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POPULATION AGING AND ECONOMIC GROWTH: FROM DEMOGRAPHIC DIVIDEND TO DEMOGRAPHIC DRAG?

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ABSTRACT

This paper examines the extent to which changes in working-age shares associated with population aging might slow economic growth in upcoming years. We first analyze the economic effects of changing working-age shares in a standard empirical growth model using country panel data from 1950–2015. We then juxtapose the estimates with predicted shifts in population age structure to project economic growth in 2020–2050. Our results indicate that population aging will slow economic growth throughout much of the world. Expansions of labor supply due to improvements in functional capacity among older people can cushion much of this demographic drag.

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1 Introduction

Population growth and age structure change dramatically as countries transition from high to low rates of mortality and fertility. These changes present an opportunity for societies to substantially raise living standards. Initially, mortality declines faster than fertility, producing a bulge of young dependents that tends to depress economic growth. However, once fertility decline accelerates and this bulge of young people progresses into working ages, economic growth can take off. The growing ratio of working-age people in the total population raises labor input; promotes productivity; and frees resources for saving, educational attainment, and innovation.

Bloom et al. (2003) label this growth take-off the *demographic dividend*. Countries harness it if they create a socioeconomic environment that beneficially employs their labor potential. The dividend dissipates once countries complete the demographic transition. However, as fertility remains below long-run replacement rates in many countries and large cohorts progress to older ages, population age structures fail to stabilize in the foreseeable future. This threatens to turn the demographic dividend into a *demographic drag*. How these powerful and unprecedented population dynamics will affect economic growth remains unclear.

In this paper, we investigate the likely consequences of contracting working-age shares—the proportion of the population that is of working age—for growth of income per capita in subsequent years. To this end, we examine the economic effects of population age structure through the lens of a standard empirical growth model that incorporates population age structure. Within this framework, we test implicit assumptions underlying research on the demographic dividend and shed light on how informative this abstraction is for past and future implications of population aging.

An important novelty of our approach is the distinction among different conceptualizations of population age structure. Conventional measures of age structure define working ages *retrospectively* based on years lived since birth (that is, based on chronological age). They classify entry into old age at the same age for different generations. However, this classification ignores changes in age patterns of health resulting from reductions in mortality and disability and thus misses heterogeneity in people's age-specific functional capacities across countries and over time (Fries 1980; Fries et al. 2011; Cutler et al. 2006, 2014). Here we contrast this retrospective perspective with a new *prospective* (or functional) concept of working ages developed by Sanderson and Scherbov (2005, 2007, 2010, 2019). They define entry into old age with a variable age threshold that depends on expected years of life ahead and that correlates, as we will show, with functional capacity in terms of mortality, disability, body strength, and cognitive capacity at the macro level. By characterizing labor potential under fixed and evolving functional capacities, retrospective and prospective measures indicate bounds for how shrinking working-age shares might affect economic growth in the years ahead.

Based on this distinction, we answer two research questions. Will foreseeable changes in the working-age share slow economic growth? And to what extent does the effect depend on variation in functional capacities as captured by a prospective concept of working ages?

The analysis proceeds in two steps. In the first step, we develop an empirical growth model that uses an accounting identity to describe the effects of population age structure on economic growth, which we then fit to country panel data from 1950–2015. In the second step, we combine the estimated parameters with demographic predictions to estimate the implications of population aging for projected growth of income per capita in 2020–2050. Our projections contrast scenarios for retrospective and prospective measures of working-age shares with a counterfactual scenario in which population age structure is fixed. Quantitative differences among these scenarios indicate a range for the effect of changes in working-age shares on the pace of economic growth; moreover, they allow us to gauge the extent to which expansions in labor supply associated with improvements in functional capacity can counteract this effect.

We fit our empirical model for 145 countries observed in five-year intervals throughout 1950–2015. The specifications leverage within-country variation in working-age shares in a dynamic panel that allows for economic convergence and controls for physical and human capital, quality of economic institutions, population health, and growth trends. Identifying the effects of working-age shares on economic growth is challenging because variation in population age structure may be endogenous and effects need not be uniform across countries and over time. We address these challenges in four ways. First, we verify that the estimates match the parameter constraints our model imposes on the causal effects of population age structure on economic growth. Second, we deal with reverse causality and other confounding factors by instrumenting changes in working-age shares with the predicted inflow of young people into working ages based on cohort sizes in preceding periods. Third, we demonstrate the results' stability with respect to sample composition and observation period. Fourth, we show that the results are robust to measuring population age structure with workforce data, estimating alternative models and specifications with richer instrument sets, adding control variables, and calibrating selected parameters.

The model successfully reproduces patterns of economic growth observed in the data. Our estimates match parameter restrictions on the economic effects of population age structure, conform with stylized facts of the growth literature, and closely replicate per capita income levels in within-sample projections. Specifically, the results document that shifts in population age structure significantly affect economic growth. A 1 percent increase in the working-age share (0.5 percentage points on average) raises income per capita by about 1 percent. In addition, a 1 percent greater working-age share amplifies growth by 0.1–0.4 percent in subsequent periods. These patterns are stable across specifications and over time and obtain for both Organisation of Economic Co-operation and Development (OECD) and non-OECD countries.

We combine the empirical estimates with demographic predictions and project economic growth in 2020–2050. These projections show that future growth depends not only on how population age structures change as cohorts pass through the age distribution but also on how labor potential changes with improvements in functional capacity as longevity rises. Contractions in working-age shares will slow growth; however, gains in functional capacity thanks to higher life expectancy can cushion perhaps half of this slowdown. Without population aging, income per capita in OECD countries is projected to grow on average by 2.5 percent annually between 2020 and 2050. With population aging, growth is projected to slow by 0.8 percentage points if we measure working ages retrospectively but only by 0.4 percentage points if we measure working ages prospectively. These values define bounds for the average demographic drag across OECD countries with and without the potential gains from expansions in labor supply due to improved functional capacities. Whether or not these gains can be realized depends on labor markets and institutions. In contrast, population aging is projected to spur average growth of income per capita in non-OECD countries. When we focus on the country level, we find pronounced differences in growth that depend on heterogeneity in the pace and scale of demographic change.

Caution in interpreting projected economic growth is necessary. How much economies will grow depends on factors that are not fully foreseeable today such as technological progress. Our projections approximate growth processes that are exogenous to the model by extrapolating trends in the data. If our extrapolations systematically overstate or understate actual growth, projected income per capita *levels* will be inaccurate. However, the purpose of this exercise is *not* to accurately predict these levels. Instead, we seek to quantify the contribution of changes in population age structure to economic growth by comparing alternative projections across which only population age structure is varied and everything else is held constant. As the exogenous growth trends enter each projection, they do not change the *differences* between projections. Hence, the projected effects of changes in working-age shares on growth we derive from these differences are insensitive to the exact specification of exogenous growth processes, which is a key feature of our methodology.

The results offer novel insights into the economic ramifications of population aging in later stages of the demographic transition. Previous work documents that a falling youth share in the population creates the opportunity for a demographic dividend (Bloom and Freeman 1988; Bloom and Williamson 1998; Bloom and Canning 2000, 2008; Bloom et al. 2003; Mason 2007; Bloom et al. 2009). However, the implications of a rising old-age population are still debated. This debate ranges from pessimistic predictions about inflationary pressure and economic stagnation due to shrinking populations (Goodhart and Pradhan 2020; Jones 2022) to modest negative effects of population aging on living standards (for example, National Research Council 2012, in the context of the United States of America). Some contributions even argue that capital deepening and automation may (at least temporarily) promote growth (Cutler et al. 1990; Acemoglu and Restrepo 2017).

Recent evidence finds negative economic effects of population aging in simulations or samples that are restricted to few countries, often the United States (Sheiner 2014; Cooley and Henriksen 2018; Aksoy et al. 2019; Gagnon et al. 2021; Maestas et al. 2023). Here we examine the economic effects of population aging globally, using a framework that encompasses previous models designed to analyze the demographic dividend (Kelley and Schmidt 2005; Crespo Cuaresma et al. 2014; Lutz et al. 2019; Kotschy et al. 2020). In doing so, we contribute a new stylized fact to this literature by demonstrating that a demographic drag will be the norm as countries advance through the later stages of the demographic transition. The results document that population aging will slow economic growth in 70 countries of our sample—virtually all those whose working-age shares contract in the near future.

Our findings for prospective aging also add a new perspective on the quantitative importance of population aging for economic growth. For example, Maestas et al. (2023) predict 0.6 percentage points lower income per capita growth in 2020–2030 using variation in the (retrospective) population share age 60 and older across U.S. states (Aksoy et al. 2019 report a comparable estimate based on vector autoregression for a subsample of OECD countries). Our projections predict a similar slowdown of 0.54 percentage points in this period for retrospective aging (upper bound) but only a 0.26 percentage point reduction for prospective aging (lower bound). Hence, the economic consequences of population aging will likely be less severe than retrospective measures of aging suggest. The consideration of both retrospective and prospective aging will become ever more crucial for economic analyses as people live longer and healthier lives (Lutz et al. 2008).

Finally, the evidence highlights that, over and above improved welfare, there are sizable economic gains due to increased population health and longevity. In developed countries, life expectancy and functional capacity improve predominantly in adulthood and especially after 65 (Eggleston and Fuchs 2012). These improvements shape how people learn, work, and save over the life course and thus promote income growth and wellbeing (Bloom et al. 2007; Cervellati and Sunde 2013; Sánchez-Romero et al. 2016; Hansen and Strulik 2017; Kotschy 2021; Scott 2021a,b,c; Dalgaard et al. 2022a). Our results demonstrate that gains in age-specific functional capacities thanks to changing age patterns of health can help counteract negative consequences of population aging for growth by enabling people to expand economic activity into older ages. The projections for retrospective and prospective aging constitute bounding cases that identify the economic gains associated with such expansions. Whereas retrospective working-age shares describe the case in which economic activity stays constant, prospective working-age shares describe the case in which economic activity expands with longevity. Whether countries can harness these gains will depend on people's preferences for retirement and the extent to which labor markets and health and social policy facilitate retaining workers productively in the workforce.

2 Conceptualization of Population Age Structure

To gauge the plausible consequences of population aging for economic growth, we distinguish between retrospective and prospective conceptualizations of population age structure. The two concepts differ in how they define the correspondence between age and functional capacity.

Retrospective (or chronological) measures of population age structure determine entry into old age by counting people's years lived since birth and comparing them with a *fixed* threshold. While these measures are easy to compute, they assume populations' age-specific functional capacities are stable across countries and over time. Consider an old-age ratio that calculates the proportion of people age 65 and older relative to the working-age population 20–64. Using this metric to compare age structure over time posits that the average 65-year-old in 2020 is similarly functional as a 65-year-old in 1970 or 2050 (conditional on other determinants of productivity such as human capital and technology). However, gains in life expectancy indicate that functional capacity is improving over time—a fact colloquially summarized by "70 is the new 60." In the United States, for example, life expectancy at age 65 rose from 15 to 19 years in 1970–2020 and is projected to reach 23 years by 2050 (United Nations 2022). If we believe 65 is the right age to categorize an average U.S. citizen in 1970 as old, classifying 65-year-olds in 2050 as old will inflate the measured old-age population and deflate the measured working-age population.

Prospective measures of population age structure evolve with functional capacity to facilitate comparisons across countries and over time. These measures, which were pioneered by Ryder (1975) and generalized by Sanderson and Scherbov (2005, 2007, 2010, 2019), determine entry into old age with a *variable* prospective old-age threshold (POAT) that changes with people's remaining life expectancy and that can exceed or fall short of 65 years. Sanderson and Scherbov define this threshold as the age at which remaining life expectancy falls below 15 years to match life expectancy at age 65 in low-mortality countries around 1970 (Sanderson et al. 2017). Under this definition, the prospective old-age threshold in the United States was about 65 in 1970 and 72 before the Covid-19 pandemic struck in 2020, and it is predicted to reach 76 by 2050 (Lutz et al. 2018). Analogous to the retrospective metric, one can construct a prospective old-age ratio that calculates the proportion of people equal to or older than the prospective old-age threshold relative to the working-age population 20–POAT. By relying on an evolving age threshold, this ratio balances intergenerational and cross-country differences among old-age and working-age populations.

Validity of prospective measures requires that changes in the old-age threshold derived from remaining life expectancy reflect improvements in age-specific functional capacity. Our analysis relies on this threshold rather than other potential proxies of age-specific functional capacity, such as physiological aging (Dalgaard et al. 2022b), (upper) body strength (Bohannon 2019), or cognitive capacity (Skirbekk et al. 2012), because the necessary data are readily available for past and future

Table 1: Prospective old-age threshold and functional capacity

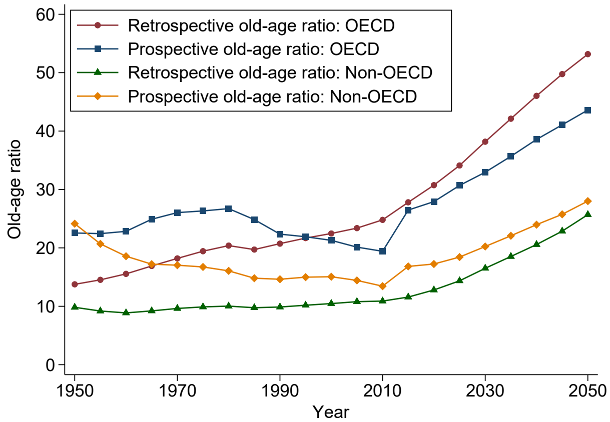
Dependent variable: prospective old-age threshold	Proxy for functional capacity			
	Life expectancy at age 65 (1)	Average deficits per person aged 50–79 (2)	Maximum grip strength (3)	Immediate word recall (4)
Regression coefficient	0.88***	−122.01***	0.13**	0.51**
	(0.04)	(28.94)	(0.06)	(0.23)
R^2	0.96	0.96	1.00	1.00
Within R^2	0.48	0.05	0.04	0.09
Countries	183	181	22	22
Observations	3842	1086	76	79

Note: This table shows correlations between the prospective old-age threshold (defined as the age at which remaining life expectancy falls below 15 years) and proxies for functional capacity in terms of mortality (1), physiological aging (2), body strength (3), and cognitive capacity (4). Data on the prospective old-age threshold are obtained from Lutz et al. (2018), data on life expectancy are from the World Population Prospects (United Nations 2022), data on physiological aging stem from Dalgaard et al. (2022c), and data on physical prowess and cognitive capacity are aggregated from the English Longitudinal Survey of Ageing (Banks et al. 2021), the Health and Retirement Survey (HRS 2022), and the Survey of Health, Ageing and Retirement in Europe (Börsch-Supan 2022). Measures of maximum grip strength and immediate word recall are age-corrected measures to account for country-specific quadratic age trends in the population age 50 and older. All regressions include country fixed and time effects. Standard errors are clustered at the country level and reported in parentheses. Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

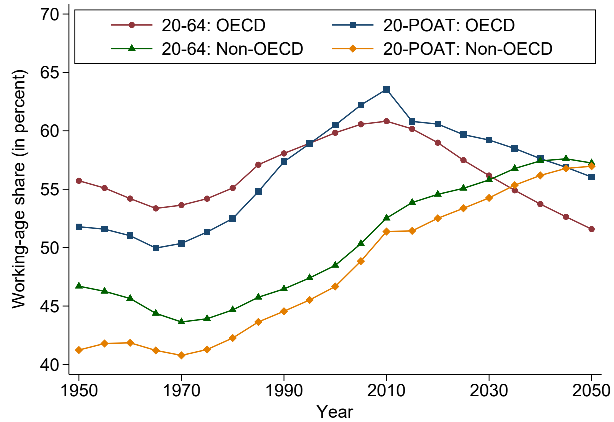
periods across many countries. Nevertheless, we can test the extent to which the prospective old-age threshold correlates with functional capacity in these dimensions for the countries and periods for which data are available. To this end, we regress the prospective old-age threshold on life expectancy at age 65, average deficits per person aged 50–79, and maximum grip strength and immediate word recall in the population age 50 and older, while controlling for country fixed and time effects (Table 1). The prospective old-age threshold significantly correlates with all proxies of functional capacity. A one-year increase in life expectancy at 65 is associated with a 0.9-year rise in the threshold. Likewise, a one-standard deviation increase in maximum grip strength (2.11 kilograms) is associated with a 0.27-year rise in the threshold, and a one-standard deviation increase in immediate word recall (0.5 words more recalled out of a list of 10) is associated with a 0.25-year rise. Conversely, a one-standard deviation decrease in average deficits per person 50–79 (about 0.008 deficits per person) is associated with a 1.08-year rise in the threshold.

Retrospective and prospective measures of population age structure can produce qualitatively and quantitatively different demographic trends. Figure 1 contrasts retrospective and prospective old-age ratios and working-age shares for OECD and non-OECD countries between 1950 and 2050. Panel (a) displays an upward trend in old-age ratios since 2010 reflecting population aging in most countries around the world. However, two striking features are evident. First, OECD countries look younger when we employ prospective instead of retrospective measures, whereas non-OECD countries look older. Hence, the retrospective measures conceal considerable variation in functional capacity. Second, the retrospective old-age ratio trends almost monotonically upward, whereas the prospective ratio reveals prolonged phases in which populations grow younger rather than older. Such patterns emerge when improvements in life expectancy outpace population aging.

Panel (b) depicts working-age shares for OECD and non-OECD countries, which differ appreciably depending on how working ages are defined. While prospective working-age shares



(a) Old-age ratios



(b) Working-age shares

Figure 1: Differences between retrospective and prospective measures of population age structure

Note: This figure shows trends in old-age ratios and working-age shares for OECD and non-OECD countries. The figure compares trends for a retrospective definition of working ages (20–64) and a prospective one (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years. Retrospective old-age ratios refer to the quotient of people age 65 and older relative to those aged 20–64. Prospective old-age ratios instead refer to the quotient of people equal to or above the POAT relative to those aged 20–POAT. Working-age shares refer to the proportion of people in the total population that are of working age. Data source: Lutz et al. (2018).

exceed retrospective working-age shares in OECD countries after 1995, they fall short of them in non-OECD countries throughout all periods. After 2010, population aging implies opposite trends in working-age shares between OECD and non-OECD countries. While retrospective and prospective working-age shares shrink and diverge in OECD countries, they grow and converge in non-OECD countries. By 2050, the two shares differ by 5 percentage points (about 10 percent of the potential workforce) in OECD countries, whereas they all but coincide in non-OECD countries.

