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# DemoGravity: World Population and Trade in the 21<sup>st</sup> Century

# Abstract

The availability and composition of labor is fundamental for the structure of international trade. This points towards the importance of demographic transitions that affect trade through, for example, changing capital-labor ratios, urbanization dynamics, or changes in the composition of demand over the life cycle of individuals. Key in this respect is the so-called demographic dividend, which is the potential economic growth stemming from lower dependency ratios. We use the gravity model to link long-run changes of the demographic dividend to changes in the level of world trade for the 21st century. All the scenarios that we distinguish point towards the same conclusion: Compared to the current situation, North America and Europe will no longer be the center of global trade in 2100 due to their aging populations. In contrast, South Asia and Sub-Saharan Africa will experience a substantial increase in their share of world trade throughout the remainder of this century, while the impact of the demographic drag facing China will be most pronounced around 2060.

JEL-Codes: F100, J110, O110.

Keywords: demographic transition, trade, income, gravity model.

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# 1. Introduction

Labor is a fundamental explanatory factor for the structure and size of international trade flows. In Ricardian models and modern variants thereof, such as Eaton & Kortum (2002) and Melitz (2003), labor productivity determines the structure of international trade flows. In Heckscher-Ohlin models, relative factor endowments (including labor) explain the composition of trade flows. Moreover, the size of the market measured by labor (income) – the so-called home-market effect – is a determinant of net exports. Geographic lumpiness, or the agglomeration of production factors within countries, also has explanatory power in relation to trade flows. Although the channels through which demographic changes may affect the structure and level of trade differ, changes in labor supply are fundamental in explaining how trade flows evolve over time. This puts demographic transitions at the center stage in understanding the evolution of world trade flows.

As we document in the next section, the world is aging, which significantly affects the workingage population. The world's share of working-age population peaked around 2010. The United Nations (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 (i.e., 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, while in the United States it is close to, but below 2.1.<sup>2</sup>

These demographic transitions will result in major shifts in the distribution of the world population across countries. In general, the bulk of the world population will shift away from advanced economies towards developing and emerging economies. Moreover, the age distribution across countries will also change. In aging countries, the dependency ratios increase, whereas in fertile countries the dependency ratios decrease. This development potentially offers growth opportunities for younger societies. The macro-economic consequences of changing age distributions are well-known; it will affect decisions on savings and investment, pension and health systems, and growth in general (Bloom, 2011; Bloom et al., 2003; Bloom & Williamson, 1998; Eggertsson et al., 2019). Countries need to adapt to these changes. We focus on the trade consequences.

Importantly, there is no clear-cut relationship between structural demographic transition, income, and trade; it depends on national policy responses to these changes. The macroeconomic consequences are well-known (see, e.g., Maestas et al., 2023). Consumption patterns can change over the life cycle of individuals: aging societies tend to trade less than younger societies. Consequently, the demand for non-tradable services related to ageing could increase at the expense of traded commodities in aging society (Lee et al., 2008; Fernandez-Villaverde & Krueger, 2007). In response to demographic changes, governments in aging economies could, for example, invest in technology, export upgrading or longevity to compensate for age-related labor productivity decreases of aging populations (Kotschy & Bloom, 2023; Cai & Stoyanov, 2016; Gu & Stoyanov, 2019; Wu et al., 2021; see Goodhart & Pradhan, 2020, for a

<sup>&</sup>lt;sup>2</sup> Summary demographic data are readily available. See, e.g., <u>https://data.oecd.org/pop/population.htm.</u> For long-term estimates of historical demographic transition, see Delventhal et al., 2021.

survey). Openness could thus be positively related to the size of the working-age population or demographic dividend; the larger the working-age population, the more trade (Tian et al., 2011; Fukomoto & Kinugasa, 2017). This points towards the importance of income for the level of trade. In their analysis of OECD countries in the post-war period, Baier & Bergstrand (2001) found that average world trade growth is explained by income growth (67%), tariff reductions (25%), and transport cost reductions (8%). Because income is related to the demographic dividend, we can use this relationship to make long-term predictions about world trade.

Our aim is to describe global shifts in the geographical distribution of world trade that are related to projected changes in the world's demographic composition. A model that is suited to analyze these changes in world trade is the gravity model, where bilateral trade depends, among other variables, on income. Kopecky (2023) uses the gravity model to estimate the relationship between demographic changes and current account deficits or surpluses.<sup>3</sup> We do not make predictions of current account deficits as this would involve detailed knowledge of the saving and investment responses of economies regarding aging and how these responses affect the current account. We have a more modest approach and describe possible geographical shifts of global trade caused by demographic transition, without discussing how demography may affect long-term national comparative advantages or structural change. Our approach allows us to illustrate geographical shifts of trade flows due to demographic changes in the size and age composition of national labor supply.

The remainder of the paper proceeds as follows. Section 2 illustrates global trends in the share of the working-age population in total population. The UN expects a global decline in the share of the working-age population, but regional developments differ markedly. Next, we relate these demographic trends to changes in international trade in Section 3, where we estimate a structural gravity model to determine the relationship between demographic composition and international trade. In Section 4, we evaluate how changes in income resulting from demographic changes, the so-called demographic dividend, would have an additional impact on international trade. Section 5 discusses our findings and concludes.

<sup>&</sup>lt;sup>3</sup> Kopecky (2023) makes long-term trade predictions by using the non-demographic parameters fixed at their 2013 value but allowing for demographic changes. However, the current account surpluses and deficits in this study are not based on the standard micro-foundations that are common in the recent gravity literature. In addition, time-varying multilateral resistance terms are not accounted for.

# 2. Demographic Dividend<sup>4</sup>

- The United Nations Population Fund (UNFPA) defines the demographic dividend as:<sup>5</sup> "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)."
- How the demographic dividend evolves, matters for economic growth. The UNFPA notes: "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."

Some of the social-economic issues that are related to demography are discussed in Bloom et al. (2003) and Mason (2007). These studies find that about one-third of the growth 'miracle' in East-Asia between 1965-1990 is accounted for by increases in the demographic dividend (Bloom & Finlay, 2009).



Figure 1 Working-Age Population (15-64 years, %); Selected Regions, 1950-2100

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

Figure 1 illustrates the predictions made by the UN. The figure shows the changes in population age structure for the working-age group – defined by 15 to 64 years – as a percentage of total population for the World as a whole, Europe, India, and Africa for the period 1950-2100.<sup>6</sup> Two observations stand out when inspecting Figure 1.

