



Combining remaining life expectancy and time to death as a measure of old-age dependency related to health care needs

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Abstract

Public concern about the rising number of older dependent citizens is still based mainly on standard population aging indicators. This includes the old-age dependency ratio (OADR), which divides the state pension age population by the working age population. However, the OADR counts neither the dependent elderly nor those who provide for them. This paper builds on previous research to propose several alternative indicators, including the health care (HC) need-adjusted real elderly dependency ratio and the HC need-adjusted dependent population-to-tax rate. These indicators consider improvements in old-age survival and time to death in order to better define the health care needs of the dependent old-age population and to better approximate their financial burden. We define the old-age population dependent on health care as those above the age at which remaining life expectancy is 15 years or less and are expected to die within 5 years. We use data from the US to illustrate differences between the proposed new and standard measures. Results show that, as a share of the total population, the old-age population dependent on health care has virtually not changed since 1950. Moreover, increases in GDP and state tax revenue have outstripped population aging almost continuously since 1970, irrespective of the indicator used, and they are expected to continue to do so during the coming decade. The demand for health care services is therefore not being fueled by population aging but instead by other factors such as progress in medical knowledge and technology, costs of hospitalization, and the increasing use of long-term care facilities.

Keywords Ageing · Time to death · Measures of population aging · Economic measures of ageing · Health care · Life expectancy · United States

JEL Classification I15 · J11 · J14

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Background

Identifying past, current, and future levels of population aging greatly depends on how they are measured. There is, however, still no consensus on which indicators are best to use, and it is therefore not clear as to how aged a society really is. This is partly because the different driving forces behind population aging (i.e., a decline in fertility, mortality, and net migration loss) affect specific ages more than others. If, for instance, a population aging indicator considers the whole population in its calculations, as is the case with the proportion of the population aged 65 and older (Prop 65+), changing fertility levels will have a more immediate effect on the level of population aging. If, on the other hand, the non-adult population is excluded from the dependency ratio, as is done with the old-age dependency ratio (OADR), declining fertility rates will affect the ratio only when the smaller birth cohorts reach working age (Spijker, 2015).

The OADR is perhaps the most frequently used indicator of population aging. Specifically, the OADR is the ratio of the number of those who have reached the state pension age (usually taken as 65) to the number of working age adults (usually taken as 16–64) and is considered a measure of the dependent elderly population relative to those who financially support them. In the US, the OADR increased from 13 elderly per 100 working-age persons in 1950 to 25 in 2018, and it may reach 37 per 100 by 2050. This level of population aging has worried policy makers because there are now more older dependent citizens for every worker paying tax and social security, which is leading to greater demands on social insurance as well as on health and welfare systems while the prevalence of morbidity and disability is also increasing (Doyle et al., 2009; Polder et al., 2002; Sanderson & Scherbov, 2010; Wolf & Amirkhanyan, 2010). However, the OADR is not fit for purpose, to use a quality assurance term, as it counts neither the dependent elderly nor those who provide for them. It merely takes a cut-off point for defining tax-paying adults (age 16 usually being the lower bound because it marks the end of compulsory school attendance and age 64 being the upper bound because, until recently, 65 has been the statutory pension age), and it assigns adults accordingly to either of the ratio's two sides. Neither cutoff is even remotely adequate for capturing today's "average" reality in most countries, as many young adults continue their education until their (early) twenties, while it ignores the fact that 65-year-olds in 2018 could expect to live an average of 6 more years than in 1950 (20 vs. 14 years; www.mortality.org). In other words, OADR and similar measures exaggerate the extent, speed, and impact of population aging due to the fact that they are based solely on fixed chronological ages and consider everyone of working age to be employed. This can be misleading, because they implicitly assume that there will be no progress in important factors such as remaining life expectancies, disability rates, changes in labor force participation, economic growth, or taxation (Spijker, 2015; Lutz et al., 2008b; Sanderson & Scherbov, 2010). Moreover, for the same reasons, standard measures of population aging fail to capture country differences in dependency rates.

In consequence, alternative indicators have been developed to address the above-mentioned changes. Sanderson and Scherbov (2007) devised the so-called prospective age approach, in which the old-age threshold is based on the age at which the expected remaining life expectancy (RLE) equals 15 years (henceforth abbreviated as RLE15). (Balachandran et al., 2019) further adjusted this measure to account for cross-country differences in the exceptionality of reaching RLE15 by considering the adult survival ratio in a benchmark country (Japan) when calculating the share of elderly; while Spijker and MacInnes (2013) argued that the population who pays for elderly health and wellbeing should be

