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Comment

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# Avoiding overestimates of climate risks from population ageing

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Population ageing is expected to lead to significant rises in climate risks because vulnerability rises sharply throughout people's later years. When assessing the vulnerability of older people, however, what's important isn't the number of years someone has lived (i.e. "chronological age") but rather their functional abilities and characteristics; the latter is better captured by remaining life expectancy or "prospective age". Here, we show that assessing growth in the size of older populations using a prospective rather than chronological age perspective can help avoid overestimates of future risks to climate change. Compared to an analysis based on chronological age, the projected increase in the vulnerable population share seen in the prospective age analysis is considerably lower. The differences between the two perspectives increase with age, decrease with country income level, and are larger in futures that give priority to sustainable development. Thus, while ageing certainly poses major challenges to societies facing climate change, these may be smaller than thought. Prospective age offers a relatively easily implemented alternative for projecting future vulnerability that better accounts for rising longevity.

Population ageing poses major challenges to societies across the globe[1]. When combined with climate change, which is already increasing the frequency and intensity of meteorological extremes[2], ageing is expected to contribute to significant rises in population vulnerability[3,4]. Climate change brings health risks across all age groups, particularly children (e.g. via undernutrition and infectious diseases)[5], but older people are amongst the most susceptible due to, for example, compromised thermoregulation, reduced mobility, weaker immune systems, and chronic diseases[6]. Further, vulnerability amongst older people tends to rise sharply throughout people's later years[7–9], and the relative size of older populations is growing[10]. Even so, older people and changing age structures have too often been neglected in climate impact studies; the World Health Organization has called not only for this gap to be urgently filled, but for healthy ageing to become a key pillar of climate resilience plans[6].

In a recent Comment article in this journal, Harrington and Otto brought attention to these issues, noting that when older people are represented in climate impact studies, they are typically identified using a binary definition, with all people aged 65 years and above labeled as "old"[11]. They pointed out that, given contemporary population structures and dynamics, this approach misses important within-group changes amongst the "old": that is, the disproportionate rises in the numbers of "old old". As vulnerability tends to rise continuously with age, failure to account for these structural changes is likely to result in large underestimates of future climate risks.

Harrington and Otto illustrated the potential magnitude of this by showing striking plots of expected future growth of older populations. In the plots, ageing was represented as population growth for a given age group relative to the baseline year 2020, calculated as population in a given year divided the population in 2020 (We use this definition of population growth throughout).

First, using the United Nations' World Population Prospects (UN WPP)[12], countries were grouped by income level ("high", "upper-middle", "lower-middle", and "low", based on the World Bank criteria), and plots of projected population growth out to 2100 were shown for people aged 65 years+, 75 years+, and 85 years+ (see Harrington and Otto, Fig. 1[11]). Population growth in the two older groups dwarfed that in the 65+ group, with the differences increasing as the income level of the country group decreased. The message was clear: to understand and address future climate-related challenges, especially in countries with the least resources, we need a finer-grained representation of people at older ages.

Second, to assess ageing in futures giving more or less priority to sustainable development, plots were shown of global population growth for people aged 85 years+ against people aged 65 years+ under three Shared Socioeconomic Pathways (SSPs) (see Harrington and Otto, Fig. 2[11])[13]. Here, the future giving the highest priority to sustainability (SSP1) showed by far the fastest rises in the oldest part of the population, compared to SSP2 (a "middle of the road" future) and especially SSP3 (which gives low priority to sustainability). That is, trade-offs were evident, with either a larger older - i.e. more vulnerable - population facing lower climate-related challenges, or vice versa.

We agree that these are crucial insights. In this Comment we aim to augment them by highlighting that while using multiple older age groups can help avoid underestimates of future climate risks, basing these groups on fixed "chronological ages" – that is, the number of years someone has lived – may contribute to overestimating risk. For instance, in any given cohort, population average mortality risk from heat stress rises with chronological age, but across-cohorts population average risk tends to be declining over time at any given age[8,14–16]. Harrington and Otto allude to such trends that generally accompany rising life expectancies[11]. Here, we illustrate an approach to assessing future ageing that better accounts for population-level changes in longevity by adopting "prospective age", a concept developed in a series of ground-breaking contributions by the demographers Warren Sanderson and Sergei Scherbov[17–21].

