educational distribution is highly diverse, and this heterogeneity must be considered when making projections. Table 5.1 shows the heterogeneity in the shares of the population aged 65+ by levels of education in Asia, in Europe, and in a selected country from each continent.

Table 5.1: Share of elderly in Asia, Europe, India, and the Netherlands by levels of education, 2015

Region/Country	**Share of 65+ population by level of education**						**Total share of 65+ population**
	No Education	Incomplete Primary	Primary	Lower-Secondary	Upper-Secondary	Post-Secondary	
Asia	2.29	0.86	1.90	1.10	0.96	0.45	7.57
Europe	0.32	0.71	3.45	4.31	5.96	2.86	17.60
India	3.33	0.49	0.65	0.33	0.53	0.30	5.64
Netherlands	0.00	0.47	3.29	5.66	5.56	2.93	17.92

Source: Human Capital Database (2018 revision) (Lutz et al., 2014b)

Table 5.1 clearly shows the heterogeneity in the educational composition of the 65+ population in Asia and Europe. Of the people aged 65+ in Asia, the largest share have no education (30.3%), whereas only a small share (5.9%) have the highest educational level (post-secondary). However, of the people aged 65+ in Europe, only a small share have no education (1.8%), while much larger shares have lower-secondary (24.5%), upper-secondary (33.8%), or post-secondary (16.3%) education. Heterogeneity in the educational distribution can also be observed when comparing European and Asian countries. For example, in the Western European country of the Netherlands, 0% of the 65+ population have no education, and around 80% have lower-secondary or higher education; whereas in the South Asian country of India, around 60% of the 65+ population have no education, and only 0.3% have post-secondary education. Thus, the countries where the share of elderly in the population is large differ by educational composition: i.e., in some of these countries (mostly in Europe), a majority of the 65+ population have relatively high levels of education; whereas in other countries (mostly in Asia), a majority of the elderly population are uneducated or have lower levels of education. These differences in the educational composition of the elderly population can contribute to heterogeneity in population ageing trends across these continents.

There is relatively little previous research on future population ageing by educational level. Most of the existing studies on this topic relied on traditional measures, such as the share of people aged 65+ in the population, or the age dependency of the elderly population (World Health Organization, 2015). However, these measures do not account for differences in educational composition across populations. Age-specific characteristics like age-specific mortality and survival rates may vary by educational group. For example, highly educated people tend to have a longer remaining life expectancy and greater chances of surviving to higher ages. Thus, highly educated individuals may enter “old-age” at higher ages than their less educated counterparts. Among the alternate approaches aimed at redefining “old-age” based on changes in the age-specific characteristics of populations (Chu, 1997; d’Albis & Collard, 2013; Kot, S. M., Kurkiewicz, 2004; Ryder, 1975; Sanderson & Scherbov, 2005), the comparative prospective old-age threshold (CPOAT) measure of population ageing by Balachandran et al. (2019) provides a framework for robust comparisons of ageing across populations with varying mortality experiences. The CPOAT provides a dynamic “old-age threshold” that changes across time and populations based on adults’ remaining life expectancy and survival rates to higher ages. In addition, how a change in the future educational composition of the population would affect projected population ageing has not previously been investigated.

In this paper, we illustrate future ageing scenarios by different levels of education across Asia and Europe using the CPOAT. We also look at how future scenarios of population ageing in Asia and Europe would change if the levels of education among these populations changed.

5.2 Data and Method

5.2.1 Data

To estimate future population ageing in a comparative and prospective manner, we used projected age- and sex-specific life table data and projected age-specific survival ratios by different levels of education for Asia and Europe (and its different regions). Both datasets are available for five-year periods between 2015 and 2050.

For the projected life table data, we used the medium-fertility variant data from the Population Division of the Department of Economic and Social Affairs, United Nations (United Nations, 2019). For the projected data on age-specific survival ratios by different levels of education, the medium scenario (under the assumption of Shared Socio-economic Pathway 2, SSP2) provided by the Human Capital Database (2018 revision) (Lutz et al., 2014b) of the Wittgenstein Centre for Demography and Global Human Capital are used. The medium scenario (SSP2) of age-specific survival ratios is based on a combination of medium fertility, medium mortality, medium migration, and the Global Education Trend education scenario. The Global Education Trend scenario assumes that educational participation is steadily improving over time. The medium scenario is the most likely path for each country or region (Lutz et al., 2014b). Thus, the medium scenarios provided by Human Capital Database are comparable to the medium variant in the UN life table data. In line with the International Standard Classification of Education (ISCED), which is used to compare education statistics across countries with distinct educational systems, the data from the Human Capital Database is available across six educational categories. In the order of increasing educational attainment, the categories are (i) no education, (ii) incomplete primary education, (iii) primary education, (iv) lower-secondary education, (v) upper-secondary education, and (vi) post-secondary education.

While the UN dataset provides data by five-year age groups from age zero to age 85+, the Human Capital Database provides data by five-year age groups from age zero to age 100+. In order to compare the data across the two datasets, we make a logistic fit of the mortality rates from the 75-80 and 80-85+ age groups in the UN life table data, and then use the fit to recalculate the UN life table across countries for five-year age groups from age zero to age 100+ (Kannisto, 1994; Stockwell et al., 1973).

5.2.2 Methods

The comparative prospective old-age threshold (CPOAT) proposed by Balachandran et al. (2019) stipulates an "old-age threshold" after accounting for differences in life expectancy and adult survival levels across populations. The authors have used the CPOAT to compare different populations against a *benchmark population;* Japan of 1972. The remaining life expectancy (RLE) at age 65 in Japan in 1972 was 15 years, and the proportion of the adult population (population above age 15) surviving to age 65 was 0.829 (called the adult survival ratio (ASR) at age 65). A multiplication of these ASR and RLE (ASR*RLE) values yields 12.4. The CPOAT of other populations is defined as the age at which their ASR*RLE value is closest to 12.4. The authors analogize their measure to the concept of comparing purchasing power across currencies with a benchmark currency (usually the US dollar). Unlike traditional thresholds that do not change over time or across populations, the CPOAT is a dynamic and forward-looking measure of population ageing. It has been found to be robust for comparisons across populations with varied mortality patterns. The CPOAT is a realization of the characteristics approach, (Sanderson & Scherbov, 2013) which sought to explain population ageing based on age-specific characteristics.

To empirically estimate the CPOAT for countries in Asia and Europe by educational levels and sex for every five-year period between 2015 and 2050, we adopt three steps:

Step 1: Formulation of life tables by educational levels and by sex

Using the age-specific survival rate, we formulate life tables by six educational levels and by sex for Asian and European regions in the following order: (i) using the age-specific survival rate, the number of person-years lived (${}_nL_x$ in the life table) is obtained for six levels of education for both sexes; (ii) using the UN life table data, the region and the sex-specific average years lived in an age interval by a person who dies in the interval (${}_na_x$ in the life table) is obtained; (iii) keeping ${}_na_x$ constant across different levels of education, the age-specific mortality rates (${}_nm_x$ in the life table) are obtained; and (iv) the resulting age-specific mortality rates are used to formulate life tables for the corresponding educational level by sex.

*Step 2: Estimation of ASR*RLE by age across educational levels and sex*

ASR by age group for each educational level is calculated for the corresponding life tables by dividing the number of survivors of a particular age by the number of survivors at age 15. RLE across different age groups are calculated from the same life tables. By multiplying ASR by RLE, the corresponding ASR*RLE values are estimated across age groups.

A linear interpolation is then executed to obtain ASR*RLE values by single ages from the five-year age group values. Such a linear interpolation is warranted, as a sensitivity analysis in which we used more advanced interpolation techniques (e.g., TOPALS; Beer 2012) also generated the same results. Moreover, another sensitivity analysis with separate linear interpolations for ASR and RLE prior to their multiplication produced the same age-specific results.

Step 3: Estimation of CPOAT and shares of elderly

The projected CPOAT is obtained for six different levels of education by sex by finding the age at which the age-specific projected values of ASR*RLE in the corresponding life tables is closest to 12.4. We also estimate the shares of elderly in the population across Asia and Europe using the CPOAT by comparing the percentage of the population above the CPOAT to the total population. The results of this calculation are called the *baseline* scenario, which is based on the Global Education Trend scenario.

5.2.3 Alternate scenarios of future education

We formulated two alternative future scenarios in which the populations hypothetically have higher educational levels than in the baseline scenario. In scenario (1), the whole population have at least upper-secondary education. In scenario (2), the whole population have the highest educational level (i.e., post-secondary education). We call the results obtained from *step 3* the *baseline scenario.* In scenario (1), we assume that the entire population of a particular region have the same CPOAT as that of the population with upper-secondary education, with the exception of the population with post-secondary education. For the population with post-secondary education, the CPOAT is unaltered compared to baseline scenario. In scenario (2), we assume that the entire population of a region have the same CPOAT as the population with post-secondary education.