3 The Effects of Population Age Structure on Economic Growth

We examine the effects of population age structure on economic growth through the lens of a standard aggregate production model that expresses output as a function of input factors and total factor productivity (see, for example, Barro 1991; Mankiw et al. 1992; Caselli 2005; Jones 2005, 2016). This abstraction provides a theoretical framework through which we can assess the economic consequences of population aging with respect to retrospective and prospective definitions of working ages, holding other determinants of economic growth constant. Hence, we can determine the extent to which countries' growth trajectories differ with respect to how quickly and healthily their populations age.

Suppose time $t = 1, 2, \dots, T$ evolves discretely and there are $i = 1, \dots, I$ countries. Each country produces aggregate output Y_{it} (which equals aggregate income in a closed economy) using stocks of physical capital K_{it}, human capital H_{it}, and labor L_{it} as inputs:

$$Y_{it} = A_{it} K_{it}^{\alpha} H_{it}^{\beta} L_{it}^{1-\alpha-\beta}. \tag{1}$$

The parameters $\alpha, \beta \in (0,1)$ denote the income elasticities with respect to physical and human capital. A_{it} denotes total factor productivity, which describes the economy's stock of technology and efficiency. All income elasticities sum to unity, such that production exhibits constant returns to scale consistent with competitive factor and output markets. We assume all workers are identical and inelastically supply one unit of labor, so that the human capital stock H_{it} equals the number of workers L_{it} multiplied by average human capital per worker h_{it} (Lucas 1988).[1]

Expressing income in per worker units then yields

$$y_{it} = A_{it} k_{it}^{\alpha} h_{it}^{\beta}, \tag{2}$$

where $y_{it} = Y_{it}/L_{it}$ denotes income per worker and $k_{it} = K_{it}/L_{it}$ denotes capital per worker. Because we are interested in economic welfare per person, we multiply y_{it} by the working-age share $w_{it} = L_{it}/N_{it}$ to translate income from per worker into per capita units:

$$\tilde{y}_{it} = \frac{Y_{it}}{N_{it}} = \frac{Y_{it}}{L_{it}} \frac{L_{it}}{N_{it}} = y_{it} w_{it} = A_{it} k_{it}^{\alpha} h_{it}^{\beta} w_{it}. \tag{3}$$

This formalization implies that change in population age structure has first-order effects on income per capita growth so long as physical or human capital cannot perfectly substitute for labor input.

Taking logs and first-differencing expresses the model in growth rates:

$$\Delta \ln \tilde{y}_{it} = \Delta \ln A_{it} + \alpha \Delta \ln k_{it} + \beta \Delta \ln h_{it} + \Delta \ln w_{it}. \tag{4}$$

We model productivity growth $\Delta \ln A_{it}$ as a conditional convergence process in which countries converge to their long-run productivity potential (Bloom et al. 2004):

$$\Delta \ln A_{it} = \lambda \left[\ln A_{it}^{*} - \ln A_{it-1} \right] + \varepsilon_{it}. \tag{5}$$

A_{it}^{*} denotes country i's period-specific productivity potential in its long-run equilibrium, $\lambda \in (0,1)$

[1] For simplicity and without loss of generality, we restrict h_{it} to the consideration of education and account separately for other dimensions of human capital, as we specify subsequently. Alternatively, these dimensions can be meaningfully incorporated in h_{it} by assuming human capital is an argument in a generalized Mincerian wage equation (see, for example, Hall and Jones 1999; Bils and Klenow 2000; Bloom et al. 2022). The exact specification of h_{it} is inconsequential for the projected effects of population aging on economic growth.

denotes the rate at which a country adjusts toward this potential from productivity A_{it-1} in the preceding period, and ε_{it} denotes idiosyncratic productivity shocks. Accordingly, a country grows faster the further it is away from its productivity potential.

This specification of productivity growth allows countries' long-run productivity potentials to differ even after technological diffusion is complete. We assume the productivity potential is a function of the world technology frontier, as captured by time effects τ_t; human capital at the beginning of each period determining the country's capacity to innovate (Romer 1990; Strulik et al. 2013); and country-specific factors x_{it}, which may include demographic, economic, geographic, and institutional characteristics, as we specify subsequently. By including human capital not only as a production factor but also as an engine of technological development, the model precludes potential bias that arises if one of these channels is omitted (Sunde and Vischer 2015). We approximate productivity in the preceding period by income per worker times a factor ρ. Under these assumptions, productivity growth reads

$$\Delta \ln A_{it} = \lambda \left[\tau_t + \gamma \ln h_{it-1} + x'_{it}\delta - \rho \ln y_{it-1} \right] + \varepsilon_{it}. \tag{6}$$

Adding ρ allows us to test whether additional variables influence the speed at which a country converges to its productivity potential. If $\rho = 1$, the convergence speed depends only on the distance between past productivity and its current potential. However, human capital may not only be a production factor but may also facilitate the adoption and implementation of existing technologies (Nelson and Phelps 1966; Benhabib and Spiegel 1994, 2005; Cervellati et al. 2023). We incorporate this mechanism by assuming $\rho = (1 + \frac{\theta}{\lambda} \ln h_{it-1})$. Conditional on income per worker, a country then converges faster the more human capital it has.

Translating income into per capita units and plugging the ensuing expression into (4) yields our estimation equation:

$$\begin{aligned} \Delta \ln \tilde{y}_{it} \quad = \quad & \lambda \left[\tau_t + \gamma \ln h_{it-1} + x'_{it}\delta - \ln \tilde{y}_{it-1} + \ln w_{it-1} - \frac{\theta}{\lambda} \ln h_{it-1} \left(\ln \tilde{y}_{it-1} - \ln w_{it-1} \right) \right] \\ & + \alpha \Delta \ln k_{it} + \beta \Delta \ln h_{it} + \Delta \ln w_{it} + \varepsilon_{it}. \end{aligned} \tag{7}$$

According to this model, growth in income per capita $\Delta \ln \tilde{y}_{it}$ has four components. The first component comprises growth in the input factors: physical capital $\Delta \ln k_{it}$, human capital $\Delta \ln h_{it}$, and the working-age share $\Delta \ln w_{it}$. The second component accounts for countries' productivity potentials, which depend on productivity growth at the world technology frontier τ_t; human capital available for innovation and adoption of technologies $\ln h_{it-1}$; and country-specific characteristics x_{it}, which include the quality of economic institutions, population health, and country fixed effects in the main analysis. The third component consists of past income per capita $\ln \tilde{y}_{it-1}$; the past working-age share $\ln w_{it-1}$; and their interactions with human capital $\ln h_{it-1}\left(\ln \tilde{y}_{it-1} - \ln w_{it-1}\right)$, which govern convergence to the productivity potential. Finally, the fourth component is an idiosyncratic productivity shock ε_{it}, which serves as the model's error term. The log structure allows us to interpret the parameters for all input factors including the working-age share as elasticities.

We fit equation (7) with a dynamic panel leveraging variation in explanatory variables over time and across countries. Our strategy for identifying the effects of population age structure on economic growth has four aspects: i) we test whether the estimated parameters for the working-age share match the constraints our model imposes on its economic effects, ii) we instrument changes in the working-age share to deal with reverse causality and other potential confounding factors, iii) we inspect parameter stability with respect to sample composition and observation period, and iv) we probe the results' robustness with respect to alternative data and model specifications.[2]

First, we test whether the estimated parameters of the working-age share match the constraints on the economic effects of changes in population age structure that are implied by the accounting identity we use to transform income into per capita units in our model. The extent to which changes in population age structure affect economic growth depends on the size of two effects: a growth effect of changes in the working-age share, $\Delta \ln w_{it}$, over the interval $(t-1,t)$, and a level effect of the working-age share at the beginning of this interval, $\ln w_{it-1}$. Our model constrains the growth effect to unity and the level effect to λ under the null hypothesis. Significant differences from these values would indicate misspecification of the production function or endogeneity of the working-age share. The tests support our empirical specification if they fail to reject the null hypothesis.

Second, we use an instrumental variables approach that takes advantage of the persistence in population age structure over time. We instrument changes in the working-age share over the interval $(t-1,t)$ with the population share of young people aged 15–19 in $t-1$ who reach working ages in the subsequent period (Figure 2). This instrument uses variation in the predicted inflow of young workers into the working-age population based on the pre-period's cohort size (Kotschy and Sunde 2018 and Maestas et al. 2023 have previously used variants of this instrumentation). The extent to which working-age shares vary depends on persistent heterogeneity in cohort sizes across countries that originates from differences in the timing and speed of the demographic transition. As cohorts pass through the age structure, populations with more imbalanced cohort structures tend to experience more pronounced adjustments in working-age shares and thus economic growth. We do not consider variation in the outflow out of working ages in the main analysis (but in robustness

[2] An alternative to fitting our model with panel data would be to calibrate and simulate it; however, estimation has at least two advantages. First, it allows us to assess whether a uniform analytical framework can trace the economic effects of transformations in population age structure across different samples, as work on the demographic dividend implicitly assumes. Without such regularity one would learn little from comparing demographic trajectories across countries. Second, estimation allows us to incorporate country-specific heterogeneity with respect to growth and convergence dynamics in the analysis.

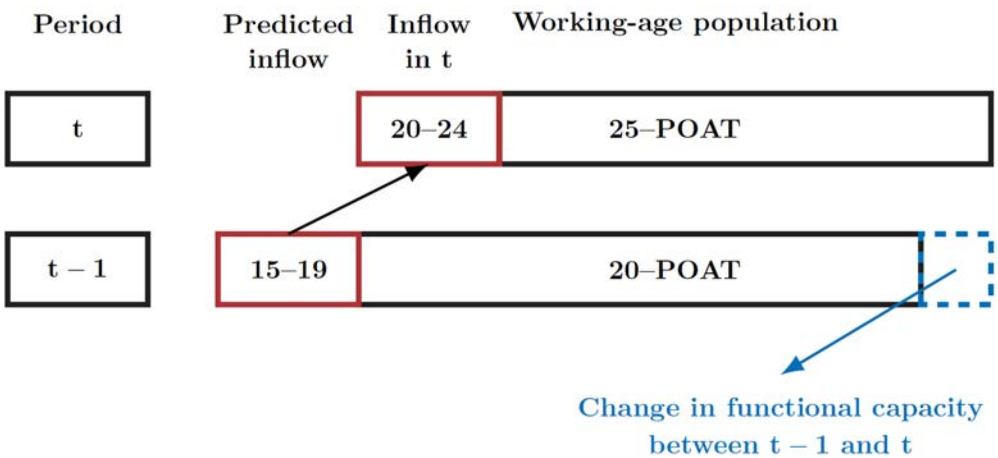


Figure 2: Instrumentation of changes in the working-age share

Note: This figure illustrates the first stage of our instrumental variables strategy. Changes in the working-age share over the interval $(t-1, t)$ are instrumented with the population share aged 15–19 in period $t-1$ as the predicted inflow into working ages (20–POAT). Working ages evolve with changes in the prospective-old threshold between periods $t-1$ and t, as indicated by the dashed rectangle (which may be positive, negative, or zero).

checks) because differences in the prospective old-age threshold across countries and over time severely complicate accurate predictions of it. By drawing on lagged rather than contemporaneous variation, our approach accounts for potential confounding factors and severs the causal link from economic growth to population age structure—which, for example, may operate through migration or population health.

The validity of this approach relies on the assumption that, conditional on covariates (including economic performance in $t-1$), the population share aged 15–19 in period $t-1$ predicts economic growth only through changes in the working-age share in the first stage. This assumption requires that productivity shocks in period t (captured by the error term) do not causally affect the population share aged 15–19 in period $t-1$. It is plausible if future workers do not adjust their current economic behavior because they systematically anticipate future productivity shocks beyond what can be expected from economic performance in previous periods. While we cannot test this identifying assumption directly, we provide indirect evidence supporting its plausibility in additional specifications that resort to 10-, 15-, and 20-year cohort lags for predicting the inflow into working ages. As these lags grow larger, the instrument relies on variation closer to a cohort's birth period, such that forward-looking behavior or economic trends that drive income growth over the interval $(t-1, t)$ become less and less likely to drive population age structure.

Third, we check the results' stability with respect to sample composition and observation period. To this end, we estimate the empirical model for OECD and non-OECD countries separately and reproduce the main results for abridged panels that exclude early or late periods. These exercises verify that shifts in population age structure affect economic growth to a similar extent over time and across countries. Effect stability is important for the methodological approach for two reasons. It justifies the assumption of a production function approach to analyze the economic consequences of contracting working-age shares across countries and over time, and it is a necessary precondition for out-of-sample projections of economic growth for the years ahead.

Fourth, we examine the results' robustness with respect to measuring population age structure with workforce data, adding control variables, and calibrating selected model parameters. The main analysis conceptualizes population age structure with the working-age share (the population share of the potential workforce) rather than the workforce share (the population share of the actual workforce) because the latter may correlate with productivity shocks that affect labor force participation over the business cycle. To confirm the appropriateness of this choice, we reproduce the main findings with specifications predicated on the workforce share. Furthermore, we control for potential influences on economic growth of disability, population size, young-age and old-age ratios, trade openness, democracy, geography, and ethnic fractionalization. Finally, we rule out multicollinearity between the explanatory variables by calibrating the effects of population age structure on economic growth in accordance with the parameter constraints of our theoretical model.

4 Data Sources and Coding

We estimate the parameters of our model with unbalanced panel data for 145 countries observed in five-year intervals throughout 1950–2015. Data on income, measured by gross domestic product, and physical capital are from Penn World Tables (Feenstra et al. 2015). Information on population age structure and educational attainment is obtained from the Wittgenstein Centre for Demography and Human Capital (Lutz et al. 2018) and available in five-year brackets. Appendix A.1 presents a list of the countries in our sample and descriptive statistics.

We combine the population counts to construct retrospective working-age shares, which we define as the proportion of people aged 20–64 in the total population, and prospective working-age shares, which we define as the proportion of people aged 20–POAT in the total population.

Data on educational attainment are coded according to the International Standard Classification of Education. We collate this information and construct population shares composed of individuals who have obtained post-primary—that is, secondary or more—education to measure human capital.

The main analysis controls for population health measured by life expectancy at birth (data drawn from United Nations 2022) and quality of economic institutions measured by the Fraser Institute's index of economic freedom (Gwartney et al. 2017; Murphy and Lawson 2018). The economic freedom index captures five aspects of institutions: i) size of government; ii) quality of the legal system and property rights; iii) stability of money and access to foreign currencies; iv) barriers to international trade; and v) regulation of credit markets, labor, and businesses. It varies on continuous scale between 0 and 10, where higher values indicate higher institutional quality.

In additional analyses, we control for disability measures from the Global Burden of Disease study (data obtained from Vos et al. 2020); health deficits per working-age person compiled by Dalgaard et al. (2022c) from the same source; population size, young-age, and old-age ratios (Lutz et al. 2018); the ratio of imports plus exports to output (Feenstra et al. 2015); the composite polity score (Marshall and Gurr 2020); the percentage of land area located in the tropics and within 100 kilometers of a coast or navigable river (Mayer and Zignago 2011); and ethnic fractionalization (Alesina et al. 2003). Finally, we use the workforce share as an alternative measure of population age structure (International Labour Organization 2021).

5 Population Age Structure and the Demographic Dividend

5.1 Do Shifts in Population Age Structure Predict Economic Growth?

We begin our analysis by testing whether population age structure predicts economic growth as the demographic dividend stipulates. Table 2 shows ordinary least squares estimates for two specifications of equation (7): one with uniform growth trends and convergence ($\rho = 1$) and one with country-specific growth trends and convergence ($\rho \neq 1$). The latter includes country fixed effects and interactions that allow for the possibility that countries converge faster if they have more human capital to adopt existing technologies. Estimates are corrected for mechanical bias arising in dynamic panel models with fixed effects and few time periods (Nickell 1981; Breitung et al. 2022).

Population age structure correlates positively with economic growth. A 1 percent increase in the working-age share associates with a 0.4–0.7 percent rise in income per capita (growth effect). The estimated effects are larger for retrospective than prospective working-age shares and significant at conventional levels. In addition, a 1 percent higher working-age share in period $t-1$ is associated with 0.1–0.3 percent higher income per capita (level effect). Both growth and level effects suggest population aging creates the opportunity for a demographic dividend.

However, the growth effects of the working-age share do not match the parameter constraint of unity the aggregate production model implies. We test this constraint with a Wald test and report the corresponding p-values at the bottom of the table. Except for specification (4), the estimated growth effects differ significantly from unity. These findings contrast with the estimated level effects, which match their parameter constraint of λ throughout all specifications. Together, the results portend potential endogeneity of growth of the working-age share.

We address this concern with an instrumental variables approach that leverages variation in the predicted inflow into working ages based on the population share of the age group 15–19 in the previous period. Estimates are obtained from two-stage least squares and system general

Table 2: Ordinary least squares results: Population age structure and economic growth

Dependent variable: income per capita growth	Prospective working ages (20–POAT) Uniform growth trends and convergence (1)	Prospective working ages (20–POAT) Country-specific growth trends and convergence (2)	Retrospective working ages (20–64) Uniform growth trends and convergence (3)	Retrospective working ages (20–64) Country-specific growth trends and convergence (4)
Growth of working-age share	0.40***	0.41***	0.62***	0.70***
	(0.12)	(0.15)	(0.15)	(0.23)
Log working-age share ($t-1$)	0.10	0.18	0.12**	0.27
	(0.06)	(0.14)	(0.06)	(0.17)
R^2	0.32	—	0.32	—
Within R^2	0.27	—	0.27	—
p-value growth effect	0.00	0.00	0.01	0.20
p-value level effect	0.52	0.57	0.27	0.30
Countries	145	119	145	119
Observations	1340	1169	1340	1169

Note: This table shows a positive correlation between the working-age share and economic growth. Estimates are obtained from ordinary least squares for a panel of 145 countries in five-year intervals throughout 1950–2015. Specifications (1) and (2) define working ages as 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. Specifications (3) and (4) define working ages as 20–64. All specifications include covariates and control for time effects. Specifications (2) and (4) further add country fixed effects and use Breitung et al.'s (2022) estimator to correct the mechanical bias arising in dynamic panels with few time periods. The sample slightly shrinks as this estimator drops countries with interior missing values in their time series. Standard errors are clustered at the country level and reported in parentheses. Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

method of moments, which removes the bias that arises in dynamic panel models with fixed effects and few time periods by instrumenting the lagged dependent variable with higher-order lags in a first-differenced and a levels equation (Arellano and Bover 1995; Blundell and Bond 1998). Because panel general method of moment estimators tend to suffer from many weak instruments (Roodman 2009), we resort to the minimum necessary for estimation: the second lag of income per capita in the first-differenced equation and the lagged difference of income per capita in the levels equation. We create one instrument for each variable rather than for each time period. In addition, we instrument growth of the working-age share by the population share of the age group 15–19 in period $t-1$ in the first-differenced equation and by the difference of this share between periods t and $t-1$ in the levels equation. These choices limit the instrument count to four.