<sup>&</sup>lt;sup>4</sup> Our analysis of demographic changes is based on Brakman et al. (2024); a more in-depth discussion of the demographic dividend under a large range of projection scenarios can be found here and is summarized in Appendix B.

<sup>&</sup>lt;sup>5</sup> <u>https://www.unfpa.org/demographic-dividend#0</u>.

<sup>&</sup>lt;sup>6</sup> There is not one ideal definition of the working-age population. Various options are possible. We could for example take the 18-64 years group if we argue that schooling can end at 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 later retirement

First, the World *itself* is in a demographic transition: the World's share of the working-age group rose from a minimum of 56.8 per cent in 1966, to a maximum of 65.3 per cent in 2012, followed by a decline to 59.5 per cent in 2100. Second, there are large variations across countries. Figure 1 illustrates, for example, that the share of working-age population for Europe reaches a maximum of 68.2 per cent in 2008 and will subsequently fall to a minimum of 54.0 per cent in 2100. So, the share of the working-age population is *higher* than for the World until 2020 and *lower* thereafter. 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. Finally, Africa's share of working-age population rises from a minimum of 52.0 per cent in 1984 to 65.8 per cent in 2077.<sup>7</sup>

In the remainder of this paper, we link national demographic composition and its potential impact on incomes (i.e., the demographic dividend) to the level of trade. Doing so sheds light on how regions' share of world trade may change throughout this century subject to expected demographic transitions. The structural gravity model is a useful tool to empirically evaluate the correlation between demographic transition and international trade. The key problem that we face is to separate the effects of the national demographic composition on trade from the effect of the demographic dividend on trade. We do this in two complementary ways.

First, in section 3, we stay as close as possible to the standard gravity model. In the conventional empirical framework, importer-year and exporter-year fixed effects that account for time-varying multilateral resistance terms (MRTs) will absorb variation in country-specific variables that vary over time – in our case, changes in the national shares of working-age population. A way to circumvent this problem is to estimate how much of the variation in the importer-year and exporter-year fixed effects can be explained by the national demographic composition. Once this is established, we can extrapolate this part of the fixed effects – the part explained by demography – by using the UN demographic predictions. The gravity model then translates these estimates into trade flows.

Second, in section 4, we also account for the effect of demographic dividend on income itself, i.e., income changes that are explained by the share of working-age population. This effect is added to trend income projections, which allows us to analyse various scenarios. These income projection scenarios – detailed in Appendix B – account for long-term income trends that are distinct from demographic influences on income. The gravity model again translates these income developments into trade predictions.

schemes. Alternative definitions lead to similar dynamic age structure adjustments over time. Our definition of the working-age population uses the 15-64-year-old age bracket. Kotschy and Bloom (2023) make the definition of working-age population cohort dependent.

<sup>&</sup>lt;sup>7</sup> We will explore the consequences of changes in regional demographic compositions over time. Given that the world itself is in a demographic transition (see Section 2), our definition of a region's demographic composition in the remainder of the paper is its working-age (15-64 years) population as a share of its total population, minus the World average.

# 3. Approach 1: Fixed Effects

# Linking demographic composition to international trade

We employ a structural gravity model trade to examine how changes in the national share of working-age population are related to world trade. As said, a challenge in this regard is that national demographic changes are calculated at the country-year level. In the context of a structural gravity model with (at least) time-varying multilateral resistance terms, this implies that parameter estimates for demography-based explanatory variables will be collinear with the conventional exporter-year and importer-year fixed effects.

The empirical trade literature grapples with the question how to identify the effects of variables of interest that are collinear with either the exporter-year, importer-year, and/or exporter-importer fixed effects. Two prominent solutions have recently been proposed.

One approach is provided by Heid et al. (2021), who propose that the effects of country-specific characteristics, such as nondiscriminatory trade policies, can be identified in structural gravity models as long as both domestic and foreign trade are included. In this case, the explanatory variable of interest can be identified by interacting this variable with an indicator variable for international trade, the so-called "border" dummy. This technique has been adopted to examine, for example, the consequences on trade stemming from institutional quality (Beverelli et al., 2024) or landlockedness (Gyawali, 2023).<sup>8</sup>

Another solution is provided in Egger & Nigai (2015). Their paper addresses the problem of unobserved-trade-cost bias in structural gravity models. They propose a two-step procedure for panel data. The first step is to decompose bilateral trade into the underlying exporter-year, importer-year and exporter-importer components (i.e., in our setting, fixed effects), which reflect trade cost equivalents that do not suffer from omitted variable bias. In the second step, the partial effects of (un)observable trade costs on total trade costs are estimated. This procedure has appealing properties because the decomposition of trade into its country-year and country-pair components is consistent with a large class of trade models and respects general-equilibrium constraints (i.e., total income equals total expenditure).

# Procedure

Our first approach is inspired by the two-step procedure in Egger & Nigai (2015), which has recently been applied to evaluate the time-invariant effects of EU integration (Spornberger, 2022) and topography (Frensch et al., 2023) on trade. While these studies focus on explaining the pair-fixed effects in the second step, ours will explore the country-time-varying nature of the relevant fixed effects subject to changes induced by demographic developments. Our "Fixed Effects" approach proceeds as follows.

*Step 1*. Decompose observed trade (for the years 1990-2019) into its country-year and country-pair components and save the fixed effects obtained from estimating:

<sup>&</sup>lt;sup>8</sup> In our context, this method is less suitable because we need to simultaneously identify parameter estimates for *both* the interaction term of the exporter's demographic composition with the border dummy, as well as for the interaction term of the importer's demographic composition with the border dummy. In unreported results, only one of these two terms could be identified due to collinearity.

(1)  $X_{ij,t} = \exp[\beta_0 + \gamma_{i,t} + \delta_{j,t} + \zeta_{ij}] \times \varepsilon_{ij,t}.$ 

Here, the dependent variable is exporter (*i*)'s exports to importer (*j*) in year (*t*), which is decomposed into exporter-year fixed effects ( $\gamma_{it}$ ), importer-year fixed effects ( $\delta_{jt}$ ) and country-pair fixed effects fixed effects ( $\zeta_{ij}$ ). The exporter-year and importer-year fixed effects represent country-time-varying multilateral resistance terms, while the directional pair fixed effects account for asymmetric bilateral trade costs and control for unobserved country-pair characteristics affecting bilateral trade flows (Baier & Bergstrand, 2007; Bergstrand et al., 2013). Our model also accounts for both international and intranational trade flows (Bergstrand et al., 2015; Yotov, 2012, 2022).

