CHAPTER 2

THE RISE OF THE SILVER ECONOMY: GLOBAL IMPLICATIONS OF POPULATION AGING - ONLINE ANNEXES

Online Annexes 2.1 to 2.3 to Chapter 2 of the April 2025 World Economic Outlook lay out the data sources, sample coverage, variable definitions, and methodologies used in the main text. The first annex presents the sample of economies covered throioughout the chapter. The subsequent annexes follow the structure of the chapter and lay out the data sources, variable definitions, and methodologies used in the main text.

Online Annex 2.1. Sample Coverage

The analysis in the chapter covers a broad sample of advanced economies (AEs) and emerging market and developing economies (EMDEs). The data sources and country coverage vary across different parts of the analysis, as indicated in Online Annex Table 2.1.1.

Online Annex Table 2.1.1. Sample of Countries Included in the Empirical and Model

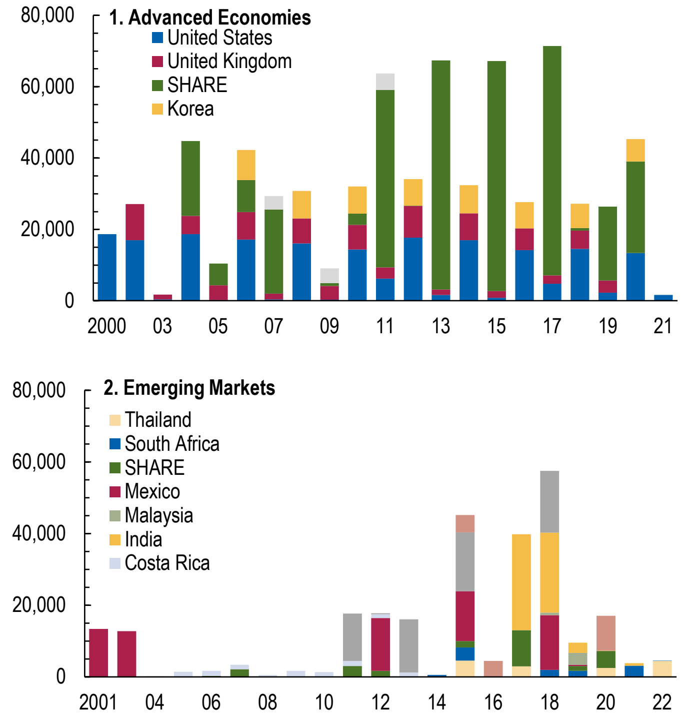
Coverage	Sources
Empirical analysis of healthy-aging	
Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, and Switzerland	Wilkens, Jenny, Michael Markot, Ziqi Zhou, Chrys Xie, Aidan Cole, Drystan Phillips, and Jinkook Lee. 2024. Harmonized Survey of Health, Ageing and Retirement in Europe (SHARE). Version G. Accessed through Gateway to Global Aging Database.
Brazil	Lima-Costa, Maria Fernanda, Juliana Vaz de Melo Mambrini, Fabiola Bof de Andrade, Paulo R. B. de Souza, Maurício T. L. de Vasconcellos, Anita L. Neri, Erico Castro-Costa, James Macinko, Cesar de Oliveira. 2023. Cohort Profile: The Brazilian Longitudinal Study of Ageing (ELSI)
China	Phillips, Drystan, Hunter Green, Sarah Petrosyan, Kanghong Shao, Jenny Wilkens, & Jinkook Lee. 2024. The China Health and Retirement Longitudinal Study (CHARLS). Accessed through Gateway to Global Aging Database.
Costa Rica	Rosero-Bixby, Luis ,William Dow, Sandy Chien, Ashley Lin, Drystan Phillips, Jenny Wilkens &Jinkook Lee. 2024. Costa Rican Longevity and Healthy Aging Study (CRELES). Accessed through Gateway to Global Aging Database.
India	Chien, Sandy, Codi Young, Drystan Phillips, Jenny Wilkens, Yuxuan Wang, Alden Gross, Erik Meijer, Marco Angrisani, and Jinkook Lee. 2023. Longitudinal Aging Study in India (LASI). Version A.3. Accessed through Gateway to Global Aging Database.
Japan	Matsuyama, Hirokazu, Drystan Phillips, Sandy Chien, Hidehiko Ichimura, and Jinkook Lee. 2023. Japanese Study of Aging and Retirement (JSTAR). Accessed through Gateway to Global Aging Database.
Korea	Park, Hae Yeun, Yuxuan Wang, Jenny Wilkens, Drystan Phillips, and Jinkook Lee. 2023. Korean Longitudinal Study of Aging (KLoSA). Version E.2. Accessed through Gateway to Global Aging Database.
Malaysia	Mansor, Norma. 2019 . Malaysia Ageing and Retirement Survey,. Social Wellbeing Research Centre (SWRC). Mansor, Norma, Halimah Awang, Nur Fakhrina Ab Rashid, Yamunah Devi Apalasamy, Nurul Diyana Kamarulzaman, Lih Yoong Tan, Kama Firdaus Subbahi, Chin Lung Tan, Drystan Phillips, Jenny Wilkens, and Jinkook Lee. 2024. Malaysia Ageing and Retirement Survey (MARS). Accessed through Gateway to Global Aging Database.
Mexico	Michaels-Obregon, Alejandra, Drystan Phillips, Jenny Wilkens, Rebeca Wong, and Jinkook Lee. 2023. Mexican Health and Aging Study (MHAS). Version C.2. Accessed through Gateway to Global Aging Database.
South Africa	Berkman, Lisa F. 2023. Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa (HAALSI). Agincourt, South Africa, 2015-2022. Inter-university Consortium for Political and Social Research.
Thailand	National Institutes of Development Administration. 2015. Well-being of the elderly in Thailand: Health Aging and Retirement in Thailand (HART).
United Kingdom	Wilkens, Jenny, Yuxuan Wang, Giacomo Rebellato, Youngha Oh, and Jinkook Lee. 2024 English Longitudinal Study on Ageing (ELSA). Accessed through Gateway to Global aging Data.
United States	Wang, Yuxuan, Aidan Cole, Hunter Green, Jenny Wilkens, Drystan Phillips, and Jinkook Lee. 2023. Health and Retirement Study in the United States (HRS). Version D. Accessed through Gateway to Global Aging Database.
Model-based analysis	
Australia, Austria, Belgium, Canada, China, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Ireland, Italy, Japan, Luxembourg, Netherlands, Poland, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom, and the United States. LIC *bloc* : Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Comoros, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Ethiopia, Ghana, Guinea, Guinea-Bissau, Haiti, Honduras, Kenya, Kyrgyz Republic, Lao P.D.R., Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Nepal, Niger, Nigeria, Republic of Congo, Rwanda, Senegal, Sierra Leone, Sudan, São Tomé and Príncipe, Tajikistan, Tanzania, The Gambia, Togo, Uganda, Yemen, Zambia, and Zimbabwe.	Auclert, Adrien, Hannes Malmberg, Frederic Martenet, and Matthew Rognlie.2024. “Demographics, Wealth, and Global Imbalances in the Twenty-First Century.” Revised version of NBER Working Paper 29161. Calibration codes provided by the authors. External Wealth of Nations database. International Labour Organization (ILO). Organisation for Economic Co-operation and Development (OECD). Penn World Table version 10.01. United Nations, Department of Economic and Social Affairs, Population Division (2024). World Population Prospects 2024, Online Edition. World Economic Outlook database. World Inequality Database (WID).

Note: LIC = low-income countries.

Online Annex 2.2. Healthy Aging

The empirical analysis of healthy aging and its implications for labor market outcomes for older workers uses microdata surveys with close to one million observations for individuals aged 50-90 in 29 advanced economies (AEs) and 12 emerging market economies (EMs) during 2000–22 (Online Annex Figure 2.2.1).[1] Data for all countries except for Brazil, South Africa, and Thailand are pre-harmonized in the [Gateway to Global Aging]database, the portal through which the data is accessed. The analysis utilizes the surveys' data on:

Online Annex Figure 2.2.1. Empirical Analysis: Country and Time Sample Coverage
(Number of observations)



Sources: Gateway to Global Aging Data; national microdata sources; and IMF staff calculations.
Note: The sample includes 29 advanced economies (including 24 European countries and Israel covered in the SHARE dataset) and 12 emerging market economies (including 6 European countries in the SHARE dataset). SHARE = Survey of Health, Ageing and Retirement in Europe.