At core, prospective age asks us to reconsider how we conceptualize age itself. When assessing the implications of population ageing, what matters most is not years already lived (i.e. chronological age) but rather older people's functional abilities and characteristics; for instance, their health, disabilities, and cognitive abilities[6,19,22]. In the case of climate change-related risks, older people are not vulnerable *qua* having lived for many years; the loss of ability typically associated with ageing is only loosely related to a person's chronological age[22]. Instead, rising prosperity combined with medical and public health advances (along with other changes) has resulted in a delay of ageing-associated deterioration to ever older ages (rather than a slowing of the rate of deterioration)[23]. Given this postponement, ageing is more strongly correlated with remaining life expectancy; i.e. life expectancy conditional on having reached a given chronological age[22]. Thus, prospective age is measured using remaining life expectancy, which is readily available as a column in standard life tables.

When assessing future vulnerability and risk from climate change, there is no fixed relation between chronological and prospective age. As societies progress and longevity rises[24], chronologically older populations become prospectively "younger" (i.e. remaining life expectancy increases at any given chronological age). This implies - all else being equal – likely declining vulnerability to climate-related impacts in older populations at any given chronological age. This is confirmed by studies of heat stress[8,14,15], and similar vulnerability patterns are likely in situations where mobility matters such as disasters[25]. Failure to account for these cohort differences may lead to overestimates of future risk resulting from climate change.

Prospective age can be used to generate equivalents of various standard measures of population ageing, but here we adopt a "prospective old-age threshold" (POAT) approach[21]. The latter defines a group as "old", not when they have reached a specific chronological age (e.g. 65 years), but when they have less than a given number of years left to live; that is, groups are considered old when they are approaching the end of their lives. Following Sanderson and Scherbov[22], we use a remaining life expectancy of 15 years to define the POAT. To do so, we take a standard life table for a given population in a given year and identify the chronological age where the remaining life expectancy is 15 years. This gives the current value of the moving chronological age at the POAT, with the "old" population defined as the total number of people aged at or above this chronological age. We also define the "mid old to old old" and the "old old" populations using remaining life expectancy thresholds of 10 years and 5 years, respectively.

To illustrate the very different impressions of the future generated by a prospective age versus a chronological age perspective, we show similar plots to those produced by Harrington and Otto[11]. Firstly, based on the UN WPP medium projections[10], Fig.1 shows population growth from 2020 to 2100 (relative to the baseline year 2020) for populations chronologically aged 65 years+ (pink solid), 75 years+ (purple solid), and 85 years+ (green solid), grouping countries by income. We interpret the three age groups as representing all "old" people (65 years+), "mid to old old" people (75 years+), and "old old" people (85 years+). In the same plots, we also show population growth for corresponding groups defined using POATs; i.e. people with remaining life expectancies of 15 years or less (pink dashed; representing all "old"), 10 years or less (purple dashed; representing "mid to old old"), and 5 years or less (green dashed; representing "old old") (Conditional life expectancies for single years of age are available from the UN WPP[10]). We show the numbers underlying the plots in the Supplementary Table 1.

In Fig. 1 the difference between the chronological and prospective age perspectives on population ageing is clearly evident. Population growth in each prospective group (dashed lines) is considerably lower than in the corresponding chronological group (solid lines of the same color), with the absolute differences (i.e. gaps between the lines) rising as age increases and as the income level of the country group moves from high to low. For instance, the largest population growth in the chronological groups at 2100 is a 32-fold increase in the "old old" in low income countries (from 0.8 million in 2020); in the corresponding prospective group, growth is still high but only 10-fold. For comparison, in high income countries over the period 1950 to 2020, the population of the "old old" increased 14-fold from a chronological perspective and rose 3-fold from a prospective persective[10]. That is, even from a prospective age perspective, the rate of growth of the oldest part of the population in low income countries is likely to bring major challenges.

