Demographic Components of Future Potential Old-Age Support Ratios

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We analyzed the effects of momentum of population aging, mortality, fertility, and international migration on dynamics of potential old-age support ratios (POASRs) over the period 2010-2050 in ten countries with advanced population aging. POASRs are expected to be further halved over this period. Momentum of population aging is by far the largest factor contributing to the decline in POASRs, contributing on average 100% to the total decline. Expected improvements in mortality further contribute to decline in POASRs, 14% on average. International net migration generally offsets the effect of mortality improvement with an opposite contribution of -13%. Although, there is a large variation among countries. Changes in fertility found to have virtually no effect on the trends in POASRs. Description of the decomposition method and discussion of available policy options are included as well. The large effect of the momentum of population aging is of a particular importance as it could be interpreted as deferred liabilities of governments for financial support of future retirees.

Introduction

The world population is growing older. By the mid-century, potential old-age support ratios (POASRs)[2] are anticipated to decline in all countries and areas of the world except for a few countries in Africa (United Nations, 2019). The median POASR is expected to decline from 9.5 to 3.5 over the 40-year period from 2010 to 2050. Minimum POASR in 2050, 1.2, is projected to be in Japan, followed by Republic of Korea, Spain, Greece, Italy, with 1.3 reached in all countries by 2050.{{}}

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[1] Disclaimer: The views expressed here do not imply the expression of any opinion on the part of the United Nations Secretariat

[2] We define potential old-age support ratio (POASR) as the ratio of the population aged 20–64, P(20-64), to the population aged 65 years and older, P(65+). The inverse of this ratio is the conventional old-age dependency ratio. These are measures of potential support needs. It is based on the notion of old age as a period of dependency, during which persons tend to rely upon the working-age population for financial support. If a person started working at 20 and retired exactly at 65, this ratio would show how many people of working age would need to support a single retiree. Of course, in the real world the situation is more complex than that but nevertheless this ratio is a good indicator of support needed. This is also one of the measures of population aging.

How much of the expected decline in POASR is a function of the projected changes in fertility, mortality, and net migration? How much of it would occur even if the current vital rates would not change over the projection period? This article attempts to quantify the effects of the major demographic components, fertility, mortality, net migration, and the current demographic conditions, on future decline in POASRs. This decomposition could be useful for understanding the relative weight of key demographic factors that drive population aging and can inform policies and programs aimed at balancing impending demographic changes and social, economic, and health objectives.

Trends in the potential old-age support ratios over the period 2010-2050 and summaries of projections

For analysis we selected ten countries[3] with advanced population aging in 2010[4] from the 2019 Revision of the World Population Prospects (United Nations, 2019). Table 1 provides a summary of estimates and projections. In 2010, the median POASR in this group of countries was 3.65, with the highest value observed in the United States, 4.59, and the lowest in Japan, 2.64.

Projections of POASRs for 2050 are produced by the cohort component method under certain assumptions regarding future trends in fertility, mortality, and international net migration. Population projections prepared by the United Nations are based on a theoretical framework known as demographic transition. Over the course of the demographic transition, populations move from a regime of high fertility and high mortality to a regime of low fertility and low mortality. For the countries that have completed their demographic transitions, mortality is still assumed to be declining but fertility is expected to fluctuate around or below a level of about two children per woman or be gradually recovering to a replacement level over the long run after hitting an all-time low. Short-term migration assumptions are based on recently observed flows of international net migration. Over the long run, net migration flows are assumed to be declining towards zero mostly because of the high level of uncertainty associated with future migration flows. For age schedules of net migration, Rogers-Castro model is commonly used.

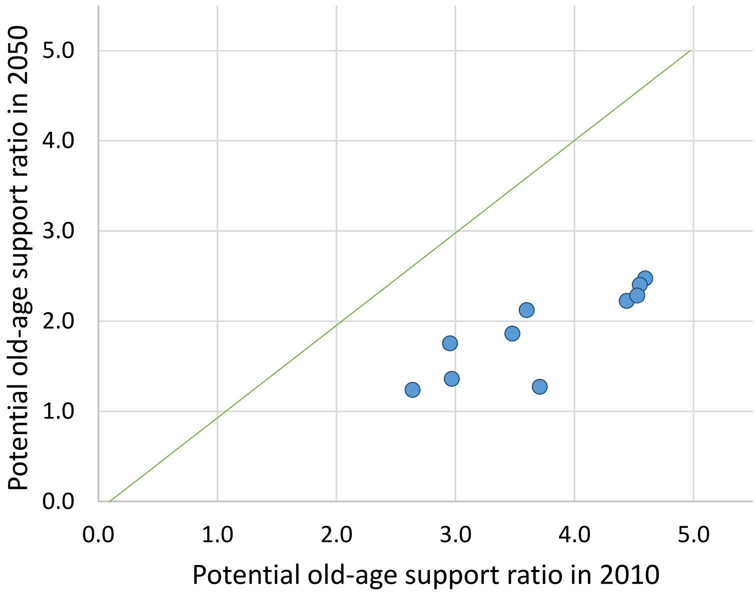
Among ten countries analyzed here, total fertility rate (TFR[5]) is projected to increase for four countries and decline for six with the largest increase in Japan, 0.29 live births per woman, and the largest decline in New Zealand, 0.30 births per woman (Table 1). In none of the countries, fertility is

[3] Australia, Canada, France, Germany, Italy, Japan, New Zealand, Spain, United Kingdom, and the United States of America
[4] The year 2010 was selected because the U.N. estimates and projections were published in 2019. Usually, empirical data on population age structures and demographic indicators are available with a delay of one or two years so the latest empirical data for the 2019 revision were available for the year about 2017. The U.N. estimates are produced for quinquennial periods thus making 2010 the latest decade based on empirical data.
[5] The total fertility rate (TFR) is the average number of live births a woman would have over the course of her lifetime if current age-specific fertility rates remained constant throughout her childbearing years (normally between the ages of 15 and 49 years). The current total fertility rate is an indicator of the level of fertility at a given time.

projected to reach the replacement level[6] by 2050. Death rates are expected to decline by adding on average 4.6 years to life expectancy at birth. The lowest increase in life expectancy at birth is projected for the United States, 4.2 years, and the largest for Germany, 5.4 years. Japan is expected to retain its place as the country with the highest life expectancy at birth: 83.3 years in 2010 and 87.9 years in 2050. Immigration in all countries is expected to outnumber emigration resulting in positive international net migration flows. Annual averages of net migration flows are ranging from one million per annum for the United States to about 13 thousand in New Zealand.