considered as only those in paid employment rather than everyone of working age (however defined). Rather than using life expectancy or RLE, researchers have also formulated population aging indicators in terms of disability (Sanderson & Scherbov, 2010), active life expectancy (Manton et al., 2006), and health status (Muszyńska & Rau, 2012). However, such measures rely on health data, which is satisfactory when analyzing one moment in time or a short period, but it is less so for longer trends and projections. This is because comparisons over time are complicated by a lack of long time series data, modifications in health concepts, and changes in the perception of health and disability among the population due to technological innovation and cultural changes. The alternative indicators proposed in the present study are insensitive to these issues, as they are based only on deaths. In order to quantify the elderly population who most likely has health care (HC) needs, our indicators combine the RLE's population average measurement with a time to death (TTD) of < 5 years at any age above the RLE15 threshold. The proposed indicators also use denominators that are sensitive to economic fluctuations, as the public policy perspective argues that it is important to consider both sides of the old-age dependency ratio when estimating future state government HC costs.

The next section proposes different adjustments to the definition of old age and of the population who supports them. These adjustments then lead to alternative aging indicators to measure the (financial) burden of old age dependency at the population level. Using these alternative old-age dependency indicators, the Results section compares US population aging levels and includes projections up to 2050. The article concludes with some implications and applications of this work.

Method

The level of old-age dependency depends on how the old-age and working-age populations are defined. Old-age dependency is usually expressed as a ratio, whereby the elderly population is counted in the numerator. This is then divided by the working-age population (the denominator) and multiplied by 100. However, as detailed below, both populations are based solely on fixed chronological ages. This can be misleading, because they implicitly assume that there will be no progress in important factors such as remaining life expectancies, changes in labor force participation, economic productivity, or government taxation (Spijker and MacInnes, 2013; Spijker, 2015).

Adjusting the numerator

Counting the (dependent) elderly

While fixed age boundaries linked to the statutory pension age are traditionally used to separate the old-age from the working-age population, the main process that currently causes population aging—declining *old-age* mortality—makes age a poor measure of its progress. When lifespans lengthen, any given age becomes a marker that is reached earlier along the life course. In 1950, the mean period life expectancy for women in the US aged 65 was 15 years. Data for 2018 show that this has risen to 21 years (resp. 13 and 18 years for men) (www.mortality.org). We can best capture this changing significance of age by taking into account that the age of a population in a particular year comprises two components: the *years lived* of its members (their ages) and their *years left* (i.e., for the same year and

a given age, the RLE according to the period life table). This is crucial, because many behaviors and attitudes (including those related to health) are more strongly linked to RLE than age (Cocco & Gomes, 2012; Hamermesh, 1985; Post & Hanewald, 2012; Solinge & Henkens, 2010). Using both years lived and years left also helps remind us that populations and individuals are rather different things.

The OADR defines all people above the statutory pension age as dependent, regardless of their economic, social, or medical circumstances. This overlooks the fact that rising RLEs render these elderly younger, healthier, and fitter than their peers in earlier cohorts. We know that at least some forms of disability are being postponed to later ages. Good data on population health by age is available only for the last couple of decades, but RLE data is a robust substitute because it provides a more accurate picture of the extent of aging by taking account of falling old-age mortality. Therefore, following Sanderson and Scherbov (2007, 2010) and others (Lutz et al., 2008a, 2009; Ryder, 1975), the age at which RLE equals 15 years is considered a better alternative threshold of elderly dependency, and the population at and above this age is considered the old-age population (henceforth abbreviated as RLE15–), although this is more precisely estimated when calculated for each sex separately (Spijker and MacInnes, 2013). Dividing RLE15– by the total population, we obtain the proportion of dependent elderly (Prop RLE15–). This indicator can be considered as a life expectancy-adjusted proportion of old-age people in a population. How RLE15 and RLE15– are calculated is explained in detail in Sanderson and Scherbov (2007). When calculating RLE15, we did not consider Balachandran et al.'s (2019) adjustment of adult survival until the old-age threshold, because their time trend observations revealed virtually no difference from Sanderson and Scherbov's method.

Counting the dependent elderly who require health care: using time to death as an approximation

Although considering RLE15– as the elderly dependent population is nevertheless a clear improvement over taking a static age of 65+, it remains a population *average* measurement. It can therefore still be criticized for including many older people who consider themselves healthy, as many persons in the corresponding age group (e.g. 70+) are likely to live another 20 years. Conversely, there are others who are expected to die within one, two, or five years (also known in the literature as their thanatological age, their remaining years of life, or time to death—hereafter TTD). Moreover, the literature clearly shows that TTD is a better indicator for HC expenditure, as most acute HC costs are incurred during the last 5 years of life, with little impact from the actual (chronological) age of the person who is being treated or cared for (Christensen et al., 2009; Miller, 2001; Sanderson & Scherbov, 2010). On the other hand, RLE15– does provide a way to define the general elderly population in an era of ever improving old-age survival. We therefore propose making the numerator a subset of the earlier defined old-age population (RLE15–), namely those who have a TTD of less than 5 years ($TTD < 5$). This is now our HC need-adjusted dependent old-age population. The method for calculating $TTD < 5$ is explained in detail in Riffe and Brouard (2018), but it basically involves decomposing and restructuring a population (for our purposes, only those of RLE15– ages) by remaining years of life (here, < 5 years) using information contained in the life table.