Table 1 shows the percent decrease in population growth in the year 2100 when prospective groups are used instead of chronological groups (For instance, if population growth in corresponding chronological and prospective age groups were 20 and 8, then then percent decrease would be (20-8)/20 = 0.6, or 60%). The declines are smallest in high income countries but still range from 20% to 29%. In low income countries, the decreases range from 39% to 68%. From the perspective of future vulnerability to climate impacts, perhaps the most important finding is that the biggest declines are seen for the oldest age groups in the countries with the least resources; for instance, when prospective age groups were used, there was a 76% decline in relative population growth of the "old old" in lower-middle income countries. (As a further illustration, we use an alternative measure of prospective age to conduct an equivalent analysis in the Supplementary Methods).

Secondly, using alternative population projections according to the SSPs[26], we plot the relative growth in the global population (compared to 2020) out to 2100 for "old old" against "old" populations (Fig. 2). The prospective age perspective clearly shows the trade-offs between the size of the vulnerable population (i.e. the number of older people) and the climate challenges they face are much smaller than a chronological age perspective suggests, with by far the biggest difference for the most sustainable future (SSP1). This is the case in terms of both population growth (i.e. in Fig. 2, the squares are much closer together than the circles) and the size of older populations (i.e. in Fig. 2, the squares are much closer to the origin than the circles). For SSP1, adopting prospective age shows that the "old" population grows only slightly faster than in the other two scenarios (x-axis), but that the "old old" fraction grows considerably more rapidly (y-axis), resulting in an end-of-century population 1.5 to 2 times larger than under SSP2 and SSP3 (see the legend in Fig. 2). That is, as pointed out by Harrington and Otto[11], under sustainable development pathways (i.e. SSP1), specific policies are needed to prepare for rapid growth of older populations. Using prospective age emphasizes the need for these to target the "old old", but also shows the size of this population is likely to be considerably smaller than thought.

Our analysis has three major implications for climate change impact studies. Firstly, when considering ageing and changing population structures, adopting a prospective age lens will provide a very different and probably more realistic assessment. As Sanderson and Scherbov have pointed out, "Population ageing will certainly be a source of many challenges in coming decades. But there is no reason to exaggerate those challenges through mismeasurement"[27]. In line with this, our results demonstrate the potential for chronological age-based assessments to vastly overstate likely future risk trajectories.

Secondly, as prospective age is tied to older people's functioning and characteristics, it is expected to be more strongly linked to vulnerability than chronological age. In epidemiological studies, it is standard practice to track