Application of the cohort component method produces projections of population by age and sex, from which POASRs for the year 2050 are derived (Table 1). Potential old-age support ratios are projected to decline in all countries from a median level of 3.65 in 2010 to 1.99 in 2050, a drop of 1.66 or 45% of the initial level (Fig. 1).

Figure 1. Changes in potential old-age support ratios between 2010 and 2050



Countries: Australia, Canada, France, Germany, Italy, Japan, New Zealand, Spain, United Kingdom, and United States of America

Accelerated aging is expected to take place in the group of countries with high support ratios (POASR > 4.5), Australia, Canada, New Zealand, and the United States, traditionally high immigration countries. By 2050, POASRs in this group of countries are expected to drop to levels between 2 and 2.5 catching up with United Kingdom and only shy of that of Germany and France. This development will lead to convergence of levels of support ratios over time (variance in POASRs declines from 0.56 in 2010 to 0.23 in 2050). The support ratio in Japan was already quite low in 2010, about 2.6. By 2050, it is expected to decline even further, to reach 1.2, the lowest of all

[6] Level of fertility needed for a population to replace itself, slightly higher than 2.0 live births per woman. Maintaining fertility at replacement level in the long run leads to a stationary population with zero population growth.

countries. Projection for Spain somewhat stands out: starting with a relatively high level of POASR, 3.7, it exhibits the fastest decline dropping to a level of 1.3 by 2050.

Table 1. Summary of population projections for the period from 2010 to 2050

	Potential Old-Age Support Ratio			Total fertility rate			Life expectancy at birth			Net migration
Country	2010	2050	Change	2010-15	2045-50	Change	2010-15	2045-50	Change	2010-2050
Australia	4.55	2.40	-2.15	1.89	1.72	-0.17	82.4	86.9	4.6	151,917
Canada	4.44	2.22	-2.21	1.60	1.59	-0.01	81.8	86.8	5.0	247,453
France	3.48	1.86	-1.62	1.98	1.83	-0.15	81.9	86.2	4.3	65,283
Germany	2.95	1.76	-1.20	1.43	1.70	0.27	80.5	85.9	5.4	231,004
Italy	2.97	1.36	-1.61	1.42	1.49	0.07	82.4	87.0	4.7	127,229
Japan	2.64	1.24	-1.40	1.41	1.70	0.29	83.3	87.9	4.6	56,133
New Zealand	4.53	2.29	-2.24	2.04	1.74	-0.30	81.3	86.6	5.3	13,432
Spain	3.71	1.27	-2.44	1.33	1.57	0.25	82.5	87.0	4.5	21,591
United Kingdom	3.60	2.12	-1.47	1.87	1.77	-0.09	80.9	85.3	4.4	186,824
United States	4.59	2.48	-2.12	1.88	1.81	-0.07	78.9	83.1	4.2	1,014,546

Methodology and Illustrative Cases

A widely accepted procedure of attribution of changes in potential old-age support ratio, or any indicator of population aging for that matter, to the changes in major demographic components—fertility, mortality, and migration—is yet to be developed. Whether fertility or mortality is the major driver of population aging in contemporary populations is still debated (Caselli and Vallin, 1990; Preston and Stokes, 2012; Lee and Zhou, 2017; Murphy, 2017). In this article, to compute a decomposition of a change in potential old-age support ratio, we build on the methodology of comparative population projections developed and applied for studying changes in population structures by Hermalin (1966), United Nations (1956), United Nations (1988), and Grigsby (1991). By comparing different projections based on different assumptions regarding changes in fertility, mortality and migration, contribution of each demographic factor together with that of the initial demographic conditions on the change in population composition could be assessed.

Potential old-age support ratio in the initial year, 2010, is an attribute of the current age structure. The age structure itself is a product of past demographic processes that have operated over last hundred years or more. Without births, deaths, and migration, the population alive at the moment, will get older by one year simply with the passage of each calendar year. Five years later, the population at ages from 5 and over would have the same size and age structure as the initial population from age 0 and over. With no fertility, P(0-4) will be zero. In other words, age structure will be shifted rightwards by 5 years on the age axis. Five years earlier, POASR will be equal to

P(20-59) / P(60+) of the initial population. Natural tendency for POASR of such population would be approaching zero, as eventually the entire population will be older than 65 years of age.

With the institution of a time-invariant schedule of fertility, and still no mortality or migration, population growth and population composition will depend on the level of fertility. If fertility is *high*, the total population will grow indefinitely and eventually exponentially at an *intrinsic rate of increase, r* (Lotka, 1939; Coale, 1973). The age structure will increasingly resemble that of a negative exponential curve and the age pyramid will converge to a typical smooth cone–shaped pyramid with a very broad base and very rapid narrowing over age. The potential old-age support ratio in this population model will approach a limit defined by *r*. Numerical example of a population model with such parameters is given in the Appendix A.

If fertility is *low* and the resulting intrinsic rate of increase is negative, $r < 0$, annual births will approach zero, population growth will halt, total population size will stabilize, and potential old-age support ratio will decline approaching zero. When the number of annual births becomes negligible, population dynamics will be similar to that of the model with no fertility, no mortality, and zero migration, with age structure simply shifting rightwards on the age scale. The limiting age structure will incorporate births that occurred over the transitional period from the initial year to the year when the number of annual births became negligible (Appendix B).

Mortality reduces size of cohorts surviving both to the ages below and above 65 and therefore could contribute both to decline or increase in POASR depending on the initial population composition and age schedule of death rates. As shown by Lotka (1922), constant age-specific fertility and mortality rates in a population closed to migration will eventually produce a stable population with a constant age structure. Even if fertility is low, below replacement level, and population is declining, the age composition will eventually stabilize[7]. In the case of a stable population, POASR approaches a limit implied by the age structure of the stable population. Stationary population, a special case of stable population, is produced if fertility stays at the replacement level for a long time. In this case, population growth is zero and age structure is defined by the current life table, L_x column (e.g. Preston *et al.*, 2001).

Effect of international net migration on POASR trend depends on the ages of migrants relative to the ages of general population and on the relative volume of in- and out-migration. Similar to the effect of mortality, net migration could contribute both to decline and increase in POASR. The mean age of migrant populations is usually younger than the average age of populations of modern developed countries and substantial inflow of migrants will have a tendency to reduce POASR, at least in the short run until migrants themselves will grow older.