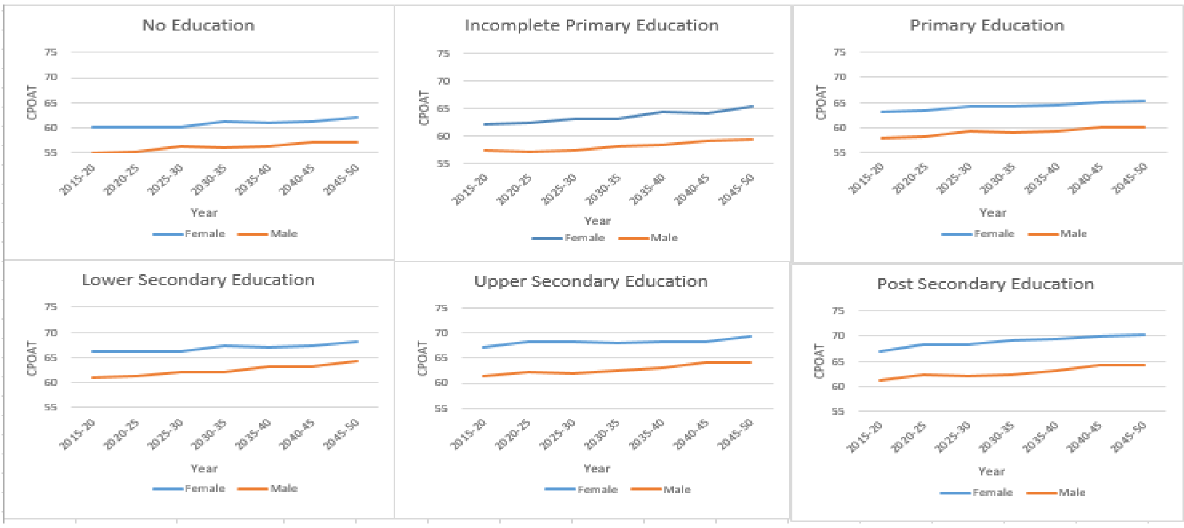
5.3 Results

5.3.1 Projected CPOAT for Asia and Europe by educational levels and by sex

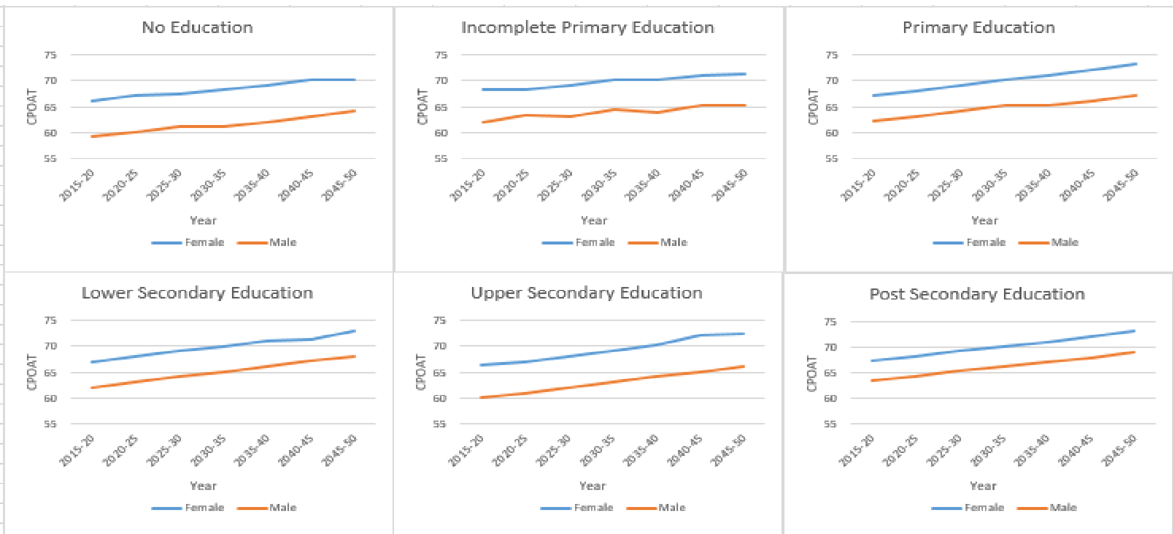
Figure 5.1 shows the results of the projected CPOAT by six different educational levels and by sex for the 2015-2050 period for Asia and Europe.

Figure 5.1: Comparative prospective old-age threshold by educational levels and by sex, 2015-2050

a) Asia



b) Europe



Between 2015 and 2050, the CPOAT is increasing over time across all six educational levels in Asia and Europe. For any given level of education, the corresponding CPOAT values are higher for Europe than for Asia. The CPOAT generally rises with the level of education. For any given level of education, the CPOAT is higher for females than for males. However, the changes in the CPOAT have distinct patterns by levels of education across Asia and Europe.

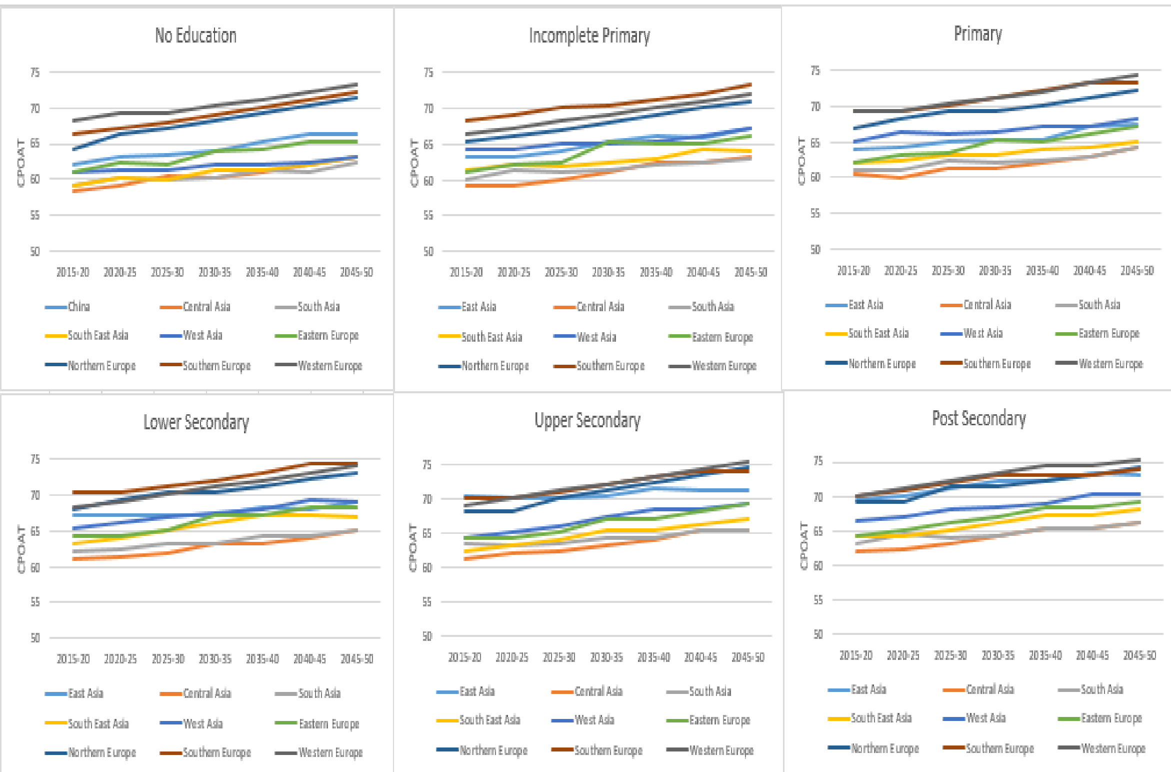
For the uneducated, the projected CPOAT values for the 2015-2020 period are as low as 60.15 (females) and 55.04 (males) in Asia, compared to 66.21 (females) and 59.19 (males) in Europe. Likewise, for the highly educated (post-secondary level), the projected CPOAT values for the 2015-2020 period are 67.02 (females) and 63.32 (males) in Asia and 67.39 (females) and 63.34 (males) in Europe.

Regional variations in projected CPOAT in Asia and Europe

Given the vastness of and regional variations within Asia and Europe, the overall patterns in the CPOAT do not necessarily reflect its regional distinctions. Based on the UN classification on geographical locations, we explore CPOAT variations across five Asian and four European regions. Figure 5.2 (a-b) shows the results of the projected CPOAT in regions of Asia and Europe across six educational levels and by sex for the 2015-2050 period.

Figure 5.2: Comparative prospective old-age threshold for regions in Asia and Europe across educational levels, 2015-2050

a) Females



b) Males

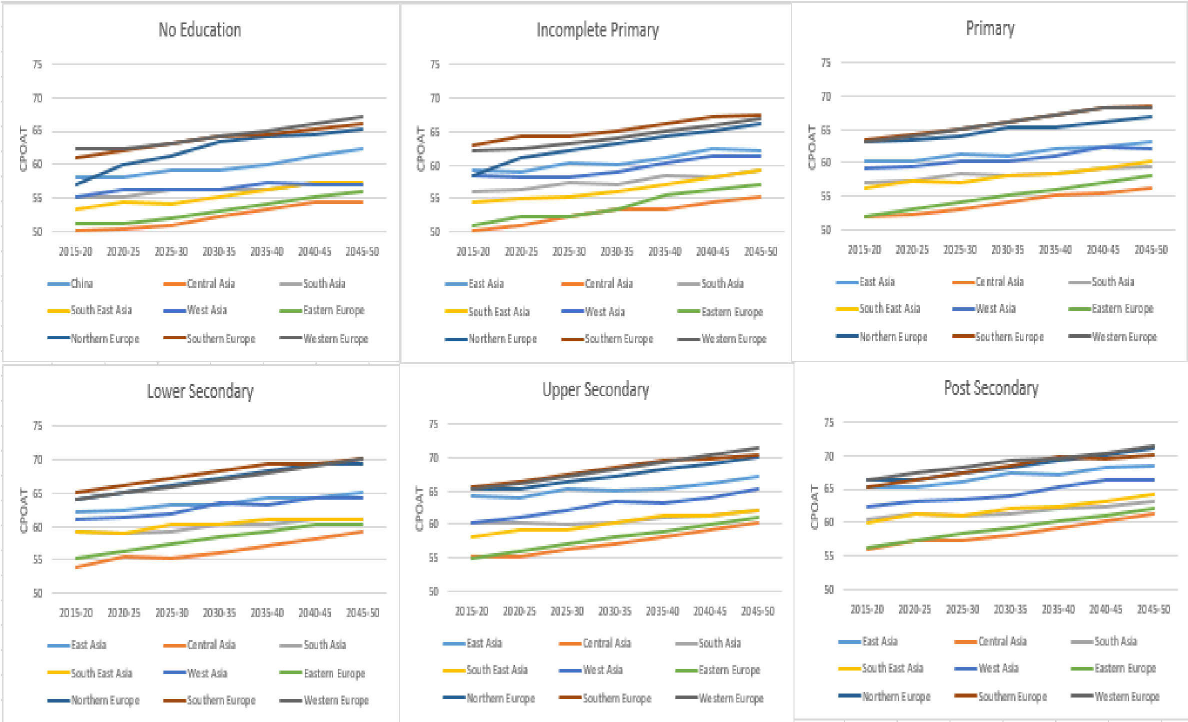


Figure 5.2 (a-b) clearly shows that across educational levels, Western Europe and Northern Europe have the highest CPOAT values for different years, while Central Asia has the lowest CPOAT values. South Asia and South East Asia also have lower CPOAT values at lower educational levels. Southern Europe has considerably higher CPOAT values for certain levels of education (especially at the lower-secondary level). For females with no education, the CPOAT in 2015-2020 is 68.18 for the region with the highest values (Western Europe), and is 58.33 for the region with the lowest values (Central Asia). For males with no education, the CPOAT in 2015-2020 is 62.36 in Western Europe and 50.15 in Central Asia.

5.3.2 Future population ageing by educational levels

We estimate the projected shares of elderly by educational levels in Asia and Europe using the CPOAT values estimated in Figures 5.1 and5. 2. Table 5.2 (a-b) shows the shares of elderly across educational levels for the 2015-2020 and 2045-2050 periods for females and males.