Table 3 reports instrumental variable results. Shifts in population age structure affect economic growth. A 1 percent increase in the working-age share raises income per capita by 0.8–1.0 percent. These growth effects differ significantly from zero and match the parameter constraint of unity. In addition, a higher working-age share in period $t-1$ expedites growth by 0.1–0.4 percent. The level effects are larger but less precise when the model allows for country-specific convergence. Together, the growth and level effects imply that countries can harness a sizable demographic dividend when they transition from high to low rates of mortality and fertility. The parameter estimates for the remaining covariates match stylized facts in the literature on economic growth (Appendix A.2).

Diagnostic tests support instrument validity. The first stage and reduced form show significant positive correlations between the prospective inflow into working ages and growth of the working-age share and economic growth. First-stage F-statistics greater than 200 confirm instrument relevance. Likewise, Windmeijer's (2018) rank test rejects underidentification in the general method of moments specifications. The AR(1) and AR(2) serial correlation tests corroborate the validity of

Table 3: Instrumental variable results: Population age structure affects economic growth

Dependent variable: income per capita growth	Prospective working ages (20–POAT)		Retrospective working ages (20–64)	
	Uniform growth trends and convergence (2SLS) (1)	Country-specific growth trends and convergence (GMM) (2)	Uniform growth trends and convergence (2SLS) (3)	Country-specific growth trends and convergence (GMM) (4)
Growth of working-age share	0.79***	0.98***	0.89***	0.92***
	(0.23)	(0.25)	(0.23)	(0.24)
Log working-age share ($t-1$)	0.13*	0.44	0.14**	0.24
	(0.07)	(0.34)	(0.06)	(0.18)
First stage				
Log population share 15–19 ($t-1$)	0.14***	—	0.15***	—
	(0.01)	—	(0.01)	—
Reduced form				
Log population share 15–19 ($t-1$)	0.11***	—	0.13***	—
	(0.03)	—	(0.03)	—
First-stage F-statistic	230.2	—	475.3	—
p-value growth effect	0.36	0.92	0.62	0.75
p-value level effect	0.28	0.36	0.19	0.38
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.63	—	0.34
Underidentification test p-value	—	0.00	—	0.00
Hansen test p-value	—	0.38	—	0.27
Diff-in-Hansen test p-value	—	0.20	—	0.11
Excluded instruments	1	4	1	4
Countries	145	145	145	145
Observations	1340	1289	1340	1289

Note: This table shows that population age structure affects economic growth. Estimates are obtained from two-stage least squares (2SLS) and system general method of moments (GMM) for a panel of 145 countries in five-year intervals throughout 1950–2015. All specifications instrument growth of the working-age share with the lagged population share of the age group 15–19. In specifications (1) and (2), the working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In specifications (3) and (4), the working-age population comprises people in the age range 20–64. All specifications include covariates and control for time effects. Specifications (2) and (4) additionally account for country fixed effects by transforming the data with forward orthogonal deviations. The system GMM estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are clustered at the country level and reported in parentheses. Standard errors in GMM specifications are computed with the two-step procedure and corrected for sample size (Windmeijer 2005). Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

lagged variables for instrumentation. They rule out that residuals follow a near-unit root process and buttress the null hypothesis that residuals exhibit no higher-order serial correlation. Finally, the Hansen and difference-in-Hansen tests maintain the null hypothesis that the excluded instruments be orthogonal to the residuals.

5.2 Are the Effects of Population Age Structure Stable across Samples?

Our empirical model implicitly assumes that population age structure affects economic growth to the same extent across countries and over time. This assumption echoes the notion that every country can collect a demographic dividend when it transitions from high to low rates of mortality and fertility. Without such regularity, developing countries could learn little from historical episodes in developed countries and projections of future growth would be futile. To test whether the effects of population age structure on economic growth are stable with respect to sample composition and over time, we re-estimate specification (1) of Table 3 for OECD and non-OECD countries and abridged samples spanning the periods 1950–2000 and 1965–2015: see Table 4. If the stability assumption

Table 4: The effects of population age structure on economic growth are stable across samples

Dependent variable: income per capita growth	Full sample (1)	OECD countries (2)	Non-OECD countries (3)	Sample 1950–2000 (4)	Sample 1965–2015 (5)
Growth of working-age share	0.79***	0.95***	0.57*	1.00***	0.72***
	(0.23)	(0.34)	(0.33)	(0.31)	(0.23)
Log working-age share $(t-1)$	0.13*	0.22***	0.10	0.21**	0.10
	(0.07)	(0.08)	(0.08)	(0.09)	(0.07)
First stage					
Log population share 15–19 $(t-1)$	0.14***	0.11***	0.14***	0.14***	0.14***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Reduced form					
Log population share 15–19 $(t-1)$	0.11***	0.11**	0.08*	0.14***	0.10***
	(0.03)	(0.04)	(0.05)	(0.04)	(0.03)
First-stage F-statistic	230.2	102.8	97.4	129.3	240.9
p-value growth effect	0.36	0.89	0.20	1.00	0.23
p-value level effect	0.28	0.16	0.55	0.07	0.56
Countries	145	34	111	123	145
Observations	1340	399	941	915	1223

Note: This table shows the stability of the effects of population age structure on economic growth across samples. The estimates are obtained from two-stage least squares for a panel of 145 in five-year intervals countries throughout period 1950–2015. All specifications instrument growth of the working-age share with the lagged population share of the age group 15–19. The working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. The table shows results for the full sample (1), OECD countries (2), non-OECD countries (3), and abridged samples spanning the periods 1950–2000 (4) and 1965–2015 (5). All specifications include covariates and control for time effects. Standard errors are clustered at the country level and reported in parentheses. Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

applies, estimated parameters of the working-age share should be similar across samples.

The effects of population age structure on economic growth are stable across all samples. Increases in the working-age share raise income per capita. These growth effects are not significantly different from one another or from unity. A higher pre-period level of the working-age share further promotes income growth. High values of the first-stage F-statistics indicate instrument relevance. Estimates for the general method of moments specification with country-specific growth trends and convergence confirm these findings (Appendix A.3).

The results' stability across samples supports our approach of examining the economic consequences of population aging through an aggregate production model, and it justifies using our parameter estimates to project future economic development.

5.3 Additional Results and Robustness Analysis

Appendix A.4 presents results for additional analyses that support the validity of our instrumental variables approach and that demonstrate the robustness of our results with respect to use of workforce data, estimation of alternative specifications with richer sets of covariates, and calibration of selected parameters. These analyses document quantitatively similar effects of population age structure on economic growth when i) regressions are predicated on workforce shares that incorporate labor force participation; ii) changes in working-age shares are instrumented with 10-, 15-, and 20-year cohort lags or both the predicted inflow into and outflow out of working ages; iii) covariates are added for physiological aging and disability, population size, young-age and old-age ratios, trade openness, quality of democratic institutions, geography, and ethnic fractionalization; and they show iv) that results for the covariates do not react sensitively when the economic effects of population age structure are calibrated in accordance with the parameter restrictions of our model. These results support our empirical approach and indicate that heterogeneity in population health and composition, economic trade, political systems, and geography do not drive the main findings.

6 From Demographic Dividend to Demographic Drag?

6.1 Predictive Power of the Model and the Demographic Dividend

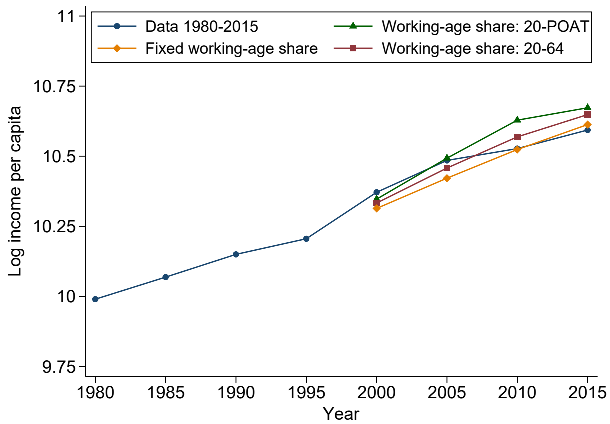
We next investigate the ramifications of population aging for future economic growth. To this end, we combine the empirical estimates with demographic predictions and project income per capita.

A prerequisite for these projections is that our model reasonably predicts changes in economic growth originating from shifts in population age structure when applied out of sample. We verify the model fulfills this condition by testing its predictive power within sample. To this end, we partition the data into an estimation sample from 1950 to 1995 for which we fit the model and a projection sample from 2000 to 2015 for which we compute economic growth using the fitted parameters.

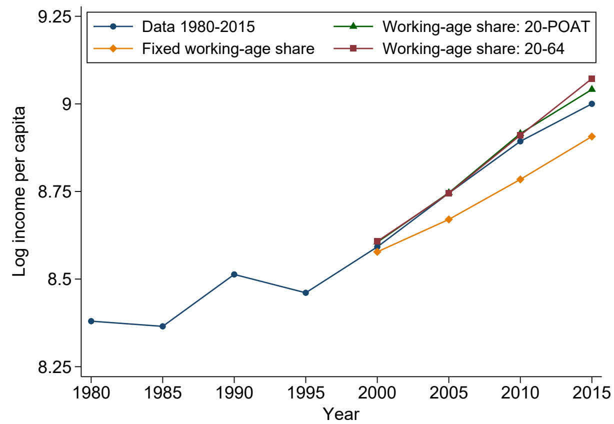
We distinguish among three projection scenarios for income per capita: i) a no-aging scenario in which we counterfactually fix working-age shares at their 1995 level, ii) a retrospective-aging scenario in which working-age shares vary with cohort structure but not with prospective old-age thresholds, and iii) a prospective-aging scenario in which working-age shares vary with both cohort structure and prospective old-age thresholds. In all scenarios, we assign each country the technological growth rate at the frontier and assume capital accumulation, education, population health, and institutional quality follow country-specific trajectories in the data. By only varying population age structure across scenarios, the projections shed light on the model's capability to predict changes in economic growth associated with population aging.

Figure 3 compares observed and projected economic growth in OECD and non-OECD countries. All projections capture the upward trends in income per capita and reasonably match the observed growth trajectories when the model injects values of working-age shares consistent with population counts in the data. If anything, the projected values slightly exceed the observed ones after the productivity shock of the 2007–2008 financial crisis. The results do not differ appreciably between the retrospective-aging and prospective-aging scenarios as both trended similarly in 1995–2015.

Notably, the model understates income per capita in the no-aging benchmark when compared with the data for non-OECD countries. This gradient reveals that shifts in working-age shares yielded an average demographic dividend worth 10 percent of income per capita in 2000–2015. We find no such dividend for OECD countries because average working-age shares barely changed over



(a) OECD countries



(b) Non-OECD countries

Figure 3: Predictive power of the model: 2000–2015

Note: This figure compares observed and projected income per capita for OECD and non-OECD countries in 2000–2015. The projections are based on parameters derived from estimating specification (1) of Table 3 over an abridged sample 1950–1995. The figure compares observed income per capita with three projections predicated on fixed working-age shares (as of 1995), retrospective working-age shares (20–64), and prospective working-age shares (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years.

this period. These differences indicate that the model successfully traces the economic effects of changes in population age structure. Moreover, they rule out that projected and observed income per capita solely match because we impose common technological trends on all countries. If this were the case, economic growth in OECD and non-OECD countries should mirror one another.

The model also predicts economic growth at the country level (Appendix A.5). For example, projected per capita incomes fit the observed ones in the United States and China. This consistency corroborates the model's capability to reproduce growth patterns at different development stages: starting from a lower level, China has grown five times faster than the United States over this period. The projections further match economic growth in other aging economies such as Germany, Japan, and the Republic of Korea. In contrast, the model cannot predict the economic stagnation in Italy, where total factor productivity and competitiveness have stalled for structural reasons that are unrelated to population aging (Pellegrino and Zingales 2019). However, while such country-specific trends may provide an inaccurate prospect of income per capita levels, they do not impair estimation of the economic effects of shifts in working-age shares, which we derive from income differences across projection scenarios that partial out these trends.

6.2 Future Growth and the Demographic Drag

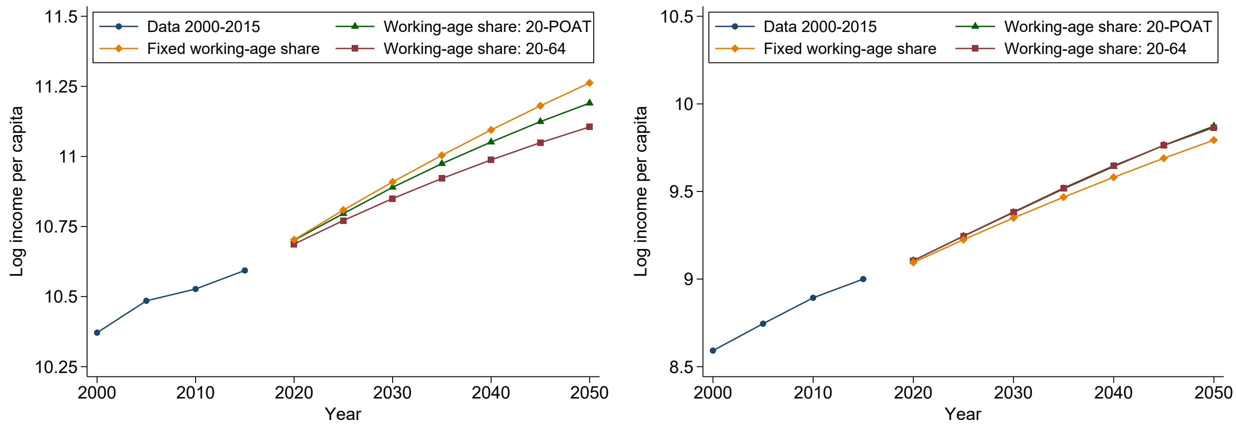
To determine how future shifts in working-age shares might affect economic growth, we combine our empirical estimates over the full sample 1950–2015 with demographic predictions and project income per capita out of sample for 2020–2050.

We distinguish among three projection scenarios for income per capita: i) a no-aging scenario in which we counterfactually fix working-age shares at their 2015 level, ii) a retrospective-aging scenario in which working-age shares vary with cohort structure but not with prospective old-age thresholds, and iii) a prospective-aging scenario in which working-age shares vary with both cohort structure and prospective old-age thresholds. In all scenarios, we assign countries a common technological growth trend derived from the time effects and extrapolate their capital stocks with the average accumulation rate in the sample (these assumptions are relaxed in sensitivity analyses). We use demographic predictions to extend the education and population health series until 2050 and fix the quality of economic institutions at 2015 levels. By only varying population age structure across scenarios, we elicit the likely consequences of changes in working-age shares for economic growth: differences between the no-aging and retrospective-aging scenarios reflect the effects of changes in cohort structure, whereas differences between the retrospective-aging and prospective-aging scenarios reflect the effects of changes in functional capacity in terms of remaining life expectancy.

Figure 4 displays projected economic growth for OECD and non-OECD countries in 2020–2050. Expected contractions in working-age shares will drag economic growth. According to the no-aging scenario, income per capita in OECD countries will grow on average by 2.5 percent annually between 2020 and 2050 if population age structure is fixed at 2015 levels. This growth rate shrinks by one-third to approximately 1.7 percent if the labor potential decreases as predicted by the retrospective-aging scenario. In contrast, the growth rate shrinks only by one-sixth to 2.1 percent if the labor potential decreases as predicted by the prospective-aging scenario, which presumes an average increase in prospective old-age thresholds of 4.5 years in 2020–2050. Hence, expanding economic activity through improvements in functional capacity can cushion perhaps one-half of this demographic drag (about 0.4 percentage points of annual income per capita growth).[3]

In contrast, expected expansions in working-age shares will promote economic growth. According to the no-aging scenario, income per capita in non-OECD countries grows on average by 3.4 percent annually if working-age shares are fixed at their 2015 level, whereas it grows by 3.8 percent if working-age shares evolve according to the retrospective-aging and prospective-aging

[3] The annual growth rates between 2020 and 2050 for each scenario $j \in \{1,2,3\}$ are computed according to $\widehat{g}_j \approx (100/30) \cdot \left(e^{\widehat{y}_j^{2050}} - e^{\widehat{y}_j^{2020}}\right) / e^{\widehat{y}_j^{2020}}$, where $\widehat{y}_j^{2020}$ and $\widehat{y}_j^{2050}$ denote projected log income per capita in 2020 and 2050. The demographic drag (or dividend) is then calculated as the difference in growth rates between the corresponding aging and no-aging scenarios. For example, the demographic drag under the prospective-aging scenario is derived by $\widehat{DD} = (100/30) \cdot \left[\left(e^{11.26} - e^{10.70}\right) / e^{10.70} - \left(e^{11.19} - e^{10.70}\right) / e^{10.70} \right] \approx 0.4$. Further rates are obtained analogously.



(a) OECD countries

(b) Non-OECD countries

Figure 4: Projected income per capita: 2020–2050

Note: This figure shows projected income per capita for OECD and non-OECD countries in 2020–2050. The projections are based on the parameters estimated in specification (1) of Table 3. The figure contrasts income per capita across three projections predicated on fixed working-age shares (as of 2015), retrospective working-age shares (20–64), and prospective working-age shares (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years.

scenarios. On average, these countries will thus enjoy a demographic dividend worth 0.4 percent annual growth. Unlike in OECD countries, projected per capita incomes do not differ appreciably between retrospective and prospective measures of population age structure. This contrast occurs because prospective old-age thresholds across non-OECD countries almost coincide with 64 in 2050 and only exceed it thereafter.

To inspect the economic effects of changes in working-age shares at the country level, we calculate annual growth rates in 2020–2050 and compute the corresponding demographic drags and dividends for each country in our sample (see footnote 3 for details). Figure 5 charts the results for OECD countries. These estimates constitute bounds for the demographic drags and dividends under fixed and variable functional capacity, holding cohort structure constant. Differences between these bounds thus indicate the economic gains of expansions in labor supply associated with improvements in functional capacity thanks to changing age patterns of health.