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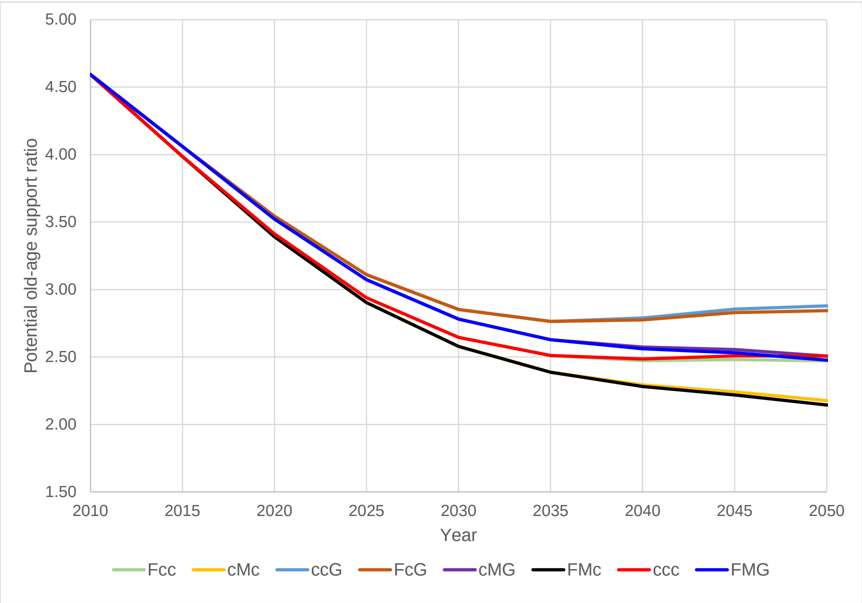
[7] A prevalent syndrome of beliefs is that the population is aging if fertility is low. It is not the case as demonstrated by Lotka. It comes likely from a widely popularized concept of demographic transition where transition from high levels of mortality and fertility to low ones leads to aging of population.

A projection variant starting with the age structure in the year 2010 and with constant schedules of fertility and mortality at the levels prevailing in the initial year, and zero migration, produces a change in POASR even if the vital rates remain unchanged over the projection period. The change in POASR in this case could be attributed to the initial demographic regime. All demographic factors in the initial year, age structure, fertility, and mortality, play a role in the change of POASR. In all countries analyzed here, this projection variant results in decline of POASRs and hence in population aging. It would be appropriate to call the decline in POASR expected under the assumptions of this projection variant as due to the built-in momentum of population aging as the population continues to age without changes in vital rates (Grisby, 1991). For the United States, trajectory of POASR due to momentum of populating aging is shown in Fig. 2, series ccc. The support ratio falls from 4.59 in 2010 to 2.51 in 2050, with most of the decline taking place before 2035. The ultimate level of POASR that could be reached under the current schedules of mortality and fertility is 2.31. This is a level of support ratio in a stable population defined by the current schedules of mortality and fertility, independent of the initial age composition. As evident from Fig. 2, virtually all convergence to the limiting level of POASR, more than 90%, occurs over next 25 years, before 2035.

Figure 2. Comparative Projections for the United States for Computing Decomposition of Change in the Potential Old-Age Support Ratio



Legend: Fcc – varying fertility, constant mortality, zero net migration; cMc – constant fertility, varying mortality, zero net migration; ccG – constant fertility, constant mortality, nonzero net migration; FcG – varying fertility, constant mortality, nonzero net migration; cMG – constant fertility, varying mortality, nonzero net migration; FMc – varying fertility, varying mortality, zero net migration; ccc – constant fertility, constant mortality, zero net migration (momentum of population aging); FMG – varying fertility, varying mortality, nonzero net migration.

The FMG variant (Fig. 2) shows the trajectory of the U.S. potential old-age support ratio under assumptions of changing fertility, mortality, and non-zero net migration. Parameters for the series of future vital rates and net migration flows are taken from the medium variant of the 2019 Revision of the World Population Prospects (United Nations, 2019)[8]. In this projection variant POASR declines by 2.12 from the initial value 4.59 in 2010 to 2.48 in 2050. This variant is the best bet on the future by the United Nations Population Division.

The change in POASR over the projection period 2010-2050 in FMG variant is both due to momentum of population aging and due to *changes* in all demographic components—fertility, mortality, and net migration. Our aim is to construct a decomposition of the decline of 2.12 in POASR by all four factors. Our baseline variant is the momentum of population aging—the variant that produces a trajectory of POASR under the current unchanging demographic conditions (Fig. 2, series ccc). To disentangle effects of fertility, mortality, and migration, we construct six additional projections as follows: 1) Fcc – varying fertility, constant mortality, zero net migration; 2) cMc – constant fertility, varying mortality, zero net migration; 3) ccG – constant fertility, constant mortality, nonzero net migration; 4) FcG – varying fertility, constant mortality, nonzero net migration; 5) cMG – constant fertility, varying mortality, nonzero net migration; and 6) FMc – varying fertility, varying mortality, zero net migration. The set of projections (Fig. 2) produces six possible transition sequences with each of them could be used to advance POASR from its level in 2010 to its level in 2050 of the variant FMG (Table 2). A change in POASR between two projections in a single transition, produces an estimate of a contribution of a single demographic component to the total change. For example, for the transition sequence (1), Table 2, difference between POASR in 2010, 4.59, and POASR in 2050, variant ccc, 2.51, could be attributed to the momentum of population aging. The difference between POASR in 2050 in the variant ccc, 2.51, and the variant Fcc, 2.47, could be attributed to the projected decline in fertility over the period 2010-2050, from TFR=1.88 in 2010-2015 to TFR=1.81 in 2045-2050 or by -0.07, as compared to the constant fertility of the ccc variant (TFR=1.88, Table 1). Fertility is the only component that differs between two projections. Similarly, the difference between POASR, variant FMc, 2.14, and POASR, variant Fcc, 2.47, could be attributed to the changes in mortality over the projection period as the only difference between two variants is that the Fcc variant uses constant mortality schedule of the year 2010 for the entire projection while in the FMc variant death rates are declining according to the built-in assumptions of the FMG variant (in this variant life expectancy at birth is increasing from 78.9 to 83.1, Table 1). Finally, the difference between FMG, 2.48, and FMc, 2.14, could be attributed to the effect of positive net migration. The FMG projection variant assumes a net inflow of about 1 million per annum (Table 1) while in the FMc projection variant net migration is assumed to zero.

[8] This variant could be considered as the best guess at future trends by the United Nations. Instead of the U.N. projections, projections prepared by other institutions and organizations could be used as well.

