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Demography and Income in the 21st Century: A Long-Run Perspective

Abstract

Population forecasts indicate that the world is facing massive demographic changes during the 21st century. This does not only involve the development of the total global population, but (more importantly) will also affect the population and age distribution across countries in a fundamental way. In this paper we focus on the income consequences of these changes for the global income distribution. Key in this respect are changes in the so-called demographic dividend associated with the share of the working-age population in the total population. We link the predicted long-run changes of the demographic dividend to income projections. Our findings are as follows. First, show that historically the impact of demography on economic growth indicates that a one per cent higher demographic dividend results in about 0.22 percentage points higher growth rate. Second, we use UN population projections on population size and the associated age-distribution to predict income changes for the remainder of this century. Third, we illustrate how the *center of income gravity* shifts from advanced economies, like Europe and North America, towards developing and emerging economies, like South Asia and Africa. This potentially has consequences for the current global economic powers, that will see their influence on world affairs decline.

JEL-Codes: F430, J110.

Keywords: demography, income.

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1. Introduction

The world population started its rapid growth in the 19th century, reached a growth peak in the middle of the 20th century and is expected to stabilize in the 21st century. The world population reached 1 billion people in 1804, 2 billion in 1930, and 8 billion in 2023. The United Nations (UN) expects the 10 billion mark to be reached in 2058 and the maximum of 10.4 billion in the 2080s.[2] These numbers illustrate the substantial demographic transitions that took place during last two centuries. The regional- and country-level variation in the timing of this demographic transition is, however, larger than the total population numbers indicate, even after the total population stops growing in this century. The age distribution across nations in combination with rising life expectancies will continue to change.

As we document in the next section, the world is aging. This will affect the productive part of the population (the working-age population). The world's share of working-age population peaked around 2010. The UN expects that this share will start to decline significantly from 2028 onwards. The general trend, however, disguises important regional differences. Fertility rates are well below 2.1 – which is the fertility rate necessary for a stable population – in Russia, Thailand, Japan, Brazil, China, and most European countries. It is above 2.1 in sub-Saharan Africa, some Asian countries, and India. The fertility rate in the US is close to, but below 2.1.[3]

These demographic developments will result in major shifts in the distribution of the world population across countries. In general, the share of the world population will shift away from advanced economies in the direction of developing and emerging economies. An important consequence of this shift is that the age distribution across countries will also change. In aging countries, the dependency ratios increase, whereas in fertile countries the dependency ratios decrease. The macro-economic consequences of changing age distributions are important; it will affect savings and investment decisions, pension and health systems, and growth in general (Bloom, 2011; Bloom and Finlay, 2009; Bloom and Williamson, 1998). Countries will need to adapt to these changes. Governments in aging economies could, for example, invest in technology or export upgrading to compensate for age-related labor productivity reductions of aging populations (Cai and Stoyanov, 2016; Gu and Stoyanov, 2019; Wu et al., 2021; see Goodhart and Pradhan, 2020, for a survey). Furthermore, consumption patterns change over the life cycle of individuals. In aging societies, the demand for non-tradable services that are related to ageing could increase at the expense of traded commodities (Lee et al., 2008; Fernandez-Villaverde and Krueger, 2007).

Our aim is to describe global shifts in the geographical distribution of income that are related to global shifts in the demographic dividend associated with the share of working-age population in the total population. We do not make predictions of the responses of economies following demographic changes. This would involve detailed knowledge of the saving and investment responses of economies regarding aging, detailed knowledge of changing consumption and investment patterns over the life cycle, and how these responses affect

[2] UN World Population Prospect 2022.
[3] Summary demographic data are readily available. See, e.g.: https://data.oecd.org/pop/population.htm.

productivity. This is beyond the scope of this article. We have a more modest approach and try to describe possible geographical shifts of global income caused by demographic dynamics.

We analyze the relationship between income and the demographic dividend between 1990 and 2020 and find that a one per cent higher demographic dividend results in about a 0.22 percentage points higher growth rate. This allows us to predict and illustrate how the global *center of income gravity* will shift during this century subject to demographic changes. Our main finding is that this center of income gravity will shift away quite dramatically from the established industrial powerhouses to developing and emerging markets.

The setup of the paper is as follows. In section 2 we discuss and illustrate global trends in the demographic dividend. The UN expects a global decline in the share of working-age population, but regional developments differ markedly. In section 3 we relate the demographic trends to economic growth by using income and population data for 194 countries between 1990 and 2020. Section 4 uses the results to introduce a Base scenario for income projections for the remainder of this century, taking demographic trends into consideration. As responses to population dynamics are not clear-cut, we also evaluate seven possible alternative growth scenarios relative to the Base scenario. In section 5 we focus on the evolution of income at the country level. Section 6 discusses our findings and concludes.

2. Demographic Dividend

Studies on demographic transitions have a long history. At the beginning of the 20th century, empirical observations for birth and death rates made by the (American) Warren Thompson (1887-1973) and Adolphe Landry (1874-1956) of France resulted in four (sometimes five) demographic stages in society; from near equality of birth and death rates at high levels to near equality of birth and death rates at low levels (see, e.g., Coale, 1989). Associated with the transition processes are adjustments in the age structure of the population over time; initially with an increase in the share of young people, followed by an increase in the share of working-age population (coinciding with a decline of young people and a rise of older people), and finally with a rise in the share of older people.

The dynamics of a changing age structure creates the opportunity of a so-called *demographic dividend*, which is defined by the United Nations Population Fund (UNFPA) as[4]:

> "the economic growth potential that can result from shifts in a population's age structure, mainly when the share of the working-age population (15 to 64) is larger than the non-working-age share of the population (14 and younger, and 65 and older)."

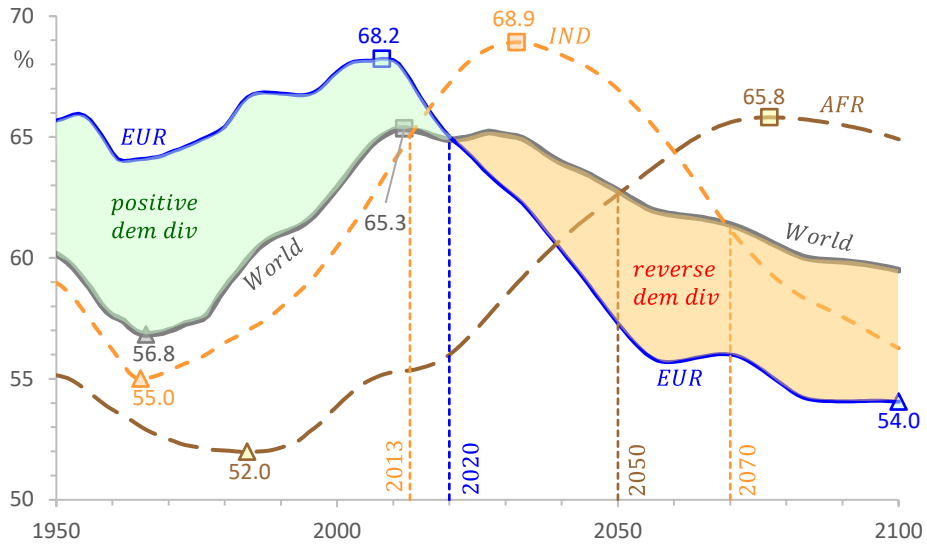
As the UNFPA notes, many issues play a role in order to reap the potential benefits:

> "Countries with the greatest demographic opportunity for development are those entering a period in which the working-age population has good health, quality education, decent employment and a lower proportion of young dependents. Smaller numbers of children per household generally lead to larger investments per child, more freedom for women to enter the formal workforce and more household savings for old age. When this happens, the national economic payoff can be substantial."

[4] Demographic dividend (unfpa.org)

Some of these issues are discussed in case studies in Bloom, Canning, and Sevilla (2003), while attempts to measure aspects of the demographic dividend are reported in Mason (2007).

Figure 1 Working-Age Population (15-64 years, %); World, Europe, India, and Africa, 1950-2100



Source: created using UN World Population Prospects 2022 (medium variant) data; working-age population (15-64 years age bracket) as a percentage of total for respective area; note: vertical scale starts at 50; EUR = Europe; IND = India; AFR = Africa; dem div = demographic dividend.

Figure 1 illustrates the changes in population age structure for the working-age group as a percentage of the World total, Europe, India, and Africa for the period 1950-2100. Note that, depending on a country's specifics and economic development profile, we could focus on different age brackets to determine the 'working age' group, for example from 18-64 if we argue that schooling requires attendance until about 18 years old, or 15-60 if we focus on countries with relatively early retirement systems, or 18-67 if we analyze countries with substantial schooling and later retirement systems. These alternative possibilities lead to similar dynamic age structure adjustments over a longer period of time, so henceforth our definition of working-age is the 15-64-year-old age bracket.