*Step 2*. Regress the saved exponentiated country-year fixed effects on the main explanatory variable of interest (also see Anderson & Yotov, 2016):

(2)  $\exp[\delta_{i,t}] = \exp[\beta_1 + \eta_1 X_{i,t} + \theta_i + \iota_t] \times \varepsilon_{i,t}$ 

(3) 
$$\exp[\gamma_{j,t}] = \exp[\beta_2 + \eta_2 X_{j,t} + \lambda_j + \mu_t] \times \varepsilon_{j,t}$$

In Eq. 2, the exporter-year fixed effect is regressed on the exporter's time-varying explanatory variable  $(X_{i,t})$ , an exporter fixed effect  $\theta_i$ , and a year fixed effect  $\iota_t$ . Analogously in Eq. 3, the importer-year fixed effect is regressed on the importer's key explanatory variable of interest, an importer fixed effect  $(\lambda_i)$  and a year fixed effect  $(\mu_t)$ .

Step 3. Predict the exporter-year and importer-year fixed effects for the full sample 1990-2100:

(4) 
$$\exp[\hat{\delta}_{i,t}] = \exp[\hat{\eta}_1 X_{i,t} + \hat{\theta}_i + \hat{\iota}_t] \times \varepsilon_{i,t}$$

(5) 
$$\exp[\hat{\gamma}_{j,t}] = \exp[\hat{\eta}_2 X_{j,t} + \hat{\lambda}_j + \hat{\mu}_t] \times \varepsilon_{j,t}$$

Note here, that country-time-varying data on demographic composition are available for the period 2020-2100. Moreover, the country-level fixed that were saved in step 2 are constant for any given country across 1990-2019 and can be readily extended to cover 2020-2100. However, the year fixed effects require the additional assumption that all future time trends are identical to those captured by the 2019 fixed effect. In other words, we 'freeze' the world as it was observed in 2019 so that we can subsequently analyze the evolution of world trade *only* subject to changes induced by the demographic changes outlined above.

*Step 4*. Predict bilateral trade for the period 1990-2100. This is done by reinserting the predicted country-year fixed effects from step 3 into the gravity model of step 1, assuming that the estimated country-pair fixed effects remain constant for all country-pair-year triplets:

(6) 
$$\hat{X}_{ij,t} = \exp\left(\hat{\gamma}_{i,t} + \hat{\delta}_{j,t} + \hat{\zeta}_{ij}\right) \times \varepsilon_{ij,t}$$

We follow the literature and estimate Eq. (1) - (6) with Pseudo-Poisson Maximum Likelihood (PPML) to account for the prevalence of zero trade flows and heteroskedasticity in the data (Santos Silva & Tenreyro, 2006; Correia et al., 2020; Frensch et al. 2023). Following the recommendations in Egger & Tarlea (2015), standard errors are clustered at the country-pair level in Eq. (1) and (6) and at the country level in Eq. (2) – (5).

## Data

The trade data are from the USITC Gravity Portal and cover international and intranational trade flows for 255 countries across 170 industries including agriculture, energy/mining, manufacturing and services, and covers the period 1990-2019. An important feature of these data is that they were not estimated with statistical techniques or imputed with a gravity model, which makes this dataset suitable for estimation in our analysis (see Borchert et al., 2021, 2022). The trade data are aggregated at the country-pair-year level because the focus of our analysis is on how demographic transitions affect the volume of bilateral trade flows over the long run, but not – absent any knowledge of future policy responses and technological developments – the composition of sectoral trade or changes in underlying sources of comparative advantage. See Table A1 in Appendix A for a list of the 192 countries in our final dataset.

Demographic composition data are provided by the United Nations (UN) World Population Prospects 2022 (<u>https://population.un.org/wpp/</u>). We use the available data for 1990-2100 from the Medium and No-change projection scenario.<sup>9</sup> For each projection scenario, we use national population in the 15-64-year-old age bracket and total population. Demographic composition (in percentage points) is calculated as the national share of the working-age population minus the world average (see Brakman et al., 2024, for details). For robustness, we additionally control for an index of real total factor productivity (TFP, at constant national prices, 2017=1) with data obtained from the Penn World Table 10.01 (Feenstra et al., 2015).

## Results, step 1 and 2

As explained above, step 1 is to decompose bilateral trade into its country-time and countrypair components and saving the exporter-year, importer-year, and exporter-importer year fixed effects. In step 2, we estimate Eq. (2) and Eq. (3) by regressing the country-year fixed effects on country-time-varying demographic composition under three different scenarios. Table 1, column (1) shows a positive and statistically significant relation between demographic composition and the exporter-year fixed effects. One concern may be that productivity differences across countries and over time may be correlated with national demographic fundamentals. We therefore add TFP as an additional control in column (2). Note that while adding this variable substantially reduces the number of observations due to missing TFP data, the point estimate for exporter demographic composition is virtually the same. The same conclusions generally apply to our findings for the regressions of the importer-year fixed effects in columns (3) and (4).<sup>10</sup>

<sup>&</sup>lt;sup>9</sup> The Medium scenario projects future levels of national fertility, mortality and international migration based on a range of probabilistic methods that take (similar) countries' past experiences into account. In the No-change scenario, fertility and mortality are assumed constant at their 2022 levels for the remainder of the century.

<sup>&</sup>lt;sup>10</sup> In unreported regression results, we find that the point estimates for demographic composition are very stable across the Medium and No-change scenarios. These results are available from the authors upon request.

	(1)	(2)	(3)	(4)
	$\exp[\delta_{i,t}]$	$\exp[\gamma_{i,t}]$	$\exp[\delta_{j,t}]$	$\exp[\gamma_{j,t}]$
DemCom <sub>i,t</sub>	0.0854	0.0847		
	$(0.0135)^{***}$	(0.00993) ***		
TFP <sub>it</sub>		0.994		
0,0		$(0.404)^{*}$		
DemCom <sub>i t</sub>			0.0349	0.0403
			(0.0106)***	(0.0118)***
TFP <sub>it</sub>				0.663
<u>)</u> ,c				$(0.225)^{**}$
Constant	0.484	-0.439	-0.605	-1.173
	$(0.0244)^{***}$	(0.403)	(0.0123)***	(0.225)***
Observations	1,183,204	693,062	1,183,204	696,497
Exporter FE	Yes	Yes	No	No
Importer FE	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 1 Fixed Effect and Demographic Dividend Regressions

Notes: PPML results for Eq. (2) in columns 1-2, and for Eq. (3) in columns 3-4. Robust standard errors in parentheses are clustered by exporter (column 1-2) and importer (column 3-4). *DemCom* is demographic composition based on the Medium projection. *TFP* is total factor productivity in constant prices. \* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001.