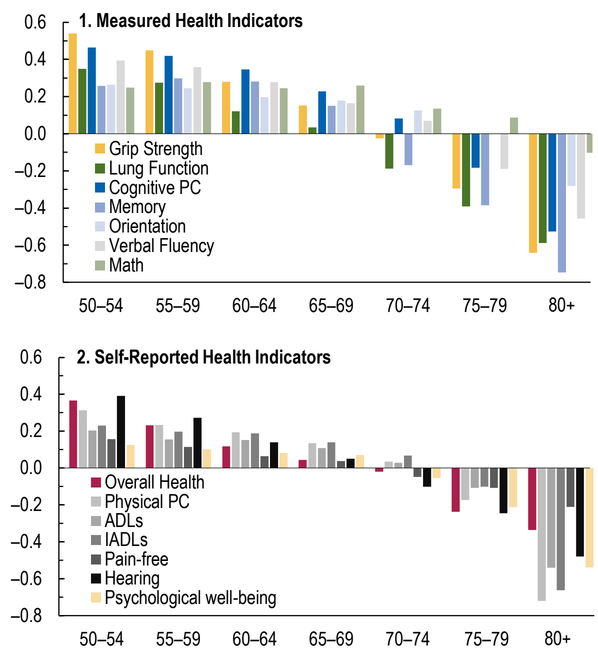
- *Health indicators*: These include (i) measured indicators of physical ability (grip strength, lung function) and cognitive ability (memory, orientation, verbal fluency, and math); (ii) self-reported indicators on overall health, physical ability (including ease of performing activities of daily living, or ADLs, instrumental activities of daily living, or IADLs, the frequency of feeling pain, and hearing ability), and a composite index of psychological well-being; (iii) health behaviors such as smoking, alcohol consumption, frequency of exercise, as well as body-mass index; and (iv) the incidence of chronic diseases based on the diagnosis of 17 different chronic diseases.[2]

[1] Data is obtained from 13 different microdata surveys with the choice of countries based on data availability. The sample is restricted to (i) start in 2000 (previous data is only available for the United States) and (ii) only consider individuals aged 50-90 to enhance cross-country comparability. The sample includes multiple survey waves, as available for most countries, with the exception of India, Ireland, and Malaysia (where only one wave is available). Data for all countries—except for Brazil, South Africa, and Thailand—are pre-harmonized in the Gateway to Global Aging Database, the portal through which the data is accessed. The data for Brazil, South Africa, and Thailand have been harmonized before inclusion in the sample.

[2] The survey questions comprise the following: (i) for measured health—respondents' maximum hand grip strength (in kg), maximum lung function breathing test measurement, the number of words respondents can recall from a list (memory), whether respondents correctly report today's date (orientation), the number of animals the respondent can list within one minute (verbal fluency), and how many correct subtractions the respondent can make out of five trials (math); (ii) for self-reported health—respondents rate their own overall health and hearing on a 1-5 scale, whether they experience difficulty in performing a range of ADLs (getting in/out of bed, bathing, dressing, eating, walking across the room) and IADLs (managing money, taking medications, shopping for groceries, and preparing a hot meal), and answer 12 questions that are aggregated into a multi-dimensional measure of quality of life in older adults (the CASP index that comprises four main domains—control, autonomy, self-realization, and pleasure). The chronic diseases include high blood pressure, arthritis, high cholesterol, heart disease, diabetes,

- *Labor market outcomes*: age of retirement (if applicable); extensive margin of labor supply and employment (dummy variables for labor force participation, working for pay, and unemployment); intensive margin (hours worked per week, and weeks worked per year); and labor earnings.
- *Socio-economic characteristics*: age; gender; rural/urban location dummy; educational attainment (at most primary, secondary, or tertiary); household wealth; and country of residence.

Online Annex Figure 2.2.2. Physical and Cognitive Capacity of Older Individuals, by Age Group
(Health score, average)



Sources: Gateway to Global Aging Data; national microdata sources; and IMF staff calculations.
Note: The health scores have been standardized to mean zero and standard deviation one and averaged across different age groups. Cognitive PC is the first principal component of the memory, orientation, verbal fluency, and math cognitive functions. Physical PC is the first principal component of activities of daily living (ADLs), instrumental activities of daily living (IADLs), pain frequency, and hearing.

Importantly, the analysis distinguishes between indicators of measured and self-reported health and focuses on the indicators with the highest sample coverage and survey questions' comparability across countries. For ease of comparability, the different health indicators are standardized to have zero mean and unit standard deviation. The various health measures considered in the analysis tend to decline with age, as reported in Online Annex Figure 2.2.2.

The empirical strategy consists of two parts:

1. Is there evidence of healthy aging? To study whether health has been improving over time, various health indicators ($H_{i,t}$) are regressed – one at a time – on a time trend (*t*), controlling for a vector ($\boldsymbol{X}_{i,t}$) of individual socio-economic characteristics (age, gender, education, log household wealth) and country fixed effects. To explore evidence of heterogeneous healthy aging effects, time trends are allowed to differ across different groupings: (i) emerging market versus advanced economies; (ii) by gender; (iii) by urban versus rural locations; (iv) by educational attainment (at most primary, upper secondary, and tertiary); and (v) by household wealth quintile. Standard errors are clustered at the country level.

$$H_{i,t} = \alpha_0 + \alpha_1 t + \boldsymbol{\theta X}_{i,t} + \varepsilon_{i,t}$$

psychological disorders, osteoporosis, cataracts, cancer, lung disease, ulcers, stroke, asthma, urinary incontinence, Alzheimer's, kidney disease, and Parkinson's disease.

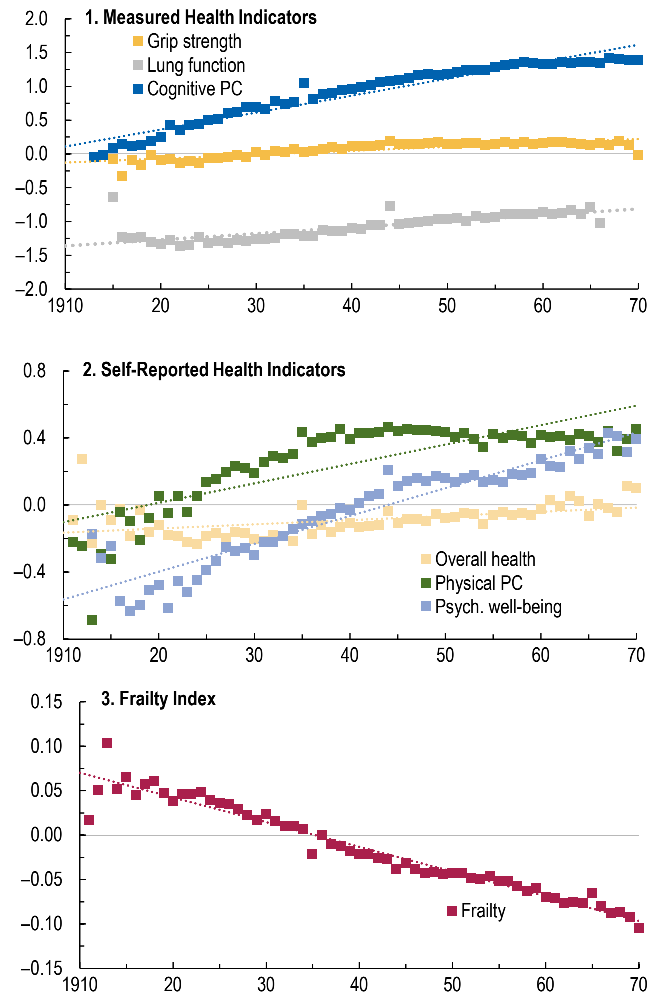
2. What does better health imply for labor market outcomes?