Almost all OECD countries are predicted to experience an economic slowdown in the upcoming decades. In fact, this demographic drag will be the norm among countries that advance through later stages of the demographic transition: population aging is projected to slow economic growth in 70 countries—virtually all the countries in our sample that will see their working-age shares shrink as large cohorts progress to old ages. The intuition behind this result is simple. Time-staggered declines in mortality and fertility and baby booms have created large cohorts that tended to propel economic growth by raising labor quantity and productivity when they entered and passed through working

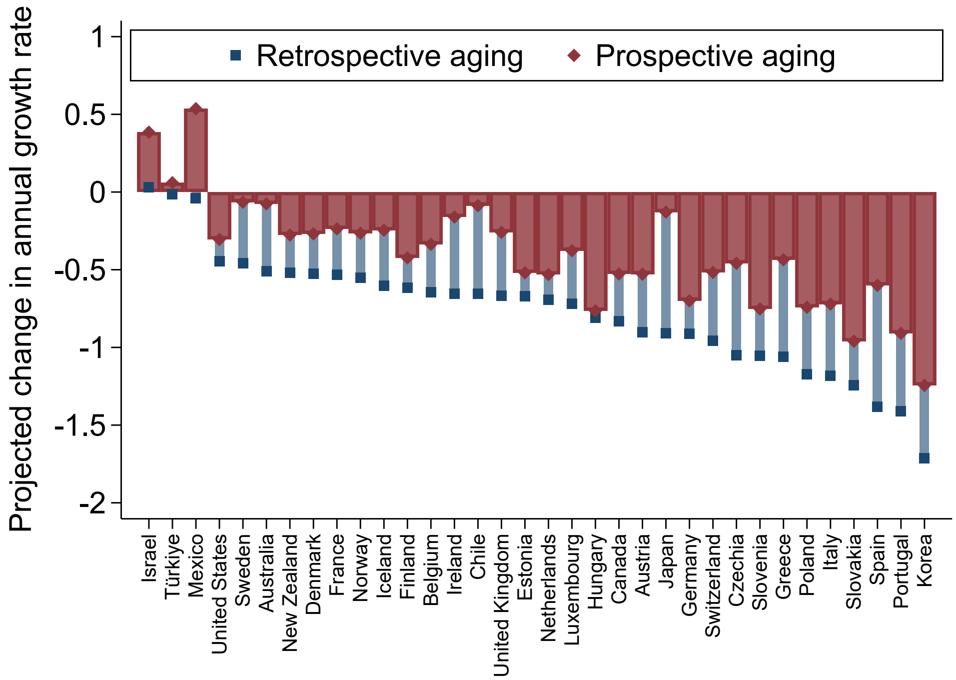


Figure 5: Projected change in annual growth rates for OECD countries

Note: This figure depicts the projected cumulative change in annual growth rates in 2020–2050 in OECD countries. It contrasts the estimated demographic drags and dividends based on the retrospective-aging scenario with the estimated demographic drags and dividends based on the prospective-aging scenario. The projections are predicated on the parameters estimated in specification (1) of Table 3.

ages. When these large cohorts leave working ages, labor quantity will decline and resources that otherwise could promote productivity will be bound for consumption at old age. Without sufficient migration or increases in functional capacity, education, automation, and technological progress to compensate for these effects, a demographic drag follows the demographic dividend.

The extent to which population aging affects economic growth depends not only on cohort structure but also on how labor potential changes with improvements in functional capacity as longevity rises. The estimated demographic drag in OECD countries is smaller under the prospective-aging scenario, which incorporates increases in remaining life expectancy, than under the retrospective-aging scenario, which abstracts from them. Although a deceleration in income per capita growth occurs in either scenario, the prospective-aging scenario indicates that the economic consequences of population aging will likely be less severe than projections based on cohort structure alone suggest. The differences between retrospective and prospective measures vary across countries and can be sizable. Under retrospective aging, the annual growth rates of income per capita are projected to decline by 0.91 percentage points (pp) in Japan, 0.66 pp in Chile, and 0.46 pp in Sweden, whereas under prospective aging they are projected to decline only by 0.13 pp in Japan, 0.09 pp in Chile, and 0.06 pp in Sweden. Because remaining life expectancy is comparably high among older people in these countries, most of the demographic drag can be compensated if economic activity expands into older ages. If, instead, remaining life expectancy is comparably low among older people, only a smaller portion of the demographic drag can be compensated. This case pertains to several countries in Eastern and Southern Europe and to Germany and the Netherlands. Across all OECD countries, up to one-half of the demographic drag can be compensated by changes in labor supply due to improved functional capacity, with projected values for the United States close to this average.

Expected population aging creates the opportunity for a demographic dividend in many non-OECD countries that are in earlier stages of the demographic transition (Appendix A.6). In these countries, income per capita tends to grow more the faster populations age and the healthier they are. In many, however, projected income per capita is lower under prospective aging than under retrospective aging because functional capacity is so low that the prospective old-age threshold falls short of 65 years. Hence, projections for prospective aging provide a more realistic upper bound for economic growth than projections based on cohort structure alone.

6.3 Endogenous Capital Formation

To this point we have abstracted from possible effects of population aging for capital formation that arise if people adjust their life-cycle savings to prepare for longer spells in retirement (Bloom et al. 2007). The baseline projections extrapolate capital stocks with the average accumulation rate observed in the sample. This assumption reflects an extreme case in which all countries have access to a competitive international capital market in which investment cost and return equalize. On the other extreme, capital accumulation may solely depend on domestic savings, which contract when a significant proportion of the population starts dissaving for retirement. We consider the latter case by computing projections in which we endogenously determine physical capital stocks. To this end, we regress growth of capital per worker on all other explanatory variables of our empirical model:

$$\Delta k_{it} = \lambda^k \left[\tau_t^k + \gamma^k \ln h_{it-1} + x_{it}' \delta^k - \ln \tilde{y}_{it-1} + \ln w_{it-1}\right] + \beta^k \Delta \ln h_{it} + \Delta \ln w_{it} + \varepsilon_{it}^k. \qquad (8)$$

The superscript k highlights that parameters and residuals need not be identical to those obtained for our income regression. We use the results to iteratively update capital stocks and per capita incomes in 2020–2050. Endogenizing capital formation augments the economic response to population aging: income per capita grows even more when working-age shares expand and even less when working-age shares contract (Appendix A.7). Improvements in functional capacity can counteract roughly one-third of the demographic drag in OECD countries.[4]

[4]Improvements in life expectancy may not only shape capital formation but also educational attainment. Our projections account for this possibility by extending the education series in a way that incorporates foreseeable changes

6.4 Additional Results and Sensitivity Analysis

Appendix A.8 presents results for additional analyses that confirm the findings of our baseline projections for workforce data, alternative assumptions regarding exogenous growth processes, shorter time horizons, and calibrated prediction models. These analyses document similar effects of population aging on economic growth when i) workforce shares are used to predict income per capita, ii) projections are predicated on general method of moment specifications that allow for country-specific growth trends and convergence, iii) income per capita is projected until 2030 and 2040 rather than 2050, and iv) growth and level effects of population age structure are calibrated to match the parameter restrictions of our model. These results show that our main findings are not sensitive to model choice and assumptions about the measurement of population age structure and the time horizon of our projections.

7 Concluding Remarks

As many countries complete the demographic transition, their populations age. While a growing working-age share thanks to aging has been a source for economic growth, contracting working-age shares now threaten to turn the former demographic dividend into a demographic drag.

In this paper, we investigate the consequences of changes in working-age shares for economic growth. We develop an aggregate production model and fit it in a dynamic panel for 1950–2015 to project income per capita in 2020–2050. The novelty of our approach lies in the distinction between retrospective and prospective concepts of population age structure, which allows us to gauge the extent to which population aging might slow economic growth as large cohorts pass through to older ages and to determine by how much extensions of working ages with improvements in functional capacity can counteract this slowdown.

Our findings document that a demographic drag will be the new norm in the upcoming decades; however, future economic growth depends not only on how cohort structures change but also on how labor potential changes with improvements in functional capacity as longevity rises. While contracting working-age shares will slow economic growth, changes in labor supply through improvements in functional capacity can cushion much of this slowdown. Hence, the consequences of population aging for economic growth will likely be less severe than demographic predictions of cohort structure suggest. Although migration and technological progress can reduce the demographic drag by cushioning labor shortages, automating physically demanding tasks, and creating age-friendly jobs (Acemoglu and Restrepo 2017, 2022; Acemoglu et al. 2022), they will be insufficient to counteract the demographic drag alone. In this context, our findings indicate substantial gains for

in educational attainment, including demographic shifts.

policies that enable older people to remain economically active, including productive nonmarket activities (Bloom et al. 2020). While higher functional capacity tends to increase people's propensity to work full time at older ages, it need not raise labor force participation (Appendix A.9). Whether such an increase occurs depends on the extent to which labor markets and health and social policy facilitate retaining workers in the workforce. Potential policies along these lines include creating incentives for remaining in employment, promoting safe workplaces, providing access to an adequate safety net regarding healthcare and retirement, reducing social inequalities conducive to ill health, and meeting people's needs in dealing with caregiving responsibilities (Berkman et al. 2022).

We conclude with four cautionary remarks. First, projecting the effects of population aging on economic growth involves considerable uncertainty. Among other things, it is difficult to reliably predict the occurrences of technological innovations, climate change, pandemics, and war and their impacts on per-capita income and its growth rate. Economic growth may well be slower than in the past (Gordon 2015). Therefore, we view our projections not as forecasts of economic growth but as estimates of the economic implications of global population aging trends based on available information and economic conditions today. Second, our results rely on the assumption that prospective measures of population aging reflect variation in age-specific functional capacities. While our evidence confirms that this is the case, we cannot rule out the possibility that alternative measures capture this variation more effectively. So far, potential alternatives such as function-based dependency ratios (Skirbekk et al. 2012, 2022) and healthy life expectancy (Vos et al. 2020) do not offer straight-forward approaches to modeling the economic gains associated with expansions of labor potential due to changing age patterns of health. How different measures of prospective aging and functional capacity compare with one another is a fruitful avenue for future research. Third, our analysis is silent with respect to the fiscal implications of population aging. A rising number of elderly people can pressure the adequate provision of pensions, healthcare, and long-term care (Rouzet et al. 2019), which might necessitate an increase in taxes that further slows economic growth. In theory, extending economic activity into older ages can absorb fiscal strain from social security systems and cushion this effect. Fourth, our analysis abstracts from distributional differences in economic activity around old-age thresholds. Because this abstraction accurately represents average functional capacity, it is inconsequential for projected growth of income per capita. Nevertheless, policies aimed at expanding economic activity into the older ages can have distributional and related welfare implications. Measuring this effect is a worthwhile area for future research.

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Supplemental Appendix for
Population Aging and Economic Growth: From Demographic Dividend to Demographic Drag?

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Abstract

This appendix contains additional information and material referenced in the text.

A Supplemental Appendix

A.1 Sample Composition and Descriptive Statistics

Table A.1: Countries in the sample

Country	In OECD (by 2015)	Country	In OECD (by 2015)	Country	In OECD (by 2015)
Albania	—	Georgia	—	Pakistan	—
Algeria	—	Germany	✓	Panama	—
Angola	—	Ghana	—	Paraguay	—
Argentina	—	Greece	✓	Peru	—
Armenia	—	Guatemala	—	Philippines	—
Australia	✓	Guinea-Bissau	—	Poland	✓
Austria	✓	Haiti	—	Portugal	✓
Azerbaijan	—	Honduras	—	Qatar	—
Bahamas	—	Hungary	✓	Republic of Korea	✓
Bahrain	—	Iceland	✓	Republic of Moldova	—
Bangladesh	—	India	—	Romania	—
Belgium	✓	Indonesia	—	Russian Federation	—
Belize	—	Iran	—	Rwanda	—
Benin	—	Ireland	✓	Saudi Arabia	—
Bolivia	—	Israel	✓	Senegal	—
Bosnia & Herzegovina	—	Italy	✓	Serbia	—
Botswana	—	Jamaica	—	Sierra Leone	—
Brazil	—	Japan	✓	Singapore	—
Bulgaria	—	Jordan	—	Slovakia	✓
Burkina Faso	—	Kazakhstan	—	Slovenia	✓
Burundi	—	Kenya	—	South Africa	—
Cabo Verde	—	Kuwait	—	Spain	✓
Cambodia	—	Kyrgyzstan	—	Sri Lanka	—
Cameroon	✓	Latvia	—	Suriname	—
Canada	—	Lebanon	—	Sweden	✓
Central African Republic	—	Lesotho	—	Switzerland	✓
Chad	—	Lithuania	—	Syrian Arab Republic	—
Chile	✓	Luxembourg	✓	Tajikistan	—
China	—	Madagascar	—	Thailand	—
Colombia	—	Malawi	—	Togo	—
Congo	—	Malaysia	—	Trinidad and Tobago	—
Costa Rica	—	Mali	—	Tunisia	—
Côte d'Ivoire	—	Malta	—	Türkiye	✓
Croatia	—	Mauritius	—	Uganda	—
Cyprus	—	Mexico	✓	Ukraine	—
Czechia	✓	Montenegro	—	United Arab Emirates	—
Dem. Rep. of the Congo	—	Mongolia	—	United Kingdom	✓
Denmark	✓	Morocco	—	United Republic of Tanzania	—
Dominican Republic	—	Mozambique	—	United States of America	✓
Ecuador	—	Myanmar	—	Uruguay	—
Egypt	—	Namibia	—	Venezuela	—
El Salvador	—	Nepal	—	Viet Nam	—
Estonia	✓	Netherlands	✓	Yemen	—
Eswatini	—	New Zealand	✓	Zambia	—
Ethiopia	—	Nicaragua	—	Zimbabwe	—
Fiji	—	Niger	—		
Finland	✓	Nigeria	—		
France	✓	North Macedonia	—		
Gabon	—	Norway	✓		
Gambia	—	Oman	—		

Note: This table lists all 145 countries contained in the full sample and their OECD member status.

Table A.2: Descriptive statistics

Variable (units)	Observations	Mean	Standard deviation	Minimum	Maximum
Functional capacity at older ages					
Prospective old-age threshold (in years)	3842	64.57	5.02	50.35	79.00
Life expectancy at age 65 (in years)	4053	14.73	3.28	4.10	26.36
Deficits per person 50–80 (number of deficits)	1086	0.12	0.01	0.10	0.14
Maximum grip strength (in kilograms)	85	33.02	2.12	27.64	36.77
Immediate word recall (number out of 10 words)	89	5.26	0.50	3.61	6.15
Income per capita and capital per worker					
Income per capita growth (in log points)	1340	0.10	0.16	−0.73	0.73
Income per capita in $t-1$ (in log points)	1340	8.86	1.22	5.60	12.23
Growth of capital per worker (in log points)	1340	0.10	0.15	−0.77	1.04
Population age structure and education					
Growth of working-age share 20–POAT (in log points)	1340	0.02	0.04	−0.24	0.31
Working-age share 20–POAT in $t-1$ (in log points)	1340	−0.75	0.18	−1.24	−0.19
Growth of workforce share 15–POAT (in log points)	663	0.02	0.05	−0.19	0.24
Workforce share 15–POAT in $t-1$ (in log points)	663	−0.97	0.18	−1.56	−0.32
Growth of working-age share 20–64 (in log points)	1340	0.01	0.03	−0.09	0.17
Working-age share 20–64 in $t-1$ (in log points)	1340	−0.71	0.16	−1.03	−0.20
Growth of workforce share 15–64 (in log points)	663	0.01	0.04	−0.16	0.21
Workforce share 15–64 in $t-1$ (in log points)	663	−0.97	0.17	−1.62	−0.29
Growth of post-primary education (in log points)	1340	0.14	0.11	−0.01	1.05
Post-primary education (in log points)	1340	−1.23	1.07	−7.06	0.00
Control variables					
Life expectancy at birth (in log points)	1340	4.17	0.18	3.42	4.43
Economic freedom (on scale of 0–10)	1340	6.12	1.27	2.35	8.83
Deficits per working-age person (in log points)	769	−9.22	1.63	−14.37	−4.96
Deficits per working-age person (weighted, in log points)	769	−2.90	0.11	−3.09	−2.61
Disability-adjusted life years (in log points)	772	10.56	0.48	9.66	12.14
Years lived with disability (in log points)	772	9.25	0.16	8.95	9.64
Population size (in log points)	1340	9.22	1.61	5.06	14.15
Young-age ratio (ratio, >0)	1340	90.0	39.4	21.7	182.6
Old-age ratio (ratio, >0)	1340	13.0	7.5	0.2	49.4
Trade openness (as % of GDP)	1340	0.49	0.52	0.00	8.56
Quality of democratic institutions (on scale of 0–1)	1268	0.65	0.35	0.00	1.00
Land area in the tropics (in %)	1278	0.47	0.47	0.00	1.00
Land area within 100 kilometers of coast (in %)	1278	0.38	0.35	0.00	1.00
Ethnic fractionalization (on scale of 0–1)	1315	0.44	0.26	0.00	0.93
Economic activity at older ages					
Propensity to work full time beyond age 62 (in %)	85	0.74	0.17	0.37	1.00
Labor force participation in age group 63–75 (in %)	90	0.11	0.10	0.01	0.60

Note: This table reports descriptive statistics for the full sample of 145 countries. The prospective old-age threshold (POAT) denotes the (country- and time-varying) age at which remaining life expectancy falls below 15 years. Income figures refer to gross domestic product (GDP) per capita, measured in millions of international US dollars. Measures for maximum grip strength and immediate word recall refer to averages among the population age 50 and older. Propensity to work full time beyond age 62 measures the population share of people aged 50–62 who state a positive probability of working full time beyond age 62.

A.2 Parameter Estimates for Covariates in the Main Analysis

Table A.3 shows that the parameter estimates for the covariates in the instrumental variables specifications match the stylized facts in the literature on economic growth. Lagged income per capita correlates negatively with growth over the subsequent five years. According to our estimates, countries converge to their long-run productivity potential at an annual rate of 1.2–2.6 percent, concurring with previous estimates of about 2 percent (Durlauf et al. 2005). Capital accumulation in turn promotes income growth. The estimates document a factor share of approximately one-third. This figure parallels national income accounts data for developed countries (Jones 2016). Human capital boosts growth both as a production factor and as an engine of technological progress (Krueger and Lindahl 2001). Finally, population health and quality of economic institutions predict economic growth (Bloom et al. 2004; Rodrik et al. 2004).