Figure 1 clearly shows a difficulty we have to tackle when evaluating the impact of a changing age structure on economic growth for a country or group of countries because the World *itself* is in a demographic transition as well: the World's share of the working-age group falls from 60.2 per cent in 1950 to a minimum of 56.8 per cent in 1966, rising again to a maximum of 65.3 per cent in 2012, followed by a gradual decline to 59.5 per cent in 2100. This is a substantial variation of 8.5 percentage points in a period of 46 years (from 1966 to 2012). To evaluate the potential for a particular country or region, such as Europe, India, or Africa in Figure 1, to grow faster or slower as a result of demographic transition, we need a proper benchmark to compare it to, not only from a population-structure perspective, but also from a time-dependent economic growth perspective relative to this population structure. We follow the Van Marrewijk (2019) approach and take the World as this benchmark for both aspects. If the world is divided into $i \in I = \{1,..N\}$ countries or regions with index i, we therefore *define* the demographic dividend for a country or region i in period t as the share of the working-age

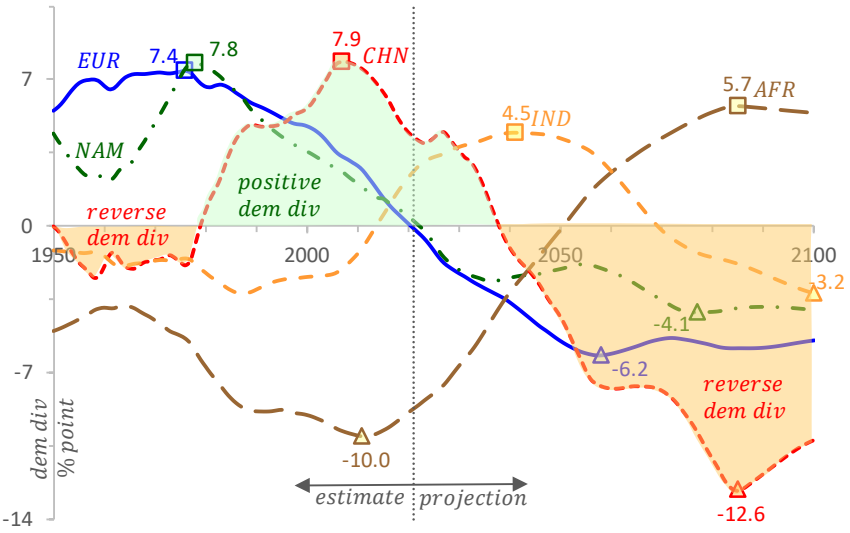
population in that year in percentage points *minus* that of the World in percentage points, see equation (1). The demographic dividend for the World as a whole is therefore always zero.

$$DemDiv_{it} = \frac{WorkingAgePop_{it}}{TotalPop_{it}} - \frac{\sum_{i \in I} WorkingAgePop_{it}}{\sum_{i \in I} TotalPop_{it}} \quad (1)$$

Figure 1 shows that the share of working-age population for Europe reaches a maximum of 68.2 per cent in 2008 to decline to a minimum of 54.0 per cent in 2100. Moreover, as illustrated, the share of the working-age population is *higher* than for the World up to 2020 and *lower* thereafter. Europe has thus benefited from a positive dividend up to 2020 and a *negative* (or *reverse*) dividend thereafter. Similarly, India's share of working-age population varies from a minimum of 55.0 per cent in 1965 to a maximum of 68.9 per cent in 2032. Moreover, India has a reverse dividend from 1950 to 2013 and from 2070 onwards, while it has a positive dividend from 2013 to 2070. Finally, Africa's share of working-age population varies from a minimum of 52.0 per cent in 1984 to a maximum of 65.8 per cent in 2077, leading to a reverse dividend up to 2050 and a positive dividend thereafter.

Figure 2 shows the evolution of the demographic dividend for some important countries and regions from 1950 to 2100. It indicates that Europe and North America have benefited from a *positive* demographic dividend since 1950 up to 2020 (Europe) and 2022 (North America), with a maximum of about 7.5 percentage points in the 1970s. This has allowed Europe and North America to maintain high post-war per capita growth rates for a long time. From now until the end of the 21st century both regions face a substantial *reverse* demographic dividend, making it harder to maintain high per capita growth rates. For North America, the average in the period 2023-2100 is about -2.9 percentage points, with a minimum of -4.1 in 2077. For Europe, the average is about -4.8 percentage points, with a minimum of -6.2 in 2058.

Figure 2 Demographic Dividend; Europe, North America, China, India, and Africa, 1950-2100



Source: created using UN World Population Prospect 2022 data, medium variant; dem div = demographic dividend = working age population (15-64 years, %) *minus* World working age population (%) for respective area in that year; EUR = Europe; NAM = North America; CHN = China; IND = India; AFR = Africa.

The shaded areas in Figure 2 highlight the developments in China, where there was a (mild) *reverse* demographic dividend from 1950 to 1978, a substantial and *positive* demographic dividend from 1979 to 2037 (with a peak of 7.9 percentage points in 2007), and an enormous

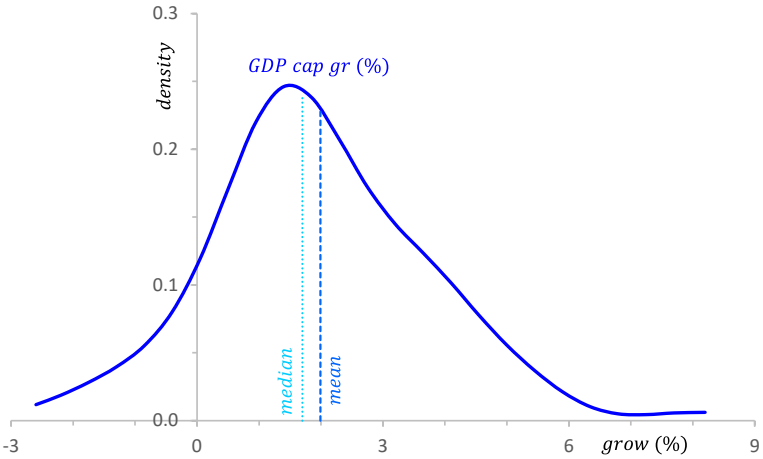
reverse dividend afterwards with a minimum of no less than -12.6 percentage points in 2085. The recent period of rapid economic growth in China initiated by the Economic Reform process of 1978 thus perfectly coincides with a substantial *positive* dividend. After the peak of 7.9 percentage points in 2007, however, there is a rapid decline all the way to a minimum of -12.6 percentage points in 2085, indicating that China is facing fundamental demographic problems to sustain its per capita growth rates.

Figure 2 also shows that India is following a milder and delayed version of China's demographic dividend, with a *reverse* dividend from 1950 to 2013, a *positive* dividend from 2014 to 2069 (with a peak of 4.5 percentage points in 2041), and a *reverse* dividend again thereafter. Its recent booming economy thus coincides with a period of positive dividends. Finally, Figure 2 helps us to better understand why economic growth per capita in Africa has been so low in the recent past as Africa has had an enormous average reverse dividend of -7.2 percentage points in the period 1950-2022, with a minimum of -10.0 in 2011. For the remainder of the 21st century there will be a *reverse* dividend up to 2050 and a *positive* dividend (with a peak of 5.7 percentage points in 2085) thereafter. African growth prospects thus only start to look brighter in the second half of the 21st century.

3. Dividend and Income Growth

What is the relationship between the demographic transition and economic growth? The demographic dividend for a country or region clearly changes over time. Moreover, the impact on economic growth obviously has a long-term character. We start with a baseline evaluation of the connection between trend growth and average demographic dividend in a period, before discussing robustness with four alternative specifications. We use GDP per capita PPP (in constant 2017 int. dollars) from the World Development Indicators online as our income per capita indicator. This is available for many countries from 1990 onwards, which gives us a maximum of 33 observations in the period 1990-2022. For each country we compute a simple income per capita growth trend for this period (based on the number of actual observations).

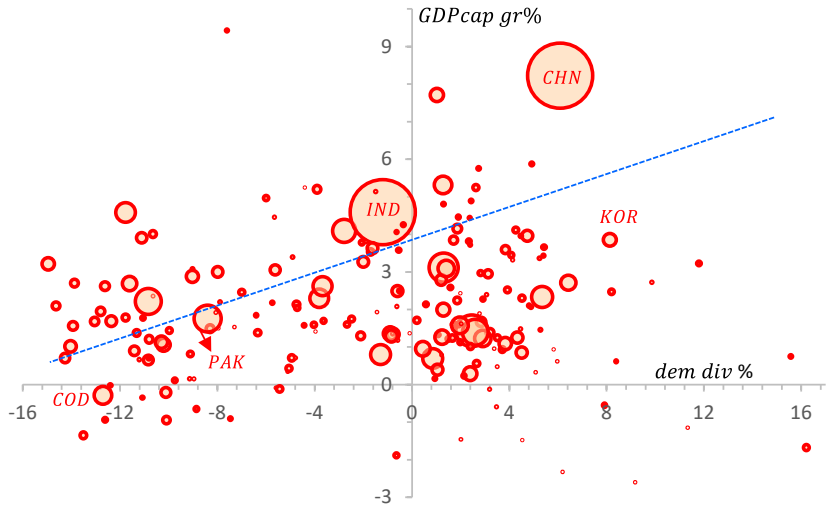
Figure 3 Income per Capita Growth Trend; kernel density, 1990-2022



Source: created using World Development Indicators data; GDP per capita PPP (in constant 2017 int. $); median = 1.70; mean = 1.99; s.d. = 1.82; based on normal density, band width $1.06\hat{\sigma}n^{-1/5}$; 194 countries included; period adjusted base on available observations (min = 10 years, max = 33 years, mean = 31.7 years).