Table 5.2a: Shares of elderly using CPOAT by educational levels for different regions, females (in %), 2015-2020 and 2045-2050

Region	*No Education*		*Incomplete Primary*		*Primary*		*Lower-Secondary*		*Upper-Secondary*		*Post-Secondary*		*Total*	
	2015-2020	*2045-2050*	*2015-2020*	*2045-2050*	*2015-2020*	*2045-2050*	*2015-2020*	*2045-2050*	*2015-2020*	*2045-2050*	*2015-2020*	*2045-2050*	*2015-2020*	*2045-2050*
Asia	4.36	3.60	1.26	1.25	2.39	3.25	0.87	4.24	0.76	2.80	0.25	1.53	9.88	16.68
East Asia	2.50	0.69	1.90	1.62	4.31	4.31	2.38	10.24	1.54	4.55	0.27	2.28	12.90	23.69
Central Asia	0.20	0.08	0.37	0.05	0.88	0.12	1.78	1.14	4.01	9.75	1.16	2.79	8.39	13.92
South Asia	5.54	6.67	0.66	0.96	0.82	1.92	0.34	1.31	0.40	1.92	0.18	1.00	7.94	13.78
South East Asia	2.04	1.10	2.26	1.68	3.52	5.49	0.57	2.81	0.55	3.19	0.34	1.60	9.29	15.87
West Asia	2.64	2.13	1.17	1.07	1.49	2.84	0.33	1.45	0.59	1.97	0.53	1.58	6.74	11.05
Europe	0.44	0.18	0.82	0.20	4.09	1.12	4.96	3.87	4.91	10.36	2.03	5.97	17.26	21.71
Eastern Europe	0.13	0.14	0.24	0.05	3.38	0.23	4.88	1.90	8.50	14.46	2.91	6.54	20.03	23.33
Northern Europe	0.02	0.09	0.03	0.03	1.52	0.23	8.27	4.72	3.75	6.07	3.31	6.79	16.91	17.92
Southern Europe	1.44	0.30	3.74	0.78	6.92	2.49	3.17	6.94	1.97	8.30	1.07	6.01	18.32	24.82
Western Europe	0.31	0.22	0.05	0.06	4.58	1.61	5.26	2.92	6.40	9.44	1.84	5.93	18.44	20.18

Table 5.2b: Shares of elderly using CPOAT by educational levels for different regions, males (in %), 2015-2020 and 2045-2050

Region	*No Education*		*Incomplete Primary*		*Primary*		*Lower-Secondary*		*Upper-Secondary*		*Post-Secondary*		*Total*	
	2015-2020	2045-2050	2015-2020	2045-2050	2015-2020	2045-2050	2015-2020	2045-2050	2015-2020	2045-2050	2015-2020	2045-2050	2015-2020	2045-2050
Asia	2.65	2.14	1.31	1.04	3.15	2.88	2.04	5.30	1.59	4.12	0.75	2.45	11.50	17.92
East Asia	1.04	0.23	1.58	0.83	4.60	2.53	3.86	11.88	1.82	5.10	0.91	3.70	13.81	24.26
Central Asia	0.08	0.09	0.18	0.06	0.43	0.14	1.62	1.29	6.02	9.86	2.17	3.06	10.50	14.50
South Asia	4.71	4.00	1.01	1.00	1.52	2.59	0.83	2.34	1.24	3.50	0.72	1.95	10.03	15.38
South East Asia	1.43	0.73	1.88	1.38	4.72	4.96	1.13	3.90	1.38	4.63	0.61	1.95	11.15	17.56
West Asia	1.70	1.50	0.91	1.28	2.35	2.70	0.65	2.79	0.94	3.19	0.89	2.72	7.44	14.18
Europe	0.22	0.18	0.55	0.18	2.70	0.92	3.70	3.61	7.38	10.61	3.65	5.86	18.20	21.36
Eastern Europe	0.07	0.17	0.07	0.09	1.50	0.33	3.61	2.41	14.28	16.28	4.50	6.05	24.03	25.33
Northern Europe	0.01	0.09	0.01	0.05	1.31	0.23	6.10	4.68	5.10	6.80	3.94	6.53	16.48	18.37
Southern Europe	0.56	0.29	2.42	0.61	5.52	2.10	4.03	7.53	3.28	8.55	2.28	5.72	18.10	24.80
Western Europe	0.26	0.19	0.03	0.07	2.95	1.30	2.24	2.08	7.99	9.84	4.10	7.11	17.57	20.59

Table 5.2 (a and b) shows clear differences in the shares of elderly across educational levels in Asia and Europe. Europe has larger shares of female and male elderly than Asia in both 2015-2020 and 2045-2050. Although the overall shares of elderly are increasing over time across the regions, the changes in the shares of elderly by educational composition paints a different picture. In Europe, the shares of elderly are larger among the higher educated groups (lower-secondary, upper-secondary, and post-secondary levels) and smaller among the lower educated groups. The reverse is true for Asia, where the shares of elderly are larger among the less educated groups. Broadly, these patterns hold for the regions within each continent. For instance, the shares of elderly among the uneducated group are especially large in South Asia. Similarly, Northern Europe has the largest shares of elderly with post-secondary education.

5.3.3 Can future scenarios of population ageing be changed by increased investments in education?

As we mentioned in the methodology section, we will consider two alternate future scenarios in Asia and Europe with hypothetical changes in educational investments and compare them with the *baseline scenario.* The resulting shares of elderly across the two alternate scenarios and the baseline scenario for the 2045-2050 period are displayed in Table 5.3. To facilitate comparisons, we also show the shares of elderly for the 2045-2050 period based on the traditional old-age threshold of 65.

Table 5.3: Shares of elderly with assumed higher levels of education for different regions in Asia and Europe by sex (in %), 2045-2050

	Shares of elderly (%) in 2045-2050							
Region	*Shares of elderly (%) based on old-age threshold of 65*		*Baseline Scenario: Medium scenario of future educational distribution*		*Scenario 1: The whole population have at least upper-secondary education*		*Scenario 2: The whole population have post-secondary education*	
	Female	Male	Female	Male	Female	Male	Female	Male
Asia	18.16	15.26	16.68	17.92	14.36	16.46	13.50	14.77
East Asia	28.33	23.73	23.69	24.26	21.56	22.62	19.04	21.63
Central Asia	12.21	8.62	13.92	14.50	13.89	14.34	13.22	13.59
South Asia	12.37	10.81	13.78	15.38	12.46	13.65	11.67	12.81
South East Asia	16.92	13.38	15.87	17.56	14.69	16.26	13.83	14.41
West Asia	13.25	11.83	11.05	14.18	10.00	12.52	9.30	11.79
Europe	29.74	24.16	21.71	21.36	20.67	20.67	19.42	18.62
Eastern Europe	27.54	19.20	23.33	25.33	21.70	24.00	21.70	22.48
Northern Europe	26.20	23.22	17.92	18.37	16.57	17.47	16.57	16.43
Southern Europe	36.28	31.12	24.82	24.80	23.64	23.04	23.64	23.04
Western Europe	30.18	26.21	20.18	20.59	19.96	20.26	18.69	19.16

Using Table 5.3, the shares of elderly in the Asian and European regions can be compared across different scenarios by sex. Compared to the baseline scenario, the shares of elderly are smaller for all of the regions across both scenario (1) and scenario (2). In addition, the shares of elderly are smaller in scenario (2) than in scenario (1). In scenario (1), the shares of elderly are 14.36% for females and 16.46% for males in Asia and are 20.67% for both females and males in Europe. In scenario (2), the shares of elderly decrease to 13.50% for females and 14.77% for males in Asia and to 19.42% for females and 18.62% for males in Europe. Among the regions, Southern Europe has the largest shares of female elderly and Eastern Europe has the largest shares of male elderly in scenario (1); and Southern Europe has the largest shares of both female and male elderly in scenario (2). West Asia has the smallest shares of elderly in both scenarios. Across the regions, the shares of elderly are smaller in scenario (2) than in scenario (1), and are, in turn, smaller than in the baseline scenario. The shares of elderly in Europe and of elderly females in Asia are smaller in the *baseline scenario* than when the traditional old-age threshold of 65 is used, but the shares of elderly males in Asia are slightly larger in the former scenario.

It is also worth noting that the decreases in the shares of elderly in scenario (1) and scenario (2) relative to the baseline scenario are not same across the regions or by sex. The decreases are quantified in Appendix Table 5.1. The decreases in the shares of elderly across scenarios is larger in Asia than in Europe. In general, within Asia, the decreases are larger for East Asia. In Europe, Eastern Europe has the largest decreases. In regions with high CPOAT values such as Western Europe, the decreases in the shares of elderly from the baseline scenario to scenario (1) are not large (less than 0.5%), whereas the decreases are considerably greater from the baseline scenario to scenario (2).

5.4 Discussion

5.4.1 Summary of results

We compared the educational differentials in future population ageing trends in Asia and Europe using a measure that enabled us to compare population ageing across populations and over time. We found that the projected values of the comparative prospective old-age threshold (CPOAT) are higher among populations with higher levels of education. This pattern is shown to hold over time for both women and men in all regions of Asia and Europe, although there are regional variations in the trajectory of the increasing trend. While the total projected share of elderly is smaller in Asia than in Europe, the shares of elderly with higher educational levels are much larger in Europe. Correspondingly, Asian regions have much larger shares of elderly who have little or no education. The shares of elderly with the highest level of education are larger among males than females in both continents. An analysis of future scenarios with higher levels of education for the whole population showed decreases in the future shares of elderly in Asia and Europe and its regions, with the decreases being larger in Asia than in Europe. In developed regions (such as Western Europe), the shares of elderly decrease substantially only when the highest educational levels are attained for the whole population.

5.4.2 Explanation of the results

Our finding that the CPOAT is higher for populations with higher educational levels is explained by the higher life expectancy levels and adult survival ratios among populations with higher education (Lutz and Samir, 2011). A higher CPOAT value means that "old-age" starts at higher ages. Thus, population ageing seems to be occurring at varying paces depending on the educational level of a population. In an educated population, "old-age" begins at higher ages. Similarly, females have higher life expectancy levels than their male counterparts, which explains their higher CPOAT values (Balachandran et al., 2017). The lower life expectancy and adult survival levels in Asia (except in East Asia) and Eastern Europe (Lloyd-Sherlock et al., 2012; Vallin & Meslé, 2004) shed light on why these regions have lower CPOAT values than Western and Northern Europe. Similarly, the lower adult survival ratios in Central Asia are well-documented, (Lopez et al., 2006) and explain the lower CPOAT values in the region.

Although the future shares of elderly are larger in the European regions, the shares of less educated elderly are larger in the Asian regions. The higher income levels, better educational infrastructure, and greater investments in education in Europe are chiefly responsible for this pattern.

An important observation of our analysis is that in alternate future scenarios in which less educated populations have higher levels of education, the projected shares of elderly decrease. This finding holds across regions and among women and men. The increases in life expectancy and adult survival ratios associated with increases in education are mainly responsible for the decreases in the shares of elderly. In such alternate future scenarios, we also find that decreases in the shares of elderly are much larger in Asia than in Europe. Because the current educational infrastructure in Asia is of worse quality, the life expectancy and adult survival ratios in Asia are also lower. Because the base levels in Asia are low, improvements in life expectancy and adult survival ratios in Asia would be greater if improvements in education are also implemented. This explains why Asia gains more in terms of shares of elderly in alternate future scenarios with higher educational levels. Our analysis also shows that in developed regions like Western Europe, the future share of elderly declines substantially only when the whole population reach the highest educational level. This suggests that given the already high levels of basic education in Europe, substantial changes in life expectancy and adult survival ratios would occur there only if investments were made in the highest educational levels.

5.4.3 Evaluation of the method

For our analysis, we used a comparative and prospective measure of ageing instead of the conventional chronological age 65. The educational heterogeneity across elderly populations is high, and the remaining life expectancy and ratios of adults surviving to higher ages vary across educational levels (Samir & Lentzner, 2010). Hence, our method provides a more holistic perspective on population ageing than earlier analyses, and highlights ageing differentials within and across populations. Therefore, it provides a much clearer view on future ageing as a result of increased educational attainment than the existing measures, which consider future population ageing based on either an abstract chronological age such as 65 or on one characteristic only (such as RLE). As educational levels rise, the future shares of elderly are projected to be lower than the conventional measures and analysis based on one characteristic indicate (Lutz et al., 2014; Sanderson & Scherbov, 2015).