Table A.3: Population age structure and economic growth: Full results

	Prospective working ages (20–POAT)		Retrospective working ages (20–64)	
Dependent variable: income per capita growth	Uniform growth trends and convergence (2SLS) (1)	Country-specific growth trends and convergence (GMM) (2)	Uniform growth trends and convergence (2SLS) (3)	Country-specific growth trends and convergence (GMM) (4)
Log income per capita ($t-1$)	−0.06***	−0.13***	−0.06***	−0.08***
	(0.02)	(0.06)	(0.02)	(0.03)
Growth of capital per worker	0.32***	0.30***	0.32***	0.32***
	(0.04)	(0.05)	(0.04)	(0.04)
Growth of working-age share	0.79***	0.98***	0.89***	0.92***
	(0.23)	(0.25)	(0.23)	(0.24)
Log working-age share ($t-1$)	0.13*	0.44	0.14**	0.24
	(0.07)	(0.34)	(0.06)	(0.18)
Growth of post-primary education	0.23**	0.17	0.23**	0.23**
	(0.11)	(0.12)	(0.11)	(0.10)
Log post-primary education ($t-1$)	0.03**	0.41	0.03**	0.19
	(0.01)	(0.37)	(0.01)	(0.19)
Log post-primary education ($t-1$) ×	—	0.15	—	0.07
working-age share ($t-1$)	—	(0.18)	—	(0.10)
Log post-primary education ($t-1$) ×	—	−0.03	—	−0.01
log income per capita ($t-1$)	—	(0.03)	—	(0.02)
Economic freedom	0.03***	0.04***	0.03***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)
Log life expectancy at birth	0.17**	0.17**	0.18**	0.17**
	(0.07)	(0.08)	(0.07)	(0.07)
First-stage F-statistic	230.2	—	475.3	—
p-value growth effect	0.36	0.92	0.62	0.75
p-value level effect	0.28	0.36	0.19	0.38
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.63	—	0.34
Underidentification test p-value	—	0.00	—	0.00
Hansen test p-value	—	0.38	—	0.27
Diff-in-Hansen test p-value	—	0.20	—	0.11
Excluded instruments	1	4	1	4
Countries	145	145	145	145
Observations	1340	1289	1340	1289

Note: This table shows the full set of results for the specifications in Table 3. Estimates are obtained from two-stage least squares (2SLS) and system general method of moments (GMM) for a panel of 145 countries in five-year intervals throughout 1950–2015. All specifications instrument growth of the working-age share with the lagged population share of the age group 15–19. In specifications (1) and (2), the working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In specifications (3) and (4), the working-age population comprises people in the age range 20–64. All specifications control for time effects. Specifications (2) and (4) additionally account for country fixed effects by transforming the data with forward orthogonal deviations. The system GMM estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are clustered at the country level and reported in parentheses. Standard errors in GMM specifications are computed with the two-step procedure and corrected for sample size (Windmeijer 2005). Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

A.3 Effect Stability in General Method of Moment Specifications

An important implicit assumption in work on the demographic dividend is that the effects of population age structure on economic growth are stable across countries and over time. If this were not the case, comparisons of countries' demographic trajectories would provide limited insights as to economic growth, and policy recommendations based on historical episodes would have little bearing for other periods. We confirm this stability assumption for two-stage least squares specifications that assume uniform growth trends and convergence (Table 4 in the text) and general method of moment specifications that account for country-specific growth trends and convergence (Table A.4).

Table A.4: General method of moments results: The effects of population age structure are stable across samples

Dependent variable: income per capita growth	Full sample (1)	OECD countries (2)	Non-OECD countries (3)	Sample 1950–2000 (4)	Sample 1965–2015 (5)
Growth of working-age share	0.98***	1.19***	1.12	1.07***	0.92***
	(0.25)	(0.30)	(0.74)	(0.25)	(0.26)
Log working-age share ($t-1$)	0.44	0.60**	1.20	0.54**	0.42
	(0.34)	(0.30)	(1.26)	(0.26)	(0.36)
p-value growth effect	0.92	0.52	0.87	0.77	0.76
p-value level effect	0.36	0.23	0.47	0.13	0.42
AR(1) p-value	0.00	0.01	0.00	0.00	0.00
AR(2) p-value	0.63	0.93	0.93	0.70	0.64
Underidentification test p-value	0.00	0.01	0.31	0.00	0.00
Hansen test p-value	0.38	0.16	0.76	0.92	0.43
Diff-in-Hansen test p-value	0.20	0.12	0.85	0.84	0.22
Countries	145	34	111	123	145
Observations	1289	374	915	864	1223

Note: This table shows the stability of the effects of population age structure on economic growth across samples. The estimates are obtained from system general method of moments for a panel of 145 countries in five-year intervals throughout 1950–2015. The table shows results for the full sample (1), OECD countries (2), non-OECD countries (3), and abridged samples spanning the periods 1950–2000 (4) and 1965–2015 (5). All specifications include covariates and control for time and country fixed effects. They instrument growth of the working-age share with the lagged population share of the age group 15–19 in the differences equation and with the lagged first difference of this share in the levels equation. The estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are computed with the two-step procedure, corrected for sample size (Windmeijer 2005), and reported in parentheses. Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

A.4 Additional Results and Robustness Analysis

Workforce estimates. In the main analysis, we measure countries' labor potentials with working-age rather than workforce shares because labor force participation tends to correlate with productivity over the business cycle. To test whether our findings hinge on this measurement choice, we construct workforce shares from population counts and data on labor force participation, which are available from 1990 onward (reducing sample size by about half). For reasons of data availability, we focus on the population age 15 and older. Estimates predicated on workforce shares are quantitatively similar to those based on working-age shares, as Table A.5 shows. According to the two-stage least squares specifications, a 1 percent increase in the workforce share (about 0.4 percentage points) raises income per capita by 1 percent. The corresponding parameters for the general method of moments specifications are larger but less precise and not significantly different from unity. Estimates for the lagged workforce share are positive but only significant when country-specific growth trends and convergence are considered.

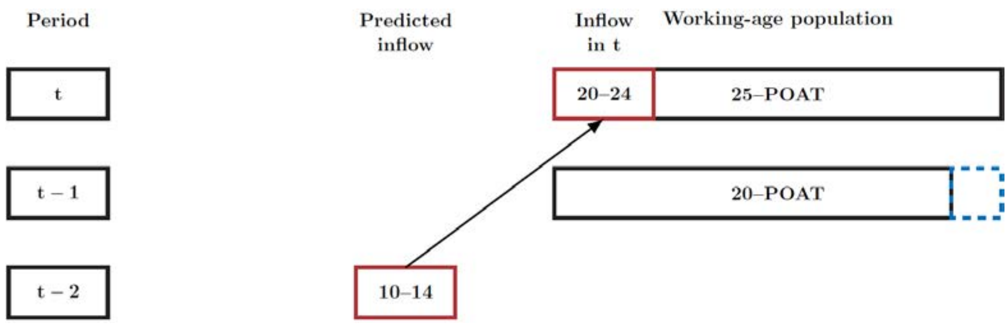
Table A.5: Workforce share and economic growth

	Prospective working ages (20–POAT)		Retrospective working ages (20–64)	
Dependent variable: income per capita growth	Uniform growth trends and convergence (2SLS) (1)	Country-specific growth trends and convergence (GMM) (2)	Uniform growth trends and convergence (2SLS) (3)	Country-specific growth trends and convergence (GMM) (4)
Growth of workforce share	1.03**	1.94***	0.96***	2.06***
	(0.42)	(0.67)	(0.36)	(0.75)
Log workforce share ($t-1$)	0.00	0.41**	0.03	0.25*
	(0.04)	(0.20)	(0.04)	(0.13)
First stage				
Log population share 10–14 ($t-1$)	0.07***	—	0.09***	—
	(0.01)	—	(0.01)	—
Reduced form				
Log population share 10–14 ($t-1$)	0.07**	—	0.08***	—
	(0.03)	—	(0.03)	—
First-stage F-statistic	39.1	—	69.7	—
p-value growth effect	0.95	0.16	0.91	0.16
p-value level effect	0.11	0.38	0.25	0.45
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.04	—	0.02
Underidentification test p-value	—	0.02	—	0.01
Hansen test p-value	—	0.87	—	1.00
Diff-in-Hansen test p-value	—	0.91	—	0.99
Excluded instruments	1	4	1	4
Countries	145	145	145	145
Observations	663	663	663	663

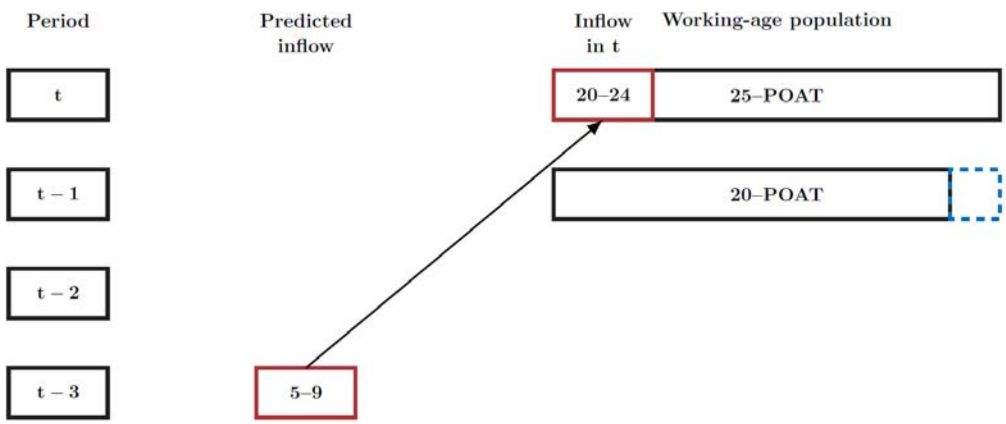
Note: This table shows the results' robustness for specifications that measure population age structure with the workforce share. Estimates are obtained from two-stage least squares (2SLS) and system general method of moments (GMM) for a panel of 145 countries in five-year intervals throughout 1950–2015. The workforce share is computed by multiplying the working-age population with the average labor force participation rate of the population age 15 and older. All specifications instrument growth of the workforce share with the lagged population share of the age group 10–14. In specifications (1) and (2), the working-age population comprises people in the age range 15–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In specifications (3) and (4), the working-age population comprises people in the age range 15–64. All specifications include covariates and control for time effects. Specifications (2) and (4) additionally account for country fixed effects by transforming the data with forward orthogonal deviations. The system GMM estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are clustered at the country level and reported in parentheses. Standard errors in GMM specifications are computed with the two-step procedure and corrected for sample size (Windmeijer 2005). Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Alternative specifications of instrumental variables. The identification assumption of our empirical strategy requires that unobserved heterogeneity in period t does not causally affect the population shares in previous periods that we use to predict the inflow into working-age shares. This assumption would be violated if people anticipated future productivity shocks and adjusted their behavior such that population age structure changed. While we cannot test this assumption directly, we can provide indirect evidence of its plausibility by instrumenting working-age shares with more distant (but still predictive) lags of cohorts that reach working ages in period t. Intuitively, effects of forward-looking behavior are less likely the further an instrument's variation lies in the past. We instrument changes in the working-age share in period t by the population shares of age group 10–14 in $t-2$ (10-year lag), of age group 5–9 in $t-3$ (15-year lag), and of age group 0–4 in $t-4$ (20-year lag): see Figure A.1 for an illustration. Table A.6 shows that the corresponding parameters are similar to our baseline estimates and close to unity with few exceptions, with the results appearing especially stable when accounting for country-specific growth trends and convergence. Furthermore, overidentification tests in specifications that combine all lags do not reject the null hypothesis that these instruments provide the same information.

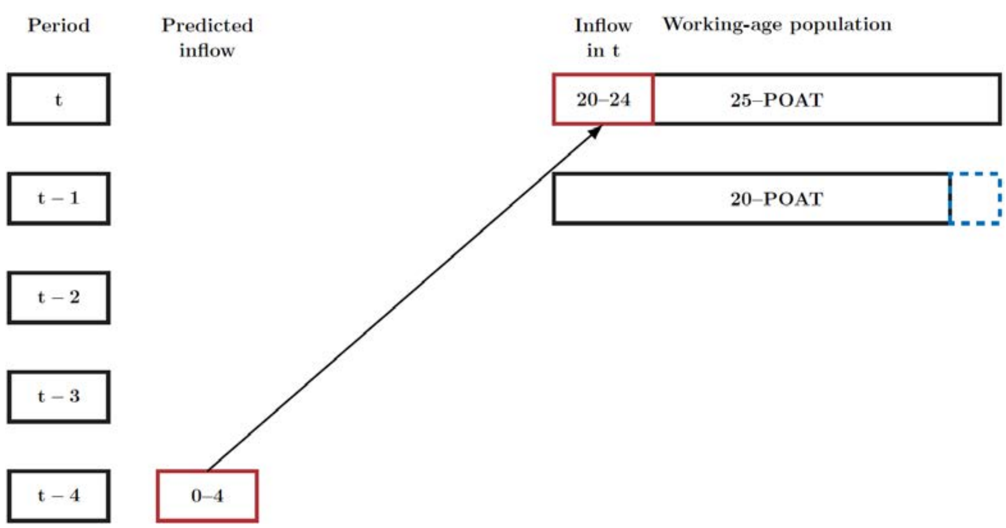
Another way to indirectly probe the identification assumption is to use the demographic structure to predict the outflow out of the working ages. To this end, we include the population share of age group 60–64 in period $t-1$ as another instrument in our specifications. Table A.7 reports the respective estimates, supporting the baseline results. However, because prospective old-age thresholds differ across countries and evolve over time, past cohort size can only provide an imprecise taxonomy of being in and out of the working-age population and has much lower predictive power than the inflow into working ages. The results should thus be seen as suggestive.



(a) 10-year lags



(b) 15-year lags



(c) 20-year lags

Figure A.1: Instrumentation of the working-age share with more distant lags

Note: This figure illustrates the first stage of our instrumental variables strategy in additional robustness specifications: see Table A.6. Rather than relying on five-year lags of the population share 15–19, these specifications instrument working-age shares with 10-year lags of the population share 10–14, 15-year lags of the population share 5–9, and 20-year lags of the population share 0–4. Working ages (20–POAT) evolve with changes in the prospective-old threshold over time, as indicated by the dashed rectangle (which may be positive, negative, or zero).

Table A.6: Results for alternative lag specifications

Dependent variable: income per capita growth	5-year lag (1)	10-year lag (2)	15-year lag (3)	20-year lag (4)	All lags (5)
Panel (a): Prospective working ages: 2SLS					
Growth of working-age share	0.79***	0.62***	0.46*	0.35	0.80***
	(0.23)	(0.23)	(0.23)	(0.26)	(0.24)
First-stage F-statistic	230.2	203.3	194.2	147.7	73.2
p-value growth effect	0.36	0.10	0.02	0.01	0.42
p-value level effect	0.28	0.47	0.80	0.95	0.46
Hansen test p-value	—	—	—	—	0.21
Excluded instruments	1	1	1	1	4
Countries	145	145	145	145	145
Observations	1340	1289	1223	1137	1137
Panel (b): Prospective working ages: GMM					
Growth of working-age share	0.98***	0.95***	1.14***	1.12***	0.68***
	(0.25)	(0.27)	(0.35)	(0.43)	(0.24)
p-value growth effect	0.92	0.86	0.69	0.78	0.17
p-value level effect	0.36	0.24	0.32	0.52	0.57
AR(1) p-value	0.00	0.00	0.00	0.00	0.00
AR(2) p-value	0.63	0.67	0.72	0.69	0.55
Underidentification test p-value	0.00	0.00	0.00	0.00	0.00
Hansen test p-value	0.38	0.50	0.66	0.42	0.67
Diff-in-Hansen test p-value	0.20	0.33	0.36	0.22	0.46
Excluded instruments	4	4	4	4	10
Countries	145	145	145	145	145
Observations	1289	1223	1137	1066	1066
Panel (c): Retrospective working ages: 2SLS					
Growth of working-age share	0.89***	0.75***	0.62***	0.55**	0.87***
	(0.23)	(0.22)	(0.22)	(0.24)	(0.24)
First-stage F-statistic	475.3	464.8	465.7	280.7	109.3
p-value growth effect	0.62	0.25	0.08	0.06	0.59
p-value level effect	0.19	0.29	0.45	0.44	0.25
Hansen test p-value	—	—	—	—	0.29
Excluded instruments	1	1	1	1	4
Countries	145	145	145	145	145
Observations	1340	1289	1223	1137	1137
Panel (d): Retrospective working ages: GMM					
Growth of working-age share	0.92***	0.84***	1.09***	1.09***	0.69**
	(0.24)	(0.25)	(0.34)	(0.41)	(0.29)
p-value growth effect	0.75	0.51	0.80	0.83	0.28
p-value level effect	0.38	0.23	0.37	0.60	0.45
AR(1) p-value	0.00	0.00	0.00	0.00	0.00
AR(2) p-value	0.34	0.37	0.36	0.35	0.38
Underidentification test p-value	0.00	0.00	0.00	0.00	0.00
Hansen test p-value	0.27	0.29	0.48	0.34	0.62
Diff-in-Hansen test p-value	0.11	0.20	0.23	0.16	0.34
Excluded instruments	4	4	4	4	10
Countries	145	145	145	145	145
Observations	1289	1223	1137	1066	1066

Note: This table shows the results' robustness to using alternative lags for instrumentation. Estimates are obtained from two-stage least squares (2SLS) and system general method of moments (GMM) for a panel of 145 countries in five-year intervals throughout 1950–2015. The specifications instrument growth of the working-age share with the lagged population share of age group 15–19 (1), the second lag of the population share of age group 10–14 (2), the third lag of the population share of age group 5–9 (3), the fourth lag of the population share of age group 0–4 (4), and all four lags together (5). In panels (a) and (b), the working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In panels (c) and (d), the working-age population comprises people in the age range 20–64. All specifications include covariates and control for time effects. GMM specifications additionally account for country fixed effects by transforming the data with forward orthogonal deviations. The system GMM estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are clustered at the country level and reported in parentheses. Standard errors in GMM specifications are computed with the two-step procedure and corrected for sample size (Windmeijer 2005). Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A.7: Robustness: Instrumentation with inflow into and outflow out of the working-age share

Dependent variable: income per capita growth	Prospective working ages (20–POAT)		Retrospective working ages (20–64)	
	Uniform growth trends and convergence (2SLS) (1)	Country-specific growth trends and convergence (GMM) (2)	Uniform growth trends and convergence (2SLS) (3)	Country-specific growth trends and convergence (GMM) (4)
Growth of working-age share	0.67***	1.01***	0.71***	1.00***
	(0.22)	(0.26)	(0.21)	(0.25)
Log working-age share ($t-1$)	0.12*	0.44	0.13**	0.25
	(0.07)	(0.31)	(0.06)	(0.21)
First-stage F-statistic	122.3	—	269.7	—
p-value growth effect	0.13	0.97	0.18	0.99
p-value level effect	0.35	0.32	0.25	0.39
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.68	—	0.36
Underidentification test p-value	—	0.00	—	0.00
Hansen test p-value	0.03	0.07	0.04	0.11
Diff-in-Hansen test p-value	—	0.13	—	0.08
Excluded instruments	2	6	2	6
Countries	145	145	145	145
Observations	1340	1289	1340	1289

Note: This table shows that the working-age share affects economic growth when using both the predicted inflow into and outflow out of the working-age share as instruments. Estimates are obtained from two-stage least squares (2SLS) and system general method of moments (GMM) for a panel of 145 countries in five-year intervals throughout 1950–2015. All specifications instrument growth of the working-age share with the lagged population shares of the age groups 15–19 and 60–64. In specifications (1) and (2), the working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In specifications (3) and (4), the working-age population comprises people in the age range 20–64. All specifications include covariates and control for time effects. Specifications (2) and (4) additionally account for country fixed effects by transforming the data with forward orthogonal deviations. The system GMM estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are clustered at the country level and reported in parentheses. Standard errors in GMM specifications are computed with the two-step procedure and corrected for sample size (Windmeijer 2005). Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Physiological aging and disability. The prospective working-age share builds on variation in remaining life expectancy to approximate countries' labor potential. This modeling is appropriate if improvements in life expectancy reasonably capture changes in functional capacity (as the evidence in Table 1 suggests). However, a concern with this modeling might still be that remaining life expectancy primarily accounts for mortality, omitting heterogeneity in functional capacity related to physiological aging and disability. We address this concern by separately controlling for average health deficits per working-age person, disability-adjusted life years, and years lived with disability. If disability were to restrict the labor potential and impair economic growth over and above variation captured by remaining life expectancy, the parameter estimates for the working-age share in the main analysis would be biased upward. The results in Tables A.8 and A.9 refute this case. The estimated parameters do not significantly differ from those in the main analysis and match the constraints of our aggregate production model. Moreover, disability does not affect income per capita beyond its effect through working-age shares.