Figure 3 shows a kernel density plot of the income per capita growth trend for 1990-2022 for 194 countries (average number of observations per country is 31.7 years). The median growth rate is 1.70 per cent and the mean is 1.99 per cent. The lowest growth rate is -2.6 per cent for Sint Maarten (Dutch section) and the highest is 9.4 per cent for Equatorial Guinea, followed by China with 8.2 per cent. As Equatorial Guinea can be viewed as an exception (see below), we only show the range from -2.6 to 8.2.

Figure 4 Demographic Dividend and Income per Capita Growth Trend, 1990-2022



Source: created using UN World Population Prospects 2022 (medium variant) and World Development Indicators online data; GDP per capita PPP (in constant 2017 int. $) growth trend (%) 1990-2022 and average demographic dividend 1991-2021 (%); bubbles proportional to population (2022); CHN = China; IND = India; COD = Congo DR; KOR = South Korea.

Table 1 Impact of Demographic Dividend on Economic Growth, 1990-2022

Variant	coefficient	st error	t value	$\bar{R}^2$	Obs
I Baseline; GDP per capita growth trend 1990-2022, all observations					
Demographic Dividend	0.218	0.0043	50.84	0.249	194
II Robustness and alternative specifications for demographic dividend					
a. Deviating trend excluded*	0.221	0.0043	50.94	0.255	182
b. Large st errors excluded**	0.221	0.0043	50.99	0.253	179
c. GDP per person employed#	0.210	0.0047	45.27	0.208	175
d. Annual dev world growth##	0.228	0.0279	8.17	0.096	5901

Source: authors' calculations; dependent variable is GDP per capita PPP (2017 int. $) growth trend 1990-2022 for baseline, a and b, GDP per person employed PPP (2017 int. $) growth trend for c, and GDP per capita PPP (int. $) annual growth % minus world growth % for d; total population-weighted regressions in all cases; Demographic Dividend is average for the period 1990-2021 for baseline and a-c and annual observation for d; the 0.218 baseline coefficient estimate is within the 95% confidence interval for all other estimates.

* Countries excluded if 1990-2022 growth trend and 2010-2022 growth trend deviate by more than three percentage points; excluded countries are: Sudan, Angola, Libya, Un Arab Em, Myanmar, Zimbabwe, Trinidad & Tobago, Azerbaijan, Lebanon, Macao, Guyana, and Eq Guinea.

** Countries excluded if GDP per capita growth rate trend (%) standard error > 10 (more than twice the mean); excluded countries are: Tajikistan, Timor-Leste, Lebanon, Armenia, Guyana, Azerbaijan, Maldives, Georgia, Rwanda, Macao, Bosnia & Herzegovina, Nauru, Iraq, Libya, and Eq Guinea.

GDP per person employed growth trend 1991-2022, all observations.

GDP per capita annual growth % deviation from world growth, all observations.

To determine the link between trend economic growth and demographic dividend, we calculate the average demographic dividend for the countries depicted in Figure 3. The mean for the 194 countries is -1.7 percentage points and the median is -0.6. The range is from -15.0 percentage points for Uganda to 16.2 for the United Arab Emirates. Figure 4 provides an indication of this relationship using a bubble diagram, where the bubbles are proportional to population. Clear examples of *positive* demographic dividend and high growth rates are South Korea (8.1 per cent and 3.9 per cent, respectively) and China (6.1 per cent and 8.2 per cent). Clear examples of *reverse* demographic dividend and low growth rates are Congo DR (-12.7 per cent and -0.3 per cent) and Pakistan (-8.4 per cent and 1.8 per cent). On average, a one per cent higher demographic dividend results in a 0.218 percentage points higher income per capita trend growth rate, see the baseline in Table 1. This explains about 25 per cent of the variance in trend growth rates, is highly significant, and precisely estimated. It can explain, for example, about half of the difference in trend growth rates between Congo DR and China (namely 4.1 percentage points out of 8.5 percentage points).

Several aspects can be taken into consideration when evaluating our baseline estimate, mainly related to variation over time of growth and demographic dividend. We briefly discuss two robustness estimates (3*a* and 3*b* below) and two alternative specifications (3*c* and 3*d* below). All specifications lead to virtually the same estimated impact of demographic dividend on economic growth.

3a. Deviating Trend Excluded

Our baseline estimate evaluates economic growth over a 33-year period. Evidently, this can change substantially over time. A case in point is Equatorial Guinea, which starts with an income per capita of $936 in 1990, reaches a peak of $35,689 in 2008, and concludes with $14,733 in 2022. The rapid rise in the initial period is related to the discovery of large offshore oil reserves that cannot be continued indefinitely, as the second period shows. One way to identify such countries is to compare the trend rate in economic growth in the 1990-2022 period with that of a more recent (in our case the 2010-2022) period and exclude countries where the deviation exceeds some threshold (in our case 3 percentage points). This excludes Equatorial Guinea (with growth trends of 9.4 and -7.6 per cent, respectively), as well as 11 other countries (mainly in Africa and Asia, see Table 1). This reduces the number of observations to 182, but as part II*a* of Table 1 shows has virtually no effect on the estimated impact of demographic dividend on economic growth (0.221 instead of 0.218) or the share of variance explained (0.255 instead of 0.249).

3b. Large Standard Errors Excluded

An alternative robustness check regarding the volatility of economic growth is based on excluding countries with large standard deviations in annual growth rates (in our case more than twice the mean), which excludes 15 countries (mostly in Africa and Asia, including Equatorial Guinea). This reduces the number of observations to 179, but as part II*b* of Table 1 shows has virtually no effect on the estimated impact of demographic dividend on economic growth (0.221 instead of 0.218) or the share of variance explained (0.253 instead of 0.249).

3c. Income per Person Employed

A key aspect of the demographic dividend story is based on variation in the working-age population. An alternative specification can therefore focus on the impact of demographic dividend on the growth rate per employed person rather than per capita, as this automatically incorporates part of the dividend. The World Development Indicators online also provide information on GDP per employed person PPP (in constant 2017 international dollars), although less frequently and for a lower number of countries (175 instead of 194). As part II*c* of Table 1 shows, this has a small effect on the estimated impact of demographic dividend on economic growth (0.210 instead of 0.218) and slightly reduces the share of variance explained (0.208 instead of 0.249). The limited impact on the estimated coefficient is perhaps remarkable, as the methodology which focuses on income per employed person instead of income per capita already includes part of the demographic dividend itself.

3d. Annual Deviation from World Growth Rate

Our final alternative specification is the most challenging variation. Instead of looking at trend growth rates and average demographic dividend over a longer period, we allow for flexibility and analyze annual growth rates and demographic dividend. By construction, the demographic dividend takes the world as its benchmark. We do the same for the growth rates, where we use world growth in that year as the benchmark (as a control variable, if you like) and analyze annual deviation relative to world growth. As part II*d* of Table 1 shows, this approach obviously raises the number of observations substantially (from 194 to 5901) and therefore lowers the share of variance explained (from 0.249 to 0.096), but the estimated coefficient hardly changes (0.228 instead of 0.218) and remains highly significant.

4. Income Projections for the 21st Century

Using the estimated effect of the demographic dividend on economic growth of section 3, we develop and briefly describe a Base scenario and some alternative specifications of the expected aggregate impact of demographic dividend on income levels for 193 countries during the remainder of the 21st century.[5]

To characterize the evolution over time of income, population, and trade, we use the World Bank Regions with one adjustment, see Table 2. The adjustment is that we divide the large East Asia & Pacific region (EAP; 30.0 per cent of the world population in 2022) into China (CHN; 18.3 per cent of the world population) and the remainder of East Asia & Pacific (EAP$^-$; 11.7 per cent of the world population), including large countries like Indonesia, Japan, and the Philippines. There are two main reasons for doing so. First, the size of China, both in terms of population and income, is sufficiently large to deserve separate attention. Second, the demographic evolution of China differs sharply from the remaining countries of EAP, hence it makes little sense to lump these countries together in one region. We do not do the same for India and South Asia (SAS), because (i) most of SAS *is* (and remains) India (74 per cent of the population in 2022) and (ii) the demographic evolution of the other main SAS countries (Pakistan and Bangladesh) is quite comparable to that of India, so we can aggregate these countries in one region. Note that the regions differ slightly from the continents of section 2.