Table 2. Transition sequences for computing contributions of changes in fertility, mortality, and net international migration to the change in the potential old-age support ratio over the period 2010-2050 with corresponding levels of POASR in 2050 for each of the projection variant. POASR in 2010 is equal to 4.59.

(1)	POASR	(2)	POASR	(3)	POASR	(4)	POASR	(5)	POASR	(6)	POASR
ccc	2.51	ccc	2.51	ccc	2.51	Ccc	2.51	ccc	2.51	ccc	2.51
Fcc	2.47	Fcc	2.47	cMc	2.18	cMc	2.18	ccG	2.88	ccG	2.88
FMc	2.14	FcG	2.84	FMc	2.14	cMG	2.51	FcG	2.84	cMG	2.51
FMG	2.48	FMG	2.48	FMG	2.48	FMG	2.48	FMG	2.48	FMG	2.48

Table 3 shows contributions of all demographic components computed from all six transition sequences from Table 2. The estimate of contribution for each component is not necessarily the same and depends on a transition used to compute a contribution. Contribution of projected mortality improvement, for example, column M, is equal to -0.33 if computed from the transition sequence (1) while it is equal to -0.37 if computed from the transition sequence (2). In the decomposition analysis this phenomenon is commonly referred to as an interaction between components. An interaction term is the amount of change in the output variable that cannot be attributed to either of the components inducing the change of the output variable. If there were no interactions, the contributions for each of the components in Table 3 would have been the same for any of the transition sequences.

A common approach of dealing with interactions is to distribute them evenly between the contributions of components so the sum over all components is equal to unity. This is in line with the standard goal of the decomposition for producing factors that account for 100% of the total change. A caveat with this approach is that if the interaction terms are too large the change in the output variable cannot be attributed to either of the components. In this case decomposition analysis produces no useful insights.

To assess values of the interaction terms three additional rows have been added to Table 3. The row "Minimum" shows the minimum contribution of a factor out of all six transition sequences, The row "Maximum" shows the maximum, and the row "Max-Min" is the difference between maximum and minimum. It follows from Table 3, that the min-max intervals are very narrow and interaction terms are very small. This lends us confidence to proceed with distribution of interactions evenly by computing averages for each of the demographic components (the row "Average"). The last row of Table 3, "Percentage" provides percentages of contributions relative to the total change.

Table 3 conveys several key messages. In 2010, the potential old-age support ratio in the United States, P(20-64) / P(65+), was equal to 4.59. By 2050, POASR is expected to drop to a level of 2.48 under the assumptions of the FMG variant, with all components, fertility, mortality, and migration varying over time. Out of the total decline of -2.12 over the projection period 2010-2050, from 4.59 to 2.48, -2.09 or 99% is due to the momentum of population aging, or aging of the current population under the current demographic conditions, -0.04 or 2% due to assumed decline in fertility,

-0.33 or 16% due to assumed improvements in mortality, and 0.33 or -17% due to anticipated positive net migration flows. An opposite sign of contribution of net migration indicates that net migration increases the support ratio, offsetting the decline caused by three other demographic components. In other words, international net migration in the United States, with a yearly flow of about 1 million people (Table 1), is making the population of the United States younger. As seen from Table 3, the effect of net migration is virtually offsetting the effect of future reductions in death rates—contributions of both components are nearly the same but of an opposite sign, -17% vs 16%.

Table 3. Demographic components of change in potential old-age support ratio from 2010 to 2050, United States

Transition sequence	2010 a)	A	F	M	G	2050 b)	Total change
(1)	4.59	-2.09	-0.04	-0.33	0.33	2.48	-2.12
(2)	4.59	-2.09	-0.04	-0.37	0.37	2.48	-2.12
(3)	4.59	-2.09	-0.03	-0.33	0.33	2.48	-2.12
(4)	4.59	-2.09	-0.03	-0.33	0.33	2.48	-2.12
(5)	4.59	-2.09	-0.04	-0.37	0.37	2.48	-2.12
(6)	4.59	-2.09	-0.03	-0.37	0.37	2.48	-2.12
Average	4.59	-2.09	-0.03	-0.35	0.35	2.48	-2.12
Minimum			-0.04	-0.37	0.33		
Maximum			-0.03	-0.33	0.37		
Max-Min			0.01	0.05	0.04		
Percentage		99%	2%	16%	-17%		100%

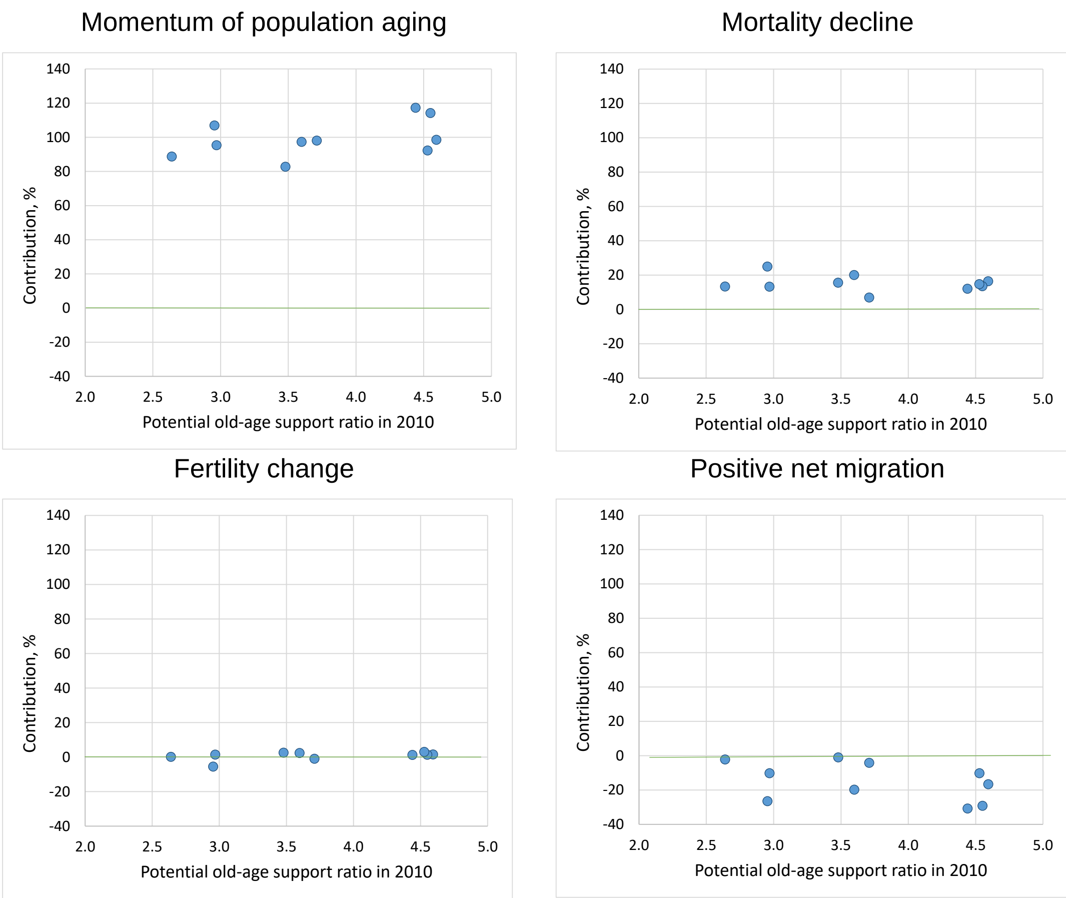
a) POASR level in 2010; b) POASR level in 2050, variant FMG. A – momentum of population aging, F – fertility, M – mortality, G – migration.