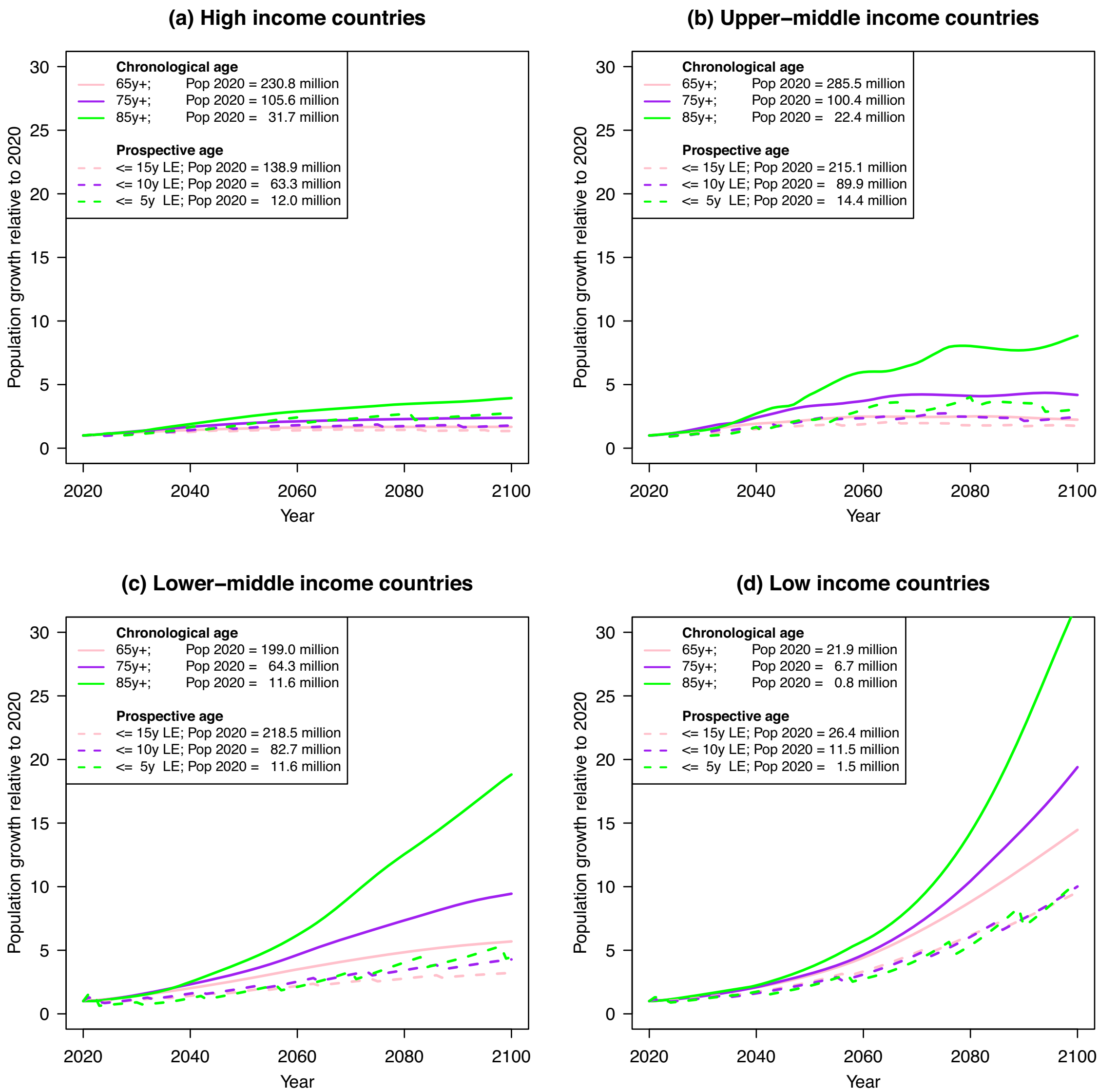


**Fig. 1 | Growth in populations of older people out to the year 2100, for countries grouped by income level.** Each panel shows population growth in chronological (solid lines) and prospective (dashed lines) age groups, relative to the population in 2020. The initial population in 2020 for each group is shown in the legend. Data are taken from the United Nations' 2022 World Population Prospects, medium variant.

risk over time in chronological age groups; but, a prospective age perspective suggests, at least part of any change in risk may be due to such groups becoming "younger"[16]. By utilizing prospective age groups, then, the influence of healthy (or unhealthy) ageing on morbidity and mortality outcomes could be controlled for; the residual change in risk may, for instance, provide an indication of the effectiveness of ongoing targeted adaptation efforts. We suggest this could also be used to advance studies aiming to project future health impacts of climate change; for instance, a study may track risk in people with ≤15 years of remaining life expectancy rather than those aged above 65 years.

Thirdly, a caveat should be borne in mind. As lifespans have lengthened, there has been longstanding debate about whether years lived with morbidity (e.g. non-communicable diseases; NCDs) have been stable, compressing or expanding (in relative or absolute terms)[28–30]. This is not explicitly captured by prospective age. If morbidity were to expand across people's later years, chronologically defined older people may remain highly vulnerable to environmental factors, especially in the context of climate change. Research in this area has been generally limited to countries with high life expectancies, and results are partly dependent on the methods used[29,30], but we briefly consider two relevant lines of investigation: one utilizing prospective age; the other assessing countries across the globe.