Adjusting the denominator

Counting the working age population

When the OADR is calculated, it is assumed that everyone of working age (often taken as between ages 16 or 20 and 64) actually works. A similar connotation is attached to the denominator used in Sanderson and Scherbov's prospective old age dependency ratio (POADR), i.e., the population aged between 20 and RLE15 (Sanderson & Scherbov, 2007). However, the knowledge economy keeps youngsters in education for longer while many older workers choose or are obliged to retire early. Using an age category to define the working population thus makes little sense. Indeed, if for whatever reason we were to count the non-employed as dependent in 2018, we would find more civilian non-institutionalized dependents of working age (60 million) than non-working elderly (42 million). On the other hand, due to greater gender equality, dual-career families, and migration, the US grew by 43 million female workers (vs. + 34 million male workers) between 1970 and 2018, according to the Current Population Survey (CPS) (www.bls.gov/cps/). Given the economic and labor market fluctuations, it therefore makes more sense that the population in paid employment should be accounted for in the denominator of a dependency ratio. If we do this while also using RLE15— as the numerator, we obtain the real elderly dependency rate (REDR) (Spijker and MacInnes, 2013). From this simple adjustment we can deduce that any increase in labor force participation (LFP) could potentially reduce the per capita costs associated with a growing elderly population while high unemployment would do the opposite. In this context, previous research has shown that—without a higher average LFP—only a minimal effect will be gained from raising the normal pension age in an attempt to reduce an excessive increase in non-working elderly and thus alleviate the economically active population's future burden of supporting them (Scherbov et al., 2014).

Considering economic productivity or tax revenue rather than population stock

Rather than considering the working-age population as the economic productivity-related denominator, another and better way to approximate the financial burden of an old-age population is to use total productivity. The standard measure of the latter is gross domestic product (GDP). It is worth noting that GDP increased faster over the last half century than the number of paid workers, and it is what generates a government's necessary income for funding health and social care. From a government policy perspective, we are not interested in per capita GDP but in the total economic output, irrespective of the number of workers. Hence, government tax revenue is another alternative denominator, given that any government expenditure on the elderly must come from taxes.

Alternative elderly dependency ratios

From the above, we can construct a series of new indicators that serve as alternatives to the proportion aged 65+ and OADR, as well as to Sanderson and Scherbov's Prop RLE15— and POADR. First of all, our real elderly population (RLE15—) can be divided by various economic productivity-related denominators in order to better approximate the

financial burden of an old-age population. When different types of units are compared, as is the case here, ratios are better known as rates:

- If RLE15– is divided by the number of people in paid employment, we obtain the real elderly dependency ratio (REDR) (Spijker and MacInnes, 2013).
- If RLE15– is divided by the economic productivity-related denominator, GDP, we obtain the real elderly to GDP rate (REDR_gdp).
- If RLE15– is divided by the total government tax revenue, we obtain the real elderly to tax rate (RLE15–/tax).

The second group of indicators maintain the same denominators but consider only the elderly RLE15– population who are expected to die within 5 years ($\text{RLE15–}\&\text{TTD}<5$), which we define as our *real* dependent population in terms of HC needs:

- If this HC need-adjusted dependent population is divided by the total population, we obtain the proportion of the elderly population with HC needs ($\text{Prop. RLE15–}\&\text{TTD}<5$).
- If this HC need-adjusted dependent population is divided by the number of people in paid employment, we obtain the HC need-adjusted real elderly dependency ratio (REDR5TTD).
- Likewise, dividing $\text{RLE15–}\&\text{TTD}<5$ by GDP, we obtain the HC need- and GDP-adjusted real elderly dependency rate ($\text{RLE15–}\&\text{5TTD/gdp}$).
- Finally, dividing $\text{RLE15–}\&\text{TTD}<5$ by the government tax revenue, we obtain the HC need- and tax-adjusted real elderly dependency rate ($\text{RLE15–}\&\text{5TTD/tax}$).

The standard and alternative aging indicators are listed in Table 1. US data are used to illustrate their different time trends, but the calculations can be replicated for all OECD countries. Sex-specific population and mortality data come from the Human Mortality Database (www.mortality.org) (until 2018) and projected data from the US Census Bureau (www.census.gov). Employment data come from the CPS (www.bls.gov/cps/) and the GDP (measured in 2018 US\$) from The Conference Board Total Economy Database (www.conference-board.org/data/economydatabase/; adjusted version, April 2019). Tax revenue data were obtained from the OECD website (www.oecd.org).