## Results, step 3 and 4

In step 3, future levels of demographic composition are used to predict future exporter-year and importer-year fixed effects. These, in turn, are plugged back into Eq. (1) in the fourth and final step to estimate future bilateral trade flows. Figure 2 displays predicted trade for the medium scenario and observed trade in 1990-2019. An OLS regression of observed trade on predicted trade (based on the medium scenario) with no constant yields a point estimate of 1.070055 (s.e. 0.002871) and adjusted R-squared of 0.9215. Based on these goodness of fit metrics, we conclude that our four-step approach provides a reasonable method to examine how demographic dividend shapes bilateral trade.<sup>11</sup>

<sup>&</sup>lt;sup>11</sup> Given the substantial reduction in usable observations and highly similar parameter estimates for demographic composition across columns 1-2 and 3-4, respectively, we ignore regressions that include TFP for the remainder of our analyses.





Notes: Observed and predicted trade based on the medium scenario for 1990-2019. See main text for details.

To effectively characterize the evolution of international trade flows over time for different approaches, we focus on *relative* flows (per cent of world total) for suitable groups of countries. To do so we consistently, we start with the actual observations (in per cent of world total) in 2019 and then add or subtract the respective percentage point change for each approach. Regarding the 'groups of countries', we use the World Bank Regions with one adjustment, see Table 2. The adjustment is that we divide the large East Asia & Pacific region (EAS; 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 (EAS<sup>-</sup>; 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 EAS, 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 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.

Code	Region or Country; most populous nations in 2022
CHN	China
EAS <sup>-</sup>	East Asia & Pacific, excluding China
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

Figure 3 provides regional international trade projections for the eight regions of Table 2 for the period 2020-2100 using the FE approach. Since Europe and Central Asia (ECS) is by far the largest international trade region (43 per cent in 2020) its share is depicted on the righthand scale, whereas all other regions are depicted on the left-hand scale (which is half the size of the right-hand scale). In view of its relative rise in its share of the working-age population (see section 2 and Figure 1), Sub-Saharan Africa (SSF) will see a substantial increase in world trade flows, from 2 per cent in 2020 to 10 per cent in 2100. The mirror image of this is a decline in world trade flows in China (from 11 per cent to 7 per cent) and EAS<sup>-</sup> (from 17 per cent to 12 per cent). For other regions, the net effect over the entire period is modest, with an initial decline in Europe and rises in Latin America and (somewhat later) North America, compensated with reverse movements later on. Using the FE approach, the world trade shares of Europe and North America in the long run remain remarkably stable and the gain of Sub-Saharan Africa (with a rising share in its working-age population) is mainly at the expense of East Asia (with a declining share in working-age population).





Source: created using UN World Population Prospects 2022 (medium scenario), World Development Indicators online, USITC Gravity Portal, and own calculations (FE = Fixed Effect method, see main text); trade is sum of export and import, per cent of world total; see Table 2 for World Bank region abbreviations; ECS projected on right-hand scale, all other variables on left-hand scale; note right-hand scale is twice left-hand scale.

The discussion above as illustrated in Figure 3 is based on the Medium scenario of the 2022 UN World Population Prospects. The UN also evaluates a total of ten different scenarios with different assumptions regarding fertility, mortality, and international migration. Most of the variation is in fertility (high, medium, low, constant as of 2022, and instant replacement as of 2022), with only two variations for mortality (medium and constant as of 2022) and international migration (medium and zero as of 2022). To give an impression of the importance of changes in the demographic dividend using the FE approach of the medium scenario, we compare it to the FE approach if combined with the No Change scenario in which both fertility and mortality are constant as of 2022 combined with the Medium scenario for international migration.

Even with constant fertility and mortality as of 2022 for the remainder of this century, the size and age-distribution of countries will keep evolving, leading to adjustments in demographic composition over time as well and hence to adjustments in the fixed effects.



Figure 4 Comparing Regional Trade Projections; FE versus FE no Change Scenario, 2020-2100

Source: created using UN World Population Prospects 2022 (medium scenario), World Development Indicators online, USITC Gravity Portal, and own calculations (FE = Fixed Effect method and FE no Change method, see main text); trade is sum of export and import, per cent of world total; see Table 2 for World Bank region abbreviations; ECS projected on right-hand scale, all other variables on left-hand scale; note right-hand scale is twice left-hand scale; light (green) indicates higher than FE and dark (orange) indicates lower than FE.

Figure 4 compares the evolution of the trade projections of our eight regions under the FE (medium scenario) approach relative to the FE approach under the No-change scenario. To avoid cluttering the diagram, four regions are depicted in panel *a* and four regions in panel *b*. The graphs are color-coded, where light (green) shading indicates higher shares for FE No Change than for FE and dark (orange) indicates the opposite. The panels show that the No Change scenario would lead to even higher trade shares in Europe (substantial), Latin America (substantial), and North America (modest). This comes mostly at the expense of a relative decline of the share of world trade flows in Sub-Saharan Africa. The other regions (CHN, MEA, SAS, and EAS<sup>-</sup>) have variations during the remainder of the century with limited net changes relative to the FE approach at the end of the century. In other words: assuming that fertility and mortality rates remain constant at their 2022 levels will mostly underestimate the trade shares of Sub-Saharan Africa, and overestimate those of Europe, Latin America and China.

# 4. Approach 2: Income Projections

# Linking demographic composition and income

Until now, our empirical approach has assumed that the share in working-age population is directly linked to international trade by separating the country-year fixed effects into a part directly related to the national demographic composition and a residual. Yet, the share of working-age population inherently also impacts future incomes and thus gives rise to the demographic dividend: as dependency ratios decrease, more labor becomes available to contribute to economic growth and vice-versa.

In the context of a structural gravity framework, changes in income induced by demographic changes ultimately also imply changes in bilateral trade. Therefore, in this section we propose a second approach to evaluate how changes in working-age population may correlate with income and thus future trade flows. Note that it is not our aim to discuss the changes in the structure of trade and predict long-term dynamics of comparative advantage related to demographic changes. Our aim is more modest. We link long term developments in income, caused by demographic dynamics, to global geographical shifts in the pattern of trade.