Specific to prospective age, Sanderson and Scherbov have shown that, at least in Europe, the health of people reaching a POAT of 15 years appears to have been fairly stable or slowly improving over recent years[22]. The latter analyses considered the following proxies for health: 5y-survival rates, physical and mental functional limitations, and self-perceived health. Considering patterns across the globe, a recent analysis employing a method based on "Healthy Lifespan Inequality" found that there appears to have been a compression of morbidity over the last 30 years, except in high life expectancy countries, where morbidity seems to be stable[28]. When the focus

**Table 1 | Percent decrease in population growth at the year 2100 when ageing is measured using prospective compared to chronological age groups[a]**

| | High income | Upper-middle income | Lower-middle income | Low income |
|---|---|---|---|---|
| All "old" people[b] | 20% | 21% | 43% | 39% |
| "Mid and old old" people[c] | 26% | 41% | 55% | 48% |
| "Old old" people[d] | 29% | 65% | 76% | 68% |

[a]Calculations are: [(population growth at 2100 in the chronological group – population growth at 2100 in the prospective group)/(population growth at 2100 in the chronological group] * 100%.
[b]"Old" refers to the 65 years+ chronological and the ≤15 years life expectancy prospective groups.
[c]"Mid and old old" to the 75 years+ chronological and the ≤10 years life expectancy prospective groups.
[d]"Old old" to the 85 years+ chronological and ≤5 years life expectancy prospective groups.