In the Results section below, we first compare the standard indicator Prop 65+ with Prop RLE15– and Prop $\text{RLE15–}\&\text{5TTD}$, given their common denominator. Subsequently, the OADR is compared with POADR, REDR, and REDR5TTD. The latter two indicators also include an additional employment scenario (REDR emp+ and REDR5TTD emp+), where working-age LFP gradually increases until 2023 and reaches the pre-recession high recorded in 2000; and older workers' LFP increases by one percentage point annually. In the final exercise, the denominator used in REDR and REDR5TTD is replaced by GDP and government tax revenue.

Results

If we define the dependent elderly population as those at ages for which RLE is 15 years or less (RLE15–), the trend we find is very different from that observed for standard measures of aging (Fig. 1). For instance, in the 1950s, Prop. RLE15– was still higher than Prop

Table 1 Standard and alternative elderly dependency ratios and rates

Nr	Name [figure]	Abbreviation	Measured as
<i>Standard elderly dependency indicators</i>			
A	Proportion aged 65 or older	Prop 65+	$\frac{\sum_{i=65+} population_i}{\sum_{i=0+} population_i} * 100$
B	Old age dependency ratio	OADR	$\frac{\sum_{i=65+} population_i}{\sum_{i=20-64} population_i} * 100$
<i>Alternative elderly dependency indicators: overall burden</i>			
SS1	Proportion of dependent elderly	Prop RLE15-	$\frac{\sum_{i=population} RLE15-}{\sum_{i=population} 0+} * 100$
SS2	Prospective OADR	POADR	$\left(\frac{\sum_{i=population} RLE15-}{\sum_{i=population} 20+ + \sum_{i=population} RLE15-} \right) * 100$
SM3	Real elderly dependency ratio	REDR	$\left(\frac{\sum_{i=population} RLE15-}{\sum_{i=paid employment} RLE15-} \right) * 100$
4	Real elderly to GDP rate	RLE15-/gdp ^a	$\left(\frac{\sum_{i=population} RLE15-}{(\sum_{i=GDP} 1,000,000)} \right)$
5	Real elderly to tax rate	RLE15-/tax ^a	$\left(\frac{\sum_{i=population} RLE15-}{(\sum_{i=tax revenue} 1,000,000)} \right)$
<i>Alternative elderly dependency indicators: health care-related burden</i>			
6	Proportion HC need-adjusted dependent elderly ratio	Prop RLE15-&5TTD	$\left(\frac{\sum_{i=population} RLE15- \& TTD < 5}{\sum_{i=population} 0+} \right) * 100$
7	HC need-adjusted REDR	REDR5TTD	$\left(\frac{\sum_{i=population} RLE15- \& TTD < 5}{\sum_{i=paid employment} RLE15-} \right) * 100$
8	HC need-adjusted dependent population to GDP rate	RLE15-&5TTD/gdp ^b	$\left(\frac{\sum_{i=population} RLE15- \& TTD < 5}{(\sum_{i=GDP} 1,000,000)} \right)$
9	HC need-adjusted dependent population to tax rate	RLE15-&5TTD/tax ^b	$\left(\frac{\sum_{i=population} RLE15- \& TTD < 5}{(\sum_{i=tax revenue} 1,000,000)} \right)$

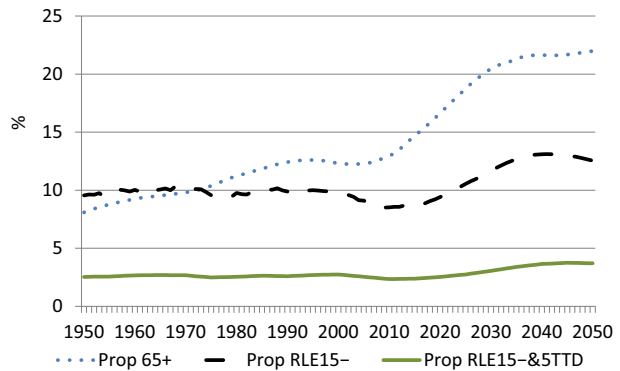
Sources: Indicators SS1 and SS2 were developed by Sanderson and Scherbov (2007); SM3 by Spijker and MacInnes (2013); indicators 4, 5 and 7 in a working paper (Spijker, 2015); while 8 and 9 have only been previously presented by the author at various conferences. Indicator 6 is completely new

For each alternative indicator, the old-age population is estimated for men and women separately, as indicated by subscript *s* in the numerator

^aThis rate can be expressed as the number of older people per US\$1 million in GDP/tax revenue

^bThis rate can be expressed as the number of older people in need of health care per \$1 million in GDP/tax revenue