In contrast to our previous approach, the underlying predictive variable in this section is projected income based on predicted changes in national shares of working-age population. We obtain these predicted incomes from Brakman et al. (2024), who calculate annual national GDP and annual national GDP per working-age person (in 2017 PPP US\$ million) for the countries in our present dataset for the period 2020-2100. Importantly, they distinguish between several projection scenarios, of which we will use the "Base" and the "No demographic dividend" scenarios. Essentially, both scenarios assume that national incomes will continue to grow by the world average of about 2% per year. Of course, various countries currently experience higher or lower growth rates than this world average, and so their growth rates are assumed to eventually (linearly) revert to the world average over a period of 50 years.

Yet, demography itself also affects economic growth. Brakman et al. (2024) find, based on all available data on the share of the working-age population and GDP per working-age person for more than 190 countries and around 30 years, that a 1 percent increase in the share of the working-age population yields about 2.2 percentage points higher income growth. This essentially quantifies the role of the demographic dividend for economic growth, ceteris paribus. Note, that this also distinguishes our second "Income Projections" approach from our "Fixed Effects" approach in section 3, because (higher) yearly growth rates accumulate over time. A priori, therefore, we expect more pronounced outcomes for the "Income Projections" approach than for the "Fixed Effects" approach.

In the "Base" income scenario, Brakman et al. (2024) project future income based on effects stemming from two channels. The first channel is the growth in GDP per person employed (i.e., excluding any effects of the demographic composition) subject to reversion to the world average of around 2%.<sup>12</sup> The second channel is the effect of the demographic dividend itself on income growth. In contrast, the "No demographic dividend" income scenario only considers

<sup>&</sup>lt;sup>12</sup> Note that this is consistent with the estimate of Kotschy & Bloom (2023), who project, without the effects of aging, a growth rate of 2.5 percent annually for OECD countries between 2020 and 2050.

income developments stemming from the first channel; additional income effects of the demographic dividend through the second channel are assumed to be zero. Appendix B provides a more extensive discussion of the underlying methods, assumptions, data, and results for projected incomes for the world economy in 2020-2100.

# Linking income and international trade

A well-known feature of the structural gravity model is that GDP (expenditure and output, respectively) play a fundamental role in determining bilateral trade flows. However, a key challenge in conventional structural gravity models is that exporter and importer incomes are collinear with the exporter-year and importer-year fixed effects, respectively, such that the income elasticities cannot be recovered. Nevertheless, we will show that point estimates for exporter and importer income can in fact be estimated when the multilateral resistance terms are defined as country-period fixed effects that cover (at least) two years. We argue that this is a feasible strategy to obtain point estimates for our main variables of interest – exporter and importer income – while also accounting for time-varying multilateral resistance terms. For our "Income Projections" approach, the main specification is:

(7) 
$$X_{ijt} = \exp[\beta_1 GDP_{it} + \beta_2 GDP_{jt} + GRAV_{ijt}\beta + \delta_{ip} + \gamma_{jp} + \varphi_{ij}] \times \varepsilon_{ijt}.$$

Here, the dependent variable again is exporter (*i*)'s exports to importer (*j*) in year (*t*), which is now regressed on GDP in the exporting and importing countries and *GRAV*, a vector of timevarying trade cost variables including membership in the World Trade Organization (WTO), a Partial Scope Agreement (PSA), Free Trade Agreement (FTA), Economic Integration Agreement (EIA), and Customs Union (CU) to account for heterogeneous trade agreements (Kohl et al., 2016; Baier et al., 2018). The trade agreement data are from Gurevich & Herman (2018).

We further include exporter-period (ip) and importer-period (jp) fixed effects to control for country-time-varying multilateral resistance terms, and the exporter-importer fixed effects for unobserved country-pair characteristics. The distinction between time *t* and period *p* is crucial to obtain parameter estimates for exporter and importer GDP. Of course, variation in exporter and importer GDP is absorbed by the corresponding country-period fixed effects when the period equals one year. Yet, a possible concern is that these fixed effects defined over longer time periods may fail to capture shorter-term variation in unobserved prices. For this reason, we will estimate Eq. (7) with period lengths varying between 1 to 5 years and explore the extent to which our main findings are sensitive to different period lengths. As before, our estimations are performed with PPML and standard errors are clustered by country-pair.

	(1)	(2)	(3)	(4)	(5)
ln(GDP).	(1)	0.783	0.642	0.742	0.567
$\operatorname{III}(\operatorname{ODF})_{i,t}$	-	$(0.11)^{***}$	$(0.28)^{**}$	$(0.742)^{**}$	$(0.14)^{***}$
1 (255)		(0.11)	(0.28)	(0.32)	(0.14)
$\ln(\text{GDP})_{j,t}$	-	1.095	0.897	0.945	0.817
		$(0.14)^{***}$	$(0.41)^{**}$	$(0.48)^{**}$	$(0.21)^{***}$
$WTO_{ij,t}$	-0.214	0.077	0.199	0.224	0.175
	$(0.10)^{**}$	(0.08)	$(0.11)^{*}$	$(0.09)^{**}$	$(0.09)^{*}$
$PSA_{ij,t}$	0.166	0.114	0.079	0.071	0.130
	$(0.07)^{**}$	(0.08)	(0.08)	(0.08)	$(0.08)^{*}$
$FTA_{ij,t}$	0.240	0.250	0.244	0.250	0.261
	$(0.11)^{**}$	$(0.12)^{**}$	$(0.12)^{**}$	$(0.12)^{**}$	$(0.12)^{**}$
$\mathrm{EIA}_{ij,t}$	-0.117	-0.170	-0.185	-0.188	-0.187
·	(0.13)	(0.14)	(0.13)	(0.13)	(0.13)
$\mathrm{CU}_{ij,t}$	0.082	0.086	0.123	0.133	0.138
-	$(0.05)^{*}$	(0.05)	$(0.05)^{**}$	$(0.05)^{***}$	$(0.05)^{***}$
Constant	14.103	-1.572	1.081	-0.168	2.369
	$(0.10)^{***}$	(1.61)	(5.60)	(6.46)	(2.79)
Fixed Effects					
Observations	888,005	888,005	888,005	888,005	888,005
Exporter-Period (ip)	Yes	Yes	Yes	Yes	Yes
Importer-Period (jp)	Yes	Yes	Yes	Yes	Yes
Exporter-Importer ( <i>ij</i> )	Yes	Yes	Yes	Yes	Yes
Period ( <i>p</i> )	1 Year	2 Years	3 Years	4 Years	5 Years

Table 3 Gravity estimates for 1990-2019

*Notes*: PPML estimates. Dependent variable is trade. Standard errors clustered by country-pair in parentheses. \* p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01.