- **Correlations.** An ordinary-least-squares (OLS) regression approach is used to estimate the association (correlation) between each health indicator and each labor market indicator ($\boldsymbol{LMI}_{i,t}$), one at a time, while controlling for a vector ($\boldsymbol{Z}_{i,t}$) of individual socio-economic characteristics (age, gender, education, log household wealth), country fixed effects, and a time trend.

$$LMI_{i,t} = \beta_0 + \beta_1 H_{i,t} + \boldsymbol{\theta} \boldsymbol{Z}_{i,t} + \beta_2 t + \varepsilon_{i,t}$$

- **Causal effects.** To address endogeneity concerns (for instance, reverse causality whereby working could affect individuals' health) and in an attempt to estimate the causal effects, a two-stage-least-squares (2SLS) regression approach is used that exploits exogenous health shocks, proxied by the incidence of chronic diseases.[3] Since the Centers for Disease Control and Prevention (CDC) states that "most chronic diseases are caused by a short list of risk factors —smoking, poor nutrition, physical inactivity, and excessive alcohol use", the regression specification also controls for these lifestyle factors. The identification strategy rests on the assumption that at least some chronic diseases—those not explained by individuals' socioeconomic factors and health behaviors—are randomly assigned. As a robustness check, an augmented inverse propensity score weighting (AIPW) estimator (Jordà and Taylor, 2016) is also used to correct for potential endogeneity of the instrument by

Online Annex Figure 2.2.3. Healthy-Aging Trends by Cohort
(Year-of-birth fixed effects)



Sources: Gateway to Global Aging Data; national microdata sources; and IMF staff calculations.
Note: This figure shows the coefficient from ordinary least squares regressions of health indicators of individuals ages 50 and older on year-of-birth fixed effects, with individual's age, gender, education, household wealth, and country fixed effects controlled for. Squares represent the point estimates whereas dotted lines represent the line of best fit. PC = principal component.

[3] The chronic disease instrument is the *share* of chronic diseases that respondents report having out of the total listed 17 chronic diseases. Results are robust to alternative definitions such as the total number of chronic diseases, a dummy indicator for whether the respondent reports having any of the chronic diseases, and a similar dummy indicator for the top 10 chronic diseases that most affect health (identified via OLS regressions of health indicators on individual chronic diseases, controlling for individuals' socio-economic conditions, country fixed effects, and a time trend).

assigning a greater weight to health shocks that are arguably more exogenous (less predictable).[4]

Online Annex 2.2.1. Evidence of Healthy Aging

The findings reveal a broad-based phenomenon of 'healthy aging', as evidenced by a broad range of physical, cognitive, and mental health indicators improving over time (positive and significant coefficient on time trend) (Online Annex Table 2.2.1).[5] Other covariates reveal that health tends to decline with age, while correlating positively with education and wealth.[6] Importantly, healthy aging gains seem to be most prominent for cognitive functions as proxied by the first principal component of the cognitive indicators, although the trend is also positive and statistically significant for other health measures. Across the different indicators, successive birth cohorts have seen smooth improvements in their health over time (Online Annex Figure 2.2.3, panels 1 and 2). Results are robust to considering a composite health measure of frailty that averages the health indicators, normalized to a 0-1 scale, where an increase implies a deterioration in health.

Online Annex Table 2.2.1. Trends in Healthy-Aging and Other Socioeconomic Determinants of Health

	Measured Health			Self-Reported Health		
	Grip Strength	Lung Function	Cognitive PC	Overall Health	Physical PC	Psych. Well-Being
	(1)	(2)	(3)	(4)	(5)	(6)
Year	0.004**	0.011**	0.020***	0.005**	0.005***	0.015***
	(0.002)	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)
Socio-Economic Controls:						
Age	-0.035***	-0.028***	-0.026***	-0.020***	-0.025***	-0.014***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Male	1.345***	0.761***	0.009	0.041*	0.036**	0.045**
	(0.025)	(0.03)	(0.029)	(0.02)	(0.015)	(0.018)
Upper Secondary Education	0.064***	0.097***	0.362***	0.217***	0.127***	0.191***
	(0.013)	(0.031)	(0.034)	(0.024)	(0.019)	(0.021)
Tertiary Education	0.081***	0.225***	0.625***	0.422***	0.227***	0.309***
	(0.016)	(0.024)	(0.042)	(0.038)	(0.027)	(0.033)
(Log) Household Wealth	0.019***	0.017***	0.029***	0.035***	0.024***	0.040***
	(0.002)	(0.003)	(0.004)	(0.005)	(0.004)	(0.003)
Constant	-7.200**	-21.642**	-39.385***	-8.416*	-8.533***	-30.601***
	(3.548)	(8.958)	(6.267)	(4.199)	(3.020)	(6.142)
Observations	460,240	217,702	382,424	731,020	628,733	345,479
R^2	0.612	0.341	0.381	0.204	0.129	0.176
Number of Countries	38	24	34	41	34	30
Country FE	✓	✓	✓	✓	✓	✓

Sources: Gateway to Global Aging Database; national microdata sources; and IMF staff calculations.

Note: The estimations come from ordinary least-squares regressions of health indicators of individuals ages 50 and older on the survey year, with individual's age, gender, education, household wealth, and country fixed effect. Standard errors are clustered at the country level controlled for. FE = fixed effect

*** p <0.01; ** p <0.05; * p <0.1.

[4] The intuition behind this estimation strategy is that less weight is given to health shocks that are more predictable based on some explanatory variables, whereas health shocks that are less predictable (more random) receive a greater weight. The weights are based on the predicted component of a probit model for the occurrence of health shocks (diagnosis of chronic diseases). The treatment-equation for the probability of experiencing a health shock controls for individuals' socio-economic factors and health behaviors, country fixed effects, and a time trend.

[5] Results are also robust to controlling for the square of the age variable and for rural location, which is excluded from the baseline specification due to missing data for some countries. Estimated first-order time trends are robust, while higher-order time trends are found to be either statistically insignificant or somewhat sensitive to the chosen health indicator and regression specification.

[6] Men tend to score higher on objective measures of physical (grip and lung strength) as well as self-rated overall health and psychological well-being.

Frailty is shown to have declined over birth cohorts (Online Annex Figure 2.2.3, panel 3), consistent with the ongoing healthy aging phenomenon, and in line with previous studies using the frailty measure; see, for example, Abeliansky and Strulik (2018, 2019) and Old and Scott (2023).

Meanwhile, there is evidence of healthy-aging trends differing across countries, but not so much across different socio-economic groups (Online Annex Table 2.2.2). Improvements in cognitive health have been faster among emerging market economies—relative to advanced economies—pointing to some cross-country convergence, yet the pace of improvement has been similar across other dimensions, suggesting that wide socio-economic health gaps persist (related to gender, urban/rural location, education and wealth). The rate of health improvements is also found to be similar across age groups.

Online Annex Table 2.2.2. Heterogeneity in Healthy-Aging Trends

	Measured Health			Self-Reported Health		
	Grip Strength	Lung Function	Cognitive PC	Overall Health	Physical PC	Psych. Well-Being
	(1)	(2)	(3)	(4)	(5)	(6)
By Country Income Group:						
AEs	0.004**	0.010**	0.020***	0.003	0.004***	0.014***
EMs	0.006*	0.022***	0.033***	0.020**	0.011	0.032***
By Age Group:						
50s	0.004**	0.011**	0.020***	0.005**	0.005***	0.015***
60s	0.004**	0.011**	0.020***	0.005**	0.005***	0.015***
70s	0.004**	0.011**	0.020***	0.005**	0.005***	0.015***
80s	0.004**	0.011**	0.020***	0.005**	0.005***	0.015***
By Gender:						
Females	0.008***	0.010*	0.022***	0.005**	0.004**	0.015***
Males	0.001	0.013**	0.018***	0.004	0.006***	0.016***
By Location:						
Urban	0.005**	0.009*	0.021***	0.006**	0.006***	0.017***
Rural	0.005*	0.014***	0.014**	0.004	0.004*	0.020***
By Education:						
Primary	0.006***	0.005	0.021***	0.004	0.002	0.010**
Secondary	0.003	0.017***	0.021***	0.007**	0.007***	0.018***
Tertiary	0.004*	0.012**	0.018***	0.002	0.008***	0.021***
By Wealth Quintile:						
1 (Lowest)	0.003	0.010**	0.019***	0.003	0.003**	0.012***
2	0.003	0.010**	0.019***	0.003	0.003**	0.012***
3	0.003	0.010**	0.019***	0.003	0.003**	0.012***
4	0.003	0.010**	0.019***	0.003	0.003**	0.012***
5 (Highest)	0.003	0.010**	0.019***	0.003	0.003**	0.012***
Socio-economic controls	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓

Sources: Gateway to Global Aging Database; national microdata sources; and IMF staff calculations.