Results

Table 4 presents results of application of the method of comparative population projections for all countries. All interaction terms are small indicating that the method produced as a useful decomposition for the components of change in the potential old-age support ratio.

The contribution of the momentum of population aging to the decline in potential old-age support ratio between 2010 and 2050, expressed as a proportion of the total decline, is the largest by a wide margin among all other components (Fig. 3). Its median contribution stands close to 100%, ranging from 83% in France to 114% in Australia and 117% in Canada. The contribution is virtually independent of the initial level of POASR (OLS $R^2 = 0.2$). It stands at 89% in Japan, the country with the lowest POASR in 2010, and 99% in the United States, the country with the largest POASR.

Figure 3. Contributions of demographic components to changes in potential old-age support ratios between 2010 and 2050 for ten countries[3]



Changes in fertility over the period 2010-2050 have a little effect on the potential old-age support ratios. Only cohorts born before the year 2030 will reach 20 years or older in 2050 to have an effect on POASR in that year. Therefore, only projected changes in fertility between 2010 and 2030 will have an impact on POASR in 2050. The median contribution of fertility is nearly zero, -0.03 or 1% of the total decline. The largest negative contribution to the decline in POASR is expected in Germany, where fertility change is expected to increase POASR in 2050 by 0.7 or about -5% driven by the projected increase in total fertility rate from 1.43 in 2010 to 1.7 in 2050 (Table 1). The largest contribution to the decline in POASR is expected in New Zealand, where total fertility rate is projected to decline from nearly replacement level, 2.0, in 2010 to a level of 1.7 in 2050 (Table 1) leading to reductions in POASR in 2050 by -0.7 or about 3%. Overall, regardless of whether fertility stays constant or changes according to the assumptions of the UN projections, the effect of fertility on potential old-age support ratios over next four decades will be negligible.

Population projections for all countries are based on an assumption of further reductions in death rates[9]. On average, all countries are expected to add 4.7 years to their life expectancy at birth

[9] The publication was prepared before the COVID-19 pandemic and does not include any impact of this pandemic on mortality levels and trends.

from 2010 to 2050. There is virtually no correlation between potential life expectancy gains and an initial level of life expectancy at birth in 2010 (Table 1). Due to higher reductions in death rates at older ages, the contribution of mortality decline is significantly higher to the growth of population at ages 65 and older, P(65+), than to the growth of population at ages 20-64, P(20-64), leading to the overall decline in POASR. For the United States, for example, future reductions in death rates are expected to add about 1 million people to P(20-64) by 2050, while 11.2 million people will be added to P(65+). Median contribution of expected mortality improvements to the decline in POASR by 2050 is -0.28 or 14% of the total change. The largest contribution of mortality is expected in the United States, where POASR is expected to drop by -0.35 due to the expected mortality reductions. Relatively to the total change in POASR between 2010 and 2050, the largest contribution is projected in Germany, 25%, followed by United Kingdom, 20% and the lowest contribution, both in absolute and relative terms, is projected to take place in Span, -0.17 or 7% only.

Net international migration in all countries is projected to be positive over the period 2010-2050 (Table 1). Its contribution is offsetting the decline in POASR because of younger age structures of migrants as compared to that of the general population (Fig. 3 and Table 4). Contrary to the effect of mortality decline, international migration in all countries leads to increases in the potential old-age support ratios. In the countries with low volume of in-migration, France, Japan, and Spain, contribution of net migration to increase in POASR is very small, a few percent. On the other hand, in Australia, Canada, and Germany, the effect of migration is quite large, from 25 to 30%.

It was somewhat unexpected to find that for many countries reductions of the potential old-age support ratios due to mortality improvements are virtually perfectly offset by contributions of net international migration (Fig. 4). For the United States, for example, mortality decline will contribute about 16% to the decline of the old-age support ratio, and virtually the same amount, but of an opposite sign, is contributed by the net international migration—this positions the point for the United States perfectly at the diagonal line in Figure 4. Similarly, as delineated by the red ellipse in Fig. 4, nearly perfectly offsetting contributions of the net international migration found in Germany, Italy, New Zealand, Spain, and the United Kingdom. In two countries, Australia and Canada, the effect of migration is much higher than that of mortality decline. Future migration flows expected in these countries are not only offsetting future mortality improvements but also mitigate the effect of momentum of population aging. On the other hand, in Japan and France, the contribution of migration is much smaller than that of mortality. In these countries there is certainly a potential to invite more skilled labor migrants to mitigate effects of population aging. Out of all demographic components, future trends in international migration are the most pliable to policy interventions and hence more uncertain.