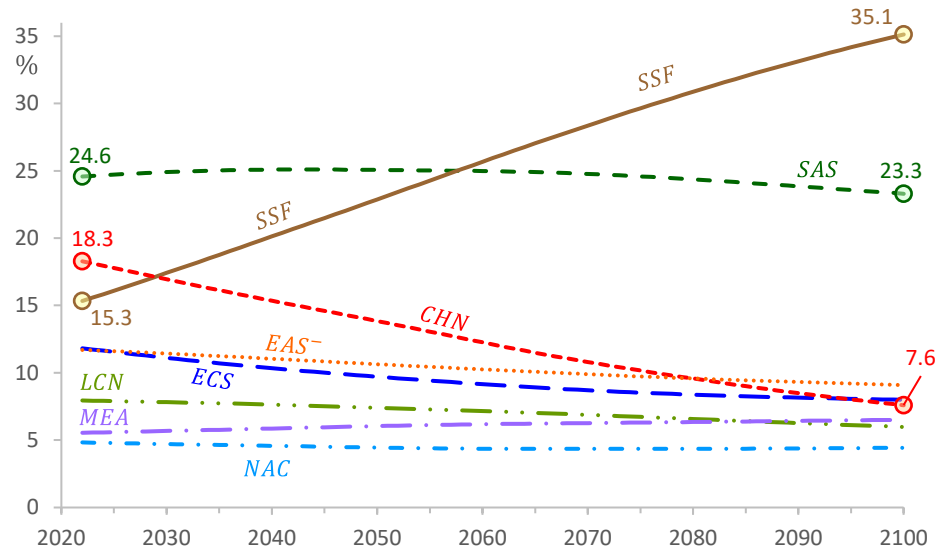
[5] One country (West Bank and Gaza) from section 3 is excluded as UN WPP 2022 does not provide data.

Table 2 World Bank Regions

Code	Region or Country; most populous nations in 2022
EAS	East Asia & Pacific; includes China, Indonesia, Japan, and the Philippines
ECS	Europe & Central Asia; includes Russia, Türkiye, Germany, and UK
LCN	Latin America & Caribbean; includes Brazil, Mexico, Colombia, and Argentina
MEA	Middle East & North Africa; includes Egypt, Iran, Algeria, and Iraq
NAC	North America; includes USA and Canada
SAS	South Asia; includes India, Pakistan, and Bangladesh
SSF	Sub-Saharan Africa; includes Nigeria, Ethiopia, Congo DR, and Tanzania
CHN	China
EAS^{-}	East Asia & Pacific excluding China

Figure 5 shows the estimated population distribution of the regions based on the medium variant of the UN's 2022 World Population Prospects. The most important change is the rise of Sub-Saharan Africa (SSF) from 15.3 to 35.1 per cent of the world's population (a rise from about 1.2 billion to more than 3.5 billion people). The share of all other World Bank regions in the world's population falls, except for Middle East & North Africa which rises by one percentage point (from 5.5 to 6.5 per cent). The most dramatic fall occurs in China, namely from 18.3 to 7.6 per cent of the world's population (from more than 1.4 billion to less than 767 million). The decline in Europe & Central Asia (ECS) is also substantial (minus 3.8 percentage points). For the other regions the relative decline in population is modest. These population projections in combination with the demographic transition will affect the world income distribution substantially, as we now discuss.

Figure 5 Regional Population Projections; per cent of world total, 2022-2100



Source: created using UN World Population Prospects 2022 (medium variant) data; see Table 2 for World Bank region abbreviations.

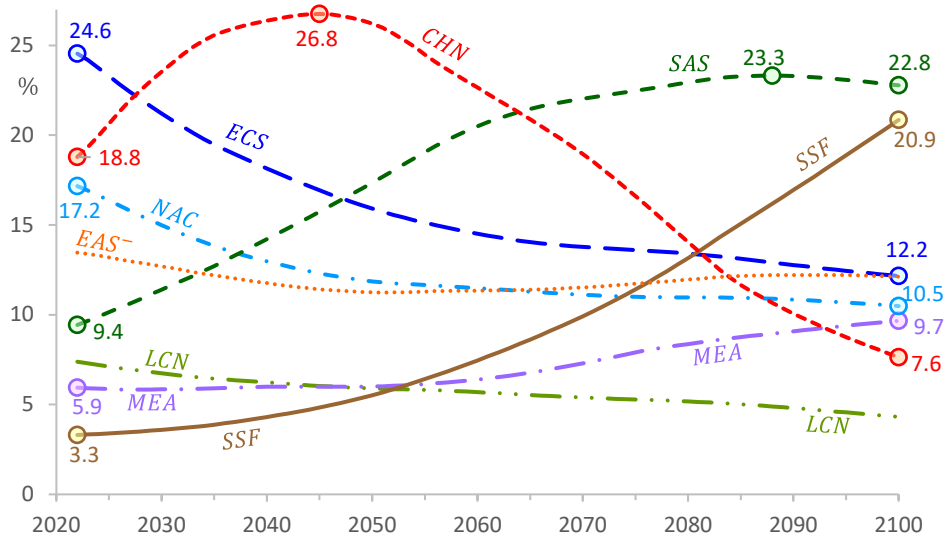
4a. Base Scenario

This sub-section briefly describes and illustrates the Base scenario income distribution projection. The next sub-sections evaluate some alternative scenarios regarding mean reversion, demographic dividend, and the initial growth rate (see Table 3 for an overview).

As the size of the working-age population is crucial for income growth, we first determine the income level per working-age population in each country in 2022. At the world level, the trend income growth over the period 1990-2022 is 2.05 per cent per year, both regarding income per capita and income per employed person. As we noted in section 3, the average trend growth for the 194 countries is 1.99 per cent per year. We therefore take 2 per cent per year as the underlying world average income growth rate.

Based on the baseline estimate of section 3, we take the demographic dividend coefficient to be 0.218 percentage points per one percentage point demographic dividend. Even after correcting for demographic dividend there are differences between countries in the current growth rate. We take this initial growth rate at the country level for the period 2010-2022, corrected for demographic dividend, as given and assume mean reversal in a period of 50 years to the world average of 2 per cent per year.[6] This 'underlying' mean reversal growth rate per year is then corrected for the demographic dividend of that year to determine the growth rate of income per working age population.[7] This is multiplied with the projected size of the working-age population to determine the total income level in each country in a year.

Figure 6 Regional Income Projections, Base scenario; per cent of world total, 2022-2100



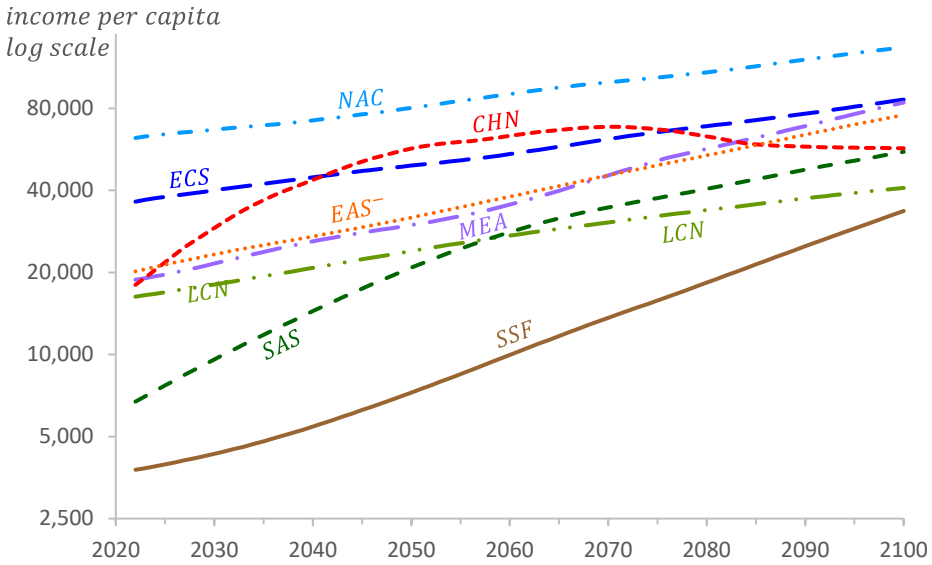
Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); income is GDP PPP (in constant 2017 int. $), per cent of world total; see Table 2 for World Bank region abbreviations.