5.5 Recommendations

The results of the scenario exercise have important implications for policymakers. A higher level of investment in education can be an effective tool for regions of Asia and Europe to tackle the ageing process. Such investments in education are more effective in regions where the educational infrastructure is less developed and younger cohorts form a large part of the population, such as Asia. Long-term investments in education are vital in these regions. Likewise, regions where the shares of elderly in the population are expected to be large, such as Western Europe, can prepare for population ageing by helping to close the educational gap through investments in the highest levels of education.

The measure we used in this study advances existing methods by accommodating the improvements in life expectancy over time, as well as the differences across populations in the likelihood of reaching higher ages. However, alongside changes in life expectancy and survival rates, there may be differentials in morbidity, cognition, productivity, labour force participation, and healthy life expectancy by levels of education (Balachandran & James, 2019a, 2019b; Skirbekk et al., 2012). Thus, we recommend that future research on ageing consider a more diverse range of human capital factors across populations, including educational gradients.

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Appendix Table 5.1: Decrease in the shares of elderly across scenarios for different regions in Asia and Europe by sex (in %), 2045-2050

Region	**Baseline scenario - Scenario (1)**		**Baseline scenario - Scenario (2)**	
	Female	*Male*	*Female*	*Male*
Asia	2.32	1.46	3.18	3.16
East Asia	2.13	1.64	4.66	2.63
Central Asia	0.03	0.16	0.70	0.91
South Asia	1.33	1.73	2.11	2.57
South East Asia	1.17	1.30	2.04	3.15
West Asia	1.05	1.66	1.74	2.39
Europe	1.03	0.69	2.29	2.74
Eastern Europe	1.62	1.33	1.62	2.85
Northern Europe	1.35	0.91	1.35	1.94
Southern Europe	1.18	1.77	1.18	1.77
Western Europe	0.22	0.33	1.49	1.43

Chapter 6 Discussion

6.1 Aim of the thesis

The aim of the PhD research was to compare current and future population ageing in Europe and Asia using new comparative ageing indicators that accommodate differentials in life expectancy, health, and human capital across their populations.

More specifically, the sub-objectives were:
1) to assess population ageing across Europe and Asia in a comparative manner;
2) to assess sex and country differences in population ageing in Europe and Asia using a multi-dimensional perspective; and
3) to assess future population ageing in Europe and Asia, educational differences therein, and their responsiveness to changes in education.

The PhD thesis adopted a comprehensive, holistic, and multi-disciplinary approach to understanding population ageing across Europe and Asia. The thesis measured population ageing by applying several state-of-the-art demographic techniques and novel methodologies to different demographic and health-related datasets. Through this approach, the PhD research provided a more comprehensive understanding of current and future population ageing in Europe and Asia, and novel tools for investigating population ageing in a comparative and multi-dimensional manner.

6.2 Summary of results

To explain population ageing in Europe and Asia, previous research has either used the traditional measures of ageing that rely on fixed old-age thresholds, such as age 65, or measures that are not fully sensitive to different mortality patterns across these regions. **Chapter 2** assessed population ageing in Europe and Asia in a comparative manner (sub-objective 1). To this end, the chapter formulated a new measure of the onset of old age (the old-age threshold), which adjusts for the changes in life expectancy over time and the cross-country differentials in the exceptionality of reaching old age. This new threshold age was called the 'Comparative Prospective Old-Age Threshold' (CPOAT). The CPOAT was lower than 65 years (in 2012) in Central Asia, Southern Asia, South-East Asia, and many Eastern European countries. In these regions, the estimates of the shares of elderly based on the CPOAT were larger than the existing estimates. In contrast, the estimates of the shares of elderly in Western, Northern, and Southern Europe based on the CPOAT were lower than those estimated using existing measures. Although the differences in population ageing between Asia and Europe diminished overall, our estimates also revealed that the diversity in ageing across Europe and Asia was greater than those based on previous measures.

Chapters 3 and 4 were devoted to the assessment of sex and country differences in population ageing in Europe and Asia using a multi-dimensional perspective (sub-objective 2). While a uni-dimensional measure might offer a simple and easily quantifiable measure of population ageing, it may not be enough to capture the differential dimensions of population ageing. In **Chapter 3,** population ageing in selected countries in Europe and Asia was assessed through a multidimensional perspective. To this end, a multi-dimensional measure was formulated that considers not only the changes in quantum of life years, but also changes in quality of life years.

The measure was called the ‘Multi-dimensional Old-age Threshold’ (MOAT), and stipulates an ‘old-age threshold’ across selected countries in Europe and Asia after simultaneously accounting for dimensions of life expectancy and of health and human capital. Using data from longitudinal surveys across countries, the estimates for the year 2010-11 highlighted that the estimates of population ageing for countries in Europe and Asia differ when the MOAT rather than existing measures is applied, primarily due to the inclusion of the quality dimensions (health, human capital). Countries that simultaneously had better performance in life expectancy and health and human capital (e.g., Western and Northern European countries) had higher MOAT values, and, consequently, a lower share of elderly. The results indicated that a country that invests more in the health and human capital of older people reduces the absolute ‘burden’ of its ageing in terms of the quality dimension. Moreover, the estimates showed the dimensions in which different countries lagged or led.

In **Chapter 4,** the gender gap in health among older adults in India and China was investigated from a multi-dimensional perspective. Unlike in many developed countries, the female life expectancy levels at older ages were lower than those of their male counterparts in India and China for most of the last century. However, in the past few decades, female life expectancy levels at older ages in India and China have rapidly improved, and are today higher than those of their male counterparts. Such improvements in life expectancy among females could lead to the conclusion that systemic gender differentials that were prevalent in these countries have been reduced. By applying a multi-dimensional perspective for the year 2010-11, we showed in this chapter that improvements in life expectancy among older females need not necessarily mean that there were improvements in dimensions of health and human capital. After considering multiple dimensions of physical, intellectual, and general health, we estimated a MOAT specific to the female and male populations in these countries. We found that females in these countries have a lower MOAT than their male counterparts, which indicates that they reach ‘old age’ earlier. The gender gap in health among older adults, which we obtained from the difference in the MOAT between males and females, was found to be higher in India than in China, and to vary considerably across provinces in these countries. The chapter highlights the need to understand the gender gap in health among older adults from a multi-dimensional perspective, and provides an innovative way to quantify such a gap.

In **Chapter 5**, an assessment of future population ageing in Europe and Asia, the educational differences therein, and its responsiveness to changes in education was provided (sub-objective 3). Based on population projections across regions of Europe and Asia by sex and education for the period between 2015 and 2050, the future values of the CPOAT, developed in Chapter 2, were obtained. The results showed that population ageing is expected to rise further, predominantly in Asia, which will result in smaller differences in population ageing between Asia and Europe. Moreover, in both Europe and Asia, and among both men and women, the estimated future old-age thresholds (CPOAT) are higher for higher educated people than for less educated people. In alternate future scenarios in which populations hypothetically have higher levels of education, the projected shares of elderly in the population decrease across all regions of Asia and Europe, but more so in Asia. Our results highlight the effectiveness of investing in education as a policy response to the challenges associated with population ageing.

In sum, **this PhD thesis** highlighted that, using the new perspective, the differences in the current and future population ageing trends between Europe and Asia are smaller than were previously estimated. However, this measure also shows that there is greater diversity in population ageing trends across regions, sexes, and educational levels than was previously estimated. More specifically, the onset of ‘old age’ was found to be earlier, and, consequently, the share of the elderly population was shown to be higher, in populations that lag in life expectancy in health and human capital attainments. This pattern appears to be especially pronounced in most Asian countries, and among particularly females in the large developing countries of Asia (India and China), but also in Eastern Europe, and among the lower educated in both Asia and Europe. In the future, population ageing is expected to rise further, predominantly in Asia, which will result in smaller differences in population ageing between Asia and Europe. In addition, in the future, population ageing is expected to be higher among the lower educated, particularly in Asia, where the responsiveness of future population ageing to an increase in education is likely to be high.

6.3 Explanations of the main findings

6.3.1 Population ageing in Europe and Asia compared

Using our novel approach, we observed higher population ageing in most Asian regions, and lower population ageing in most European regions, than was previously estimated. As a result, the differences in population ageing trends between the two continents, Asia and Europe, were found to be smaller than were previously estimated. However, substantial differences remain.

The higher population ageing found in most Asian regions through the use of our comparative ageing measure can be linked to the higher exceptionality of adults in most Asian regions (e.g., South and Central Asia) in the likelihood of reaching higher ages. The lower chances of adults in Asia reaching higher ages can directly be related to the comparatively high levels of adult mortality and lower levels of life expectancy and of health and human capital achievements in Asia than in Europe (Crimmins & Cambois, 2003; Mathers & Loncar, 2006; Shrestha, 2000).

For instance, many Asian countries face a double burden of diseases at adult ages, and thus have a higher mortality burden from both infectious diseases and non-communicable diseases (Boutayeb, 2006). Many developing countries in Asia started having higher mortality from non-communicable diseases even before they had managed to bring deaths due to communicable diseases down to lower levels. The mortality rates at adult ages from injuries and accidents are also higher in Asian countries (James et al., 2020). In addition, females in several Asian countries face an additional burden of deaths from reproductive health issues (Khan et al., 2006). Thus, as well as having high mortality rates, Asian countries have higher morbidity rates than their European counterparts (Jagger & Robine, 2011). The absence of a well-constructed health system and lower economic growth and investments in health in Asia are, in turn, responsible for the higher mortality and morbidity in Asia. As these higher mortality and morbidity levels at adult ages make reaching higher ages more exceptional among adults of Asia, the old-age thresholds in Asia are lower as estimated by our perspective, after controlling for such differences. Consequently, we concluded that the share of the population who are ageing is higher in Asia than the traditional perspective indicated, and is closer to that of the share of elderly in the population in Europe.

Asian countries also have lower cognitive and human capital achievements than European countries (Rosli et al., 2016; Skirbekk et al., 2012). Historically, many Asian countries did not gain independence until the middle of 20th century, and therefore had relatively poor educational infrastructure five to seven decades ago (Lutz & Samir, 2011). In addition to having lower investments in education and economic growth over the years, the educational infrastructure base has been lower in Asia than in Europe (Lutz et al., 2014). Hence, higher proportions of the older adult population in Asia than in Europe have lower educational achievements and cognition. Thus, when the multidimensionality in ageing perspective that takes into account differences in cognition, education, and other aspects of human capital is used, the old-age threshold is found to be earlier in Asia than when the traditional perspectives are applied. We can therefore conclude that the share of elderly in the population is higher in Asia, and that the differences in population ageing trends across Asia and Europe are smaller than those estimated by traditional perspectives.