Figure 4. Compensating effect of migration on mortality decline

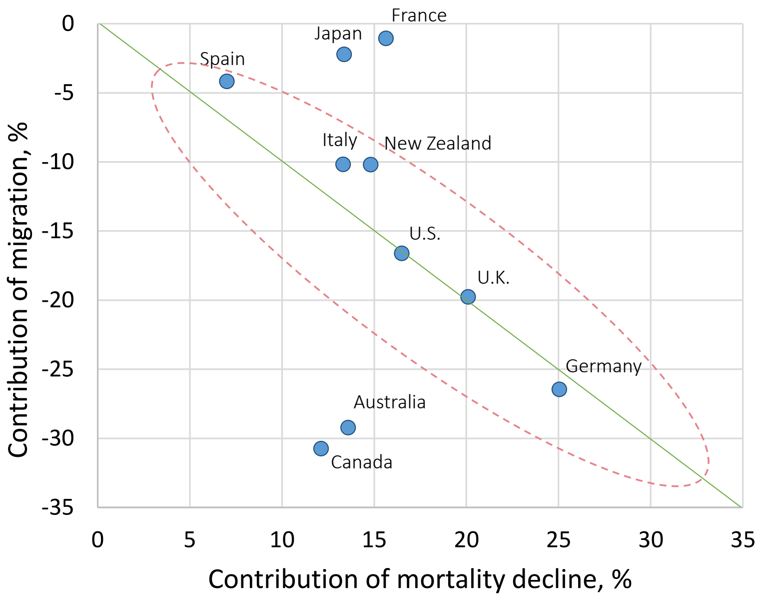


Table 4. Contributions of demographic components to changes in potential old-age support ratios between 2010 and 2050

	2010	A	F	M	G	2050	Total change
Australia	4.55	-2.45	-0.03	-0.29	0.63	2.40	-2.15
(Min, Max)			(-0.03,-0.03)	(-0.33,-0.25)	(0.59,0.66)		
Percent		114%	1%	14%	-29%		100%
Canada	4.44	-2.60	-0.03	-0.27	0.68	2.22	-2.21
(Min, Max)			(-0.03,-0.03)	(-0.31,-0.23)	(0.64,0.72)		
Percent		117%	1%	12%	-31%		100%
France	3.48	-1.34	-0.04	-0.25	0.02	1.86	-1.62
(Min, Max)			(-0.05,-0.04)	(-0.26,-0.25)	(0.01,0.02)		
Percent		83%	3%	16%	-1%		100%
Germany	2.95	-1.28	0.07	-0.30	0.32	1.76	-1.20
(Min, Max)			(0.06,0.07)	(-0.33,-0.27)	(0.29,0.34)		
Percent		107%	-5%	25%	-26%		100%
Italy	2.97	-1.53	-0.02	-0.21	0.16	1.36	-1.61
(Min, Max)			(-0.03,-0.02)	(-0.23,-0.2)	(0.15,0.17)		
Percent		95%	2%	13%	-10%		100%
Japan	2.64	-1.24	0.00	-0.19	0.03	1.24	-1.40
(Min, Max)			(0,0)	(-0.19,-0.19)	(0.03,0.03)		
Percent		89%	0%	13%	-2%		100%
New Zealand	4.53	-2.07	-0.07	-0.33	0.23	2.29	-2.24
(Min, Max)			(-0.08,-0.06)	(-0.35,-0.31)	(0.22,0.24)		
Percent		92%	3%	15%	-10%		100%
Spain	3.71	-2.39	0.02	-0.17	0.10	1.27	-2.44
(Min, Max)			(0.02,0.02)	(-0.18,-0.16)	(0.09,0.11)		
Percent		98%	-1%	7%	-4%		100%
United Kingdom	3.60	-1.43	-0.04	-0.30	0.29	2.12	-1.47
(Min, Max)			(-0.04,-0.03)	(-0.32,-0.28)	(0.27,0.31)		
Percent		97%	2%	20%	-20%		100%
U.S.	4.59	-2.09	-0.03	-0.35	0.35	2.48	-2.12
(Min, Max)			(-0.04,-0.03)	(-0.37,-0.33)	(0.33,0.37)		
Percent		99%	2%	16%	-17%		100%

Column A – contribution of momentum of population aging. Colum F – contribution of fertility. Column M – contribution of mortality. Column G – contribution of migration.

Discussion and Concluding Remarks

Forty percent of the world's countries grew older between 2000 and 2010[10]. This trend is expected to accelerate in the coming decades—by 2050 more than 80% of all countries in the world are projected to be older than today (United Nations, 2019). This development is creating a new demography of older populations and low fertility. The shift in age structures will be putting unprecedented stresses on systems of health care, financial and social support. Policy options commonly discussed to mitigate population aging are raising fertility, increasing skilled labor immigration, or increasing labor force participation of the working age population (WDA Global Longevity Council, 2022; United Nations, 2017). However, numerical metrics of their effects are often lacking.

The main objective of this article is to quantify demographic factors behind the future levels and trends in potential old-age support ratios, one of many indicators of population aging. Conventional demographic transition theory has established that declining mortality and fertility results in population aging, a shift from young age structures to older ones, but it does not provide estimates of contributions of demographic drivers of this change. This issue is addressed here by developing an extended version of the method of comparative cohort component projections[11] which permits quantification of effects of the four demographic drivers of future change in potential old-age support ratio. For example, POASR in the United States, P(20-64) / P(65+), is expected to decline from 4.59 in 2010 to 2.48 in 2050, a decline of 2.09 or 46% of the initial level. The method proposed here decomposes the decline in POASR into contributions of momentum of population aging (99%), changes in fertility (2%), mortality (16%), and net international migration (-17%). Such decomposition could prove useful for better understanding of relative weights of factors of population aging and inform policies aimed at mitigating negative effects of population aging.

Potential old-age support ratios in the ten countries analyzed here are projected to be further halved between 2010 and 2050. Momentum of population aging was found to be the most influential factor contributing to the decline in POASRs. Its median contribution is close to 100% of the total decline. Potential old-age support ratios will drop by 50% by 2050 in all countries simply because the current age structures will get older under the regime of the current vital rates. Contributions of mortality improvement and net international migration are much smaller, 13% and -14%, respectively.

[10] POASR declined by 0.5 or more per decade.

[11] The analysis here is based on the method of comparative population projections (Hermalin 1966; United Nations 1956; United Nations 1988; and Grigsby 1991) that we further extended by incorporating migration and interactions between components. The method is rather general and could be applied to study changes in virtually any indicator of population aging.

Improvements in mortality rates in several countries are nearly perfectly offset on average by an inflow of youthful international immigrants. There is, however, a high variation between countries with regards to the contribution of net migration. For the countries where high volume of in-migration is expected, Australia and Canada, contribution of net migration in absolute terms is higher than that of mortality, -30% vs. 13%. On the other hand, for the countries with low volume of in-migration such as, France, Japan, and Spain, contribution of net migration to increase in POASR is close to zero.