Note: The estimations come from ordinary least-squares regressions of health indicators of individuals ages 50 and older on the survey year, with individual's age, gender, education, household wealth, and country fixed effect controlled for. To study heterogeneous trends, the survey year (trend variable) is interacted with country groups (AEs and EMs), and individuals' age group, gender, urban/rural location, education, and household wealth, one at a time. Standard errors are clustered at the country level. AEs = advanced economies; EMs = emergency markets; FE = fixed effect; PC = principal component.

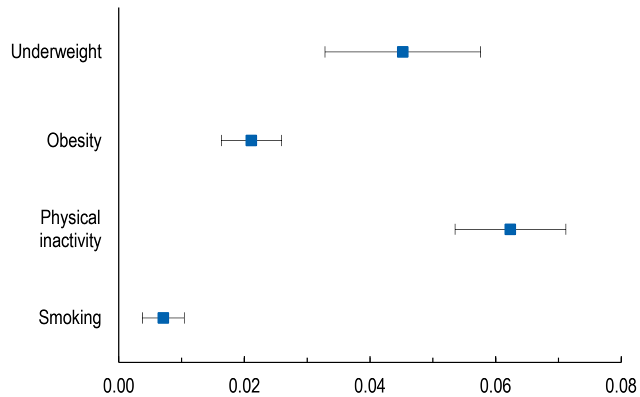
*** p <0.01; ** p <0.05; * p <0.1.

Online Annex 2.2.2. Effect of Health on Labor Market Outcomes

Better old-age health is associated with decisions to increase labor supply, along both the extensive margin (labor force participation and probability of employment) and intensive margin (hours worked per week and weeks worked per year), as well as higher total labor earnings and labor productivity (proxied by earnings per hour), and is associated with retiring at an older age (Online Annex Table 2.2.3).

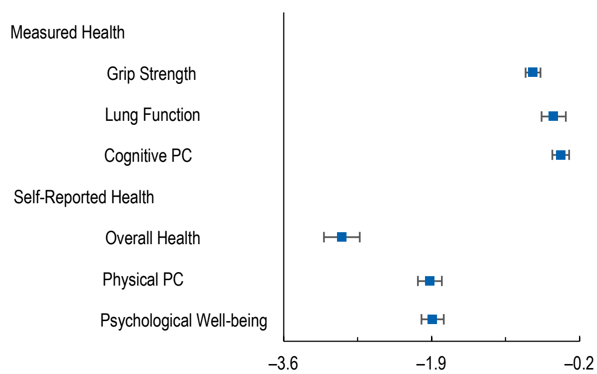
In an attempt to establish a causal relationship, chronic diseases cases (that are unexplained by individuals' socio-economic characteristics and health behaviors) are used as an instrument for exogenous health shocks. In particular, the regression includes lifestyle factors impacting overall health and the probability of developing chronic diseases—low/high body-mass index, physical inactivity, and smoking—as additional controls (Online Annex Figure 2.2.4 shows these factors are significant predictors of the composite frailty index). The first-stage regressions indicate that chronic diseases constitute a strong instrument for individuals' physical, cognitive, and mental health (Online Annex Figure 2.2.5).[7] In addition, in the second stage, the estimated impact is substantially larger than that implied by OLS regression estimates, stressing the importance of tackling potential endogeneity using an instrumental variable approach (Online Annex Tables 2.2.3 and 2.2.4).[8] Better physical, cognitive, and mental health (and lower overall health frailty), instrumented by chronic diseases, have economically significant implications in terms of raising labor supply, earnings, and productivity, and postponing retirement.

Online Annex Figure 2.2.4. Impact of Lifestyle Factors on Overall Health Frailty
(Regression coefficients)



Sources: Gateway to Global Aging Data; national microdata sources; and IMF staff calculations.
Note: This figure shows the coefficient from an ordinary least squares regression of the health frailty index (measured on a 0-1 scale) of individuals ages 50 and older on different lifestyle factors, with individuals' socio-economic characteristics (age, gender, education, wealth), the survey year, and country fixed effects controlled for. Squares represent the point estimate whereas surrounding bars represent the 90 percent confidence intervals.

Online Annex Figure 2.2.5. Impact of Chronic Diseases on Health Indicators
(Regression coefficient)



Sources: Gateway to Global Aging Data; national microdata sources; and IMF staff calculations.
Note: This figure shows the coefficient from the first stage of a two-stage least squares regression of health indicators of individuals ages 50 and older on the instrumental variable—the incidence of chronic diseases—with individuals' socio-economic characteristics (age, gender, education, wealth), lifestyle factors (underweight, obesity, physical inactivity, smoking), the survey year, and country fixed effects controlled for. Squares represent the point estimate whereas surrounding bars represent the 90 percent confidence intervals. PC = principal component.

[7] As an instrument, the incidence of chronic diseases passes the weak instrument test in all regressions, with the first-stage F-statistic exceeding the Stock and Yogo (2005) rule-of-thumb critical value of 10. In addition to controlling for socio-economic characteristics, the survey year, and country fixed effects (as in earlier specifications), the 2SLS regressions also control for lifestyle factors, finding that smoking, alcohol consumption, physical inactivity, and obesity (or higher body-mass-index) are associated with worse health outcomes.

[8] Results are robust to controlling for country-year fixed effects that capture time-varying country-level policies like changes in statutory retirement age, for example.

Online Annex Table 2.2.3. OLS Regressions: Effect of Health on Labor Market Outcomes

	Extensive Margin		Intensive Margin		Total	Labor Productivity		Retirement
	LFP	Employment	Weekly Hours	Weeks/Year	Earnings	Earnings/hr	Earnings/hr/wk	Age
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Measured Health:								
Grip Strength	0.022***	0.026**	1.069***	0.054	0.072***	0.038**	0.035**	0.579***
	(0.006)	(0.01)	(0.143)	(0.095)	(0.016)	(0.017)	(0.014)	(0.109)
Lung Function	0.013***	0,013**	0.099	0.190*	0.064***	0.053***	0.038**	0.197
	(0.004)	(0.006)	(0.183)	(0.073)	(0.014)	(0.015)	(0.014)	(0.123)
Cognitive PC	0.005	0.027***	0.501*	0.188	0.114***	0.107***	0.052**	0.746***
	(0.005)	(0.005)	(0.269)	(0.119)	(0.020)	(0.023)	(0.022)	(0.168)
Self-Reported Health:								
Overall Health	0.051***	0.026***	0.482***	0.041	0.085***	0.067***	0.051***	0.803***
	(0.006)	(0.006)	(0.115)	(0.056)	(0.019)	(0.020)	(0.016)	(0.116)
Physical PC	0.022**	0.059**	0.889***	0.430***	0.061**	0.066***	0.065***	0.757***
	(0.01)	(0.022)	(0.203)	(0.139)	(0.025)	(0.022)	(0.020)	(0.108)
Psych. Well-Being	0.011**	0.057***	0.384**	0.176**	0.079***	0.063***	0.062***	0.501***
	(0.005)	(0.009)	(0.151)	(0.079)	(0.015)	(0.014)	(0.014)	(0.101)
Composite Health Frailty:								
Frailty Index	-0.302***	-0.248***	-4.934***	-1.676***	-1.008***	-0.881***	-0.730***	-6.644***
	(0.072)	(0.071)	(1.154)	(0.511)	(0.130)	(0.134)	(0.139)	(1.016)
Socio-Economic Controls	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓

Sources: Gateway to Global Aging Database; national microdata sources; and IMF staff calculations.

Note: The estimations come from ordinary least squares regressions of labor market outcomes of individuals ages 50 and older on health indicators (one-at-a-time), with socioeconomic characteristics (age, gender, education, household wealth), the survey year, and country fixed effects controlled for. Standard errors are clustered at the country level. FE = fixed effect; hr = hours; LFP = labor force participation; OLS= ordinary-least-squares; PC = principal component; wk = week.