6.3.2 High levels of diversity in population ageing within both Europe and Asia

The PhD thesis revealed considerable diversity in population ageing trends between regions, men and women, and educational levels. In particular, levels of population ageing were found to be high in populations lagging in life expectancy and health and human capital attainments: i.e., in most Asian countries, but also in Eastern Europe, among females in the developing countries of Asia, and among the lower educated in both continents. Indeed, using our novel perspective, we found that the diversity in population ageing was even greater than was previously estimated. That is, the application of our comparative measure resulted in higher levels of diversity in ageing trends between countries and regions (Chapter 2) and between socio-economic groups (Chapter 5), whereas the use of our multidimensional measure also showed that there is considerable diversity in ageing trends between countries (Chapter 3) and between the sexes (Chapter 4).

Diversity across countries and regions

Within Asia, we observed that the onset of ‘old age’ was earlier, and population ageing was high(er) in most Asian countries, was but low(er) in Eastern Asia. Within Europe, in particular, we observed that population ageing was higher than was previously estimated in Eastern Europe (see 6.3.1 for the discussion of high levels of population ageing in most Asian countries). The finding that population ageing is high(er) in Eastern Europe can largely be explained by the fact that adult mortality in Eastern Europe is higher than it is in the rest of Europe, predominantly due to the higher prevalence of lifestyle diseases (Cockerham, 1997; Peasey et al., 2006; Trias-Llimós & Janssen, 2018). Within Asia, Eastern Asia has lower mortality and morbidity levels at different ages than the rest of Asia due to the lower prevalence of communicable and non-communicable diseases in the region (Kadota et al., 2018; Kinsella, 2000). These advantages are, in turn, linked to better economic performance and greater investments in health care systems in the Eastern Asian countries. Since our perspective accommodates the differentials in the exceptionality of adults reaching higher ages (within Europe, it is comparatively high in

Eastern Europe; within Asia, it is comparatively low in Eastern Asia), the old-age thresholds are earlier in Eastern Europe and later in Eastern Asia than the traditional perspective would indicate. Consequently, the share of elderly in the population is higher in Eastern Europe than in the rest of Europe, and the share of elderly in the population is lower in Eastern Asia than in the rest of Asia. This leads us to conclude that there is much more geographical diversity in population ageing within Europe and within Asia than conventional estimates suggest. In addition, this diversity could be due to differences in medical technology and productivity levels, among other factors, across the continents (see section 1.3.2 of the thesis for a discussion of other potential reasons for the diversity across the regions of Europe and Asia).

Diversity across sexes

In the developing countries of Asia, our multidimensional perspective on population ageing reveals that the onset of 'old age' was earlier, and, consequently, that levels of population ageing were higher among females than among males.

Substantial sex differences in the multiple dimensions of ageing (life expectancy, activities of daily living, and levels of cognition) can explain the high(er) diversity in population ageing levels that we observed. Generally, while life expectancy is higher among females, women lag in health and human capital achievements, especially in the developing countries of Asia, primarily due to the patriarchal nature of society in these countries, which is biased against females. These patriarchal gender norms discriminate against females in Asia, and result in women having less access to health and educational facilities (Deshpande, 2019; Wheaton & Crimmins, 2016). At the same time, a general overall increase in life expectancy has occurred among females and males as a result of overall economic growth and higher investments in public health. Given that there are substantial differences between males and females in multiple dimensions of life expectancy and health and human capital, the share of elderly in the population increases among females when our multidimensional perspective rather than the traditional perspective is applied; thus, our measure leads to more diversity in population ageing trends between women and men. The above findings also highlight the importance of culture (e.g., gender norms) in determining diversity in population ageing trends.

Diversity across socio-economic groups

Finally, we observed high levels of diversity across socio-economic groups (measured by educational attainment) in population ageing trends, with the lower educated in both Asia and Europe experiencing a lower old-age threshold and higher levels of population ageing than the higher educated on both continents.

These findings can again be related to differences in the exceptionality of reaching old age between those with high and those with low educational attainment. That is, people with low educational attainment generally have lower access to and utilisation of health care, and a higher prevalence of unhealthy behaviours, which results in higher adult mortality. Consequently, the exceptionality of reaching higher ages is higher among people with low than with high educational attainment (Case & Deaton, 2017; Hendi, 2017). Education reproduces and magnifies the cumulative advantage/disadvantage in health-related resources over the life course. Therefore, there is a growing gap in health among people who are more or less educated from younger to older ages (Ross & Wu, 1996). Hence, the old-age threshold is lower among the less educated, and increases as the educational level rises. This leads to a lower share of elderly among the higher educated groups and a higher share of elderly among the lower educated groups.

6.3.3. Future population ageing in Asia and Europe

In the future, population ageing is expected to increase further as a result of continued increases in life expectancy and – in Asia – continued declines in fertility. The future increases in population ageing are, however, expected to be more rapid in Asia than in Europe. As a result, the differences in population ageing trends between the two continents will be smaller than those that are currently observed.

The more rapid projected increase in the share of elderly in the population in Asia than in Europe can be linked to differences in the progression of the demographic transition between Europe and Asia. With the exception of Japan, Europe is ahead of Asia in the demographic transition, and thus has higher life expectancy at different ages and lower fertility rates. As Asia is rapidly following Europe in the demographic transition, life expectancy levels at different ages are increasing, while fertility rates are decreasing in Asia. For instance, the difference between life expectancy at birth between Europe and Asia declined from 21.4 years in 1950-55 to 5.1 years in 2015-20. Similarly, the difference between fertility rates in Asia and Europe decreased from 3.5 in 1950-55 to 0.5 in 2015-20. Unlike the traditional perspective, our novel perspective accounts for such patterns in demographic transitions, and, therefore, for the differences in population ageing trends across Europe and Asia. According to the traditional perspective, the difference in the share of elderly between Europe and Asia increased from 3.9% in 1950-55 to 10.1% in 2015-20; and the difference remains at 10.1% in 2045-50 (according to medium estimates) (UN, 2019). However, our estimates show that the difference in the share of elderly was 7.4% in 2015-20, and further decreases to 5% in 2045-50. Moreover, as the epidemiological transition follows the demographic transition (Lesthaeghe, 2010; Van de Kaa, 2004), the shares of communicable diseases are decreasing in Asia, and are following the patterns observed in Europe.

While Asia is lagging Europe in the demographic transition, the less educated lag in the transition relative to their more educated counterparts (Lesthaeghe, 2014). Hence, future levels of population ageing are expected to be higher among the lower educated, particularly in Asia. These patterns can be attributed to most Asian countries having worse educational infrastructure and, thus, lower educational levels than their European counterparts. Since the base level of educational infrastructure is lower in Asia, any policy initiative aimed at improving the infrastructure will accelerate the pace of demographic transition on the continent. Hence, the responsiveness of future population ageing to a rise in education would be greater in Asia than in Europe.

6.4 Reflections on the applied new perspective to ageing

The novel perspective on population ageing employed in this thesis has resulted in a more comprehensive and holistic outlook on current and future population ageing in Asia and Europe, and the differences therein between and within the two continents.

Our multidisciplinary approach resulted in the development of novel ageing measures that can provide for better cross-country comparisons of population ageing across Europe and Asia. These novel measures are the comparative old-age threshold (CPOAT) and the multi-dimensional old-age threshold (MOAT). These measures can be considered adjustments and extensions of the characteristics approach (Sanderson & Scherbov, 2013). The characteristics approach provided a framework for understanding and redefining population ageing by accounting for the diverse characteristics (e.g., remaining life expectancy, survival rates to higher ages, activities of daily living, cognition levels) of a population. However, our approach extends the characteristics approach by embedding a comprehensive and holistic perspective. For example, Scherbov and Sanderson (2016) proposed estimating the old-age threshold by the age at which the remaining life expectancy (RLE) equals 15 years. Our CPOAT measure adjusted this measure by also taking into account cross-national differences in the exceptionality of reaching that age. Moreover, whereas the existing applications of the characteristics approach only consider one characteristic at a time (Gietel-Basten et al., 2015; Scherbov & Sanderson, 2016), our approach simultaneously considers multiple dimensions in analysing population ageing. Applying our novel ageing measures clearly highlighted the (relative) importance of population ageing in both Asia and Europe, and the considerable diversity in ageing trends within the continents across regions, sexes, and educational levels. Furthermore, through the use of our novel ageing measures, we could provide a more detailed and more comparable perspective on future population ageing in Asia and Europe.

As well as shedding light on current and future population ageing trends, this new perspective can have important added value for other social science disciplines. The measures derived in the thesis can be applied in future studies in different disciplines like economics, sociology, and political science. For example, both of our measures, the CPOAT and the MOAT, can be used to formulate a new ‘old-age dependency ratio’. Indeed, this ratio could serve as a substitute for the current traditional measure of old-age dependency that is used in many cross-country comparisons of macro-economic models. Such macro-economic models are often used to study savings, expenditures, health care reforms, and fiscal burdens due to ageing. These models can be adjusted to provide a more comprehensive understanding of macro-economic events due to changes in population characteristics.

However, the novel methodology used in the thesis has also several caveats. First, it is important to note that when applying the CPOAT and the MOAT, the results depend on the standard population chosen for the comparison. Choosing a standard population to improve the comparability of estimates is an approach that is not unique to demography. It is, for example, also commonly used in age standardisation (Preston & Guillot, 2000). Therefore, as long as the standard population is carefully selected and clearly communicated, and is taken into account when interpreting the results, the use of a standard population can be considered a powerful tool for comparisons. Second, the multiple dimensions of ageing chosen in the thesis were based on the contexts of the two continents, and on the availability of data. Several other dimensions, such as economic participation, social connectedness, and digital literacy, are important aspects of elderly well-being and quality of life. The absence of comparable data across continents on these dimensions limited the application of the methodology to three dimensions: i.e., remaining life expectancy, activities of daily living, and level of cognition. However, given the context of the study and the availability of data, these variables nonetheless serve as a proxy for different aspects of elderly well-being such as life expectancy and health and human capital. Third, in combining these different dimensions, we did not take any normative position on the relative importance of the different dimensions considered, and we executed the same weights for different dimensions. This may have affected our results. Fourth, as our estimates of future population ageing on the two continents are based on population projections by educational level from the Wittgenstein Centre, the assumptions that underlie these projections also apply to our outcomes. For instance, one of the assumptions of these projections was that it applied a constant and country-invariant educational difference in life expectancy of four years for women and six years for men. Since the results of our methodology moves in line with the differences in life expectancy by levels of education, such assumptions will affect our results in terms of sex and country-level patterns.

6.5 Recommendations for further research

For future research, we recommend that in addition to comparing population ageing trends across countries, sexes, and educational groups, population ageing at other subgroup levels should be examined as well. For example, population ageing could be investigated between ethnic groups, religions, and occupations; and within subgroups, such as between urban and rural areas, provinces, and lower and higher socio-economic groups. Such research would be interesting given that these population subgroups differ substantially from each other with respect to health and human capital (Crimmins et al., 2011; Mackenbach et al., 2015). Moreover, countries and educational groups can be highly diverse (Herd, 2006; Mierau & Turnovsky, 2014). To capture this diversity, decentralised and focused levels of investigation of population ageing should be promoted. The meanings and the concepts of population ageing are also diverse, and differ across groups and subgroups. The multiple ways of looking at population ageing should be promoted, and various complementary measures should be derived in addition to the existing measures. Examining such decentralised levels will enable us to gain a more diversified understanding of population ageing than can be captured by a single global measure of population ageing.