We used the medium variant projection of the United Nations Population Division to derive the decomposition results (United Nations, 2019). These projections are based on the assumptions about the future trends in fertility, mortality and net migration which are uncertain. Consequently, the estimates of the demographic components for fertility, mortality and migration are also uncertain. In contrast, estimates of momentum of population aging do not rely on assumptions about the future and depend only on the current age structure of the population and the current levels of vital rates which are well known. Estimates of decline in POASRs due to momentum of population aging are therefore subject to a little uncertainty. The fact that the momentum of population aging created by demographic changes that have already occurred now accounts virtually for all of the decline in potential old-age support ratios provides incontrovertible evidence of substantial aging in each of ten countries over the next four decades[12]. Quantitative assessments of the demographic factors that drive population aging as measured by potential old-age support ratio should be of interest to policy makers concerned about the adverse effects of population aging for human welfare. Policies could be developed to affect demographic components, but their effects could be limited under the current circumstances.

There are no policies to affect the momentum of population aging as it refers to the current rather future demographic conditions. All cohorts constituting the current age structures have been born and survived to the present, and today's vital rates are well measured. A number of policies put forward by the governments are aimed at extending healthy lifespans and, consequently, reducing healthcare cost and improving quality of life. Among them are promoting active and healthy aging, expanding lifelong learning, preventing abuse of older people. Another set of policies is aimed at increasing personal contributions, and, consequently, reducing contributions of governments to financial assistance during the retirement years. This is accomplished either by extending time in the labor force or by promoting savings for retirement during the working years. These policies include promoting private savings, creating incentives for employers to retain or hire older persons, addressing discrimination against older persons at work, providing incentives for families to care for older persons, raising pension contributions of workers, and raising minimum retirement age.

[12] Now ongoing epidemics of COVID-19 might have a considerable effect on population age structure and on effect associated with the momentum of population aging, but it is subject of further analysis once reliable data becomes available.

Devising schemes for long term institutional care, expanding assisted living and old-age friendly communities, providing affordable housing for older persons is also on agenda of addressing population aging but these options are rather expensive.

Raising mortality, or more precisely old-age mortality, can counter population aging but it is not considered a valid policy option for discussion for obvious reasons. Prevailing expert view is that death rates will continue to fall in future. Unforeseen mortality shocks, for example, due to epidemics such as COVID-19 or military conflicts could reverse trends in death rates, but they are widely viewed as short-term mortality fluctuations rather than long-term trends. The existing policies are aimed at reducing mortality and thus will continue to contribute to population aging.

Raising fertility is frequently discussed in context of lessening population aging. In low fertility countries many governments implemented policies to help women to balance raising children with participation in the labor force. It has been accomplished, for example, with childcare subsidies or tax incentives for families with children with the objective of raising fertility at least to a level closer to the number of children wanted by women, because it is often below it (Thévenon, 2011). On the other hand, as discussed by Westoff (1983), once fertility drops to a very low level, it is very difficult to persuade individuals to have more children. Raising fertility is one of the options recommended by World Demographic & Ageing Forum for Japan (WDA, Global Longevity Council, 2022). As shown here, a considerable increase in fertility for Japan, from TFR = 1.4 in 2010 to TFR = 1.7 in 2050, the largest among all projection assumptions in Table 1, produced a negligible effect on the level of POASR in 2050. Apparently, policies aimed at raising fertility in Japan would not have any sizable effect on population aging over the next five decades or so. Effect of policies aimed at raising fertility could be as problematic in other countries as in Japan.

Immigration can certainly increase the potential old-age support ratio and reduce the mean age of population. There is some evidence that maintaining or increasing levels of international migration is gradually adopted by the countries to expand the size of their labor force and counter population aging. The number of countries with policies to increase rates of immigration was 24 in 2015, up from 11 in 2005. Most of the countries identified aging as "major concern" (United Nations, 2016). Preventing or reversing population aging, on the other hand, would require unprecedented and unsustainable levels of immigration which would result in rapid population growth and an increasingly higher proportion of migrants in the host population. For the United States, for example, to maintain the support ratio at level of 5.21 as in 1995 it would require increasing annual net immigration to 11 million people, a tenfold increase as compared to the current level (United Nations, 2000). Obviously, the policies aimed at increasing immigration have their limitations.

Over next decades trends in potential old-age support ratios will be dominated by momentum of population aging, by aging of existing cohorts under the current demographic conditions. The large effect of the momentum of population aging is of a particular importance as it could be interpreted as deferred liabilities of governments for financial support of future retirees. There are no feasible solutions to reverse this trend but maintaining reasonable levels of immigration and raising fertility to approximately replacement level will help to moderate population aging. Population aging should be viewed as an inherent outcome of human development that took place over the last two centuries rather than an adverse development that should be avoided and reversed. All countries in the world will eventually go through the transition to the aged societies requiring development or major changes in the systems of social security, healthcare, and social support.

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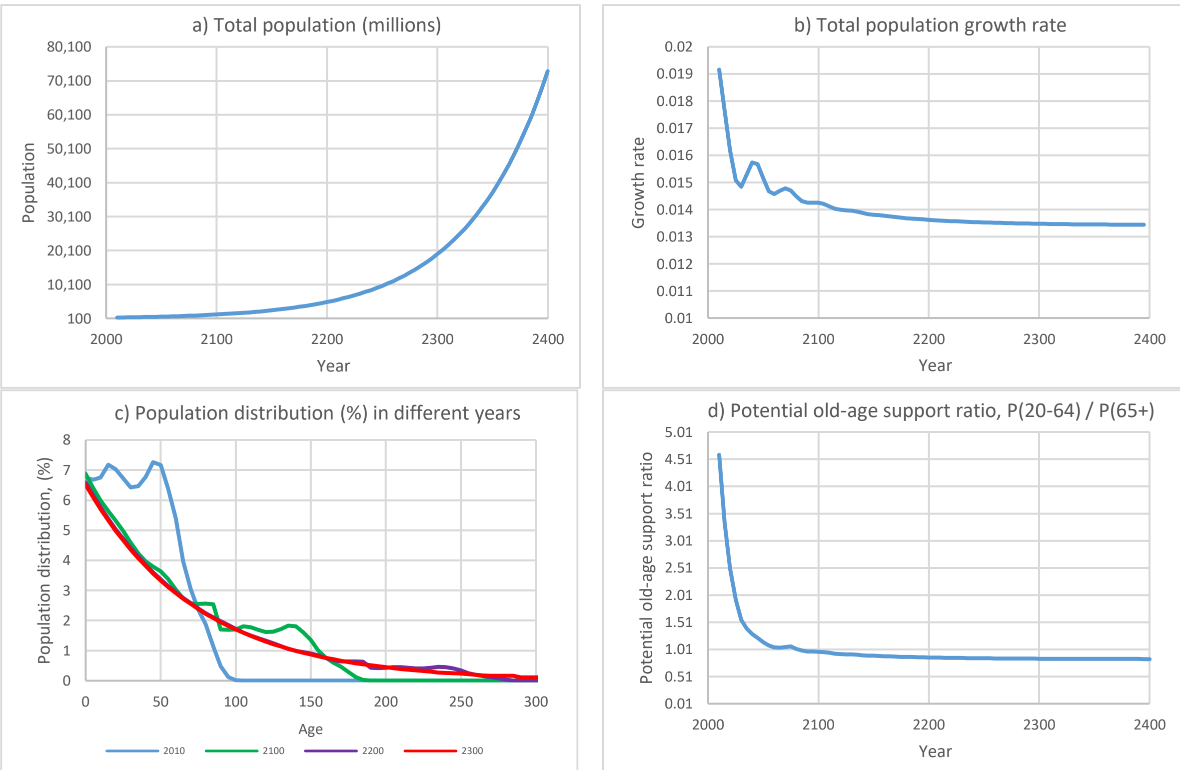
Appendix A