Figure 6 shows the evolution of the share of income for the World Bank regions in the Base scenario. China's share is expected to continue to rise to a peak of 26.8 per cent in 2045, but then declines rapidly to only 7.6 per cent in 2100. The shares of Europe & Central Asia, North America, and Latin America & the Caribbean are expected to decline fairly steadily for the remainder of the century. The share of the rest of East Asia & Pacific (excluding China) will decline initially and then rise in the 2nd half of the century. The share of the Middle East &

[6] The minimum initial growth rate is -2 per cent per year and the maximum is +8 per cent.
[7] Based on evidence for the 1990-2022 period, we impose a minimum income per working age population of 5 per cent of the population-weighted world average and a maximum of 700 per cent; due to the growth of Sub-Saharan Africa, the first restriction is not effective, while the second is for some countries (see below).

North Africa is steady initially and rises in the second half of the century. The most important increases, however, are in the remaining two regions. The share of South Asia is expected to rise rapidly to a maximum of 23.3 per cent in 2088 and then slowly declines. Indeed, India is expected to take over from China as the world's largest economy in 2075. Even more impressive, particularly in the 2nd half of the century, is the rise of Sub-Sahara Africa from a meagre 3.3 per cent of total income in 2022 to almost 21 per cent in 2100. The most important demographic dividend implications will therefore occur in China (adversely) and in South Asia and Sub-Sahara Africa (positively).

Figure 7 Regional Income per Capita Projections, Base scenario; GDP PPP, 2022-2100



Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); income is GDP PPP per capita (in constant 2017 int. $); see Table 2 for World Bank region abbreviations.

Figure 7 shows the evolution of income per capita for the World Bank regions in the Base scenario. Events are, again, most dramatic for China, where per capita income is expected to continue to rise rapidly initially, reaches a peak in 2070, and starts to decline thereafter. (It is, in fact, the only region in the figure where per capita income declines in some years). The total income effects illustrated in Figure 6 for China are thus a combination of a declining population share (initially) and a declining income level (towards the end of the century). The most impressive rise in income per capita is in South Asia (particularly until about 2065) and in Sub-Saharan Africa (particularly in the second half of the century). Indeed, towards the end of the century, the income per capita levels are about the same in China and in South Asia, while Sub-Saharan Africa manages to close the gap to the world's average income level from 78 per cent in 2022 to 41 per cent in 2100 (although it remains the world's poorest region).

4b. Alternative Scenarios and Center of Gravity

We now evaluate the impact of some alternative scenarios as summarized in Table 3. Our focus is on: (i) the time needed for mean reversion, where scenario 1 uses 30 years and scenario 2 uses 70 years; (ii) the size of the demographic dividend, where scenario 3 uses 0.200 and scenario 4 uses 0.236 (minus and plus 4.2 standard deviations, respectively); and (iii) how to determine the initial growth rate, where scenario 5 uses country trend growth for

1990-2022 and scenario 6 uses the country's relevant World Bank region growth for 1990-2022. In addition, we evaluate a scenario that completely ignores the impact of the demographic dividend, not listed in Table 3.

Table 3 Base and Alternative Projection Scenarios

		Mean reversion		Dem dividend		Initial growth	
Scenario	Base	1	2	3	4	5	6
Mean reversion	50	30	70	50	50	50	50
Dem dividend	0.218	0.218	0.218	0.200	0.236	0.218	0.218
Initial growth	country 2010-2022	country 2010-2022	country 2010-2022	country 2010-2022	country 2010-2022	country 1990-2022	WB region 1990-2022

Mean reversion in years; Dem = Demographic; dividend in percentage points; initial underlying growth in per cent; in all scenarios: world standard growth rate is 2 per cent, minimum (maximum) underlying growth is -2 (+8) per cent, minimum GDP / working age population is 5 (700) per cent of previous pop-weighted average.

For brevity, we discuss the impact of the scenarios on the evolution of the income center of gravity in the main text, see Figure 8. More detailed information on the evolution of the income shares for the main regions is provided in Figure 12 (mean reversion), Figure 13 (demographic dividend), and Figure 14 (initial growth) in the Appendix. To determine the income center of gravity, we used CEPII data on a country's latitude and longitude (plus CIA factbook data for four missing cases), where we first transformed to Cartesian coordinates, next determined the total income-weighted world average for each scenario in each year, and then transformed back to latitude and longitude. We show the evolution of the income center of gravity in (lon, lat)-space, where we list some major cities for ease of reference.[8]

Panel *a* of Figure 8 shows the evolution of the income center of gravity in the Base scenario. Starting roughly in between Kuwait and Tehran, the income center will move to the southeast (about as far east as Kabul, although more to the south) until about 2048 as the weight of China and India continues to rise. From then on it will move to the southwest as the weight of Sub-Saharan Africa continues to rise. Throughout the remainder of the 21st century the income center of gravity will thus move to the south, responding to the rising economic force of both South Asia and Sub-Sahara Africa.

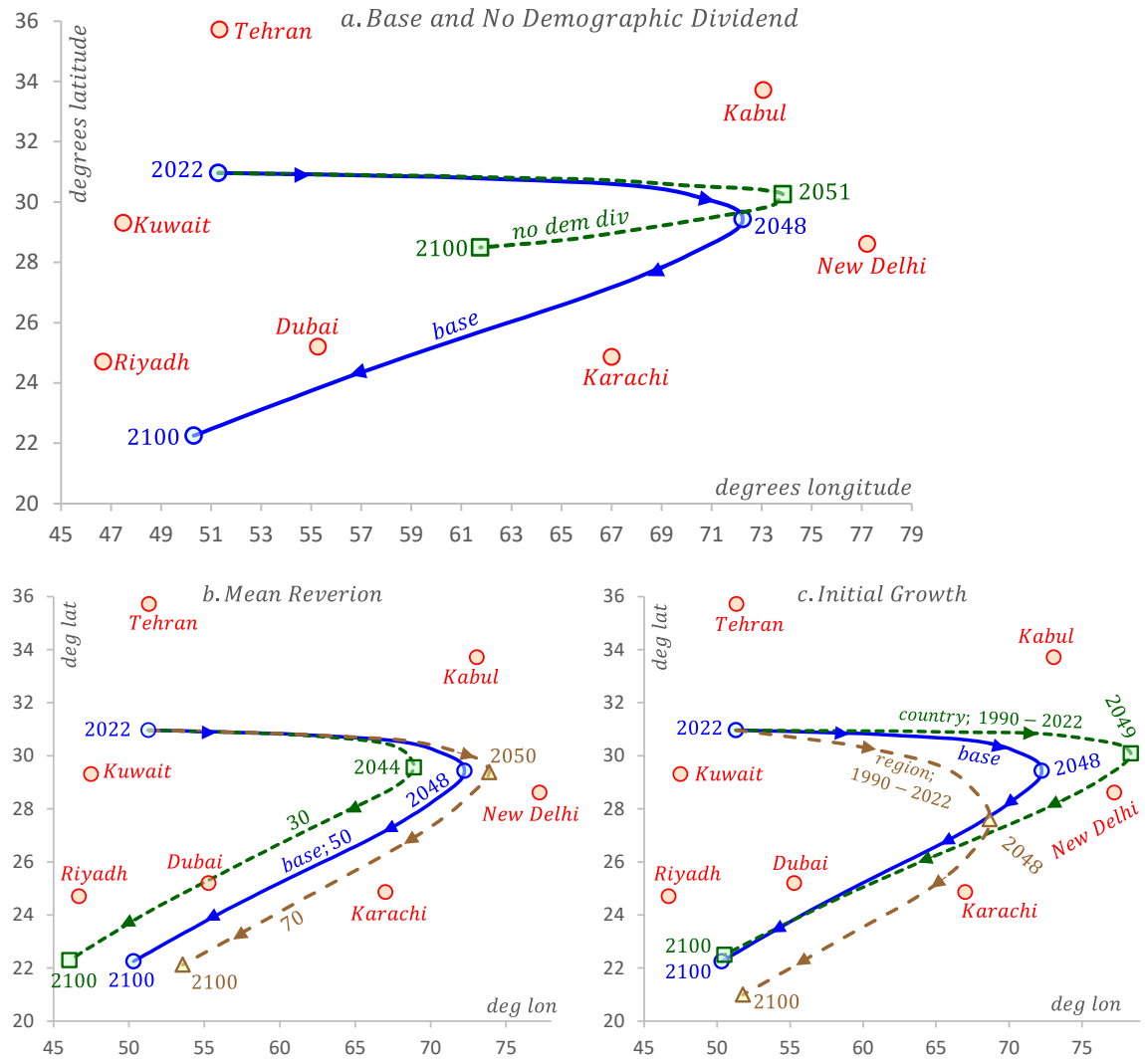
Panel *b* of Figure 8 shows rather similar movements as in the Base scenario if we vary the number of years of reversion to the mean. China's and South Asia's relative income peak will be lower and earlier if reversion is quicker and higher, and later if reversion is slower (see Figure 12 in the Appendix). As a result, the move to the east of the center of gravity is less pronounced and achieved earlier if reversion is quicker and more pronounced, and later if it is slower (panel *b* of Figure 8). The movement to the south, however, is largely unaffected.