*** p <0.01; ** p <0.05; * p <0.1.

Online Annex Table 2.2.4. 2SLS Regressions: Effect of Health on Labor Market Outcomes

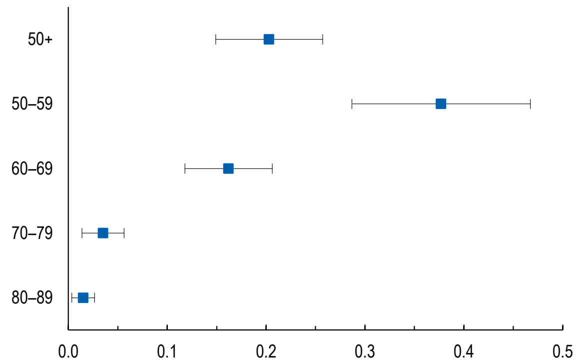
	Extensive Margin		Intensive Margin		Total	Labor Productivity		Retirement
	LFP	Employment	Weekly hours	Weeks/year	Earnings	Earnings/hr	Earnings/hr/wk	Age
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Measured Health:								
Grip Strength	0.529***	0.318***	9.840***	1.153	0.765***	0.298*	0.599***	5.350***
	(0.050)	(0.089)	(2.376)	(1.182)	(0.175)	(0.173)	(0.210)	(1.052)
Lung Function	0.794***	0.448	13.572***	2.220	2.094***	1.300*	1.365**	8.651***
	(0.144)	(0.278)	(4.660)	(2.463)	(0.703)	(0.736)	(0.677)	(2.144)
Cognitive PC	0.996***	0.919**	32.759***	4.051	1.512***	0.557	1.569*	8.779***
	(0.160)	(0.389)	(10.864)	(5.003)	(0.448)	(0.470)	(0.844)	(1.109)
Self-Reported Health:								
Overall health	0.140***	0.043***	1.924***	0.214*	0.152***	0.058*	0.097***	1.348***
	(0.015)	(0.014)	(0.358)	(0.122)	(0.032)	(0.034)	(0.028)	(0.191)
Physical PC	0.215***	0.146***	5.367***	0.449	0.423***	0.186*	0.292***	1.948***
	(0.018)	(0.044)	(1.073)	(0.291)	(0.094)	(0.105)	(0.091)	(0.304)
Psych. Well-Being	0.201***	0.152***	4.003***	0.364	0.328***	0.128*	0.192***	2.145***
	(0.015)	(0.038)	(1.105)	(0.327)	(0.071)	(0.077)	(0.056)	(0.360)
Composite Health Frailty:								
Frailty Index	-1.275***	-0.464***	-21.646***	-2.315*	-1.763***	-0.691*	-1.160***	-11.806***
	(0.093)	(0.171)	(4.534)	(1.365)	(0.367)	(0.395)	(0.322)	(1.769)
Socio-Economic Controls	✓	✓	✓	✓	✓	✓	✓	✓
Lifestyle Controls	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓

Sources: Gateway to Global Aging Database; national health surveys; and IMF staff calculations.

Note: The estimations come from two-stage-least-squares (2SLS) regressions of labor market outcomes of individuals ages 50 and older on health indicators (one-at-a-time), with socioeconomic characteristics (age, gender, education, household wealth), lifestyle factors (dummy indicators for smoking, physical inactivity, obesity, and underweight), the survey year, and country fixed effects controlled for. Standard errors are clustered at the country level. FE = fixed effect; hr = hours; LFP = labor force participation; 2SLS = two stage least squares; PC = principal component; wk = week.

*** p <0.01; ** p <0.05; * p <0.1.

Online Annex Figure 2.2.6. Heterogenous Effects of Cognitive Health on Labor Force Participation, by Age Groups
(Regression coefficient)

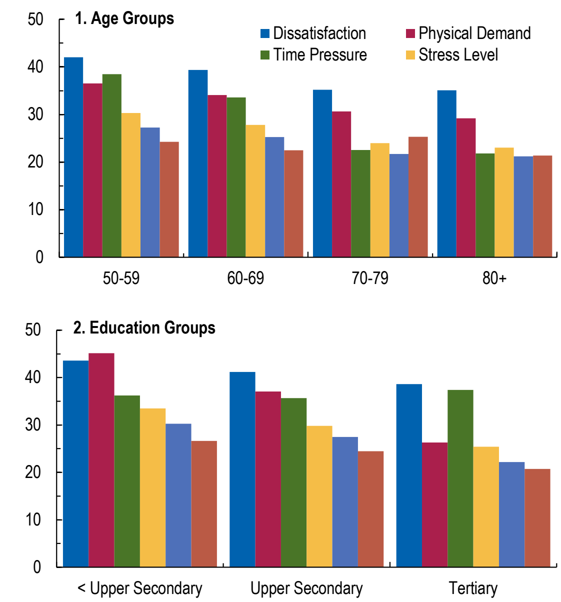


Sources: Gateway to Global Aging Data; national microdata sources; and IMF staff calculations.
Note: This figure shows the coefficient from the second stage of a two-stage least squares regression of labor force participation (dummy variable) on the first principal component of cognitive health indicators, instrumented by the incidence of chronic diseases and with individuals' socio-economic characteristics (age, gender, education, wealth), lifestyle factors (underweight, obesity, physical inactivity, smoking), the survey year, and country fixed effects controlled for. Squares represent the point estimate whereas surrounding bars represent the 90 percent confidence interval. The coefficients are re-scaled to reflect the estimated impact of 'healthy aging' (health trends) over 10 years.

As a robustness check, employing AIPW estimation—to purge any remaining endogeneity bias—delivers qualitatively similar implications of negative health shocks. The average treatment effects (of a binary indicator for the incidence of one or more chronic diseases) imply a reduction in labor supply and wage remuneration (Online Annex Table 2.2.5).[9]

To study whether the labor market implications of health improvements depend on individual and job characteristics, the 2SLS analysis is also performed separately for different sample sub-groups. Indeed, labor market effects are found to vary across age groups—for instance, generally affecting the extensive margin of labor supply for individuals in their 50s the most, followed by those in their 60s and 70s, with much lower effects for those aged 80 and above (e.g., Online Annex Figure 2.2.6). In addition, as people age, they become less willing to work in jobs that are considered less 'age friendly' (Online Annex Figure 2.2.7). These are jobs that offer lower job satisfaction, are physically demanding, entail higher stress levels, and are characterized by lack of freedom, and poor job security (Acemoglu, Mühlbach, and Scott 2022). Relatedly, better health generally has a stronger positive effect on labor market outcomes for jobs that are considered more age-friendly—suggesting a higher 'voluntary' response of labor supply for these occupations.[10]

Online Annex Figure 2.2.7. Share of Jobs with Undesirable Characteristics, by Age and Education
(Percent)



Sources: Gateway to Global Aging Data; national microdata sources; and IMF staff calculations.
Note: The figures show the share of workers that report their job being unsatisfying, physically demanding, subject to high time pressure, stressful, lacking freedom, and having poor job security.

[9] The dummy treatment variable considers the top 10 chronic diseases in terms of their impact on overall health frailty. Results are also robust to considering all 17 chronic diseases or the top 10 in terms of impact on self-rated overall health. Notably, the overlap assumption is satisfied, whereby for all types of individuals (i.e. all values of observable characteristics), there is some portion in treatment and some in control. Similar OLS estimates for the direct effect of the chronic disease dummy on labor market outcomes provides additional comfort on the instrument's validity (exogeneity).

[10] This evidence is based on running separate 2SLS regressions for individuals' whose last occupation involved high versus low (self-reported) job satisfaction, physically demanding job requirements, and stress levels, among others. Age-friendly jobs are also generally associated with

Looking into the decades ahead, with artificial intelligence (AI) bound to affect job opportunities, the impact on older-age workers and how this interacts with their health improvements, will also be key (see also Box 2.3).

Online Annex Table 2.2.5. AIPW Regressions: Effect of Chronic Disease Dummy on Labor Market Outcomes

	Extensive Margin		Intensive Margin		Total	Labor Productivity		Retirement
	LFP	Employment	Weekly hours	Weeks/year	Earnings	Earnings/hr	Earnings/hr/wk	Age
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AIPW Average Treatment Effect:								
Chronic Disease Dummy (Top 10)	-0.071***	-0.018***	-1.235***	-0.371***	-0.099***	-0.039**	-0.014***	-0.590***
	(0.008)	(0.004)	(0.109)	(0.068)	(0.020)	(0.021)	(0.010)	(0.067)
OLS Estimate:								
Chronic Disease Dummy (Top 10)	-0.080***	-0.030***	-0.880***	-0.256***	-0.064***	-0.018	-0.045*	-0.416*
	(0.007)	(0.007)	(0.307)	(0.083)	(0.015)	(0.017)	(0.022)	(0.231)
Observations	565,640	205,315	198,418	124,139	93,893	77,412	44,460	285,809
Socio-Economic Controls	✓	✓	✓	✓	✓	✓	✓	✓
Lifestyle Controls	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓

Sources: Gateway to Global Aging Database; national health surveys; and IMF staff calculations.