Table 3 presents our estimates for Eq. 7. Column (1) yields conventional parameter estimates when annual time-varying multilateral resistance terms are incorporated; estimates for exporter and importer GDP are not obtained due to collinearity. Column (2) shows that if we allow for multilateral resistance terms to vary over 2-year periods, we are also able to estimate elasticities for exporter and importer GDP. Sensitivity analyses, columns 3-5 show that increasing the length of these periods to 3-5 years provides comparable estimates. Our preferred baseline specification in Table 3 is column (2), where we use 2-year periods to control for the multilateral resistance terms. After all, the shorter the period, the more precisely our model is expected to account for short-term time-varying fluctuations in unobserved prices.

	(1)	(2)	(3)	(4)
Predicted trade	1.011	1.009	1.007	1.009
	$(0.00)^{***}$	$(0.00)^{***}$	$(0.00)^{***}$	$(0.00)^{***}$
Predicted mean	1,849.943	1,849.943	1,849.943	1,849.943
Predicted std. dev.	109,111.7	108,049.6	107,569.7	108,112.6
Period ( <i>p</i> )	2 Years	3 Years	4 Years	5 Years
$\mathbb{R}^2$	0.9951692	0.9720386	0.9605741	0.9736942
Observations	888,005	888,005	888,005	888,005

Table 4 Model fit: In-sample predictions with different periods for multilateral resistance terms

Notes: OLS estimates. Dependent variable is observed trade for 1990-2019. Independent variable is predicted trade based on Eq. (7). Standard errors in parentheses. \* p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01. The sample mean is 1,849.943 and standard deviation 110,548.9.

Our preference for the 2-year period is further corroborated in Table 4, where we regress observed trade on in-sample predicted trade. Column (1) shows the regression results when predicted trade is obtained from Eq. (7) with the period for the multilateral resistance terms set to 2 years. We observe a positive and statistically significant correlation between the predicted and observed values of trade close to unity. Moreover, the predicted and actual means are equal and the standard deviations very similar. As an overall measure of model fit, the  $R^2$  is above 0.995. Similar observations hold if we lengthen the period of the multilateral resistance terms to 3 years (column 2), 4 years (column 3), and 5 years (column 4). Nevertheless, the highest  $R^2$  obtained with the 2-year period is additional motivation for the use of 2 years as the default period in subsequent analyses.

# Procedure

How will demographic dynamics shape the pattern of international trade flows in the 21<sup>st</sup> century? We make out-of-sample predictions for bilateral trade over the period 2020-2100, using the projected incomes data for the "Base" and "No demographic dividend" projections from Brakman et al. (2024). We predict out-of-sample (i.e., 2020-2100) bilateral trade flows as follows:

*Step 1*. We estimate Eq. (7) on observed trade, exporter and importer income and the trade policy variables with p = 2 years in the multilateral resistance terms and save the fixed effects.

*Step 2*. For each country-pair, we calculate the 2-year, 3-year, and 5-year moving averages of the fixed effects for the years 1990-2019.

*Step 3*. For each country-pair, all fixed effects for the years 2020-2100 are set equal to the 2-year, 3-year, or 5-year moving averages that were calculated for the year 2019. In addition, all future time-varying policy variables are set equal to their 2019 values. The underlying assumption is that we thereby 'freeze' the world as it was in 2019, so that we can analyze changes in international trade exclusively based on projected exporter and importer income levels.

	(1)	(2)	(3)
Predicted trade, Base scenario	1.093	1.090	1.080
	$(0.00)^{***}$	$(0.00)^{***}$	$(0.00)^{***}$
Period (p)	2 Years	2 Years	2 Years
Moving Average of MRTs	2 Years	3 Years	5 Years
$\mathbb{R}^2$	0.9893484	0.9785179	0.9493322
Observations	754,141	754,141	754,141

Table 5 Model fit: In-sample predictions with moving averages of multilateral resistance terms

Notes: OLS estimates. Dependent variable is observed trade for 1990-2019. Independent variable is predicted trade based on Eq. (7) and moving averages of MRTs. Standard errors in parentheses. \* p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01.

Table 5 reports the correlation between observed and predicted trade, when trade is predicted based on 2-, 3-, or 5-year moving averages of the multilateral resistance terms. As before in Table 4, notice that the correlation is statistically significant, close to unity, and that the model fit is very high regardless of whether 2-year (column 1), 3-year (column 2), or 5-year (column 3) moving averages of the MRTs are used. Nevertheless, the best fit is obtained with 2-year moving averages with an  $R^2$  close to 0.99. Therefore, every country-pair's 2020-2100 exporter-year and importer-year (and dyad) fixed effects will equal the 2018-2019 average fixed effects obtained from estimating Eq. (7).

*Step 4*. Now that we have estimated parameters for Eq. (7) from Step 1 and determined the preferred values for all future variants of fixed effects and trade policy controls, we plug in projected GDP for the Base (or No demographic dividend) scenarios to predict out-of-sample values of bilateral trade for 2020-2100. In what follows, we explore how the center of gravity of world trade evolves over time for these two income scenarios.

# Results

Figure 5 provides regional international trade projections for the eight regions of Table 2 for the period 2020-2100 using the Base income scenario. Since Europe and Central Asia (ECS) is by far the largest international trade region (42 per cent in 2020) its share is depicted on the right-hand scale, whereas all other regions are depicted on the left-hand scale (which is half the size of the right-hand scale). A few observations for Figure 5 stand out. First, the rise and fall of China is remarkable, as its global trade share first rises from 11 per cent in 2020 to a peak of 16 per cent in 2049, followed by a decline to 8 per cent in 2100. Second, the declining trade shares in North America and particularly Europe are noteworthy. The trade share of North America declines from 15 per cent in 2020 to 10 per cent in 2100. The trade share for Europe & Central Asia declines from 42 per cent in 2020 to 13 percent in 2100. Third, and most importantly, the trade shares of South Asia (SAS), Middle East and North Africa (MEA), and Sub-Saharan Africa (SSF) will rise substantially during the remainder of this century, namely from 3 per cent in 2020 to 13 per cent in 2100 for SAS, from 5 per cent in 2020 to 13 per cent in 2100 for MEA, and from 2 per cent in 2020 to an astounding 27 per cent in 2100 for SSF. Obviously, the realization of these trends driven by demographic forces depend on many other factors, such as trade agreements, institutional stability, and how countries respond to demographic changes. Nonetheless, our analysis clearly indicates that substantial world trade shifts can be expected based on demographic adjustments.