Fig. 1 Proportion of the total population aged 65+ (Prop65+), in age groups with Remaining Life Expectancy ≤ 15 years (Prop RLE15-) and with both RLE15- and a time to death of < 5 years (Prop RLE15-&5TTD), US 1950–2050. Data sources: see main text. Prop 65+ = Proportion aged 65 or older; Prop RLE15- = Proportion Dependent Elderly. Prop RLE15-&5TTD = Proportion HC need-adjusted Dependent Elderly Ratio



65+. Around 1970, the two lines cross over each other as RLE15 surpasses age 65 due to improvements made in old-age mortality. Interestingly, Prop. RLE15- remained remarkably stable between 1950 and 2000, at around 9–10 elderly per population of 100, which is contrary to the conventional measure. Only after 2020 will there be an increasing relative demand (until ≈ 2038), but the rate of annual increase is also less than if we take the Prop 65+ trend. If we consider only those elderly who are actually expected to die within 5 years (i.e., the acute elderly health needs proxy; Prop. RLE15-&5TTD < 5), the levels after 1950 remain remarkably stable at about 3% of the total population. Only after 2020 will this proportion slowly increase, reaching 4% in 2050. This suggests that it is not population aging that is fueling the demand for health care (HC) services, but rather other factors such as progress in medical knowledge and technology, hospitalization costs, and the increasing use of long-term care facilities.

If we now exclude children and the elderly from the indicators' denominators and compare these alternative elderly dependency ratios and rates with the standard old age dependency ratio (OADR), we obtain quite different results. In the case of the prospective old age dependency ratio (POADR), once the age threshold at which remaining life expectancy equals 15 years (RLE15) is above 65, we observe the following: the ratio becomes higher than the OADR (if age 20 is used as the lower boundary of working age in both indicators) as the size of the numerator decreases and that of the denominator increases (Fig. 2). Indeed, the POADR actually fell by almost one third between 1960 and 2012, when it reached its lowest point at 12 older persons per 100 adults below the old-age threshold, while the conventional OADR was already increasing at that time. Moreover, although the POADR dependency measure is expected to increase for another two decades, it will do so at a much slower rate than the OADR, given that it considers improving life expectancy. When considering only the employed population in the denominator (i.e., the REDR indicator) between 1960 and today, we see that entering employment later and exiting earlier is more than offset by the dramatic rise in female employment: the proportion of the currently employed working-age population is higher in 2017 (70%) than it was in 1960 (62%), although it is still down from its pre-Great Recession peak (74% in 2000). Given its link with economic conditions, the REDR dependency measure experienced a slight increase in the population aging burden during the recent Great Recession, while the POADR—unaffected by economic fluctuations—still declined until 2012.

An increase in both indicators over the next two decades is expected because the increase in the elderly will not be offset by improvements in life expectancy. However, let

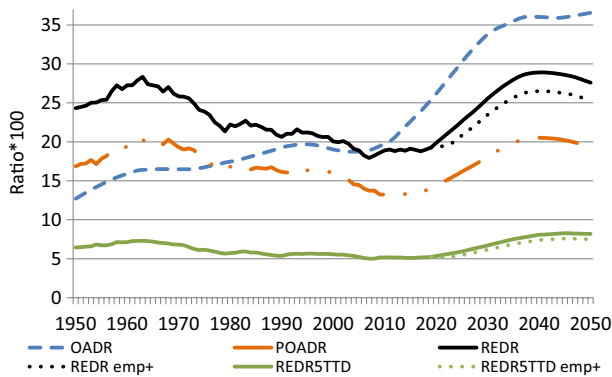


Fig. 2 The old-age dependency ratio (OADR), the prospective old-age dependency ratio (POADR) and the real elderly dependency ratio (REDR) and HC need-adjusted REDR (REDR5TTD), also with an employment scenario, US 1950–2050. Data sources: see main text. OADR=old-age dependency ratio; POADR=prospective OADR; REDR=real elderly dependency ratio; REDR emp+=REDR adjusted for increase in labor force participation; REDR5TTD=health care (HC) need-adjusted REDR; REDR5TTD emp+=REDR adjusted for increase in labor force participation. For specific details, see main text

us consider what would happen if—in order to attain rates similar to the recorded maximum in the year 2000—we were to apply an annual 1% increase in labor force participation (LFP) rates among 16- to 64-year-olds from 2018 to 2023, and then apply the same increase for ages 65–69, 70–74 and 75+ in anticipation of better health and incentives to work beyond retirement age. In that case, the rate of increase would be slower than if the LFP were held constant (compare the trends for REDR and REDRemp+ in Fig. 2). It should be mentioned that this projection is probably a conservative one, as there are no adjustments for possible effects from the Social Security retirement age gradually increasing to 67 years by 2027, disincentives to early retirement, or further progress on gender equality. The last two indicators in the graph, REDR5TTD and REDR5TTDemp+, show that the number of elderly with acute health needs (measured by a TTD of <5 years per 100 paid workers) has been stable since 1980 (between 5 and 6). Only after 2020 are the indicators predicted to rise very slowly, while the standard OADR has already been rising for close to a decade, especially since 2010 (Fig. 1). Adjusting the employment rates in the same way as before has only a minor effect on the expected HC burden.