Note: The estimations come from regressions of labor market outcomes of individuals ages 50 and older on a dummy indicator of chronic diseases, with socioeconomic characteristics (age, gender, education, household wealth), lifestyle factors (dummy indicators for smoking, physical inactivity, obesity, and underweight), the survey year, and country fixed effects controlled for. Standard errors are clustered at the country level. AIPW = augmented inverse propensity score weighting; FE = fixed effect; hr = hours; LFP = labor force participation; OLS = ordinary least squares; wk = week.

*** p <0.01; ** p <0.05; * p <0.1.

Online Annex Table 2.2.6. 2SLS Regressions: Effect of 1-Decade Health Improvements on Labor Market Outcomes

	Extensive Margin		Intensive Margin		Total	Labor Productivity		Retirement
	LFP	Employment	Weekly Hours	Weeks/Year	Earnings	Earnings/hr	Earnings/hr/wk	Age
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Measured Health:								
Grip Strength	0.023***	0.014***	0.436***	0.051	0.034***	0.013*	0.027***	0.237***
	(0.002)	(0.004)	(0.105)	(0.052)	(0.008)	(0.008)	(0.009)	(0.047)
Lung Function	0.090***	0.051	1.540***	0.252	0.238***	0.148*	0.155**	0.982***
	(0.016)	(0.031)	(0.529)	(0.280)	(0.080)	(0.084)	(0.077)	(0.243)
Cognitive PC	0.203***	0.187**	6.668***	0.825	0.308***	0.113	0.319*	1.787***
	(0.033)	(0.079)	(2.211)	(1.018)	(0.091)	(0.096)	(0.172)	(0.226)
Self-Reported Health:								
Overall health	0.006***	0.002***	0.088***	0.010*	0.007***	0.003*	0.004***	0.062***
	(0.001)	(0.001)	(0.016)	(0.006)	(0.001)	(0.002)	(0.001)	(0.009)
Physical PC	0.011***	0.007***	0.264***	0.022	0.021***	0.009*	0.014***	0.096***
	(0.001)	(0.002)	(0.053)	(0.014)	(0.005)	(0.005)	(0.004)	(0.015)
Psych. Well-Being	0.031***	0.023***	0.618***	0.056	0.051***	0.020*	0.030***	0.331***
	(0.002)	(0.006)	(0.171)	(0.050)	(0.011)	(0.012)	(0.009)	(0.056)
Composite Health Frailty:								
Frailty Index	0.034***	0.012***	0.576***	0.062*	0.047***	0.018*	0.031***	0.314***
	(0.002)	(0.005)	(0.121)	(0.036)	(0.010)	(0.011)	(0.009)	(0.047)
Socio-Economic Controls	✓	✓	✓	✓	✓	✓	✓	✓
Lifestyle Controls	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓

Sources: Gateway to Global Aging Database; national health Surveys; and IMF staff calculations.

Note: The estimations come from two-stage-least-squares regressions of labor market outcomes of individuals ages 50 and older on health indicators (one-at-a-time) — rescaled to represent effects of a 1-decade improvement in health (dividing health measures by 10 times the coefficient on the survey year obtained in Annex Table 2.2.1) — with socioeconomic characteristics (age, gender, education, household wealth), lifestyle factors (dummy indicators for smoking, physical inactivity, obesity, and underweight), the survey year, and country fixed effects controlled for. Standard errors are clustered at the country level. FE = fixed effect; hr = hours; LFP = labor force participation; 2SLS = two stage least squares; PC = principal component; wk = week.

*** p <0.01; ** p <0.05; * p <0.1.

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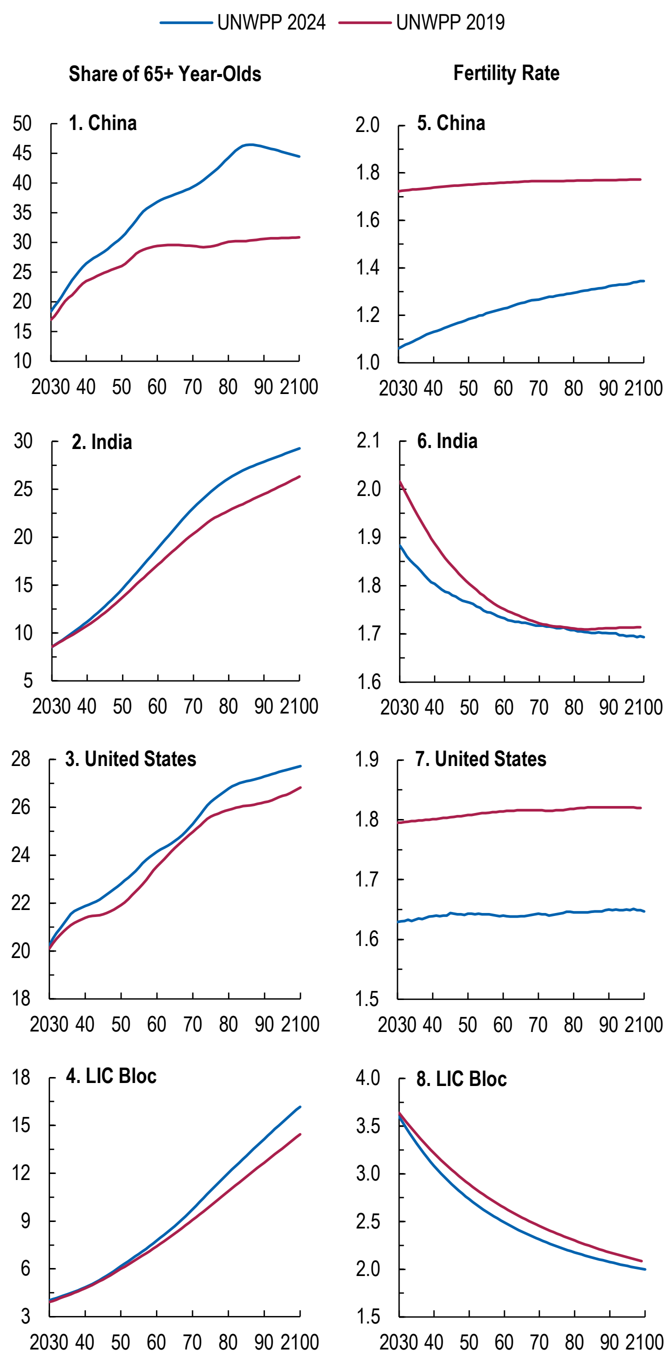
higher cognitive skill requirements, higher education, and better pay. The baseline 2SLS results (Online Annex Table 2.2.4) are also robust to controlling for job characteristics (e.g. industry/occupation fixed effects and dummy indicators for jobs being physically demanding, stressful, and subject time pressure, etc.), addressing concerns of job types potentially being correlated with individuals' health. These controls are not part of the baseline since the data are only available for a subset of countries. Results are not reported here due to space constraints.

Online Annex 2.3. The Economic Implications of Global Aging—A Model-Based Analysis

This section outlines details of the overlapping-generations (OLG) model used in the chapter's analysis, the assumptions underlying the baseline and the policy scenarios, as well as additional results. The chapter utilizes an extended version of the model of Auclert and others (2024), which incorporates country-specific demographic pyramids, and their projections based on predetermined fertility, mortality, and migration assumptions, as well as country- and age-specific labor supply profiles. The model assumes that individuals value smoothing consumption over their lifetime, including in retirement, and leaving bequests for their children. Key policies—such as retirement age, labor taxes, and social security spending—influence individuals' savings during their working lives before retirement. This framework allows for assessing the impact of policies aimed at promoting healthy aging, extending retirement age, and enhancing labor force participation. Unless otherwise noted, all functional forms and calibration follow Auclert and others (2024).

