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Article

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.

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 & MacInnes, 2013). Thanks to various improvements in medical technology, the present older adults are healthier and has less severe functional disabilities than their earlier counterparts (Christensen, Doblhammer, Rau, & Vaupel, 2009). Likewise, there have also been improvements in their intellectual capabilities (Philipov, Goujon, & Di Giulio, 2014; Skirbekk, Loichinger, & 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 & Collard, 2013; Kot, Kurkiewicz, 2004; Ryder, 1975; Skirbekk et aI., 2012). Among these, the prospective age approach by Sanderson and Scherbov

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(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 redefining the old-age threshold using RLE = 15, the approach supplement 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, De Beer, James, Van Wissen, and Janssen (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 & Peeters, 2006; Robine, Saito, & 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, & 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, & Pollard, 2011), among others. These measures tries 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, & 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 & 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 multi-dimensional 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.

2. Data and method

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 & 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 & 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 & Eggleston, 2014; Singh & 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, & Van Nostrand, 1990). Life expectancy need not necessarily reflect an improvement in functional abilities (Crimmins, Kim, & Solé-Auró, 2011; Robine & 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, & 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).

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)(Börsch-Supan, 2018; Börsch-Supan et al., 2013; Malter & 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 1.

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 & 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:

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

Table 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	The Netherlands	France	Hungary	Poland	Spain	Italy	Denmark	Sweden
Sample size	12,198	13,857	2762	5857	3076	1724	3570	3583	2276	1951

Where $\propto_{A,k}$ refers to old-age threshold value of country A using the characteristic 'k' (Sanderson & 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:

2.3.1. 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 & 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 dimensions. 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 is 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:

$$V_{S,T,i} = \frac{V_{minT_k,i} + V_{maxT_k,i}}{2}$$

Where $V_{minT_k,i}$ 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. $V_{maxT_k,i}$ is the minimum value of dimension T_k at age *i* across the countries considered and $V_{maxT_k,i}$ 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.

2.3.2. 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.

2.3.3. 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.

2.3.4. 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:

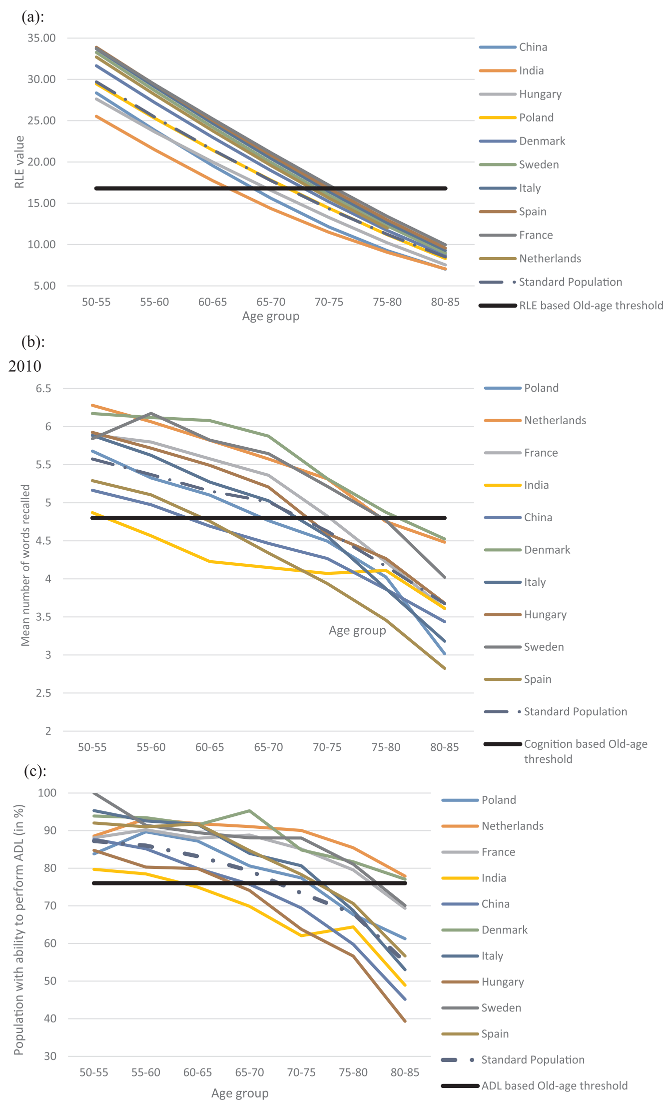

Fig. 1. (a): Remaining life expectancy across different age groups for selected countries, 2010. *Source:* Authors' calculation from UN population database (United Nations, 2010). (b): Age-specific values of mean of number of words recalled in selected countries, 2010. *Source:* Authors' calculation based on SHARE, Wave 4, 2010-11 (Malter & Börsch-Supan, 2013) and WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012). (c): Percentage of population able to perform ADL in different age groups among selected countries, 2010. *Source:* Same as in Figure 2.

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

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. 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 Fig. 1(a-c).

Fig. 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 figures in all age groups. Similarly, it can be observed from Fig. 1(b) that the average mean number of words recalled goes down with age, though the pattern of decrease are 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. Fig. 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.

The figures 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 decreases 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 Fig. 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 is 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.

3.1. 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 2.

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, Govil, Kumar, & Kumar, 2017). Lower levels of education leads to lower cognitive abilities (Mavrodaris, Powell, & Thorogood, 2013).

The divergences in the old-age threshold values in terms of different dimensions can also be observed from 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.

Table 2
Estimates of old-age threshold values for different dimensions and MOAT in selected European and Asian countries, 2010. Source: Authors' calculation from UN population database (United Nations, 2010), SHARE, Wave 4, 2010-11 (Malter & Börsch-Supan, 2013) and WHO-SAGE, Wave 1, 2007-10 (Kowal et al., 2012).

Region (1)	Country (2)	Remaining Life expectancy based old-age threshold (3)	Cognition based old-age threshold (4)	Functional abilities based old-age threshold (5)	Multidimensional old-age threshold (MOAT) (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

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 shows 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.

3.2. Rankings of countries

Table 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.

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 it 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. 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 4.

The estimation shows that Hungary and Italy has 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

Table 3
Relative Ranks of the countries across different dimensions and MOAT, 2010. *Source:* Computed based on Table 2.

Region (1)	Country (2)	Remaining Life expectancy based old-age threshold (3)	Cognition based old-age threshold (4)	Functional abilities based old-age threshold (5)	Multidimensional old-age threshold (MOAT) (6)
Asia	China	9	9	8	9
	India	10	10	10	10
Western Europe	The 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

Table 4
Shares of older persons (in percentage) in total population using different methods of population ageing for selected countries, 2010. *Source:* Computed from UN population database (United Nations Population Division, 2010).

Region	Country	Shares of older persons (in percentage)		
		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	The 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

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, The 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 purposes 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 +.

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 has 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, Scherbov, Weber, & Bordone, 2016; Sanderson & 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.

5. Recommendations

Our observation that the MOAT are 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 I 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 & Saito, 2001; Luy & Minagawa, 2014; Rieker & 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.

Conflict of interest statement

There is no conflict of interest.

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