Due to the tertiarization and automation of the US economy, economic productivity (GDP) and government tax revenues have increased over the last half-century faster than the number of workers, although government tax revenue was hit harder than GDP during the Great Recession (see the larger drop between 2008 and 2009 in Fig. 3). Both of these macroeconomic indicators also increased faster than the dependent elderly population, according to each of three definitions analyzed here (65+, RLE15–, and RLE15–&5TTD). Considering this trend up until 2030, this means that for every additional dollar gained from productivity or taxes in the US, the rise in the elderly—particularly the HC-dependent elderly—will actually be lower.

Not surprisingly, the current trend in the real number of elderly per GDP (RLE15–/gdp) does not look disconcerting either (Fig. 4), as they have experienced a huge decline since the early 1970s. If we project GDP into the future based on a predicted –3.7% in 2020, +3.2% in 2021 (OECD, 2020), and +2.3% thereafter (equivalent to the 2016–2019 average), little change in the rate can be expected (around 1.6 elderly per US\$1 million

Fig. 3 GDP, government tax revenue and the population in paid employment, aged 65+ and in ages above the threshold RLE15– since 1950 (2000 = 100), US 1950–2050. Data sources: see main text. Prop 65+ = proportion aged 65 or older; Prop RLE15– = proportion dependent elderly. Paid employment: Number of persons in paid employment; GDP = gross domestic product in 2017 US dollars; Tax: Government tax revenue

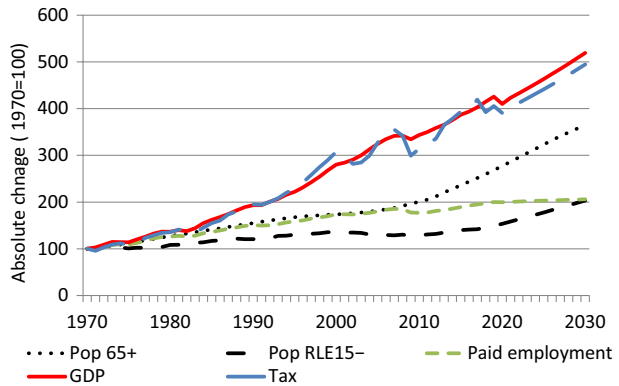
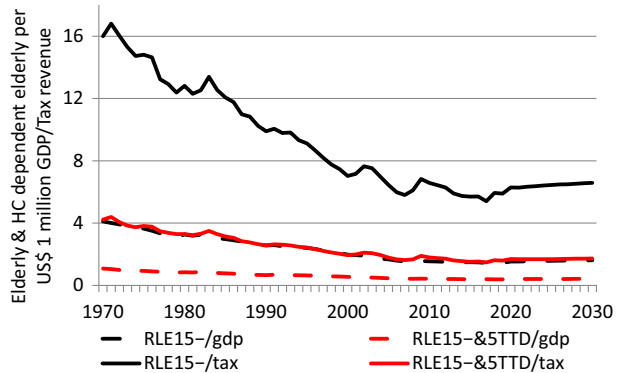


Fig. 4 The real elderly to GDP (RLE15–/gdp) and tax (RLE15–/tax) ratios and the HC need-adjusted dependent population to GDP (RLE15–&5TTD/gdp) and tax (RLE15–&5TTD/tax) rates, US 1950–2050. Data sources: see main text. RLE15–/gdp = real elderly to GDP rate; RLE15–/tax = real elderly to tax rate; RLE15–&5TTD/gdp = HC need-adjusted dependent population to GDP rate; RLE15–&5TTD/tax = HC need-adjusted dependent population to tax rate



in GDP). A similar conclusion can be drawn from the projected trend in the rate of those elderly who are expected to die within 5 years relative to GDP (RLE15–&5TTD/gdp), which hovers around 0.4 HC-dependent elderly per every 1 million equivalized US dollars produced by the economy. If we consider only government tax revenue in the denominator, the resulting dependency rates are obviously higher than the corresponding ones for GDP. Although the overall pattern for RLE15–/tax is similar to RLE15–/gdp (it declines until the late 2000s, after which it stabilizes and starts to slowly increase from 2017), several pronounced bumps can be observed. These coincide with the 1973 oil crisis, the early 1980s and early 2000s recessions, the Great Recession from 2008 to 2012, and the current (2020–21) COVID-19-induced recession. During these periods, government expenditures were cut, particularly those on HC, hitting a historic low growth rate in 2008 (Hartman et al., 2010) that likely affected the general elderly population. Economic growth between 2009 and 2017 and associated increases in tax revenue led to a decline in the real elderly to tax rate, from 6.8 to 5.4 elderly per US\$ 1 million tax dollars. Due to the reduction in tax revenue during the Trump administration and the COVID-19 epidemic, this jumped to 6.3 in 2020; and the projected value for 2030 (6.6) suggests a further marginal increase as a result of population aging.