Panel *c* of Figure 8 shows again a movement to the south combined with an initial movement to the east and then back to the west if we vary the initial growth rate. If we use country growth trends for the period 1990-2022 (rather than 2010-2022), the movement to the east is more pronounced, but the result in 2100 is basically the same. China is the main force driving this change, as its initial growth rate is higher (about 7.3 versus 5.6 per cent) and so is its peak in

[8] See also Grether and Mathys (2009), and Quah (2011), for center of gravity calculations.

relative income (see Figure 14 in the Appendix). Since there is a clear downward trend in China's growth rates since the peak in 2007, we view this scenario as highly unlikely and therefore use the more recent 2010-2022 period for our Base scenario. If we avoid more volatile country fluctuations by looking at (more stable) World Bank regional growth rates, the movement to the east weakens and the movement to the south strengthens.

Figure 8 Evolution of Income Center of Gravity, 2022-2100



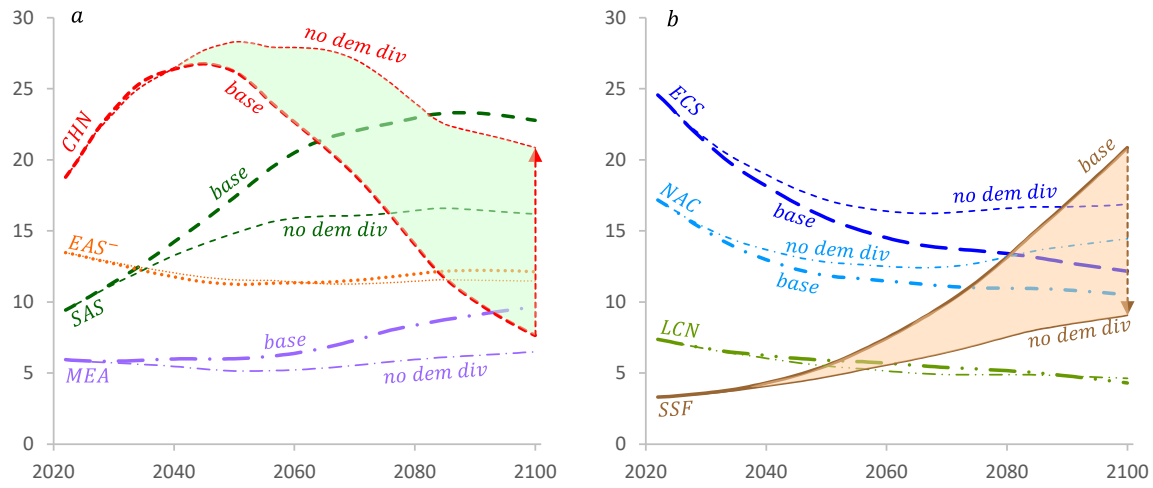
Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); Center of Gravity is GDP-weighted average for respective year; dem div = demographic dividend; deg = degrees; lon = longitude; lat = latitude.

We do not show changes in the income center of gravity path in Figure 8 for the demographic dividend scenarios 1 and 2 because they are virtually the same as the Base scenario path, despite the fact that these are substantial deviations in demographic dividend (minus and plus 4.2 standard deviations). As expected, a lower demographic dividend coefficient somewhat strengthens the shares of China, Europe, and North America and somewhat weakens the shares of Sub-Saharan Africa and South Asia (see Figure 13 in the Appendix).

4c. Ignoring Demographic Dividend

It is interesting is to analyze what happens if we completely *ignore* the demographic dividend effect (coefficient = 0). As panel *a* of Figure 8 shows this leads to a somewhat stronger movement of the income center of gravity to the east initially (up to 2051), a much more limited movement to the west thereafter, and almost no movement to the south. The evolution of income shares compared to the Base scenario is shown in Figure 9, where we highlight the impact on China and Sub-Saharan Africa. Ignoring the demographic dividend effect grossly overestimates the development of income shares of China (13.2 percentage points by 2100), Europe & Central Asia (4.7 percentage points), and North America (4.0 percentage points). It grossly underestimates the development of income share in Sub-Saharan Africa (11.8 percentage points), South Asia (6.6 percentage points), and the Middle East & North Africa (3.2 percentage points). Including the demographic dividend effect is thus crucial for understanding the evolution of income shares in the remainder of the century.

Figure 9 Regional Income, Base and No Demographic Dividend; percentage of world total, 2022-2100



Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); income is GDP PPP (in constant 2017 int. $), per cent of world total; dem div = demographic dividend; see Table 2 for World Bank region abbreviations.

5. Country Perspective

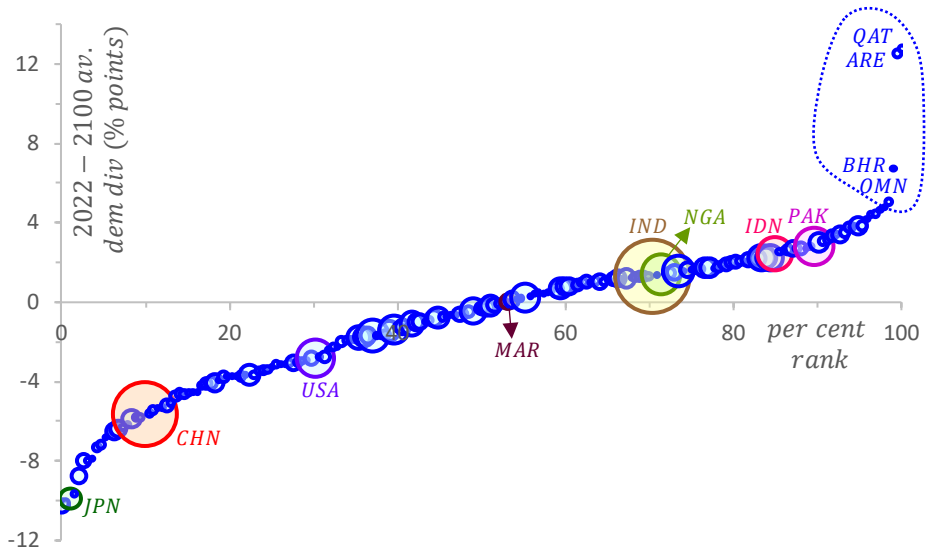
What are the consequences of demographic dividend on income developments from the perspective of individual countries? We start with a discussion of the country average demographic dividend in the period 2022-2100 before focusing on the (changes in) the most important countries from a total income perspective.

Figure 10 shows the ranked country average demographic dividend in the projection period 2022-2100 in a bubble diagram, with bubbles proportional to average population. On the far left-hand side we have countries with (on average) large reverse dividend, starting with South Korea, Hong Kong, and Japan. The first 50 countries with the lowest average demographic dividend are almost all in Europe and East Asia, with China as a large representative.[9] The next group of somewhat milder reverse average dividend includes USA, Russia, Brazil, and Mexico

[9] Some Caribbean countries are also included, as well as Malta and Niger.

(not all shown), as well as some African countries, like Congo DR. The cut-off from reverse to positive average dividend is provided by Morocco, which has an average of 0.0. We then continue with a range of countries with positive dividend, mainly from South Asia (such as India and Pakistan), Southeast Asia (including Indonesia and the Philippines), and Africa (like Nigeria and Ethiopia). The highest average dividends are observed in the Middle East, namely Oman, Bahrain and the two extreme outliers: United Arab Emirates and Qatar. Clearly, this is not based on a natural population process, but on immigration of workers from abroad in the 15–64-year-old category who return to their country of origin before retirement.

Figure 10 Average Demographic Dividend in 2022-2100; ranked, bubble diagram



Source: created using UN World Population Prospects 2022 (medium variant), see main text for details; bubbles proportional to average population size in the period 2022-2100; JPN = Japan; CHN = China; MAR = Morocco; IND = India; NGA = Nigeria; IDN = Indonesia; PAK = Pakistan; OMN = Oman; BHR = Bahrain; ARE = United Arab Emirates; QAT = Qatar; 193 countries included.