Table A.8: Controlling for average deficits per working-age person

Dependent variable: income per capita growth	Prospective working ages (20–POAT)		Retrospective working ages (20–64)	
	Uniform growth trends and convergence (2SLS) (1)	Country-specific growth trends and convergence (GMM) (2)	Uniform growth trends and convergence (2SLS) (3)	Country-specific growth trends and convergence (GMM) (4)
Panel (a): Deficits per working-age person (20–64)				
Growth of working-age share	1.19***	1.32***	1.31***	1.49***
	(0.32)	(0.40)	(0.31)	(0.42)
Log working-age share ($t-1$)	0.16*	0.53	0.15**	0.38
	(0.09)	(0.58)	(0.07)	(0.34)
Log deficits	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
First-stage F-statistic	158.6	—	326.7	—
p-value growth effect	0.56	0.43	0.31	0.24
p-value level effect	0.31	0.53	0.25	0.45
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.16	—	0.03
Underidentification test p-value	—	0.01	—	0.00
Hansen test p-value	—	0.54	—	0.57
Diff-in-Hansen test p-value	—	0.34	—	0.29
Excluded instruments	1	4	1	4
Countries	144	144	144	144
Observations	769	769	769	769
Panel (b): Deficits per working age person (20–64) weighted by population age structure				
Growth of working-age share	1.21***	1.36***	1.29***	1.49***
	(0.36)	(0.40)	(0.33)	(0.42)
Log working-age share ($t-1$)	0.16*	0.57	0.15*	0.38
	(0.09)	(0.62)	(0.08)	(0.35)
Log deficits	0.01	0.13	−0.01	0.06
	(0.06)	(0.10)	(0.06)	(0.08)
First-stage F-statistic	79.3	—	215.5	—
p-value growth effect	0.56	0.37	0.38	0.24
p-value level effect	0.30	0.53	0.24	0.48
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.19	—	0.03
Underidentification test p-value	—	0.03	—	0.00
Hansen test p-value	—	0.63	—	0.58
Diff-in-Hansen test p-value	—	0.37	—	0.30
Excluded instruments	1	4	1	4
Countries	144	144	144	144
Observations	769	769	769	769

Note: This table shows the results' robustness to controlling for physiological aging. Estimates are obtained from two-stage least squares (2SLS) and system general method of moments (GMM) for a panel of 145 countries in five-year intervals throughout 1950–2015. We measure disability by average deficits per working-age person computed from age-specific deficit rates in five-year age groups. Results in panel (a) refer to the unweighted average of deficits, whereas results in panel (b) refer to average deficits weighted by the size of five-year age groups. All specifications instrument growth of the working-age share with the lagged population share of the age group 15–19. In specifications (1) and (2), the working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In specifications (3) and (4), the working-age population comprises people in the age range 20–64. All specifications include covariates and control for time effects. Specifications (2) and (4) additionally account for country fixed effects by transforming the data with forward orthogonal deviations. The system GMM estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are clustered at the country level and reported in parentheses. Standard errors in GMM specifications are computed with the two-step procedure and corrected for sample size (Windmeijer 2005). Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A.9: Controlling for disability-adjusted measures of life loss

Dependent variable: income per capita growth	Prospective working ages (20–POAT) Uniform growth trends and convergence (2SLS) (1)	Prospective working ages (20–POAT) Country-specific growth trends and convergence (GMM) (2)	Retrospective working ages (20–64) Uniform growth trends and convergence (2SLS) (3)	Retrospective working ages (20–64) Country-specific growth trends and convergence (GMM) (4)
Panel (a): Disability-adjusted life years (DALYs) per 100000 population				
Growth of working-age share	1.28**	1.32***	1.32***	1.47***
	(0.53)	(0.39)	(0.43)	(0.41)
Log working-age share $(t-1)$	0.17	0.53	0.15**	0.36
	(0.10)	(0.57)	(0.07)	(0.34)
Log DALYs	0.02	0.07	0.00	0.04
	(0.05)	(0.06)	(0.04)	(0.05)
First-stage F-statistic	37.3	—	150.6	—
p-value growth effect	0.60	0.40	0.45	0.25
p-value level effect	0.32	0.52	0.23	0.47
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.17	—	0.03
Underidentification test p-value	—	0.02	—	0.00
Hansen test p-value	—	0.57	—	0.58
Diff-in-Hansen test p-value	—	0.36	—	0.29
Excluded instruments	1	4	1	4
Countries	145	145	145	145
Observations	772	772	772	772
Panel (b): Years lived with disability (YLDs) per 100000 population				
Growth of working-age share	0.89**	1.32***	1.07***	1.46***
	(0.35)	(0.41)	(0.36)	(0.40)
Log working-age share $(t-1)$	0.18*	0.56	0.18**	0.37
	(0.09)	(0.63)	(0.08)	(0.36)
Log YLDs	−0.08	0.11	−0.07	0.06
	(0.05)	(0.16)	(0.06)	(0.11)
First-stage F-statistic	67.7	—	139.0	—
p-value growth effect	0.76	0.43	0.85	0.25
p-value level effect	0.22	0.55	0.12	0.50
AR(1) p-value	—	0.00	—	0.00
AR(2) p-value	—	0.20	—	0.03
Underidentification test p-value	—	0.08	—	0.00
Hansen test p-value	—	0.58	—	0.59
Diff-in-Hansen test p-value	—	0.36	—	0.31
Excluded instruments	1	4	1	4
Countries	145	145	145	145
Observations	772	772	772	772

Note: This table shows the results' robustness to controlling for disability. Estimates are obtained from two-stage least squares (2SLS) and system general method of moments (GMM) for a panel of 145 countries in five-year intervals throughout 1950–2015. We measure disability by disability-adjusted years of life per 100,000 population in panel (a) and years lived with disability in panel (b). All specifications instrument growth of the working-age share with the lagged population share of the age group 15–19. In specifications (1) and (2), the working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In specifications (3) and (4), the working-age population comprises people in the age range 20–64. All specifications include covariates and control for time effects. Specifications (2) and (4) additionally account for country fixed effects by transforming the data with forward orthogonal deviations. The system GMM estimators instrument lagged income per capita using the second lag in the differences equation and the lagged first difference for instrumentation in the levels equation; the specifications use one instrument for each variable rather than for each time period (collapsed instrument set). Tests for serial correlation, underidentification, and overidentification check validity of the identifying assumptions. Standard errors are clustered at the country level and reported in parentheses. Standard errors in GMM specifications are computed with the two-step procedure and corrected for sample size (Windmeijer 2005). Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Additional controls. Another potential concern is that our instrumentation does not fully rule out other factors that determine economic growth and correlate with working-age shares. To address this concern, we estimate extended specifications in which we control for additional determinants of growth previous work in the literature suggests. These specifications account for heterogeneity with respect to population size, young-age and old-age ratios, trade openness, quality of democratic institutions, geography, and ethnic fractionalization. Table A.10 documents that including these determinants neither changes the quantitative findings nor improves the model's fit. By controlling for population composition in terms of young-age and old-age ratios, we also explicitly consider that variation in working-age shares may be driven by different age groups over the course of the demographic transition and that total factor productivity may be lower in societies with large youth or elderly populations (Kögel 2005; Aiyar et al. 2016).

Table A.10: Additional control variables

Dependent variable: income per capita growth	Baseline specification (1)	Population size (2)	Age ratios (3)	Trade openness (4)	Democratic institutions (5)	Geographic controls (6)	Ethnic tensions (7)
Growth of working-age share	0.79***	0.79***	1.43***	0.82***	0.79***	0.93***	0.79***
	(0.23)	(0.23)	(0.49)	(0.23)	(0.24)	(0.25)	(0.23)
Log of working-age share ($t-1$)	0.13*	0.14*	0.34*	0.14*	0.13*	0.09	0.13*
	(0.07)	(0.07)	(0.20)	(0.07)	(0.07)	(0.07)	(0.07)
Log population size	—	0.00	—	—	—	—	—
	—	(0.00)	—	—	—	—	—
Young-age ratio (coefficients $\times$ 100)	—	—	0.12	—	—	—	—
	—	—	(0.09)	—	—	—	—
Old-age ratio (coefficients $\times$ 100)	—	—	0.39**	—	—	—	—
	—	—	(0.19)	—	—	—	—
Trade openness	—	—	—	0.02**	—	—	—
	—	—	—	(0.01)	—	—	—
Democratic institutions	—	—	—	—	−0.03	—	—
	—	—	—	—	(0.02)	—	—
Percent land area in the tropics	—	—	—	—	—	−0.03**	—
	—	—	—	—	—	(0.01)	—
Percent land area within 100 kilometers of coast	—	—	—	—	—	−0.02	—
	—	—	—	—	—	(0.02)	—
Ethnic fractionalization	—	—	—	—	—	—	−0.01
	—	—	—	—	—	—	(0.02)
First-stage F-statistic	230.2	230.1	57.8	231.8	203.0	195.1	235.6
p-value growth effect	0.36	0.36	0.38	0.44	0.40	0.79	0.38
p-value level effect	0.28	0.27	0.17	0.27	0.31	0.65	0.35
Countries	145	145	145	145	140	138	142
Observations	1340	1340	1340	1340	1268	1278	1315

Note: This table shows the results' robustness to including additional control variables. Estimates are obtained from two-stage least squares for a panel of 145 countries in five-year intervals throughout 1950–2015. All specifications instrument growth of the working-age share with the lagged population share of the age group 15–19. The working-age population comprises people in age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. Specification (1) replicates the baseline model from Table 3. Specifications (2) to (7) separately control for log population size, young-age and old-age ratios, trade openness, democratic institutions, the percent of land area in the tropics and within 100 kilometers of the coast or navigable rivers, and ethnic fractionalization. Coefficients for the age ratios are multiplied by 100 for illustration. All specifications include covariates and control for time effects. Standard errors are clustered at the country level and reported in parentheses. Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

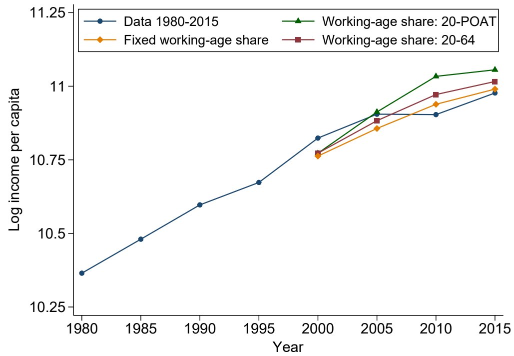
Calibrated specifications. Yet another concern might be that the estimates react sensitively to changes in the covariates. This can happen when the explanatory variables draw on similar variation. We probe the sensitivity of our results by calibrating the effects of population age structure on economic growth with the parameters our aggregate production function imposes. Specifically, we constrain the growth effect of the working-age share to unity and likewise the level effect to λ. Table A.11 presents the corresponding estimates for the covariates, which mirror those for our main specifications (reported in Table A.3).

Table A.11: Calibrated parameters for population age structure

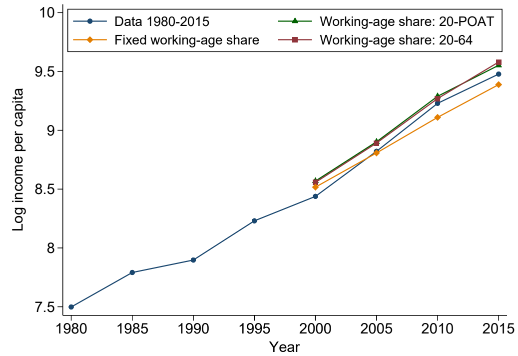
	Prospective working ages (20–POAT)		Retrospective working ages (20–64)	
Dependent variable: income per capita growth	Uniform growth trends and convergence (1)	Country-specific growth trends and convergence (2)	Uniform growth trends and convergence (3)	Country-specific growth trends and convergence (4)
Log income per capita ($t-1$)	−0.06***	−0.09***	−0.06***	−0.09***
	(0.01)	(0.03)	(0.01)	(0.03)
Growth of capital per worker	0.32***	0.29***	0.33***	0.30***
	(0.04)	(0.06)	(0.04)	(0.06)
Growth of post-primary education	0.19*	0.27*	0.20*	0.29*
	(0.10)	(0.15)	(0.11)	(0.15)
Log post-primary education ($t-1$)	0.03**	−0.03	0.03**	−0.03
	(0.01)	(0.10)	(0.01)	(0.09)
Log post-primary education ($t-1$) ×	—	0.00	—	0.00
log income per capita ($t-1$)	—	(0.01)	—	(0.01)
Economic freedom	0.03***	0.05***	0.03***	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)
Log life expectancy at birth	0.19***	0.21**	0.18***	0.17*
	(0.06)	(0.10)	(0.06)	(0.09)
R^2	0.31	—	0.31	—
Within R^2	0.23	—	0.24	—
Countries	145	119	145	119
Observations	1340	1169	1340	1169

Note: This table shows the robustness of the parameter estimates for the main covariates when calibrating the effects of the working-age share in accordance with the parameter constraints of our aggregate production function. The calibration imposes values of unity and λ on the growth and level effects of the working-age share (see equation 7). Estimates are obtained from ordinary least squares for a panel of 145 countries in five-year intervals throughout 1950–2015. In specifications (1) and (2), the working-age population comprises people in the age range 20–POAT, where POAT denotes the country-specific old-age threshold at which remaining life expectancy falls below 15 years. In specifications (3) and (4), the working-age population comprises people in the age range 20–64. All specifications control for time effects. Specifications (2) and (4) further add country-fixed effects and use Breitung et al.'s (2022) estimator to correct the mechanical bias arising in dynamic panels with few time periods. Standard errors are clustered at the country level and reported in parentheses. Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

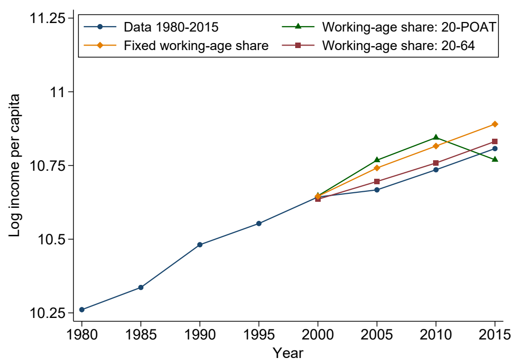
A.5 Projections for Selected Countries



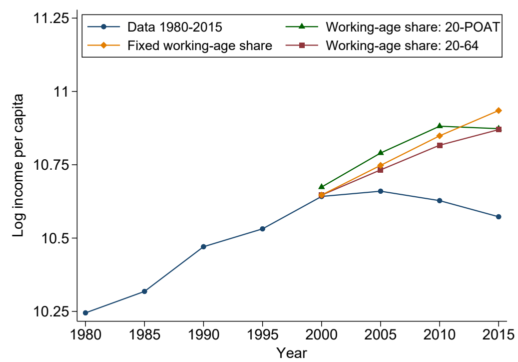
(a) United States



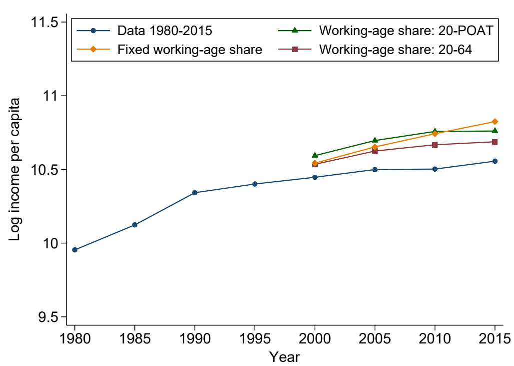
(b) China



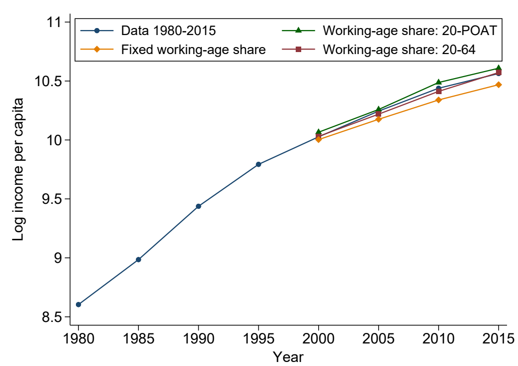
(c) Germany



(d) Italy



(e) Japan

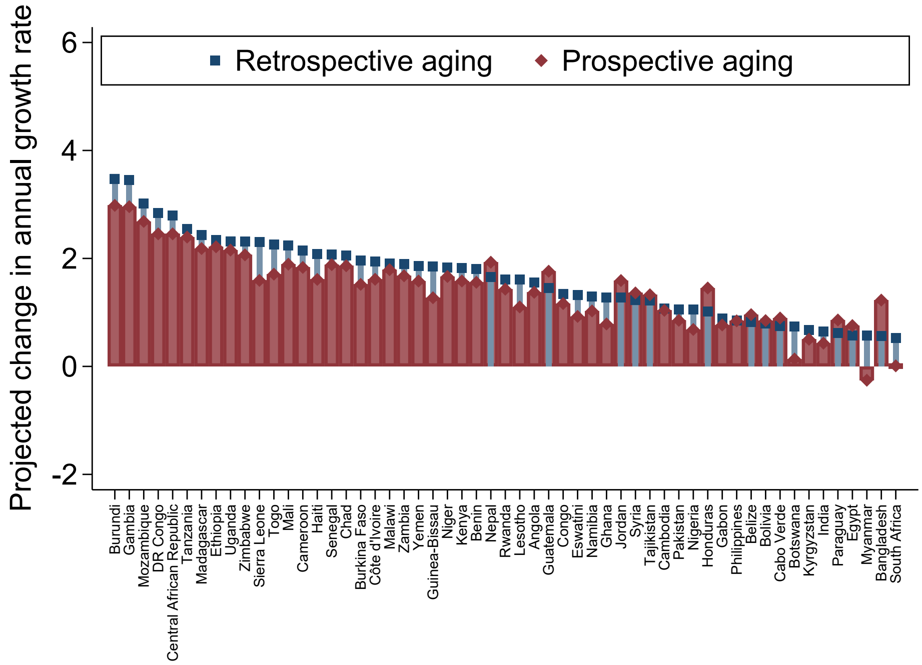


(f) Korea

Figure A.2: Predictive power of the model: Selected countries

Note: This figure compares observed and projected income per capita for selected countries in 2000–2015. The projections are based on parameters derived from estimating specification (1) of Table 3 for an abridged sample 1950–1995. The figure compares observed income per capita with three projections predicated on fixed working-age shares (as of 1995), retrospective working-age shares (20–64), and prospective working-age shares (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years.