If we now turn to our last indicator, the HC-dependent elderly population to tax rate, a slow *decline* in the elderly HC burden can also be observed between 1971 and 2017

(respectively, from 4.2 to 1.5 HC-dependent elderly per US\$ 1 million tax dollars), which was interrupted intermittently by economic downturns. Between 2017 and 2020, there was again a slight increase (to 1.7), but the rate is predicted to remain the same during the remainder of the decade.

Discussion

The type of population aging indicator used to convey a message or support a policy proposal should depend on the purpose of the exercise (Spijker, 2015). Unfortunately, policy arguments designed to contend with the negative effects of population aging still employ indicators such as the OADR and the proportion of the total population aged 65+—perhaps because of their simplicity. Instead, purely economic or combined demographic- and economic-related indicators should be used to investigate the possible effects of population aging on economic variables such as productivity or the affordability of the public pension system. This category includes the indicators presented here, which adjust the old-age population by taking into account improvements in life expectancy while also adjusting the supply side of the equation by considering either actual productivity or tax revenue.

On the other hand, if one's aim is to study changing elderly long-term health care needs, the older population expected to die within 5 years (RLE15–&5TTD) would be a preferred numerator rather than 65+ or even RLE15–, as many older people remain healthy for many years. However, at the same time, HC costs are concentrated in those last few years of life (Christensen et al., 2009; Miller, 2001; Sanderson & Scherbov, 2010). The health care need-adjusted elderly dependency rates and ratios presented here take into account this quantitatively important feature of health care spending that is ignored in the old-age dependency ratio.

In terms of applicability, although these indicators were calculated only for the US for illustrative purposes, they can be easily replicated for most OECD countries (see the Methods section for data sources). While time-series data exist for all relevant variables for at least the last three decades, any projections would require that age-specific mortality projections be obtained from national statistics offices. Regarding the denominators of labor force participation and tax revenue, researchers will need to produce their own best estimates. On the other hand, the OECD website provides long-term GDP forecasts.

Although the adequacy of the presented indicators will depend on unconsidered factors (i.e., these indicators can still be refined while other alternatives also exist; see also below), they do tell a very different story of population aging than classic measures, a detail that has several important implications for policy.

First and foremost, the OADR is a poor indicator because it gives a false picture of both the level and trend in population aging, as it takes into account neither rising life expectancies nor the fact that a substantial proportion of the working-age population does not contribute to the economic output. This is the basis for the alternatives suggested in this paper. However, one could argue that, from a pension policy point of view, 65+ could still be considered as the old-age dependent population. This is only partially true because of pre-retirement, which, in the case of the US, is possible at age 62 while the full (normal) retirement age is gradually increasing and currently stands at 66 years and 2 months for those born in 1955. In addition, not everyone is eligible for an old-age pension, because one (or one's spouse) must have worked at least 10 years. Therefore, rather than using 65+ (or RLE15– for that matter) to estimate the demographic burden of supporting old-age

pensions, a more appropriate approach would be to take all pensioners as the numerator and divide this by the number of workers. This is equivalent to Bongaarts' pensioner-to-worker ratio (PWR) (Bongaarts, 2004). However, it is also worth bearing in mind that the PWR is merely a demographic indicator that tells nothing about the actual cost of public retirement pensions per worker. At the same time, younger elderly people in particular represent major contributors to both formal and informal volunteering such as caregiving (Spijker and Schneider, 2021) for grandchildren, among others, thereby saving the state billions of dollars in child welfare costs (Silverstein, 2007). Therefore, when it comes to providing time trends and projections for the (so-called) dependent elderly population, RLE15— is more useful than 65+ because it incorporates changes in population health (which is approximated by life expectancy).

Secondly, it is wrong to assume that population aging itself will strain health and social care systems. Although a growing body of evidence has indicated an increasing prevalence of multimorbidity (Wu & Green, 2000), which is shown by further consistent evidence to be associated with a considerable economic burden (Wang et al., 2018), increasing HC costs are also driven by other factors, chiefly progress in medical knowledge and technology, hospitalization costs, and the increasing use of long-term care facilities. As others have suggested, the economic costs of old age dependency have typically been exaggerated, especially in the US (Bongaarts, 2004; Mason et al., 2006). As the results presented here have shown, economic output and even tax revenue since 1970 has increased much faster than the proportion of elderly (even in terms of the standard definition of ages 65+), despite economic downturns producing temporal declines, particularly in tax revenue.