In order to create an even more enhanced multidimensional ageing approach/measure, new dimensions of ageing should be included. In addition to taking into account remaining life expectancy, activities of daily living, and levels of cognition, such a measure could, for example, include economic participation, social connectedness, and digital literacy. Social connectedness among the elderly is of great importance for the well-being of older adults in Asian cultures (Giridhar et al., 2014). Similarly, productivity among the elderly, and opportunities to help them extend their working lives, are important aspects of elderly well-being in Europe (Hammer et al., 2015). Digital literacy among the elderly can provide important pathways to social connectedness and occupational opportunities, and thus represents an important route to the independence, dignity, and well-being of older people (Hasan & Linger, 2016). However, to develop such an enhanced multidimensional ageing approach, larger investments in comparable data on different aspects of the qualities, abilities, and well-being of older adults will be needed. Moreover, in integrating additional dimensions, particular attention should be paid to the relative weights of the different dimensions. This would require a thorough analysis of the interactions between the different dimensions. We also recommend the application of qualitative research to aid in determining the relative importance of the different dimensions based on people's own perspectives regarding well-being.

Furthermore, we recommend additional research into what is really driving the diversity of population ageing trends. As we discussed above, the observed diversity in population ageing points to the importance of culture in ageing. Qualitative research can help shed more light on the cultural factors that are driving the diversity in ageing trends. We also recommend that future studies focus on the relative importance of different socio-economic variables in determining the diversity of population ageing trends. The thesis used 'number of years of education' as a proxy for socio-economic status. However, the question of whether indicators of socio-economic status other than education, such as income, mainly determine the diversity in ageing has yet to be resolved. For instance, financial constraints due to the absence of income and employment are the main barriers to seeking adequate health care in many developing countries of Asia, whereas in non-Eastern European countries, education might be more important than income in terms of health behaviour and health care use (Leopold, 2018; van Weel et al., 2016). While the number of years of formal education reflects the broader socio-economic strata of the population, future research on the relative importance of different socio-economic variables can give us insights into the particular variables that should be invested in to postpone population ageing in different contexts.

6.6 Implications for society and recommendations for policy-makers

The results of this PhD thesis demonstrated, first, that population ageing is an important feature in both Europe and Asia, with smaller current and future differences between the two continents being found than were previously estimated. Second, the PhD research revealed that there is much more diversity in the population ageing trends across countries, sexes and socio-economic groups than was previously estimated. These results imply that population ageing is clearly a worldwide phenomenon, but that some groups are more affected than others. Given the important economic and societal consequences of population ageing, including the need for increased health care expenditures, retirement and pension reforms, and shifts in living arrangements, these findings have important implications.

On the other hand, the results of the PhD thesis also imply that 'old age' can be postponed to higher ages with appropriate policy interventions in health and human capital, especially when these interventions include both a short-term and a long-term perspective by focusing not only on the old, but on the young. Moreover, these interventions are likely to be more successful when they are targeted to specific groups at increased risk (less educated people, women in

Asia), and when they carefully take into account the specific context, including the differential consequences of population ageing.

Investments in education: Our findings indicate that investments in education will play an important role in future population ageing, particularly in Asia. Both short-term and long-term investments in education are therefore warranted.

Investments in education can postpone advent of ‘old age’ to higher ages in both Europe and Asia. The return on such investments is likely to be higher in Asia due to its lower base level of educational infrastructure. Thus, any investments in education in Asia will lead to substantial increases in life expectancy and adult survival.

In Asian countries, long-term investments in the educational infrastructure are needed. Such investments should, for example, be made in the buildings, facilities, and human resources of educational institutions; in electricity and internet connectivity; and in the quantity and quality of teachers.

However, short-term investments in education are also needed. We recommend making targeted investments aimed at improving the education of older adults in vulnerable groups. This can be achieved by diversifying adult literacy programmes (which are designed to help adults who did not receive formal education at younger ages to achieve functional literacy) in these countries. Such initiatives can result in enhanced skill development, cognition, independence, and behavioural responses to common health issues among the elderly.

Focusing on improving the education of young people, and reducing socio-economic inequalities among them, may be expected to provide long-term benefits, because the origins of healthy old age are at younger ages; i.e., health at old age is a reflection of an individual’s cumulative advantages or disadvantages.

In European countries, long-term investments in higher education are needed to close the educational gap at higher levels. These countries generally perform better in basic education. Unlike in Europe, investments in both basic education and higher education are warranted in Asian countries; with a priority on improving basic education.

Improvements in health care systems: Our findings indicate that improvements in health are crucial to postponing ‘old age’ to higher ages, and thus to reducing population ageing and its negative consequences. Special attention should be given to improving the health care systems of most Asian and Eastern European countries. Such investments in health should involve both short-term and long-term investments, and should focus on both the old and the young.

In most Asian countries – especially in the Central and South Asian countries – and in Eastern European countries, we recommend devoting special attention to improving the health care systems for the elderly, which are currently falling short. On the one hand, access to these health services is limited to older adults, but on the other, the health workers in these systems have little training in dealing with complex health issues. An important aspect of the health care systems in Asian countries is that many elderly people in Asia are reliant on informal care (e.g., care provided by family members) in the absence of well-trained health care workers. The quality of informal care is likely to be lower (e.g., less specialised, less trained) than that of formal care. Such gaps in the health care system in Asia are a major reason for the functional limitations and multi-morbidity in the regions (Pati et al., 2015). Adequate training on the specific needs of the of elderly must be provided to health care providers, and, to the extent possible, to family members. Care for the elderly can be encouraged by establishing specialised centres within hospitals that focus on the health and well-being of vulnerable populations (Borbasi et al., 2006).

We also recommend providing universal access to care for the elderly. This is a particularly important issue for Asia. Increases in the number of and the expenditures on social security programmes for the elderly are warranted in most Asian countries. Such programmes should be aimed at financing health care services and reducing the financial burdens of older adults. Paying for health care is a particular challenge for elderly people in Asia in general, and especially for those with lower education (and lower socio-economic backgrounds). For instance, among the elderly in India, around two-thirds live in villages, and have a low socio-economic status (Dey et al., 2012). A substantial share of them also have catastrophic health expenditures (Banks et al., 2017). Increasing financial support through social security programmes would go a long way towards helping the elderly in Asia access health care.

Preventive health policies aimed at reducing mortality and morbidity from lifestyle diseases are also needed in Europe and Asia, particularly in Eastern European and in most Asian countries, where they would have the largest effects. Increasing general awareness of the negative effects of lifestyle diseases – particularly those related to alcohol consumption, smoking, and obesity – can minimise their negative impacts on health. For example, warning messages could be included on alcohol and tobacco products (Hammond, 2011). Health policies aimed at reducing the consumption of alcohol, tobacco, and fast food through price regulations, such as a fat tax, could be effective (Tiffin & Arnoult, 2011). These countries could learn from the policies designed to encourage lifestyle changes in the leading countries in other parts of Europe and Eastern Asia.

Investments in health and human capital at younger ages are called for to ensure healthy ageing. The quality of health and educational systems across countries ultimately affects their populations' health and human capital achievements at adult and older ages. Health care workers and educational professionals should be trained to impart sustainable health and educational habits in their dealings with younger people. While such a life course approach should be developed in the health and educational systems across Europe and Asia, priority needs to be given to vulnerable groups, including the lower educated and women, especially in Asian and Eastern European countries.

Overall, in terms of health care system reforms, we specifically recommend (i) making improvements in overall health care systems to adequately cater for the old; (ii) ensuring universal access to elderly care; and (iii) making investments in prevention, with a focus on the young.

Focus on vulnerable groups: Our results revealed that levels of population ageing are particularly high in certain vulnerable groups who are at higher risk. Such vulnerable populations include the lower educated on both continents and women in the developing countries of Asia.

Investments in the health and human capital of the lower educated would go a long way towards postponing the point at which they reach 'old age' to higher ages. Such a focus on the lowest educated would (i) improve their overall standard of living, and, consequently, their life expectancy, survival rates, and human capital; and (ii) equip them with the ability to adapt their behavioural responses to various diseases and health issues, and, consequently, to reduce their mortality and morbidity levels. More information on the need to focus on the lower educated has been provided in the previous paragraphs.

In addition to focusing on the low-educated, as we indicated in the previous paragraphs, we recommend focusing on women in Asia. Our results also suggest that while investments in health and human capital are warranted to increase the onset of 'old age' for both genders, such investments are likely to be especially effective when directed at women in Asia, as they will go a long way towards reducing population ageing and its negative societal consequences in Asia in general, and among Asian women in particular. Among older women in Asia, their lack of autonomy in decision-making reduces their access to and utilisation of health care. Poor education is a proxy for socio-economic backwardness, which further limits Asian women's access to and utilisation of health care (Jadhav, 2014).

Furthermore, policy actions are needed that are based on subgroup-specific measures of population ageing, rather than one single international measure across countries. Such approaches can enable countries to better pinpoint those at need, and to devise more meaningful and effective policy measures.

Context-Specific Investments in the Consequences of Living Longer: Investments in the health and human capital of populations should also focus on the consequences of living longer. These consequences are likely to differ between Europe and Asia. The extension of working life and reforms in the pension system are consequences of living longer that need to be prioritised in the European context (Hammer et al., 2015). Changes in family structures and informal care-giving among the elderly are primary needs that should be prioritised as consequences of living longer in the Asian context (Giridhar et al., 2014).

Learning from experiences: More generally, to develop effective policy actions, learning from the experiences of the most advanced continent, country, or subgroup of the population might be an efficient way forward. Moreover, along the same lines, learning from the better performing groups within those populations that are at high risk – or, conversely, learning from the experiences of lower performing groups within those populations that are lower risk – could increase our insights into which strategies are effective, and which are not.

All in all, with appropriate attention from policy-makers, academia, and the society at large, population ageing in Europe and Asia could truly present an opportunity, rather than a problem.

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English Summary

Population ageing in Europe and Asia: Beyond traditional perspectives

Population ageing is the central demographic phenomenon of the century, and it is unprecedented in human history. As populations age, concerns about the effects this demographic change will have on society and on the economy are also growing. While Europe has the highest share of elderly population, Asia is following suit and has the largest absolute number of elderly people.

The prevailing understanding of population ageing is based on a traditional perspective that relies on fixed old-age thresholds, such as age 65. Moreover, traditional ageing measures are not ideal for making cross-country comparisons, and do not take into account the multiple dimensions of population ageing. Thus, these measures do not provide a holistic view of population ageing. In addition, the diversity of population ageing across countries, men and women, and socio-economic groups has often been ignored in population ageing studies, and particularly in the few existing studies on future population ageing.

The aim of this PhD research was to compare current and future population ageing in Europe and Asia using new comparative ageing indicators that take into account differentials in life expectancy, health, and human capital across European and Asian populations.