This appendix presents selected indicators of population dynamics of a hypothetical population with *high fertility*, zero mortality, and zero migration. This example is not meant to be representative of the experience of any human population and included here entirely for illustration purposes. The population projection has been computed with a 5x5 cohort component method[13] with initial population in 2010 equal to that of the United States, and with an artificial fertility schedule with total fertility rate set to be equal to 3. In this projection, total population increases from 309 million in the year 2010 to 72,943 million in the year 2400 (Appendix A, Fig.1, panel a). The growth rate of the total population declines from 0.0192 in 2010 to 0.0134 in 2400 converging to Lotka's intrinsic rate of population increase (Appendix A, Fig.1, panel b). Population distribution is converging to an exponent due to shifting of the initial age distribution to the higher ages. Even without mortality, the initial population becomes increasingly insignificant due to the growth of the total population (Appendix A, Fig.1, panel c). Finally, the potential old-age support ratio declines from 4.59 in 2010 to 0.83 in 2400 approaching a limit as well defined by the limiting population distribution (Appendix A, Fig.1, panel d)[14].

Figure 1. Selected indicators of population dynamics in a hypothetical population with high fertility, zero mortality and no migration.



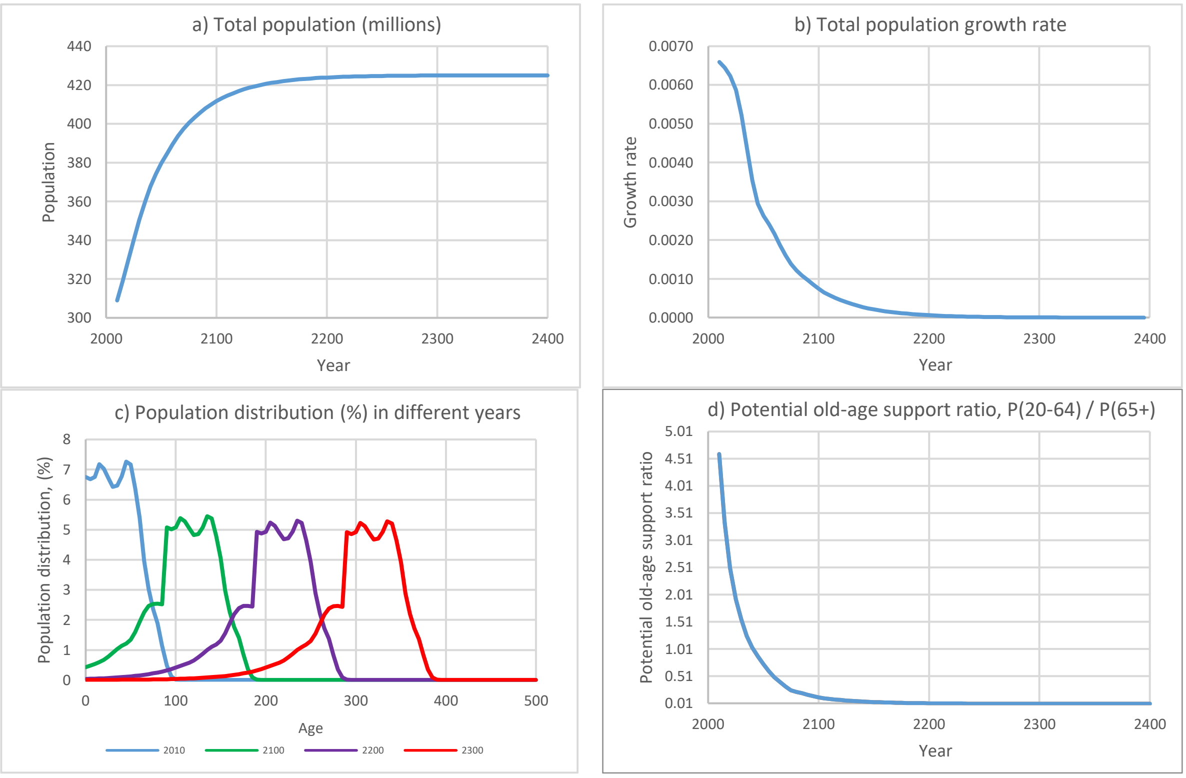
[13] 5x5 stays for 5-year age groups and for 5-year periods

[14] An Excel spreadsheet with animation of selected parameters of population projection is available from the authors.

Appendix B

This appendix presents selected indicators of population dynamics of a hypothetical population with zero mortality and migration but with *low nonzero fertility*. The population projection was computed in a similar way as in Appendix A but with the total fertility rate was set to be equal to 1, significantly below the replacement level. In this projection, total population increases from 309 million in 2010 to 425 million in 2400 (Appendix B, Fig.1, panel a). Once population size stabilizes, the growth rate drops to zero (Appendix A, Fig.1, panel b). Population distribution is shifting on the right on age scale with passage of time, and with an exponential emerging at younger ages (Appendix A, Fig.1, panel c). POASR declines to zero as eventually all population is getting older than 65 years of age (Appendix A, Fig.1, panel d)[14].

Figure 1. Selected indicators of population dynamics in a hypothetical population with low fertility, zero mortality and migration.



Appendix C

The R code for reproducibility of the results in this article is available at https://github.com/kirillfandreev/dcmppoasr5 .

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