A.6 Projected Demographic Dividends and Drags in Non-OECD Countries



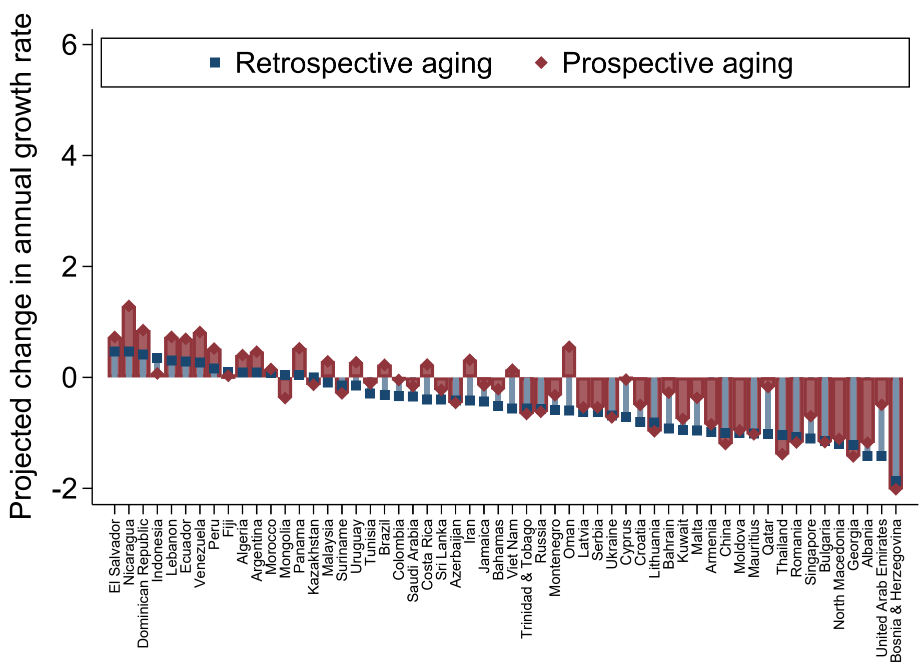
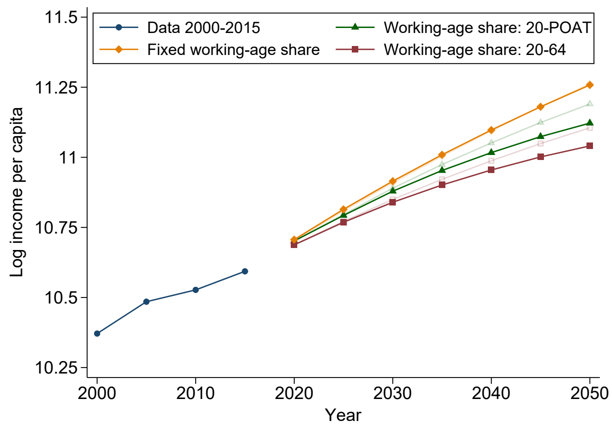


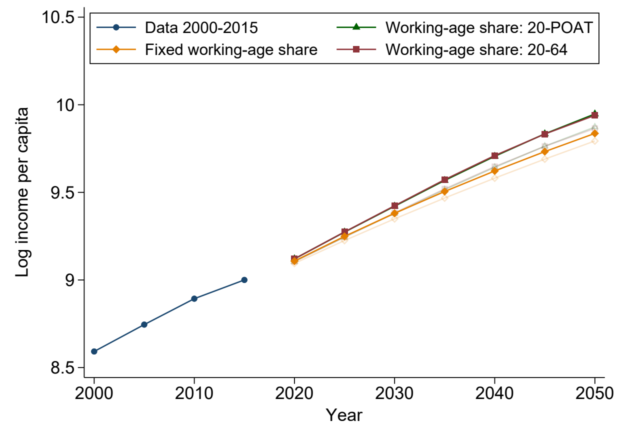
Figure A.3: Projected change in annual growth rates in non-OECD countries

Note: This figure depicts the projected cumulative change in annual growth rates in 2020–2050 in non-OECD countries. It contrasts the estimated demographic drags and dividends based on the retrospective-aging scenario with estimated demographic drags and dividends based on the prospective-aging scenario. The projections are predicated on the parameters estimated in specification (1) of Table 3.

A.7 Endogenous Capital Formation



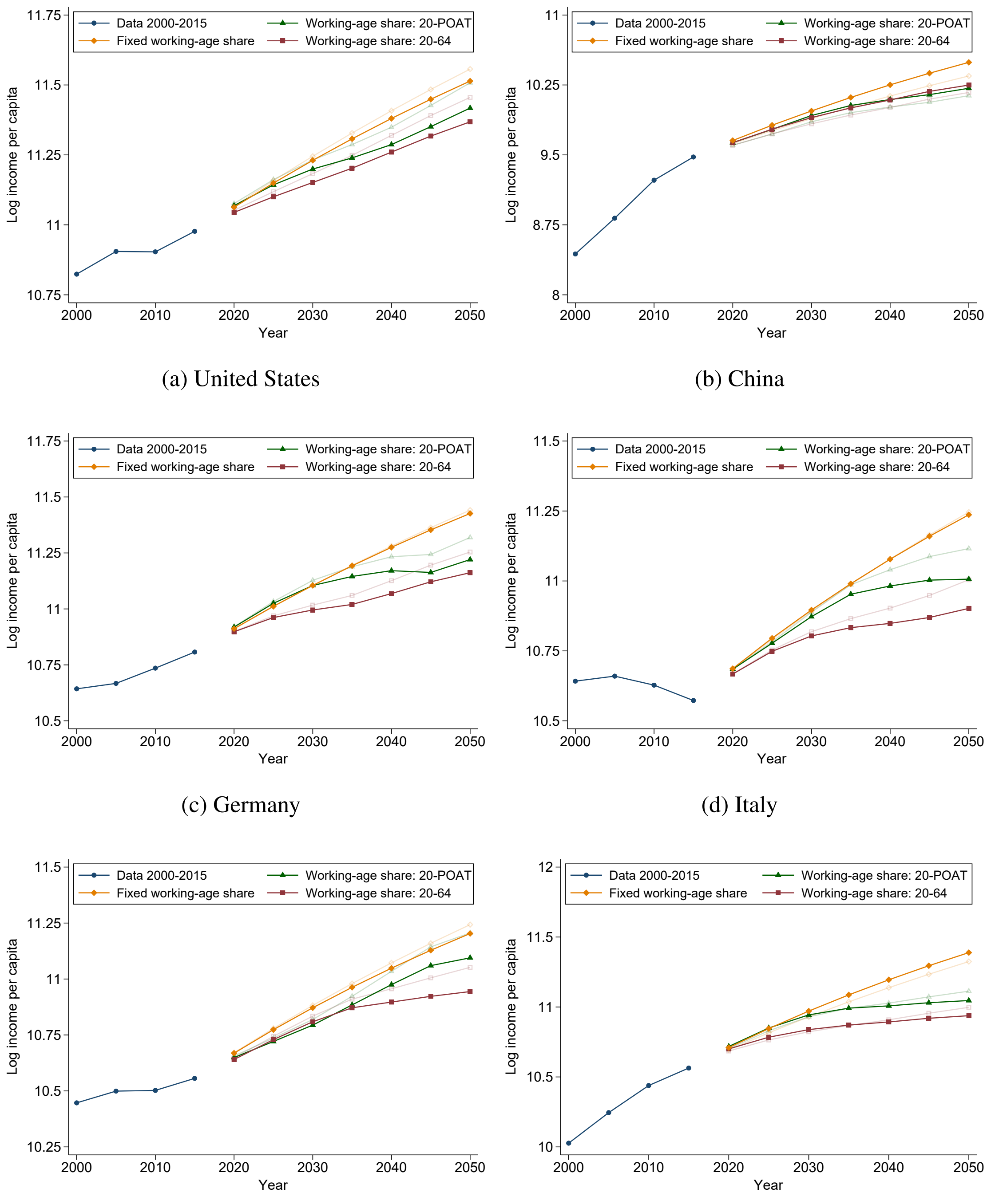
(a) OECD countries



(b) Non-OECD countries

Figure A.4: Projected income per capita: Endogenous capital formation

Note: This figure shows projected income per capita for OECD and non-OECD countries in 2020–2050. The projections are based on the parameters estimated in specification (1) of Table 3. We endogenously determine capital growth and iteratively update capital stocks and per capita incomes. The figure contrasts income per capita across three projections predicated on fixed working-age shares (as of 2015), retrospective working-age shares (20–64), and prospective working-shares (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years. Shaded lines display projected income per capita under exogenous capital formation.



(a) United States (b) China

(c) Germany (d) Italy

(e) Japan (f) Korea

Figure A.5: Projected income per capita: Endogenous capital formation

Note: This figure shows projected income per capita for selected countries in 2020–2050. The projections are based on the parameters estimated in specification (1) of Table 3. We endogenously determine capital growth and iteratively update capital stocks and per capita incomes. The figure contrasts income per capita across three projections predicated on fixed working-age shares (as of 2015), retrospective working-age shares (20–64), and prospective working-shares (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years. Shaded lines display projected income per capita under exogenous capital formation.

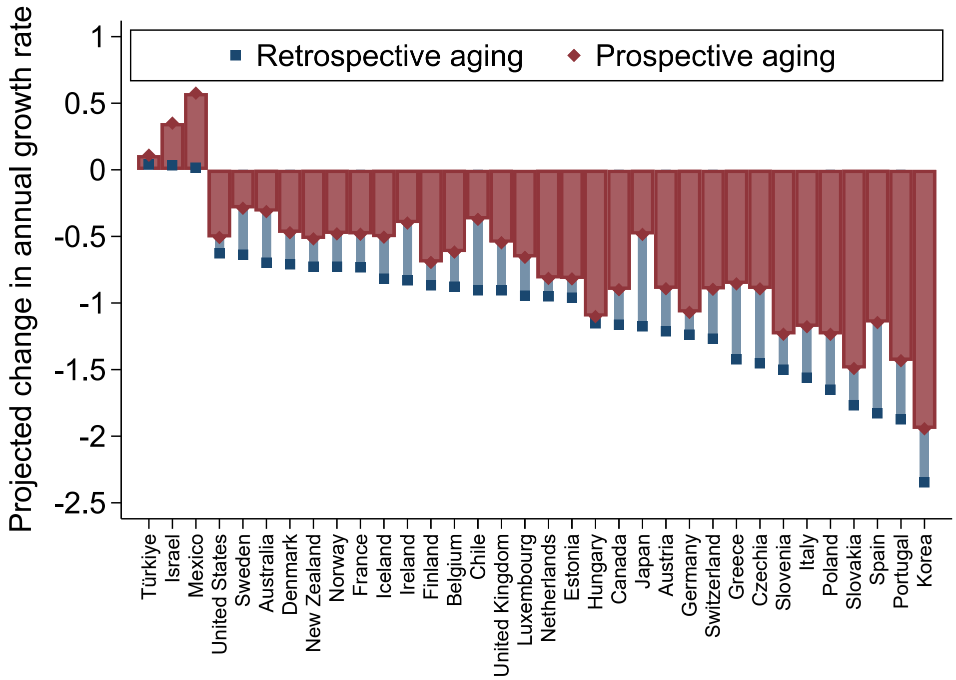
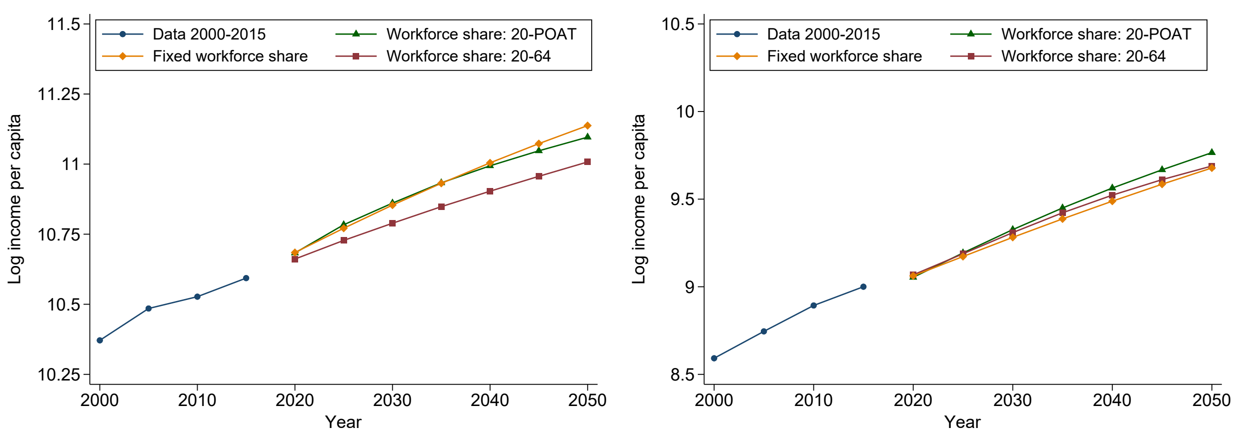


Figure A.6: Projected change in annual growth rates for OECD countries: Endogenous capital formation

Note: This figure depicts the projected cumulative change in annual growth rates in 2020–2050 in OECD countries. It contrasts the estimated demographic drags and dividends based on the retrospective-aging scenario with the estimated demographic drags and dividends based on the prospective-aging scenario. The projections are predicated on the parameters estimated in specification (1) of Table 3. We endogenously determine capital growth and iteratively update capital stocks and per capita incomes.

A.8 Additional Results and Sensitivity Analysis

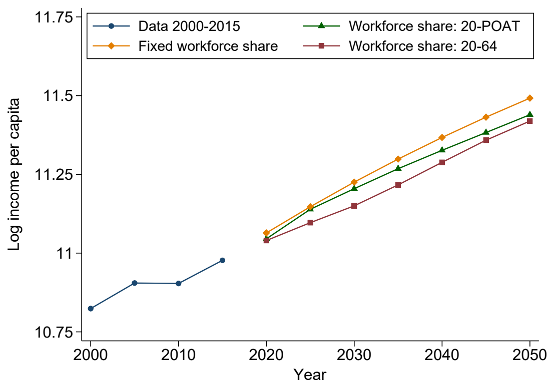
Workforce projections. The baseline projections predict economic growth based on working-age rather than workforce shares because projections of labor force participation are fraught with uncertainty—especially since the Covid-19 pandemic's unprecedented shock to labor markets (International Labour Organization 2021). Nevertheless, gauging the results' sensitivity to workforce measures is possible if one is willing to make assumptions about labor force participation in future years. One option is to assume that increasing participation among older workers balances decreasing overall participation caused by compositional shifts from prime-age to older workers, such that average labor force participation in the population remains constant. The corresponding results in Figures A.7–A.8 show similar dynamics in income per capita as the main analysis. Increases in prospective old-age thresholds can even cushion about 60 percent of the demographic drag in OECD countries. This portion increases with labor force participation, suggesting economic gains for policies that promote employment opportunities for older workers.



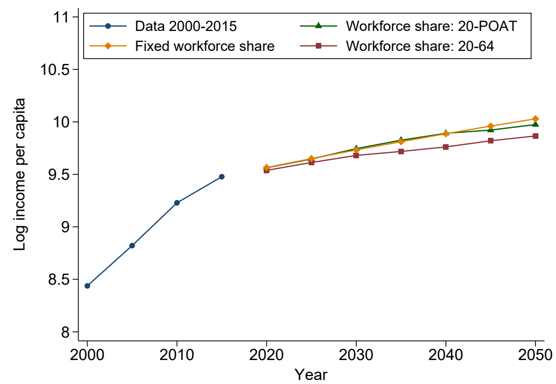
(a) OECD countries (b) Non-OECD countries

Figure A.7: Projected income per capita: Workforce estimates

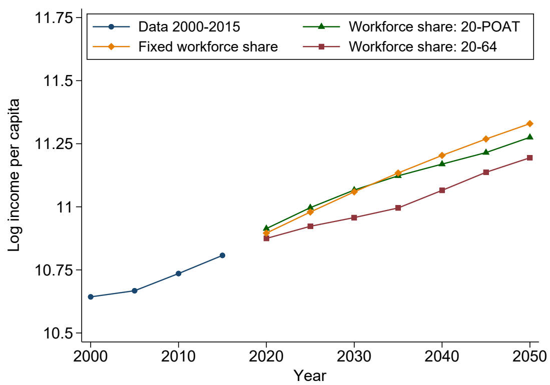
Note: This figure shows projected income per capita for OECD and non-OECD countries in 2020–2050. The projections are based on the parameters estimated in specification (1) of Table A.5. The figure contrasts income per capita across three projections predicated on fixed working-age shares (as of 2015), retrospective working-age shares (15–64), and prospective working-age shares (15–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years. Workforce shares are derived from multiplying the working-age population with the average labor force participation among people age 15 and older.