Figure 5 Regional Trade Projections Base Scenario; per cent of world total, 2020-2100

Source: created using UN World Population Prospects 2022 (medium scenario), World Development Indicators online, USITC Gravity Portal, and own calculations (Base method, see main text); trade is sum of export and import, per cent of world total; see Table 2 for World Bank region abbreviations; ECS projected on right-hand scale, all other variables on left-hand scale; note right-hand scale is twice left-hand scale.

To illustrate the importance of our estimated impact of demographic dividend on income levels via the estimated growth coefficient (0.218 percentage points per year per one per cent increase in the share of working-age population, see Table B 1) we compare the outcome of the Base income scenario with what happens if we completely ignore this effect, which we label the No Dem Div (no demographic dividend) scenario in Figure 6.

Figure 6 Comparing Regional Trade Projections; Base versus no Dem Div Scenario, 2020-2100



Source: created using UN World Population Prospects 2022 (medium scenario), World Development Indicators online, USITC Gravity Portal, and own calculations (Base method and no Demographic Dividend scenario, see main text); trade is sum of export and import, per cent of world total; see Table 2 for World Bank region abbreviations; ECS projected on right-hand scale, all other variables on left-hand scale; note right-hand scale is twice left-hand scale; light (green) indicates higher than Base and dark (orange) indicates lower than Base.

To avoid cluttering Figure 6, four regions are depicted in panel *a* and four regions are depicted in panel *b*. The graphs are color-coded, where light (green) shading indicates higher shares for the No Change scenario than for the Base income scenario and dark (orange) indicates the opposite. Ignoring the demographic dividend effect leads to substantially higher world trade shares for Europe, China, North America, and East Asia. This comes at the expense of the emerging and developing markets in Sub-Saharan Africa, South Asia (India), and Middle East and North Africa. Ignoring demographic dividend effects is therefore likely to grossly overestimate the importance of the current international trade centers such as China, Europe, and North America.

# 5. Discussion and Conclusion

In this century the geographical distribution of the global population will change fundamentally. Around 2010 the world working-age population peaked and has declined ever since. This trend, however, disguises important differences across countries. 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 between countries will change. In aging countries, the dependency ratios will increase, whereas in fertile countries the dependency ratios will decrease. The macro-economic consequences are extensively studied. The trade consequences, however, have received less attention. We focus on the income and trade consequences of long-term demographic changes that will take place in the next 80 years.

We use the gravity model of trade to predict the distribution of world trade across geographic regions for the remainder of this century. We use two complementary approaches. First, our Fixed Effects (FE) approach identifies how demographic composition, i.e., shares in working-age population, explain country-year fixed effects. The UN demographic projections are then used to predict demography-related changes in trade across countries. Second, our "Income Approach" is based on directly estimating the impact of demographic changes on income, the so-called demographic dividend. The demographic dividend's impact on income is added to long-run trend developments in income. Together, these income projections are used to estimate the impact on world trade flows in the Base income scenario. Figure 7 compares the outcome of these two approaches using two panels in a similar way as Figure 4 and Figure 6. The graphs are again color-coded, where light (green) shading indicates higher shares for the FE approach (medium scenario) than for the Incomes Approach (base scenario) and dark (orange) indicates the opposite.



Figure 7 Comparing Regional Trade Projections; Base versus FE scenario, 2020-2100

Source: created using UN World Population Prospects 2022 (medium scenario), World Development Indicators online, USITC Gravity Portal, and own calculations (Base scenario in Income approach and Medium scenario in FE approach, see main text); trade is sum of export and import, per cent of world total; see Table 2 for World Bank region abbreviations; ECS projected on right-hand scale, all other variables on left-hand scale; note right-hand scale is twice left-hand scale; light (green) indicates higher than Base and dark (orange) indicates lower than Base.

The long-run differences in these approaches are large, with the effects of the Base scenario compared to the FE approach (medium scenario) being the largest. This is expected because growth rates accumulate. Using the FE approach the world trade share for Europe remains almost constant, while it declines enormously using the Base scenario (from 42 to 13 per cent). The difference at the end of the century is about 29 percentage points. Similarly for North America, where the FE method leads to a substantially higher trade share outcome than the Base method (about 6 percentage points). The regions most affected in the opposite direction at the end of the century for world trade shares are Sub-Saharan Africa (17 percentage points lower for FE than for Base), South Asia (9 percentage points lower for FE than for Base), and Middle East and North Africa (8 percentage points lower for FE than for Base). The impact for the other two regions (LCN, and EAS<sup>-</sup>) at the end of the century is less pronounced (less than 1.2 percentage points). China stands out in the sense that the effects of the demographic drag for this country is most pronounced around 2060, the relative importance of the demographic drag becomes smaller at the end of the century.

In general, and despite different outcomes of different scenarios and approaches, one conclusion stands out. Compared to the current situation, North America and Europe will no longer be the center of global trade in 2100 as their aging populations severely impact their relative trading activities. The trade share of South Asia and Sub-Saharan Africa will rise substantially during the remainder of this century. The trade effects of the demographic drag in China will be most pronounced around 2060. Overall, our results point towards the understudied, yet important role of past and future demographic developments in generating demographic dividends that shape world trade.

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# Appendix A: Regional Classification

Table A 1 ISO3 Country Codes in Data Set

<b>Regional Classification</b>	ISO3 Country Code					
CHN (China)	CHN					
EAS <sup>-</sup> (East Asia & Pacific)	AUS	IDN	LAO	MYS	PNG	TON
	BRN	JPN	MAC	NRU	SGP	TUV
	FJI	KHM	MHL	NZL	SLB	VNM
	FSM	KIR	MMR	PHL	THA	VUT
	HKG	KOR	MNG	PLW	TLS	WSM
ECS (Europe & Central Asia)	ALB	СҮР	GEO	LTU	POL	TJK
	ARM	CZE	GRC	LUX	PRT	ТКМ
	AUT	DEU	HRV	LVA	ROU	TUR
	AZE	DNK	HUN	MDA	RUS	UKR
	BEL	ESP	IRL	MKD	SMR	UZB
	BGR	EST	ISL	MLT	SRB	
	BIH	FIN	ITA	MNE	SVK	
	BLR	FRA	KAZ	NLD	SVN	
	CHE	GBR	KGZ	NOR	SWE	
LCN (Latin America & Caribbean)	ABW	BRB	DOM	JAM	PRI	URY
	ARG	CHL	ECU	KNA	PRY	VCT
	ATG	COL	GRD	LCA	SLV	
	BHS	CRI	GTM	MEX	SUR	
	BLZ	CUW	GUY	NIC	SXM	
	BOL	CYM	HND	PAN	TCA	
	BRA	DMA	HTI	PER	TTO	
MEA (Middle East & North Africa)	ARE	DZA	IRQ	KWT	MAR	SAU
	BHR	EGY	ISR	LBN	OMN	TUN
	DJI	IRN	JOR	LBY	QAT	
NAC (North America)	BMU	CAN	USA			
SAS (South Asia)	AFG	BTN	LKA	NPL		
	BGD	IND	MDV	PAK		
SSF (Sub-Saharan Africa)	AGO	COD	GMB	MOZ	SDN	TGO
	BDI	COG	GNB	MRT	SEN	TZA
	BEN	COM	GNQ	MUS	SLE	UGA
	BFA	CPV	KEN	MWI	SOM	ZAF
	BWA	ETH	LBR	NAM	STP	ZMB
	CAF	GAB	LSO	NER	SWZ	ZWE
	CIV	GHA	MDG	NGA	SYC	
	CMR	GIN	MLI	RWA	TCD	