Table 4 Top Ten Country Income; per cent of world total 2022, 2060, and 2100

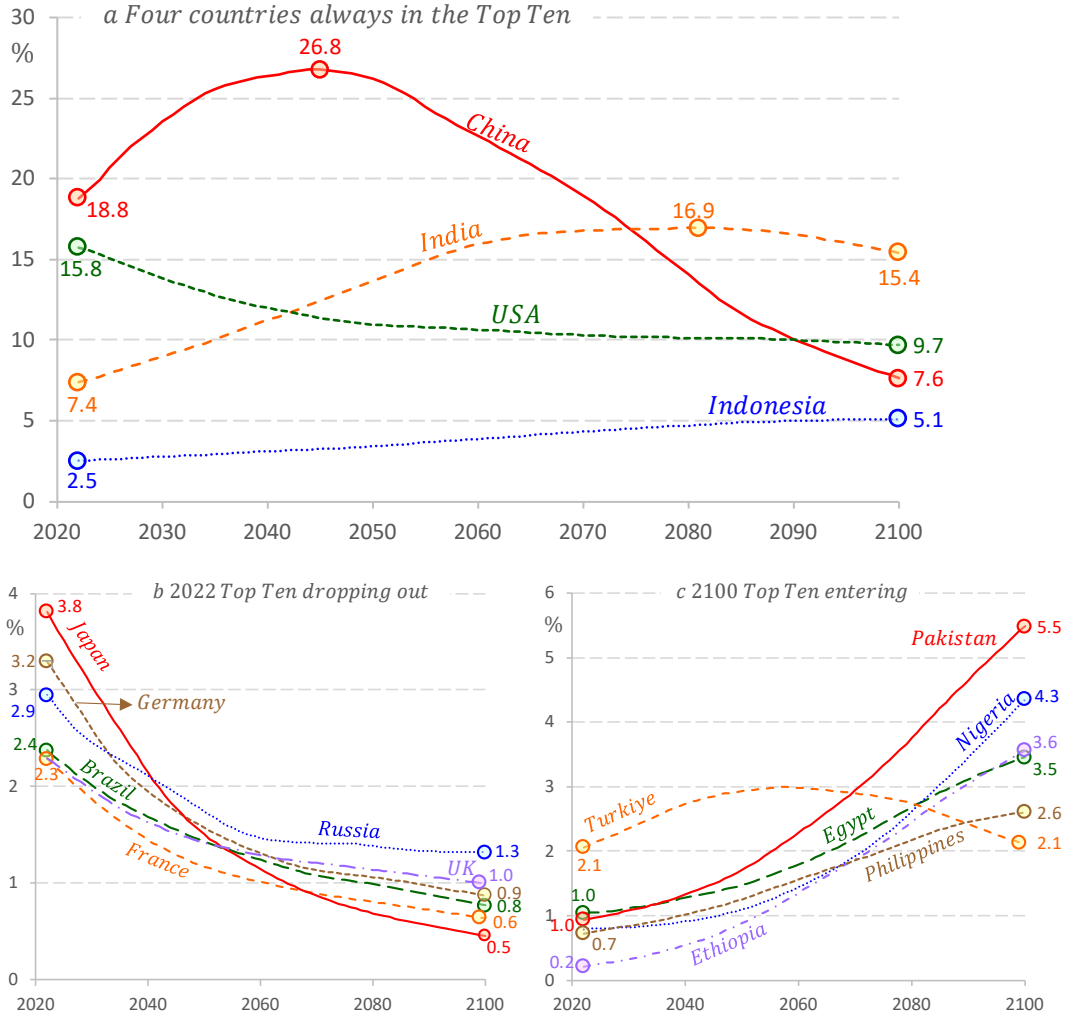
Country	2022	Country	2060	Country	2100
China	18.8	China	22.6	India	15.4
USA	15.8	India	15.9	USA	9.7
India	7.4	USA	10.6	China	7.6
Japan	3.8	Indonesia	3.9	Pakistan	5.5
Germany	3.3	Türkiye	3.0	Indonesia	5.1
Russia	2.9	Pakistan	2.3	Nigeria	4.3
Indonesia	2.5	Bangladesh	1.8	Ethiopia	3.6
Brazil	2.4	Egypt	1.8	Egypt	3.5
UK	2.3	Philippines	1.6	Philippines	2.6
France	2.3	Russia	1.5	Türkiye	2.1
Top ten sum	61.4	Top ten sum	65.0	Top ten sum	59.4

Source: own calculations, see main text for details.

For ease of reference, we concentrate on the per cent of the world total for the top ten countries, together accounting for about 60 per cent or more of total world income. Table 4 provides an overview of the top ten countries in three periods, namely 2022, 2060, and 2100. Figure 11

illustrates the evolution of the income share over time in the period 2022-2100 for most of the countries from Table 4 in three panels, where panel *a* consists of the four countries that are always in the top ten, panel *b* consists of the six 2022 top ten countries that subsequently drop out, and panel c consists of the six countries 2100 top ten countries that have entered since 2022. The missing country in Figure 11 is Bangladesh, which enters the top ten in 2048 (replacing Brazil) and exits the top ten in 2070 (replaced by Ethiopia).

Figure 11 Selected Top Ten Income Countries; per cent of world total, 2022-2100



Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); income is GDP PPP (in constant 2017 int. $), % world total.

In 2022, Europe & Central Asia (ECS) has four countries in the top ten, followed by East Asia & Pacific (EAP) with three and one each from North America, South Asia, and Latin America & Caribbean. All four European countries drop out of the top ten; France is replaced by Türkiye (another ECS country) in 2025, the UK is replaced by Pakistan in 2046, Germany is replaced by the Philippines in 2056, and Russia is replaced by Nigeria in 2061. As a result, there is only one European country left in the top ten in 2100 (with Türkiye at number 10). EAP continues to have three countries in the top ten; two of which are always in the top ten (China and Indonesia), while Japan drops out (replaced in 2051 by Egypt) and the Philippines enters (in 2056, replacing Germany). Only one American country (USA) remains in the top ten as Brazil drops out (replaced in 2048 by Bangladesh). The other country always in the top ten is from

South Asia (India); it is joined by Pakistan in 2046 (replacing UK) and by Bangladesh in 2048 (which leaves again in 2070). Three African countries enter the top ten, namely Egypt in 2051 (replacing Japan), Nigeria in 2061 (replacing Russia), and Ethiopia in 2070 (replacing Bangladesh).

Panel *a* of Figure 11 shows the evolution of the share of income for the world's most powerful countries (in economic terms) for most of the 21st century (Pakistan replaces Indonesia in the top four in 2095). As already discussed, China peaks in 2045 at about 26.8 per cent and then starts a sharp decline to around 7.6 per cent in 2100. The USA declines throughout the period from 15.8 to 9.7 per cent, rapidly up to 2050 and more slowly thereafter. It is replaced by India as the second largest economy in 2043 and regains this position from China in 2091. India becomes the world's largest economy in 2075. Its share of world income rises from 7.4 per cent in 2022 to a maximum of 16.9 per cent in 2081 and then declines to 15.4 per cent in 2100. Indonesia's share of world income continues to rise throughout the period, about doubling in relative size (from 2.5 to 5.1 per cent).

Panel *b* of Figure 11 shows 2022 top ten countries dropping out, consisting of four European countries (Russia, Germany, UK, and France), Japan, and Brazil. As expected, their share of world income declines rapidly. This holds especially for Japan, which is initially the largest of the six countries and eventually the smallest. Except for Russia, all countries see their share decline to one per cent of world income, or less. Also note that we expect the UK to become larger than Germany before the end of the century. In addition, we expect the much-heralded 'emerging market' of Brazil to do rather poorly in the remainder of the century.

Panel *c* of Figure 11 shows 2100 top ten countries entering over the period, from Africa (Egypt, Nigeria, and Ethiopia) and Asia (Pakistan, Philippines, and Türkiye [also European]). For most countries, the relative income share rises over time. The exception is Türkiye, which starts at 2.1 per cent, then rises to about 3.0 per cent to decline again to 2.1 per cent. The relative rise is particularly impressive for Ethiopia, Nigeria, and Pakistan.

6. Discussion and Conclusions

In this century the geographical- and age distribution of the global population will change fundamentally. Around 2010, the world working-age population share peaked and has declined ever since. This trend, however, disguises important regional differences. In general, the distribution of the world population will shift away from advanced economies in the direction of developing and emerging economies. An important consequence of this shift is that the age distribution across countries will change. In aging countries, the dependency ratios will increase, whereas in fertile countries the dependency ratios will decrease. We analyze the global income consequences of these demographic changes.

Our aim is to describe global shifts in the geographical distribution of income that are related to global shifts in the demographic dividend. Countries will no doubt respond to these changes. However, we do not make guesses regarding possible responses of governments following demographic changes. This would involve detailed knowledge of the saving and investment responses of economies regarding aging, specific knowledge of changing consumption and investment patterns over the life cycle, and so on. Furthermore, between now and 2100,

unpredictable events will happen, such as technological change, societal changes, climate change, natural disasters, geopolitical tensions, and so on, that also affect productivity and income. An analysis of this is beyond the scope of this article.

Our modest approach is to describe possible geographical shifts of global income caused by demographic dynamics. Although we do not have detailed information on the responses to these demographic changes, the various income scenarios that we present all strongly point towards very similar outcomes. Ignoring the important influence of changes in the demographic dividend for the global income distribution will overstate the economic importance of the current economic powerhouses in the world and understate the influence of current developing and emerging countries.