Nevertheless, urgent attention needs to be paid to the changing relationship between morbidity and remaining life expectancy (RLE). While the population that is not in good health could be approximated by counting the number of elderly people who are expected to die within 5 years ($TTD < 5$), the indicators presented here do not explicitly consider health status or (chronic) disability (a review of these indicators is provided in Spijker, 2015). For instance, even though age-specific disability rates among the older population appear to have fallen during the 1990s and 2000s (Christensen et al., 2009; Crimmins, 2004; Parker & Thorslund, 2007; Schoeni et al., 2008), the prevalence of metabolic risk factors (in particular, overweight and obesity) is higher in more recently born generations compared to those 10 years earlier at a similar age (Cámara & Spijker, 2010; Hulsegge et al., 2014). These unfavorable generation shifts are likely to lead not only to more elderly people developing overweight-related diseases like diabetes and cardiovascular disease—and doing so at younger ages—but also to aging-related diseases like osteoarthritis (Hulsegge et al., 2014). Osteoarthritis is also predicted to significantly increase as a consequence of the increasing use of cancer chemo- and radiotherapies, which lead to a rapid accumulation of senescent cells, thus augmenting the risk of cardiovascular and other chronic diseases (Kohanski et al., 2016). For some people, the current COVID-19 pandemic appears to have caused long-term health effects that have significantly impacted their quality of life (Shah et al., 2021). These examples would suggest that the aging process can speed up as well as slow down, with obvious implications for public health policy.

This clearly makes a static age boundary such as 65 a bad indicator of when old age begins, which in turn is why an old-age threshold should be adjusted for improving survival (Sanderson & Scherbov, 2007) if researchers seek to compare population aging over time or between countries. Nevertheless, the numerator could still be criticized for including many older people who consider themselves healthy. Moreover, it remains a population average measurement, as many persons in the corresponding age group may still live another 30 years, while others will die within a few years. Depending on

the purpose of the population aging indicator, the appropriate numerator to use may therefore not always be the population that is at an age where RLE is 15 years or less (RLE15–) (Spijker, 2015). This is especially true in regard to elderly HC needs and expenditure, because many components of adult HC expenditure have been shown to be driven by proximity to death (TTD), not age (Miller, 2001; Post & Hanewald, 2012). As RLE15– does provide a way to define the general elderly population in an era of ever improving old-age survival, one solution is to incorporate $TTD < 5$ in the indicator as a way to approximate acute HC needs. This is also one way to consider the changing relationship between “old” and “age” in light of not only this past century’s steady declines in mortality that have delayed the typical onset of senescence and its associated morbidities (Christensen et al., 2009; Rau et al., 2008; Vaupel, 2010) and thus HC costs, but also a possible opposite scenario for the coming decades.

To get a better insight into the (un)affordability of HC, aging indicators should also carefully consider the use of appropriate denominators, for instance by incorporating macroeconomic or labor statistics, as any government expenditure on elderly health and wellbeing comes from taxes, particularly income tax. One way to increase labor force participation would be to eliminate or reduce the current impediments to longer working lives, including sex and age discrimination and high wages among older workers in relation to productivity (Coile et al., 2016). Health is also a common concern, even though older Americans appear to have the health capacity to substantially extend their working lives. Research based on plotting the relationship between employment and mortality in 1977 compared to 2010 has suggested that the share of older men working at ages 60–64 could be 17–27 percentage points higher than it is today, and at ages 65–69 it is even 31–42 percentage points higher, with similar estimates for women (Coile et al., 2016). As the authors from this study stated, such estimates should not be taken as a reflection of how much older workers “should” work, but their results suggest that older workers are healthy enough to work another couple or so years. This is in line with the results presented here, which altogether support the viability of the proposed old-age threshold, i.e., the age at which remaining life expectancy is 15 years (currently 70 for men and 73 for women), specifically in terms of what would be considered too old for full participation in the labor market. At the same time, previous research has shown that labor force participation rates must increase in order to avoid an excessive increase in the burden on working adults who will support those who are not economically active, as, otherwise, the effects of raising the statutory pension age will be minimal. Older workers therefore need to be incited to remain employed. Among some of the labor force participation policies that are known to facilitate this are: permitting flexible working hours, improving working conditions and wages, and removing financial incentives to pre-retire (see Scherbov et al., 2014) for a review of the literature).

To conclude, although the US population is aging, the country not only has the economic potential to deal with this situation, but the actual level of population aging is much lower than is often perceived, given the improvements in old-age survival over the last half-century. By putting in place the right policies to keep older workers in the labor market longer, this portion of society will also become part of the solution.

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