# Appendix B: Income Projections<sup>13</sup>

What is the relationship between the share in working-age population and economic growth? Figure B 1 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. Growth rates vary between -2.6 per cent for Sint Maarten (Dutch section) and 9.4 per cent for Equatorial Guinea. As Equatorial Guinea can be viewed as an exception (see below), the figure only shows the range from -2.6 to 8.2 (China).

Figure B 1 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 B 2 Share in Demographic Composition and Income per Capita Growth Trend, 1990-2022



Source: created using UN World Population Prospects 2022 (medium scenario) and World Development Indicators online data; GDP per capita PPP (in constant 2017 int. \$) growth trend (%) 1990-2022 (vertical axis) and average share of working-age population corrected for the world average 1991-2021 (%, horizontal axis); bubbles proportional to population (2022); CHN = China; IND = India; COD = Congo DR; KOR = South Korea.

<sup>&</sup>lt;sup>13</sup> This section is based on Brakman et al. (2024).

To determine the relationship between (trend) economic growth and demographic composition, we calculate the average share in working-age population in the period 1991-2021 for the countries depicted in Figure B 1. This relationship is illustrated in Figure B 2 using a bubble diagram, where the bubbles are proportional to population. The slope of the relationship is positive.

Variant	coefficient	st error	t value	$\overline{R}^2$	Obs			
I Baseline; GDP per capita growth trend 1990-2022, all observations								
Share in working-age								
population	0.218	0.0043	50.84	0.249	194			
II Robustness and alternative s	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 <sup>**</sup>	0.221	0.0043	50.99	0.253	179			
c. GDP per person employed <sup>#</sup>	0.210	0.0047	45.27	0.208	175			
d. GDP per working age pop <sup>##</sup>	0.223	0.0266	8.36	0.267	194			
e. Annual dev world growth <sup>*#</sup>	0.228	0.0279	8.17	0.096	5901			

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

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; Share in working-age population 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.

<sup>#</sup> GDP per person employed growth trend 1991-2022, all observations.

## GDP per working age population growth trend 1990-2021, all observations.

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

As Table B 1 shows, on average, a one per cent higher share in working-age population leads to 0.218 percentage points higher income per capita trend growth rate, see the first row in Table B 1. It explains about 25 per cent of the variance in (trend) growth rates. Moreover, the relationship is highly significant. Note, that Table B 1 also presents some sensitivity estimates, namely: (a) excluding countries with a deviating trend (more than 3 percentage point difference with the overall trend), (b) excluding countries that have a volatile growth rate (st.dev. more than twice the mean), (c) using GDP per person employed (which requires employment data and reduces the number of observations), (d) using GDP per working age population (available for all countries and avoiding some endogeneity concerns), and (e) finally a specification that does not rely on trend growth rates but annual growth rates. The relation between demographic composition and growth rates is hardly affected by any of these sensitivity estimates. In short, the share in working-age population and income growth are strongly related to each other and a quantification of the demographic dividend itself.

Using this estimated effect of the share in working-age population on economic growth, we develop and briefly describe a base scenario and alternative specifications of the expected aggregate impact of demographic composition on income levels for 193 countries during the remainder of the 21<sup>st</sup> century.<sup>14</sup> To characterize the evolution over time of income, population, and trade, we use the World Bank Regions with one adjustment, see Table 2 in the main text.

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 before, 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.

Figure B 3 Regional Income Projections, Base Scenario; per cent of world total, 2022-2100



Source: created using UN World Population Prospects 2022 (medium scenario), 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.

Based on the baseline estimates, we take the coefficient to be 0.218 percentage points per one percentage point share in working-age population (minus the world average). We assume that it is unlikely that countries remain growth 'outliers' for the rest of the century and at some point return to 'normal' circumstances. Where normal is the growth rate of the world. We take this initial growth at the country level for the period 2010-2022, adjusted for the share in working-age population and compare this to the world growth rate. This allows us to identify countries that grow faster/slower than the world. We can experiment how fast the mean reversal of a country to the world average occurs. In the base scenario we assume it takes 50 years to return to the world average of 2 per cent per year.<sup>15</sup> This 'underlying' mean reversal growth rate per year is then corrected for the demographic dividend of that year to determine the growth rate

<sup>&</sup>lt;sup>14</sup> One country (West Bank and Gaza) is now excluded, as UN WPP 2022 does not provide data.

<sup>&</sup>lt;sup>15</sup> The minimum initial growth rate is -2 per cent per year and the maximum is +8 per cent.

of income per working age population.<sup>16</sup> This is multiplied with the projected size of the working-age population to determine total income in each country in a year.

Figure B 3 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 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 2<sup>nd</sup> half of the century. The share of the Middle East & North Africa is steady initially and rises also in the 2<sup>nd</sup> 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 2<sup>nd</sup> 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).

Table B 2 Base and Alternative	Income Projection Scenarios
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		Mean reversion		Dem d	ividend	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	country	country	country	country	country	WB region
	2010-2022	2010-2022	2010-2022	2010-2022	2010-2022	1990-2022	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.

<sup>&</sup>lt;sup>16</sup> Based on evidence for the 1990-2022 period, the minimum income per working age population is 5 per cent of the population-weighted world average and the maximum is 700 per cent; due to the growth of Sub-Saharan Africa, the former restriction is not effective, while the latter is for some Middle East countries (see below).

Figure B 4 Regional Income, Base and No Demographic Dividend; per cent of world total, 2022-2100



Source: created using UN World Population Prospects 2022 (medium scenario), 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.

We now introduce two possible income scenarios as summarized in Table B 2. 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 deviation, 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.

The evolution of income shares compared to the Base scenario is shown in Figure B 4, 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.