We analyze the relationship between income and the demographic dividend between 1990 and 2020 and find that a one per cent higher demographic dividend results in a 0.22 percentage points higher income growth rate. We use this outcome to predict and illustrate how the global *center of income gravity* will shift during the remainder of this century subject to demographic changes. More specifically, China's income share in the world is expected to continue to rise to a peak of 26.8 per cent in 2045, but then declines rapidly to only 7.6 per cent in 2100. The combined shares of Europe & Central Asia and North America will drop from 43 percent in 2020 to 23 percent in 2100. For Sub-Sahara Africa the outlook is very different. Their income share will increase from a mere 3.3 per cent of total income in 2022 to almost 21 per cent in 2100. The most important demographic dividend implications will therefore occur in China, Europe, and North America (adversely) and in South Asia and Sub-Sahara Africa (positively).

What could be the consequences of these shifts? Most likely it will affect the global distribution of economic power. This not only holds for direct political influence in the international economic institutions such as the IMF, that will see shifts in the distribution of members' quota and voting power, but also indirectly through changes in informal memberships of G7 meetings, and so on. Following the shifts in income, shifts in global trade will follow the same pattern as the global income changes. This could affect the position of the dollar as the world's main reserve currency and the global monetary system in general. We leave a detailed analysis of these political shifts to political scientists. What we pointed out in this article is that ignoring the changes in the global distribution of the demographic dividend and the consequences for global income will lead to overemphasis of the economic importance of the current economic powerhouses in the world, and play down the importance of developing and emerging countries for the remainder of the 21st century.

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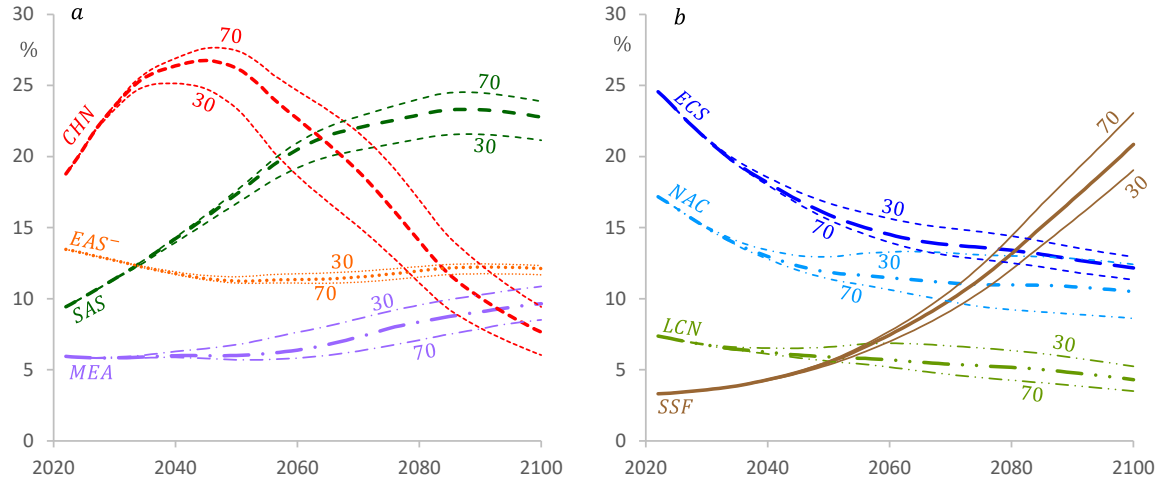
Appendix

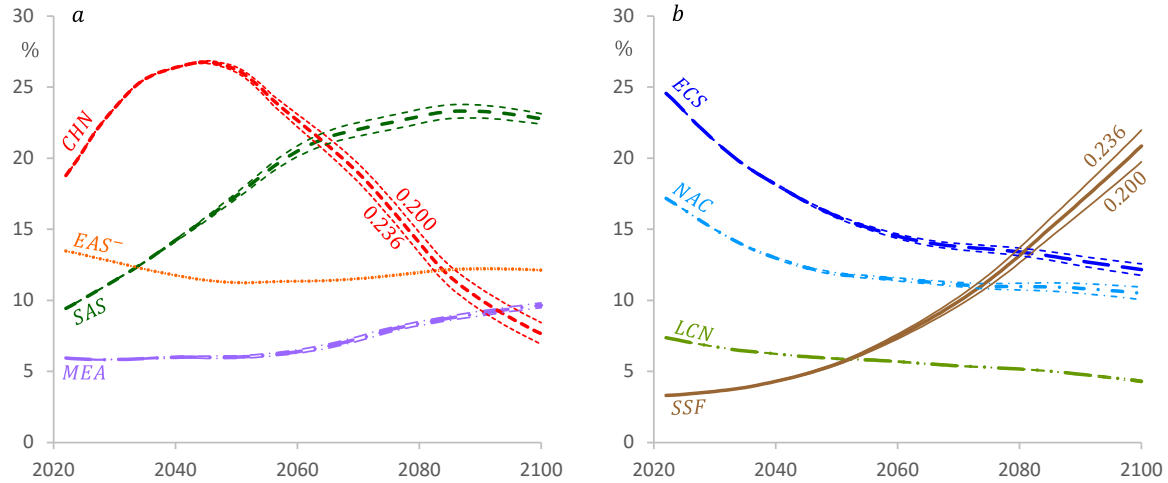
The figures below show regional income distributions for alternative scenarios. Figure 12 shows alternative mean reversion scenarios; namely 30 years and 70 years, compared to the Base scenario of 50 years. Figure 13 shows alternative demographic dividend scenarios; namely 0.200 and 0.236, compared to 0.218 in the Base scenario. Figure 14 shows alternative initial growth scenarios; namely at the country level for the period 1990-2022 and the World Bank region level for 1990-2022, compared to the country level for the period 2010-2022 in the Base scenario. See the main text for details. The main conclusion based on these Figures is that in a qualitative sense all specifications lead to virtually the same estimated impact of demographic dividend on economic growth.

Figure 12 Regional Income Projections, Mean Reversion; per cent of world total, 2022-2100



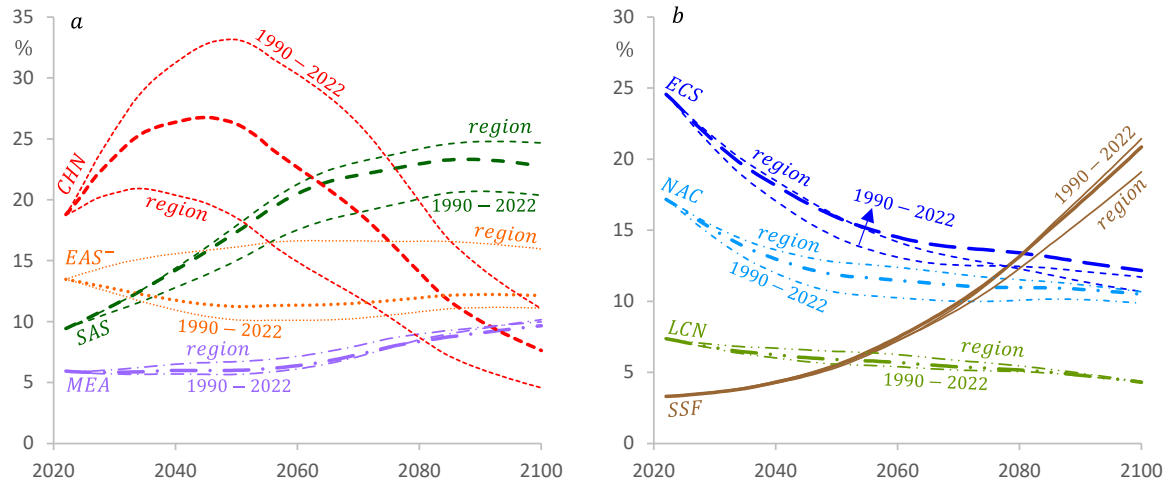
Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); income is GDP PPP (in constant 2017 int. $), per cent of world total; see Table 2 for World Bank region abbreviations; thick line is Base scenario (50 years mean reversion); 30 = 30 years mean reversion; 70 = 70 years mean reversion.

Figure 13 Regional Income Projections, Demographic Dividend; per cent of world total, 2022-2100



Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); income is GDP PPP (in constant 2017 int. $), per cent of world total; see Table 2 for World Bank region abbreviations; thick line is Base scenario (0.218 demographic dividend); 0.200 = 0.200 demographic dividend; 0.236 = 0.236 demographic dividend.

Figure 14 Regional Income Projections, Initial Growth; per cent of world total, 2022-2100



Source: created using UN World Population Prospects 2022 (medium variant), World Development Indicators online data, and own calculations (see main text); income is GDP PPP (in constant 2017 int. $), per cent of world total; see Table 2 for World Bank region abbreviations; thick line is Base scenario (initial growth based on country 2010-2022); 1990-2022 = initial growth based on country 1990-2022; region = initial growth based on World Bank region 1990-2022.