Online Annex Figure 2.3.1. The Share of 65+ Year-Olds and Fertility Rates in Selected Countries across Different Vintages of UNWPP
(Percent; live births per woman)



Sources: United Nations World Population Prospects; and IMF staff calculations.
Note: LIC = low-income countries.

Any model is a simplification of reality and, as such, carries limitations. In this model, one limitation is that it cannot speak to the potential structural transformation—such as the relative growth of the services sector and the associated decline in aggregate productivity—that population aging may induce. Another limitation is that it abstracts from modeling technological progress that responds endogenously to aging, which could boost TFP growth at the frontier. Finally, the model is geared toward low-frequency dynamics and long-term transitions, making it less suitable for investigating cyclical or higher frequency aspects, such as the adjustment costs of policy changes.

Online Annex 2.3.1. Baseline Scenario—Assumptions and Additional Results

Country coverage. The model includes 26 economies: in addition to the 25 economies considered in Auclert and others (2024)[11]—21 advanced economies and 4 emerging market economies (China, Hungary, India, and Poland)—the model includes a bloc of low-income countries (LICs). The *LIC bloc* is an aggregation of 44 economies that are expected to reach their demographic turning point after 2040. Hence, the model covers 69 countries: 21 advanced economies and 48 emerging market and developing economies.

Population projections. Demographic data are obtained from the 2024 United Nations World Population Prospects (UNWPP) projections. The model incorporates the 'medium' fertility scenario as the baseline. Counterfactual scenarios of high and low fertility scenarios that integrate the UNWPP's "high" and "low" fertility assumptions are reported in Figure 2.11, panel 2, of the main text.

Compared to the 2019 vintage used by Auclert and others (2024), the chapter uses the 2024 UNWPP vintage, which shows notable differences for some countries. Online Annex Figure 2.3.1 illustrates the differences between the 2019 and 2024 vintages of the UNWPP for selected countries. The left-side panels display the share of the population aged 65 and older, while the right-side panels show fertility rates—the number of live births per woman. The latest vintage projects a higher proportion of older individuals and marks a downward revision in fertility rates. The revisions are particularly stark for China, potentially reflecting the impact of the COVID-19 pandemic shock on population dynamics.

Online Annex Table 2.3.1 compares differences in fertility rate projections for all countries in the model between UNWPP 2019 and 2024 vintages for the years 2025, 2050, and 2075. While the overall trends remain roughly unchanged, the 2024 vintage projects considerably lower fertility rates.

[11] These are Austria, Australia, Belgium, Canada, China, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Ireland, Italy, Japan, Luxembourg, The Netherlands, Poland, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom, and the United States.

Online Annex Table 2.3.1. Fertility Rates in the 2019 and 2024 Vintages of the UNWPP
(Live births per woman)

Country	UNWPP 2019			UNWPP 2024		
	2025	2050	2075	2025	2050	2075
Australia	1.8	1.7	1.7	1.6	1.6	1.6
Austria	1.6	1.7	1.7	1.3	1.4	1.5
Belgium	1.7	1.8	1.8	1.4	1.5	1.5
Canada	1.5	1.6	1.7	1.3	1.4	1.5
China	1.7	1.8	1.8	1.0	1.2	1.3
Denmark	1.8	1.8	1.8	1.5	1.6	1.6
Estonia	1.7	1.7	1.8	1.4	1.5	1.5
Finland	1.4	1.6	1.7	1.3	1.4	1.5
France	1.8	1.8	1.8	1.6	1.6	1.7
Germany	1.6	1.7	1.7	1.5	1.5	1.6
Greece	1.3	1.5	1.6	1.3	1.4	1.5
Hungary	1.6	1.7	1.7	1.5	1.6	1.6
India	2.1	1.8	1.7	1.9	1.8	1.7
Ireland	1.8	1.7	1.7	1.6	1.6	1.6
Italy	1.3	1.5	1.6	1.2	1.3	1.4
Japan	1.4	1.6	1.6	1.2	1.3	1.4
LIC Bloc	3.9	2.9	2.4	3.9	2.7	2.2
Luxembourg	1.4	1.6	1.7	1.4	1.5	1.5
Netherlands	1.7	1.7	1.8	1.4	1.5	1.5
Poland	1.5	1.6	1.7	1.3	1.4	1.5
Slovak Republic	1.6	1.7	1.7	1.6	1.6	1.6
Slovenia	1.7	1.7	1.8	1.6	1.6	1.6
Spain	1.4	1.6	1.7	1.2	1.4	1.4
Sweden	1.8	1.8	1.8	1.4	1.5	1.6
United Kingdom	1.8	1.8	1.8	1.5	1.5	1.6
United States	1.8	1.8	1.8	1.6	1.6	1.6

Sources: United Nations World Population Prospects; and IMF staff calculations.
Note: LIC = low-income countries.

Healthy aging. Another notable departure from Auclert and others (2024) is the incorporation of healthy-aging trends into the age–productivity profiles of older workers. Specifically, the effects of healthy-aging trends on the age-specific effective labor supply are informed by the estimates reported in Online Annex 2.2. The focus is on individuals aged 50–59, 60–69, and 70–79, while other age groups are assumed to be unaffected. In particular, the improvements in the cognitive functional capacities of older individuals estimated over 2000–22 are assumed to continue accruing going forward but at a declining rate. Specifically, the rate of improvements in cognitive health is assumed to decline at a geometric rate. In turn, these improvements in cognitive health are assumed to raise effective labor supply through its impact on both labor productivity (earnings per hour worked) and total hours worked. The combined effect is measured based on the estimated impact of cognitive functionality on total labor earnings (coefficient on Cognitive PC in Online Annex Table 2.2.4, column 5). The assumed health improvements over 2023-2100 are equivalent to around one-fourth of the gains observed during 2000–22. As a result, the effective labor supply per older worker would rise by 36 percent during 2017–2100, with gains during 2023–2100 amounting to one-fourth of the gains observed during 2000–22.

Productivity. Over the long run, the model economy converges to an age-specific balanced growth path, in which each age group's asset distribution stabilizes and grows at the same rate as total factor productivity, calibrated to 2 percent per year, as in Auclert and others 2024, based on the average for the world economy over 2000–16. The model has been extended such that, during the transition period reported in the chapter (2016-2100), country-specific productivity profiles are also shaped by two other forces:

Convergence towards the frontier productivity level. Miller and Upadhyay (2002) find evidence of convergence in productivity levels between emerging market economies and advanced economies. Acemoglu, Aghion and Zilibotti (2006) argue that some emerging markets, such as countries in Latin America that have high barriers to competition, tend to converge rapidly when they are far from the frontier, with the rate of convergence slowing down as they approach the frontier.[12]

Impact of demographics on productivity growth via innovation and entrepreneurship channels. The literature suggests that TFP growth could be affected by population dynamics through innovation and entrepreneurship channels, given some evidence of a negative association between age and scientific discovery, patenting, propensity for new technology adoption, and entrepreneurship (e.g., Bussolo, Koettl and Sinnott 2015; Jones 2022; Kaltenberg, Jaffe and Lachman 2023).

To calibrate the effect of these two forces on total factor productivity (TFP) growth of individual countries in the model, the chapter utilizes the following panel regression:

$$\log\left(\frac{TFP_{t+1}^{c}}{TFP_{t}^{c}}\right) = \beta^{conv}\log\left(\frac{TFP_{t}^{c}}{TFP_{t}^{USA}}\right) + \beta^{pop}\Delta pop25\text{-}45_{t} + \beta^{pop2}\Delta pop25\text{-}45_{t-1} + \beta^{int}\log\left(\frac{TFP_{t}^{c}}{TFP_{t}^{USA}}\right)\times \Delta pop25\text{-}45_{t} + \mu_{c} + \varepsilon_{t}^{c}$$

where $\Delta pop25\text{-}45_{t+1}$ is the growth rate of the youth adult population, defined as those aged between 25 and 45 years old, TFP_{t+1}^{c} is the level of total factor productivity in country c in $t+1$, and μ_c are country fixed effects.

TFP data is obtained from the Penn World Table 10.01 (PWT). TFP growth rates are based on the welfare-consistent TFP series in PWT. The gap with the TFP level in the United States is used as proxy for distance to frontier TFP. Population data is obtained from the UNWPP.