To do so, the PhD thesis adopted a comprehensive, holistic, and multi-disciplinary approach to study population ageing across Europe and Asia. Drawing on different demographic and health-related datasets, the thesis used several state-of-the-art demographic techniques and novel methodologies to measure ageing based on insights from different disciplines.

Chapter 1 presented the background and the objectives of the dissertation, and described the current literature on current and future population ageing in Europe and Asia.

Chapter 2 assessed population ageing in Europe and Asia in a comparative manner. To this end, the chapter formulated a new measure of population ageing that stipulates a new 'old-age threshold' across countries in Europe and in Asia, which is adjusted for the changes in life expectancy over time, and the cross-country differentials in the exceptionality of reaching old age in different countries. The new threshold age is called the 'comparative prospective old-age threshold' (CPOAT). Life table data retrieved from the Human Mortality Database and the United Nations population division were used in the analysis. The results indicated that in 2012, the old-age threshold was below 65 years in Central Asia, Southern Asia, South-East Asia, and many Eastern European countries. Consequently, the shares of elderly in the population were found to be higher in these regions than the existing estimates indicated. In contrast, the shares of elderly in the population in Western, Northern, and Southern Europe were found to be lower than the shares estimated using existing measures. Although the differences in the population ageing levels in Asia and in Europe were found to be smaller overall, our estimates also revealed that the diversity in ageing both within and across Europe and Asia was greater than the diversity based on previous estimates.

Chapters 3 and 4 were devoted to the assessment of sex and country differences in population ageing in Europe and Asia from a multi-dimensional perspective.

Chapter 3 assessed population ageing in selected countries in Europe and Asia from a multidimensional perspective. A multi-dimensional measure called the 'multi-dimensional old-

age threshold' (MOAT) was formulated, which stipulates an 'old-age threshold' after simultaneously accounting for dimensions of life expectancy, health, and human capital. Based on data from longitudinal surveys across countries, the MOAT estimates for the year 2010-11 for countries in Europe and Asia differed from the existing estimates, primarily because they included health and human capital dimensions. Countries that simultaneously had higher levels of life expectancy, health, and human capital also had higher MOAT values, and, consequently, lower shares of elderly in the population. Western and Northern European countries were in this category. Moreover, the estimates revealed the dimensions in which different countries appear to be lagging or leading. The results illustrated that while a uni-dimensional measure might offer a simple and easily quantifiable measure of population ageing, it may not be able to capture the differential dimensions of population ageing.

Chapter 4 investigated the multidimensional gender gap in health among older adults in India and China. Given that over the past few decades, life expectancy at older ages in India and China rapidly improved among women than among men, it may be concluded that the systemic gender differentials in these countries have become smaller. However, our analysis, which used a multi-dimensional perspective similar to that in Chapter 3, showed that for the year 2010-11, women in these countries had lower MOAT values than their male counterparts. The gender gap in health among older adults, which was obtained from the differences in MOAT values between males and females, was found to be greater in India than in China, and to vary considerably across the provinces in these countries.

Chapter 5 assessed the future population ageing in Europe and Asia, the educational differences therein, and their responsiveness to changes in education. Based on population projections across regions of Europe and Asia by sex and education for the period between 2015 and 2050, the future values of CPOAT, developed in Chapter 2, were obtained. The results showed that population ageing is expected to increase further, predominantly in Asia, which will result in the differences in the population ageing levels between Asia and Europe decreasing. Moreover, in both Europe and Asia, and among both men and women, the estimated future old-age thresholds (CPOAT) are expected to be higher for higher educated people than for less educated people. In alternate future scenarios in which populations hypothetically have higher levels of education, the projected shares of elderly in the population decrease across all regions of Asia and Europe, but more so in Asia.

Finally, in **Chapter 6,** a summary of the results, reflections on the main findings, a discussion the newly applied perspective on ageing, and recommendations for future research and for policymaking are provided.

Overall, the PhD research highlighted that, using the new perspective, the differences in current and projected population ageing levels between Europe and Asia are smaller than were previously estimated. However, greater diversity in population ageing seems to exist across regions, men and women, and educational levels than was previously estimated. More specifically, the results showed that the onset of 'old age' was earlier that was previously estimated; and, consequently, that the shares of elderly in the population were larger in populations with lagging life expectancy, health, and human capital attainments. This pattern was found in most Asian countries, and, in particular, among women in the developing countries of Asia and in Eastern Europe, and among the lower educated in both continents. In the future, population ageing is expected to increase further, especially in Asia, which should result in the differences in the population ageing levels of Asia and Europe becoming smaller. Moreover, in the future, population ageing is expected to be higher among the lower educated, particularly in

Asia, where the responsiveness of future population ageing to increases in education is likely to be high.

The smaller differences in the current and the future population ageing levels between Europe and Asia that were found using this new perspective can be linked to the lower exceptionality of adults in Asia reaching higher ages, which may be attributed Asian populations having lower levels of life expectancy, health, and human capital achievements than their counterparts in Europe. At the same time, the considerable variation in the exceptionality of adults reaching higher ages and levels of health and human capital across regions, men and women, and socio-economic groups within Europe and Asia appears to be responsible for the greater diversity in population ageing found in this study than in previous research. The reduction in the differences in the future shares of elderly in the population between Europe and Asia can be linked to the lags in the demographic transition in Asia relative to Europe, and the expected catch up in Asia. Since the existing educational infrastructure is worse in Asia than in Europe, the responsiveness of future population ageing to increases in education should be greater in Asia than in Europe.

The novel approach to examining population ageing used in this thesis resulted in a more comprehensive perspective on current and future population ageing in Asia and Europe, and on the differences between and within the two continents. For future research, we recommend that in addition to comparing populations across countries, men and women, and educational groups, other population subgroups that differ substantially from each other with respect to health and human capital, be examined as well. Such subgroup differences include those between ethnic groups, between religions, between occupation, between urban and rural and between provinces. Such decentralized levels of understanding of population ageing needs to be promoted to extricate diversity across populations. To create an even more complex multidimensional ageing approach/measure, additional dimensions (such as economic participation, social connectedness, and digital literacy) could be included. When doing so, particular attention should be paid to the weights of and the interactions between the different dimensions. However, conducting such research would require greater investments in comparable data on different aspects of quality of life, abilities, and well-being among older adults.

Our results suggest that investments in health and human capital, especially among vulnerable groups, such as the less educated and women in Asia, are needed to delay the onset of ‘old age’ for these groups, and to reduce population ageing and its negative societal consequences. In particular, long-term investments in education could help to limit future population ageing. Furthermore, policy actions should be based on subgroup-specific measures of population ageing, rather than on a single international measure applied across countries. This approach can equip governments to better identify those in need, and to devise more meaningful and effective policy measures for helping these individuals.

With appropriate attention from policymakers, academia, and the society at large, population ageing in Europe and Asia could truly represent an opportunity, rather than a problem.

Nederlandse samenvatting

Vergrijzing in Europa en Azië: een nieuwe benadering

Vergrijzing is hét demografische verschijnsel van de eeuw. Nooit eerder in de geschiedenis van de mens verouderde de bevolking zo snel. Met de groeiende vergrijzing stijgt ook de bezorgdheid over de maatschappelijke en economische gevolgen ervan. Het percentage ouderen is het hoogst in Europa, maar Azië volgt deze trend en herbergt het meeste aantal ouderen.

Ons huidige beeld van vergrijzing is vooral gebaseerd op een traditioneel perspectief waarin vaste drempelwaarden voor 'oud zijn', oftewel '*old-age thresholds*', worden gehanteerd, zoals de leeftijd van 65 jaar. Deze traditionele leeftijdsgrenzen zijn echter niet optimaal als we vergelijkingen tussen verschillende landen willen maken. Ook laten ze niet de vele verschillende dimensies van vergrijzing zien. Zodoende krijgen we geen holistisch beeld van vergrijzing. Bovendien worden belangrijke verschillen tussen regio's en landen onderling, tussen mannen en vrouwen, en tussen mensen met een verschillende socio-economische status veelal genegeerd in onderzoeken naar vergrijzing, met name in de weinige onderzoeken naar toekomstige vergrijzing die tot nu toe zijn gedaan.

Dit promotieonderzoek heeft ten doel de huidige en toekomstige vergrijzing in Europa en Azië te vergelijken aan de hand van een aantal nieuwe vergelijkende indicatoren waarin verschillen in levensverwachting, gezondheid en menselijk kapitaal tussen bevolkingsgroepen worden meegewogen.

Dit proefschrift hanteert een brede, holistische, multidisciplinaire benadering om vergrijzing in Europa en Azië te bestuderen. Hiertoe zijn diverse datasets met demografische en gezondheidsgegevens gebruikt. Op deze data zijn een aantal geavanceerde demografische technieken toegepast, alsook de nieuwe indicatoren die we ontwikkelden om vergrijzing te meten op basis van inzichten uit verschillende disciplines.

In **Hoofdstuk 1** worden de achtergrond en doelstellingen van dit proefschrift besproken. Ook wordt in dit hoofdstuk de bestaande literatuur over huidige en toekomstige vergrijzing in Europa en Azië beschreven.

In **Hoofdstuk 2** wordt vergrijzing in Europa en Azië bestudeerd aan de hand van een vergelijkend perspectief . Hiertoe formuleren we in dit hoofdstuk een nieuwe vergelijkende indicator voor vergrijzing, aan de hand van nieuwe *old-age thresholds* waarin rekening wordt gehouden met zowel veranderingen in levensverwachting in de loop der tijd als verschillen in hoe uitzonderlijk het bereiken van een hoge leeftijd in verschillende landen is. Deze nieuwe leeftijdsdrempel noemen we de '*Comparative Prospective Old-age Threshold*' (CPOAT). Aan de hand van overlevingstafels vanuit de *Human Mortality Database* en de Bevolkingsdivisie van de Verenigde Naties hebben we berekend dat de *old-age threshold* in Centraal-, Zuid- en Zuidoost-Azië en in veel Oost-Europese landen in 2012 lager lag dan 65 jaar. Het percentage ouderen ligt in deze regio's dan ook hoger dan de bestaande schattingen aangeven. Het percentage ouderen in West-, Noord- en Zuid-Europa ligt daarentegen lager dan de bestaande cijfers doen denken. Hoewel de verschillen in vergrijzing tussen Azië en Europa over het algemeen zijn teruggelopen, laten onze schattingen ook zien dat er meer diversiteit zit in de vergrijzing tussen regio's en landen binnen Europa en Azië dan voorheen werd aangenomen.

In **Hoofdstuk 3 en 4** kijken we vanuit een multidimensionaal perspectief naar verschillen in vergrijzing tussen mannen en vrouwen en tussen landen onderling binnen Europa en Azië.