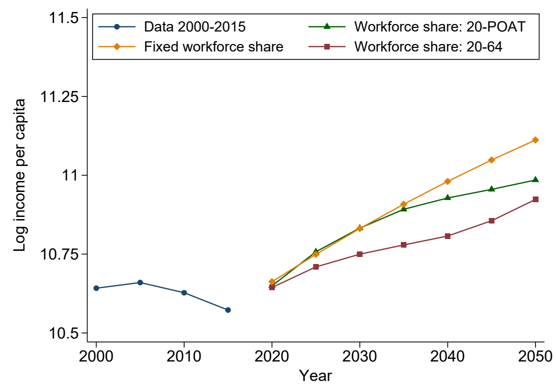
(a) United States



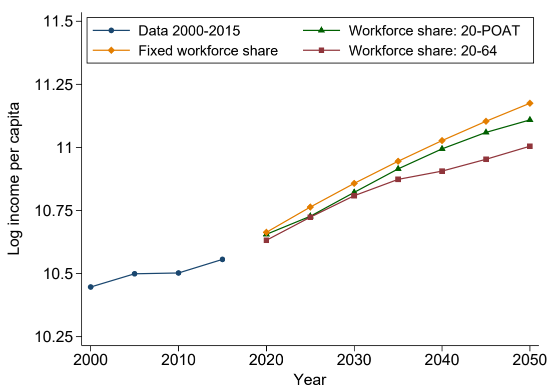
(b) China



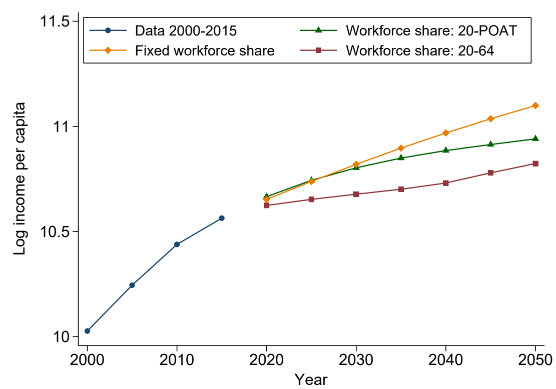
(c) Germany



(d) Italy



(e) Japan

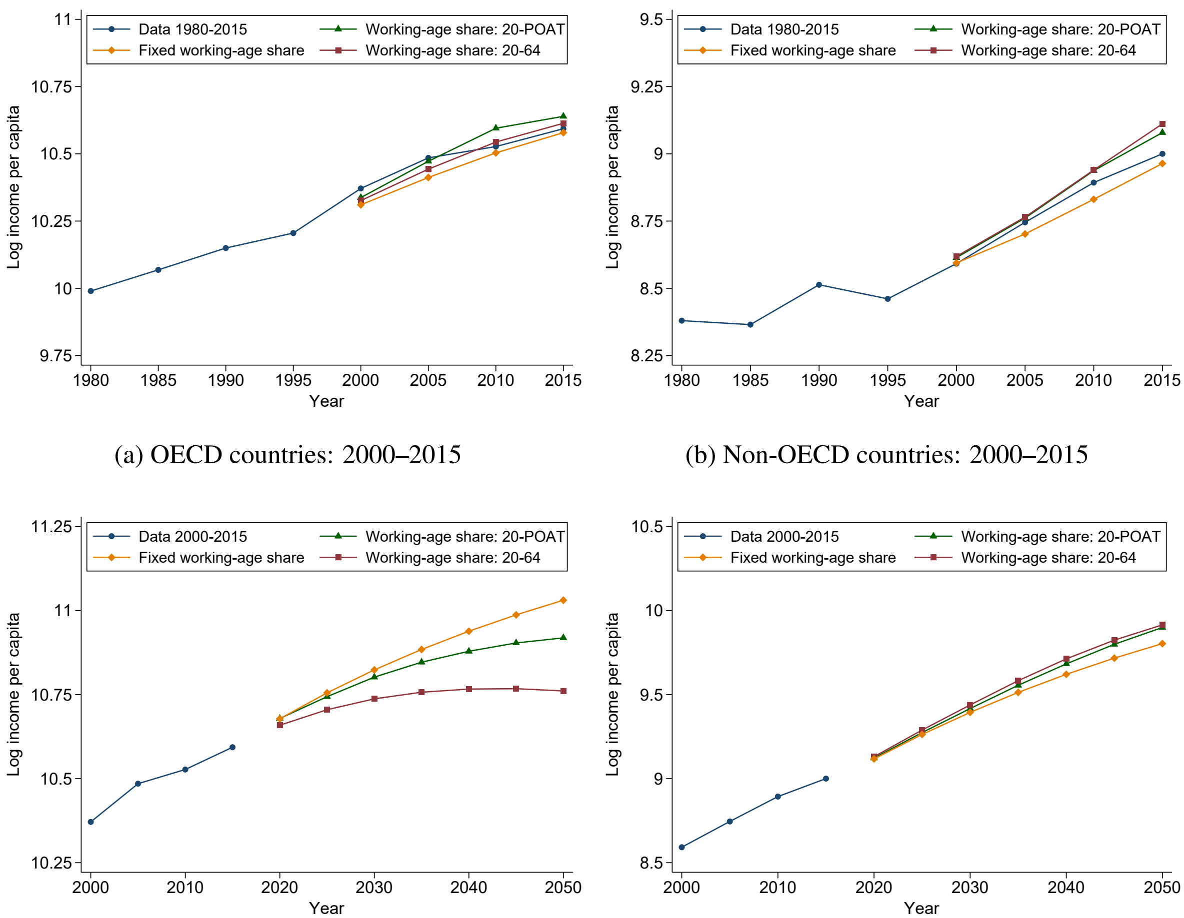


(f) Korea

Figure A.8: Projected income per capita: Workforce estimates

Note: This figure shows projected income per capita for selected countries in 2020–2050. The projections are based on the parameters estimated in specification (1) of Table A.5. The figure contrasts income per capita across three projections predicated on fixed working-age shares (as of 2015), retrospective working-age shares (15–64), and prospective working-age shares (15–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years. Workforce shares are derived from multiplying the working-age population with the average labor force participation among people age 15 and older.

Technological progress. A potential concern centers on the importance of technological growth trends for the predictions. In our baseline projections, we assume all countries follow a common growth trend to isolate variation in future income per capita related to demographic change. Our findings do not hinge on this assumption. Because the growth trend is the same across all projection scenarios, the estimated economic effects of population aging are preserved even if countries follow different growth paths. We confirm this assertion by projecting income per capita based on the general method of moments model that allows for country-specific growth trends and convergence: see Figure A.9.



(a) OECD countries: 2000–2015

(b) Non-OECD countries: 2000–2015

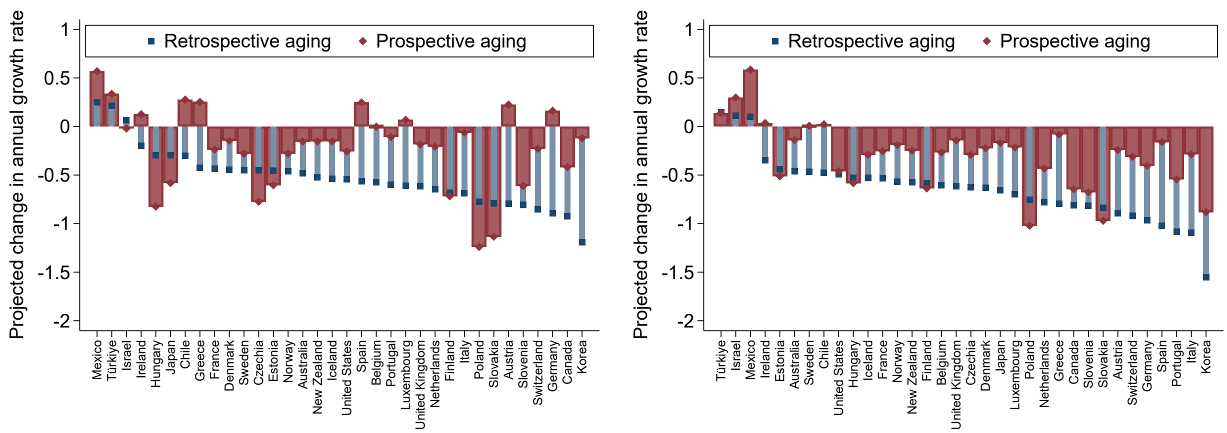
(c) OECD countries: 2020–2050

(d) Non-OECD countries: 2020–2050

Figure A.9: Projected income per capita: General method of moments specifications

Note: This figure shows projected income per capita for OECD and non-OECD countries within sample (2000–2015) and out of sample (2020–2050). The projections are based on the parameters estimated in specification (2) of Table 3. The figure contrasts income per capita across three projections predicated on fixed working-age shares (as of 1995 for the within-sample projections in panels a and b and as of 2015 for the out-of-sample projections in panels c and d), retrospective working-age shares (20–64), and prospective working-age shares (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years.

Shorter time horizons. The long time horizon of our projections raises questions about when population aging affects economic growth and whether this timing changes our finding that a demographic drag will be the norm as countries advance through the later stages of the demographic transition. To address these questions, we compute the projected change in annual growth rates in OECD countries in 2020–2030 and in 2020–2040: see Figure A.10. The projected economic consequences of population aging broadly resemble the baseline results and undergird the prediction of a future demographic drag. While predictions for the cumulative effects of population aging on annual growth rates change somewhat between periods, these changes are consistent with the timing of large cohorts entering old age. Quantitative differences between the projections under retrospective and prospective aging further indicate significant economic gains of changes in labor potential associated with improvements in functional capacity. By relying on shorter time horizons, this analysis also alleviates concerns about extrapolating technological growth trends from the past into the future.

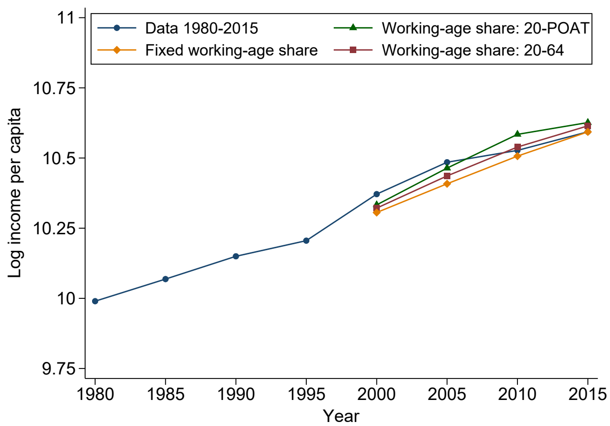


(a) 2020–2030 (b) 2020–2040

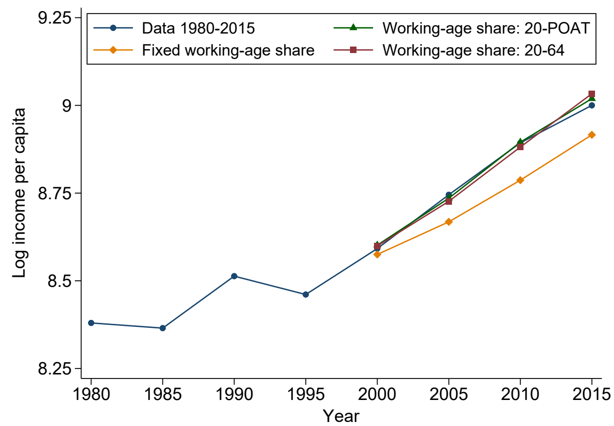
Figure A.10: Projected change in annual growth rates in OECD countries: 2020–2030 and 2020–2040

Note: This figure depicts the projected cumulative change in annual growth rates in OECD countries in 2020–2030 and in 2020–2040. It contrasts the estimated demographic drags and dividends based on the retrospective-aging scenario with the estimated demographic drags and dividends based on the prospective-aging scenario. The projections are predicated on the parameters estimated in specification (1) of Table 3.

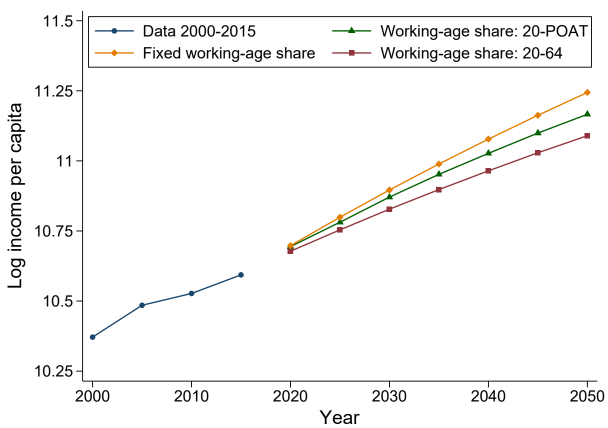
Calibration of parameters. The baseline projections rely on parameters that are estimated empirically with panel data. A potential concern is that the estimates might react sensitively to changes in the covariates. To rule out the possibility that our measures of population age structure merely absorb the effects of other covariates, we project income per capita with a prediction model in which we calibrate the growth and level effects of population age structure to unity and λ as our aggregate production model implies. The projections confirm our main findings: see Figure A.11.



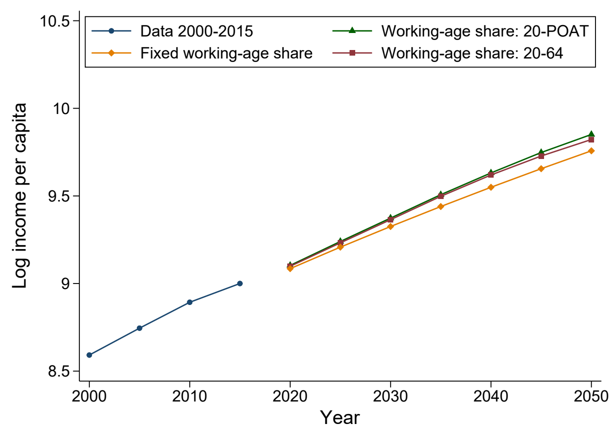
(a) OECD countries: 2000–2015



(b) Non-OECD countries: 2000–2015



(c) OECD countries: 2020–2050



(d) Non-OECD countries: 2020–2050

Figure A.11: Projected income per capita: Calibrated parameters

Note: This figure shows projected income per capita for OECD and non-OECD countries within sample (2000–2015) and out of sample (2020–2050). The projections are based on the parameters estimated in specification (1) of Table A.11, where we calibrate the growth and level effects of the working-age share to unity and λ in accordance with the parameter constraints of our aggregate production model. The figure contrasts income per capita across three projections predicated on fixed working-age shares (as of 1995 for the within-sample projections in panels a and b and as of 2015 for the out-of-sample projections in panels c and d), retrospective working-age shares (20–64), and prospective working-age shares (20–POAT), where POAT denotes the age at which remaining life expectancy falls below 15 years.

A.9 Functional Capacity and Economic Activity at Older Ages

An open question is whether people remain economically active at older ages when their functional capacities increase. To assess whether this is the case, we use aggregated data on people's intention to work at older ages and their observed labor force participation obtained from the Health and Retirement Survey (HRS 2022) and the Survey of Health, Ageing and Retirement in Europe (Börsch-Supan 2022). We regress the propensity to work full time beyond age 62 (measured by the share of people aged 50–62 who state a positive probability to work full time beyond age 62) and labor force participation in the age group 63–75 on the prospective old-age threshold (Table A.12). While the propensity to work full time at older ages tends to increase with functional capacity—a one-year rise in the prospective old-age threshold is associated with a 15 percentage point higher propensity to work full time beyond 62—observed labor force participation does not increase with functional capacity. These findings suggest that other factors, such as labor market conditions for older workers and the institutional environment, limit the extent to which economic activity extends into older ages as functional capacity improves.

Table A.12: Prospective old-age threshold and economic activity at older ages

Dependent variable:	Propensity to work full time beyond age 62 (1)	Labor force participation in age group 63–75 (2)
Prospective old-age threshold (coefficients × 100)	15.23* (8.17)	−0.77 (2.09)
R^2	0.77	0.95
Within R^2	0.04	0.00
Countries	21	22
Observations	73	79

Note: This table shows correlations between the prospective old-age threshold (defined as the age at which remaining life expectancy falls below 15 years) and the propensity to work full time beyond age 62 (1) and between the prospective old-age threshold and labor force participation in age group 63–75 (2). Propensity to work full time beyond age 62 measures the share of people aged 50–62 who state a positive probability of working full time beyond age 62 (beyond age 61 in the United States). All regressions include country fixed and time effects. Standard errors are clustered at the country level and reported in parentheses. Asterisks indicate significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

A.10 Data Acknowledgment

This study uses data from waves 1–9 of the English Longitudinal Study of Ageing (ELSA), which was developed by a team of researchers based at University College London, NatCen Social Research, the Institute for Fiscal Studies, the University of Manchester, and the University of East Anglia. The data were collected by NatCen Social Research. The funding is currently provided by the National Institute on Aging in the United States and by a consortium of United Kingdom government departments coordinated by the National Institute for Health Research. Funding has also been received by the Economic and Social Research Council.

The study also uses data from waves 1–14 of the Health and Retirement Survey (HRS), which were retrieved from the RAND HRS Longitudinal File. The RAND HRS Longitudinal File is an easy-to-use dataset based on the HRS core data. This file was developed at RAND with funding from the U.S. National Institute on Aging and the United States Social Security Administration. The HRS is sponsored by the U.S. National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan.

Finally, this study uses data from waves 1–8 of the Survey of Health, Ageing and Retirement in Europe (SHARE). The SHARE data collection has been funded by the European Commission, DG RTD through FP5 (QLK6-CT-2001-00360), FP6 (SHARE-I3: RII-CT-2006-062193, COMPARE: CIT5-CT-2005-028857, SHARELIFE: CIT4-CT-2006-028812), FP7 (SHARE-PREP: GA N°211909, SHARE-LEAP: GA N°227822, SHARE M4: GA N°261982, DASISH: GA N°283646) and Horizon 2020 (SHARE-DEV3: GA N°676536, SHARE-COHESION: GA N°870628, SERISS: GA N°654221, SSHOC: GA N°823782, SHARE-COVID19: GA N°101015924), and by DG Employment, Social Affairs & Inclusion through VS 2015/0195, VS 2016/0135, VS 2018/0285, VS 2019/0332, and VS 2020/0313. Additional funding from the German Ministry of Education and Research, the Max Planck Society for the Advancement of Science, the U.S. National Institute on Aging (U01_AG09740-13S2, P01_AG005842, P01_AG08291, P30_AG12815, R21_AG025169, Y1-AG-4553-01, IAG_BSR06-11, OGHA_04-064, HHSN271201300071C, RAG052527A), and from various national funding sources is gratefully acknowledged (see www.share-project.org). SHARE data were harmonized using information from the Gateway to Global Aging Data produced by the Program on Global Aging, Health & Policy, University of Southern California with funding from the U.S. National Institute on Aging (R01 AG030153).

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