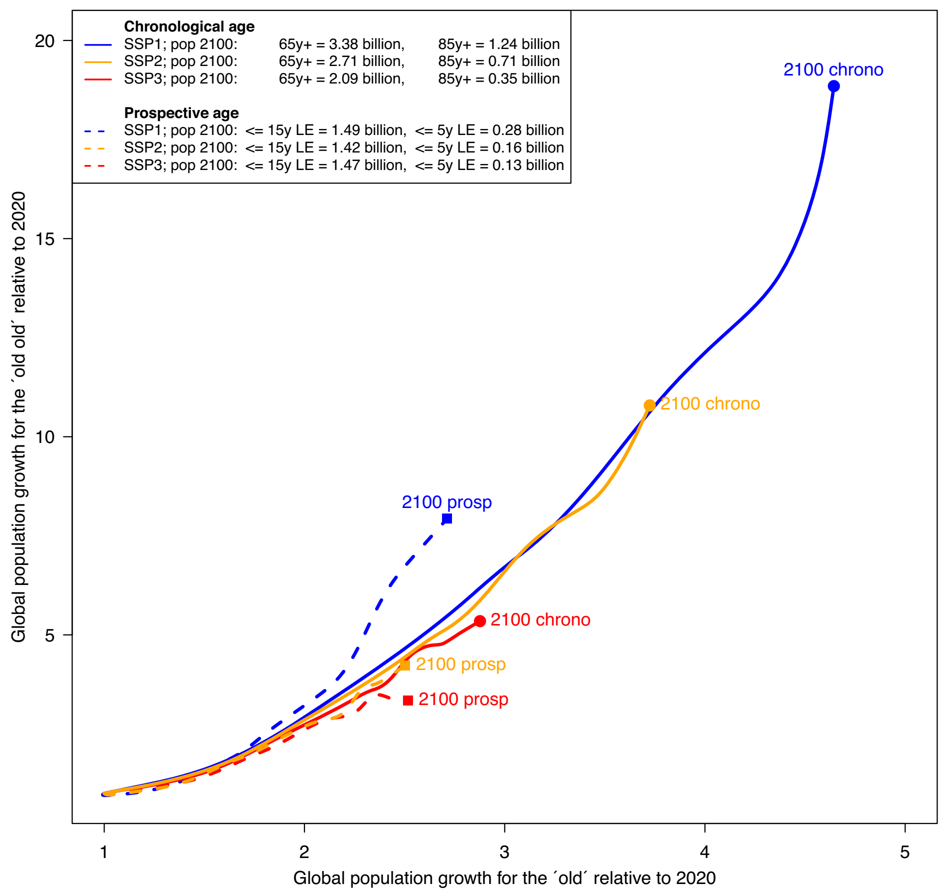


**Fig. 2 | Population growth in the "old" and "old old" in the global population out to the year 2100, under selected SSPs (v3.0).** The x- and y-axes show population growth relative to the year 2020 in the "old" (chronological age: 65 years; prospective age: ≤15 years remaining LE) and "old old" (chronological age: 85 years; prospective age: ≤5 years remaining LE), respectively. Note that the scale on the x- and y-axes differs. The lower left corner shows population in year 2020 (i.e. growth = 1) and the end of each line shows the year 2100. SSPs are indicated by the line color: SSP1 in blue, SSP2 in yellow, SSP3 in red. Chronological age groups are shown as solid lines ending in circles; prospective age groups as dashed lines ending in squares. Populations in 2100 are shown in the legend.

is restricted to people aged 65 years+, however, there appears to have been a slow expansion of morbidity in all countries[28]. The latter is not explicitly picked up by prospective age, and brings an important limitation to light.

Tying things together, prospective age provides an easily quantifiable advance (or, at the very least, a useful alternative) for understanding the relation between ageing and the risks associated with climate change. Given the possibility of – and indeed, some evidence suggesting[28] – the expansion of morbidity, any optimism arising from prospective age-based analyses should be interpreted with this in mind, though. The larger point is that ageing is a complex, multidimensional phenomenon, and studying it requires more than tallying people by chronological age[22]. Prospective age captures more of the underlying complexity than chronological age; but, neither perspective captures the full picture. Recognizing this, Sanderson and Scherbov also developed the more general "characteristics approach" to ageing, which is able to incorporate a diverse range of measures of health into a quantitative measure of age[19,22]. The latter, however, requires more data inputs; as these are unavailable in many settings, prospective age remains a useful, simple, and viable measure.

As was the case in Harrington and Otto's paper[11], our analysis tries to draw attention to the importance of better understanding and representing how general social change will strongly shape the level and distribution of future climate risks. For older people, this will influence not just their health and functioning, but also the social conditions within which they live: addressing vulnerability means considering both the physical and social aspects of ageing[31]. Arguably, a large proportion of climate impact studies have handled climate-impact drivers much more rigorously than socially-determined vulnerability[32]. This may have the knock-on effect of over-emphasizing techno-managerial solutions while (inadvertently) downplaying risk reduction via fundamental social change[33]. Our analysis underscores the possible benefits of such changes; but they are not inevitable: prospective ages may improve less than expected, and morbidity may expand in future cohorts. Thus, actions that underpin healthy ageing throughout the life course are an essential part of addressing climate change[6,34]. Prospective age, although not without limitations, offers a relatively easy way to account for the potential benefits of social change when projecting future vulnerability to climate change.

## Data availability

The United Nations population estimates and projections used in this study, which include population totals and remaining life expectancies in single years of age by country income groups, are freely available from The United Nations Department of Social and Economic Affairs (https://population.un.org/wpp/). The SSP 3.0 data are available from the SSP Scenario Explorer hosted by International Institute for Applied Systems Analysis (IIASA) (https://data.ece.iiasa.ac.at/ssp/#/login?redirect=%2Fworkspaces), and via https://zenodo.org/records/10618931.

## Code availability

Code used for the UN WPP analysis is available on request from SJL. Code used for the SSP analysis is available on request from SKC.

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## Author contributions

S.J.L. and E.S. conceptualized the use of prospective age in climate impacts studies; S.J.L. designed the research, carried out the formal analysis, and wrote the original draft; S.KC. provided the SSP data and generated the time series for chronological and prospective age groups; all authors contributed to review and editing of the final manuscript.

## Competing interests

The authors declare no competing interests.

## Additional information

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