In **Hoofdstuk 3** vergelijken we vergrijzing in een aantal landen in Europa en Azië vanuit een multidimensionaal perspectief. We formuleerden hiertoe een multidimensionale drempelwaarde, genaamd '*Multi-dimensional Old-age Threshold*' (MOAT), waarin een *old-age threshold* wordt berekend met inachtneming van de levensverwachting, gezondheid en menselijk kapitaal. Schattingen voor 2010-11 op basis van data uit longitudinale studies in verschillende landen laten zien dat de MOAT in landen in Europa en Azië anders is dan de bestaande cijfers aangeven. Dit verschil komt met name voort uit het meenemen van de dimensies gezondheid en menselijk kapitaal. Landen die beter presteren op het gebied van zowel levensverwachting als gezondheid en menselijk kapitaal, hebben een hogere MOAT en dus een lager percentage ouderen. In deze categorie bevinden zich de West- en Noord-Europese landen. De schattingen tonen bovendien aan op welke dimensies verschillende landen vooroplopen of juist achterblijven. De resultaten van dit onderzoek tonen aan dat, terwijl een ééndimensionale drempelwaarde misschien een simpele, eenvoudig kwantificeerbare indicator van vergrijzing oplevert, deze geen rekening houdt met de vele verschillende dimensies van het ouder worden van een bevolking.

In **Hoofdstuk 4** richten we ons op de multidimensionale *gender gap* op het gebied van gezondheid onder ouderen in India en China. De levensverwachting van oudere vrouwen in India en China is in de afgelopen paar decennia sneller toegenomen dan die van oudere mannen. Daaruit zouden we kunnen concluderen dat de systematische ongelijkheid tussen de seksen in deze landen is verminderd. Onze analyse, waarin we een soortgelijk multidimensionaal perspectief gebruikt hebben als in Hoofdstuk 3, laat echter zien dat vrouwen in deze landen in 2010-11 een lagere MOAT hadden dan mannen. De *gender gap* in gezondheid onder ouderen die blijkt uit het man-vrouwverschil in MOAT is in India groter dan in China. Bovendien zijn in beide landen grote variaties hierin tussen verschillende provincies zichtbaar.

In **Hoofdstuk 5** kijken we naar de toekomstige vergrijzing in Europa en Azië en onderzoeken we in hoeverre dit verschilt naar opleiding en in hoeverre mogelijke veranderingen in opleidingsniveau de vergrijzing kan beïnvloeden. Op basis van bevolkingsprojecties naar geslacht en opleidingsniveau voor de periode 2015-2050 in verschillende regio's in Europa en Azië, hebben we de toekomstige waarden voor de in Hoofdstuk 2 ontwikkelde CPOAT bepaald. Hieruit blijkt dat vooral in Azië de vergrijzing zal toenemen, waardoor de verschillen tussen Azië en Europa kleiner worden. Bovendien liggen de verwachte *old-age thresholds* (CPOAT) in de toekomst in zowel Europa als Azië en onder zowel mannen als vrouwen hoger naarmate mensen meer onderwijs hebben genoten. In hypothetische toekomstscenario's met hoger opgeleide populaties zien we de percentages ouderen overal in Azië en Europa afnemen, maar vooral in Azië.

Ten slotte worden in **Hoofdstuk 6** de onderzoeksresultaten samengevat, wordt gereflecteerd op de belangrijkste bevindingen en op het nieuwe perspectief op vergrijzing. Ook bevat dit hoofdstuk een aantal aanbevelingen voor verder onderzoek en beleid.

De belangrijkste conclusie van dit promotieonderzoek is dat volgens het nieuwe perspectief het verschil in vergrijzing tussen Europa en Azië zowel nu als in de toekomst kleiner is dan tot nu toe werd gedacht. Tussen de verschillende regio's, landen, seksen en opleidingsniveaus blijken echter grotere verschillen in vergrijzing te bestaan dan werd aangenomen. Meer in het bijzonder blijkt onder bevolkingsgroepen met een lagere levensverwachting, een slechtere gezondheid en minder menselijk kapitaal de ‘ouderdom’ eerder toe te slaan en dus de mate van vergrijzing hoger te zijn. Dit geldt voor de meeste landen in Azië, en met name voor vrouwen in Aziatische ontwikkelingslanden, maar ook voor Oost-Europa en voor lager opgeleide mensen op beide continenten. De verwachting is dat vooral in Azië de vergrijzing zal toenemen, waardoor de verschillen tussen Azië en Europa kleiner worden. Bovendien zal naar verwachting ook in de toekomst meer vergrijzing optreden onder het lager opgeleide deel van de bevolking, met name in Azië, waar een stijgend opleidingsniveau veel effect heeft op de mate van vergrijzing.

Het feit dat de verschillen in zowel de huidige als toekomstige vergrijzingscijfers tussen Europa en Azië volgens het nieuwe perspectief kleiner zijn, heeft ermee te maken dat het voor volwassenen in Azië dankzij een lagere levensverwachting, gezondheid en menselijk kapitaal minder uitzonderlijk is om een hoge leeftijd te bereiken. De grote variatie in de waarschijnlijkheid van het bereiken van een hoge leeftijd, de gezondheid en het menselijk kapitaal tussen verschillende regio’s, seksen en socio-economische groepen binnen Europa en Azië, draagt ertoe bij dat de vergrijzing sterker varieert dan eerder bevonden. De afname in de verschillen tussen de geschatte toekomstige vergrijzing in Europa en Azië kan worden gelinkt aan het feit dat de demografische transitie in Azië achterloopt ten opzichte van Europa, maar naar verwachting sneller ontwikkelt. Aangezien de bestaande onderwijsinfrastructuur in Azië minder goed ontwikkeld is, zullen toekomstige vergrijzingscijfers hier sterker reageren op een toename in het onderwijsniveau dan in Europa.

De toegepaste nieuwe benadering op vergrijzing heeft geleid tot een completer beeld van de huidige en toekomstige vergrijzing in Azië en Europa en van verschillen tussen en binnen de twee continenten. Toekomstig onderzoek zou zich idealiter niet alleen moeten richten op de vergelijking van de vergrijzing tussen landen, seksen en opleidingsniveaus, maar ook moeten kijken naar andere subgroepen die significant van elkaar verschillen in termen van gezondheid en menselijk kapitaal, zoals verschillende etnische groepen. Voor een nóg betere, multidimensionale benadering van vergrijzing zouden nog meer dimensies moeten worden meegewogen, bijvoorbeeld economische participatie, sociale verbondenheid en digitale geletterdheid. Hierbij zou bijzondere aandacht moeten worden geschonken aan de weging van en interactie tussen die verschillende dimensies. Voor dergelijk onderzoek zijn echter grotere investeringen nodig voor het verkrijgen van vergelijkbare gegevens over verschillende aspecten van de kwaliteit van leven, capaciteiten en het welzijn van ouderen.

Onze bevindingen suggereren dat door middel van investeringen in gezondheid en menselijk kapitaal, met name onder kwetsbare groepen zoals lager opgeleiden en Aziatische vrouwen, hun leeftijd waarop ze “oud” worden kan worden verhoogd, waardoor de vergrijzing en de bijbehorende negatieve maatschappelijk effecten worden beperkt. Zowel korte- als langetermijninvesteringen in het onderwijs kunnen hieraan, in het bijzonder, bijdragen. Daarnaast moeten beleidsmaatregelen worden gebaseerd op specifiek voor een subgroep geldende vergrijzingsmaten en niet op één enkele internationale maat. Hierdoor kan beleid nauwkeuriger worden gericht op de specifieke doelgroep en kan betekenisvoller, effectiever beleid worden ontworpen.

Met de juiste aandacht van beleidsmakers, de wetenschap en de maatschappij kan vergrijzing in Europa en Azië een kans worden in plaats van een probleem.

Vergrijzing in Europa en Azië: een nieuwe benadering

Vergrijzing is hét demografische verschijnsel in Europa en Azië. De manier waarop vergrijzing traditioneel wordt gemeten, bijvoorbeeld door het meten van ‘oud’ aan de hand van de leeftijd van 65 jaar, is niet optimaal als we vergelijkingen tussen verschillende landen willen maken en beschouwt niet de vele verschillende dimensies van vergrijzing. Bovendien is in eerder onderzoek vaak voorbijgegaan aan verschillen tussen landen, geslacht en socio-economische status.

In dit proefschrift wordt de huidige en toekomstige vergrijzing in Europa en Azië vergeleken aan de hand van een aantal nieuwe vergelijkende indicatoren waarin verschillen in levensverwachting, gezondheid en menselijk kapitaal tussen bevolkingsgroepen worden meegewogen.

Volgens het nieuwe perspectief is het verschil in vergrijzing tussen Europa en Azië zowel nu als in de toekomst kleiner dan tot nu toe werd gedacht. Tussen de verschillende regio’s, landen, seksen en opleidingsniveaus blijken echter grotere verschillen in vergrijzing te bestaan dan werd aangenomen. Het percentage ouderen bleek hoger te liggen in bevolkingen waar de levensverwachting, gezondheid en het menselijk kapitaal achterliepen. Dit betreft vooral de meeste landen in Azië en met name vrouwen in Aziatische ontwikkelingslanden, maar ook Oost-Europa en lager opgeleide mensen op beide continenten. In de toekomst zal de vergrijzing naar verwachting verder stijgen, met name in Azië. Vooral in Azië heeft een stijgend opleidingsniveau veel effect op de mate van vergrijzing.

De bevindingen in dit proefschrift suggereren dat door middel van investeringen in gezondheid en menselijk kapitaal, met name onder kwetsbare groepen zoals lager opgeleiden en Aziatische vrouwen, de leeftijd waarop mensen “oud” worden kan worden verhoogd, waardoor de vergrijzing en de bijbehorende negatieve maatschappelijke effecten worden beperkt.

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Arun Balachandran holds a bachelor’s in Economics from University of Kerala, India and a MSc. in Economics from Madras School of Economics, Chennai, India. He was awarded Prof. K B Pathak Memorial Award for contributions to methodological innovation in Population and Health, by Indian Association for the Study of Population and is a member of the early career task force of the International Union for the Scientific Study of Population. Based on this book, he holds a PhD in demography from the University of Groningen, The Netherlands. He is continuing his research by joining as a post-doc at the University of Maryland, USA.

Population ageing in Europe and Asia: Beyond traditional perspectives

Population ageing is the central demographic concern in Europe and Asia. Traditional perspectives on population ageing are based on fixed old-age thresholds, such as age 65, which are not ideal for cross-country comparisons, as they do not take into account the multiple dimensions of population ageing. Moreover, previous population ageing studies often ignored the diversity of the ageing processes across countries, men and women, and socio-economic groups.

This thesis compared current and future population ageing in Europe and Asia using new comparative ageing indicators that take into account differentials in life expectancy, health, and human capital across European and Asian populations.

This new perspective shows that the differences in the current and the projected population ageing trends in Europe and in Asia are smaller than were previously estimated. However, it appears that this diversity in population ageing trends is more pronounced across regions, men and women, and educational groups than was previously estimated. The share of elderly in the population has been found to be higher in populations with lagging life expectancy, health, and human capital attainments: i.e., in most Asian countries, among women in the developing countries of Asia and in Eastern Europe, and among the lower educated in both continents. In the future, levels of population ageing are expected to increase further, particularly in Asia, where the responsiveness of population ageing to increases in education is likely to be high.

Our results suggest that investments in health and human capital, especially among vulnerable groups, such as the less educated and women in Asia, are needed to delay the onset of ‘old age’ for these groups, and to reduce population ageing and its negative societal consequences.