[12] They define proximity to frontier, first, in terms of the ratio of TFP in an industry of a country to the highest industry TFP across countries. Then, they proxy this variable as the ratio of GDP per capita in a country to GDP per capita in the United States.

Online Annex Table 2.3.2. Technology Growth, Distance to Frontier, and Young Population Growth

	Growth Rate of TFP			
	(1)	(2)	(3)	(4)
Growth of 25–45 Age Group		0.0069***		0.0074**
		(0.002)		(0.003)
Growth of 25–45 Age Group (Lagged)		-0.0056**		-0.0057*
		(0.002)		(0.003)
Distance to Frontier	-0.0414***	-0.0487***	-0.0461***	-0.0509***
	(0.008)	(0.009)	(0.011)	(0.012)
Distance to Frontier * Growth of 25–45 Age Group		0.0055**		0.0039
		(0.002)		(0.003)
Constant	-0.0061***	-0.0075***	-0.0090***	-0.0101***
	(0.020)	(0.003)	(0.003)	(0.004)
Number of Observations	1,144	1,137	729	726
R^2	0.026	0.033	0.025	0.031

Source: IMF staff calculations.
Note: Estimates are from the fixed effects model that is described above. Standard errors are reported in parentheses. TFP = total factor productivity.
*** $p<0.01$; ** $p<0.05$; * $p<0.1$.

Online Annex Table 2.3.2 reports the results. Columns 1-2 show estimates over 1970–2019, while columns 3-4 show estimates over 1990–2019. Results from both samples show a similar pattern, with a statistically significant positive relationship between the young population growth rate and TFP growth, and a statistically significant negative relationship between distance-to-frontier and TFP growth, implying convergence.

Estimates from column 2 (including country fixed effects), along with the initial TFP gaps with respect to the United States, and UNWPP demographic projections are used to construct country-specific productivity profiles.

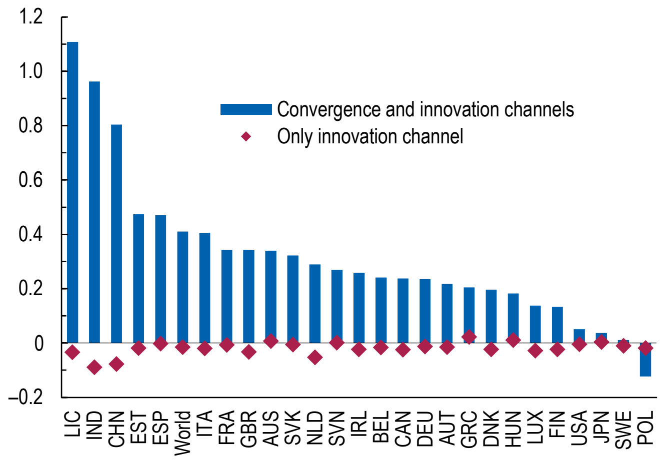
To understand the contribution of the two forces to growth projections—productivity convergence and the effect of the young population growth on innovation—Online Annex Figure 2.3.2 shows the contribution to the baseline average annual GDP growth over 2025–2100 from each of these forces. The results suggest that the age-innovation channel plays a relatively minor role in affecting average GDP growth over the projection period. In contrast, the productivity-convergence channel plays a more prevalent role.

Global capital markets. The model assumes that the extent of integration of China, India, and the *LIC bloc* into global capital markets is imperfect. This is done by introducing a time-varying wedge between domestic and global interest rates for these economies. The wedge increases the marginal product of capital in these emerging market and developing economies and can be interpreted as reflecting credit market imperfections, expropriation risk, bureaucratic inefficiencies, or corruption (Gourinchas and Jeanne 2013). Assuming perfect capital mobility, capital accumulation adjusts so that the wedge-adjusted return in these economies matches the interest rate observed in advanced economies.

The interest rate wedge in the model is set initially to 300 basis points. This is consistent with the evidence in Gerding, Henriksen, and Simonovska (2025), who compute equity returns for 22 developed markets (1970–2020) and 15 emerging markets (1988–2020)—covering roughly two-thirds of world GDP. Their data indicate that the mean return differential between EMs and AEs is approximately 330 basis points. The wedge is assumed to declines gradually in the model—as these economies are assumed to continue undertaking credit and capital market reforms and strengthening their governance frameworks and institutions—and to dissipate by 2070.

Online Annex Figure 2.3.2. Contribution of TFP Convergence and Innovation to GDP Growth

(Average contribution to baseline GDP growth, 2025–2100, percentage points)



Source: IMF staff calculations.
Note: The bars and diamonds denote annual averages over the reported periods. The values for "World" denote averages for the economies included in the model. Data labels in the figure use International Organization for Standardization (ISO) country codes. LIC = bloc of low-income countries; TFP = total factor productivity.

Fiscal policy. Labor taxes, retirement replacement rates, and effective retirement ages are calibrated to match targets in the data, following Auclert and others (2024). In the baseline, effective retirement ages are assumed to increase by one month per year over 60 years in all countries, except for India and the *LIC bloc* (where the effective retirement age are assumed to remain unchanged because life expectancy at retirement is below 15 years). The debt-to-GDP ratio of each country is assumed to evolve as projected in the October 2024 *World Economic Outlook* up to 2029 and to remain stable thereafter. To meet the debt objective each year, governments are assumed to adjust a mix of policy instruments—namely, labor tax rates, replacement rates determining transfers to retirees, and other government spending—such that one-third of the necessary budget adjustment falls on each of the following instruments: labor tax rate, transfer spending, and other government spending.

Online Annex 2.3.2. Policy Scenarios--Assumptions and Additional Results

The chapter uses the extended model to assess the growth and fiscal dividends from three policy levers: tackling the decline in participation rates of older but pre-retirement age individuals, extending working lives as life expectancy rises, and narrowing gender participation gaps. A set of policy scenarios considers the implications of implementing policies that address these issues one at a time as well as all together, in a combined policy scenario. Each scenario assumes that all model economies engage in policy changes at the same time, but the magnitude and pace of the policy outcome (e.g., the assumed increase in effective retirement age or female labor force participation) and, consequently, the growth and fiscal dividends, depend on the room for improvement that each country initially has on each policy dimension. The rest of the section provides details on the policy scenario assumptions and reports additional exercises not included in the main text.

Healthy aging policies. In addition to the age-specific increases in effective labor supply resulting from healthy aging in the baseline, this scenario assumes additional country-specific gains reflecting policy-induced health improvements that imply catching up with the frontier. Specifically, country-specific cognitive health gaps vis-à-vis the frontier country are reduced by one-fourth by 2100.[13] In other words, the frontier country (Sweden) is assumed to see health improvements at the same rate as under the baseline, while other countries are assumed to narrow the gap with the frontier over time. The additional improvement in cognitive capacity of older individuals over the long run is equivalent, on average across countries, to about 49 percent of the estimated gains over 2000–22. The corresponding improvement in terms of effective labor supply per old worker is equivalent to about 59 percent of the estimated gains over 2000–22. Policies affecting retirement age are assumed unchanged in this scenario.

Higher effective retirement age. In this policy scenario, country-specific effective retirement ages are assumed to increase at a faster pace than under the baseline, in line with rising life expectancy, if life expectancy at retirement is 20 years or more—in line with prospective old-age thresholds (Sanderson and Scherbov, 2010; Kotschy and Bloom 2023). More precisely, at any given year *t*, if life expectancy at retirement in *t-1* exceeds 20 years, the effective retirement age at *t* is increased by 3 months. In all other cases, the effective retirement age evolves as in the baseline scenario. For most countries, this policy results in longer working lives compared to the baseline, but for some (e.g., China, Canada, USA, UK, and the *LIC bloc*) the effective retirement age would remain at the same level than under the baseline for several decades.

The assumed increase in effective retirement age under this policy scenario is in line with recent observed gains. For instance, this scenario would result in a median increase in the effective

[13] Country-specific initial health levels are taken to be the country fixed effects in an OLS regression of cognitive health measures principal component on socio-economic factors (age, gender, education, wealth), the survey year, and a time trend (see the regression specification in Online Annex Table 2.2.1). For countries with missing data on some of the cognitive health indicators, the fixed effect for the closest comparator country (considering other health indicators) is used as proxy. The *LIC bloc* is assumed to have the same initial health level as India.

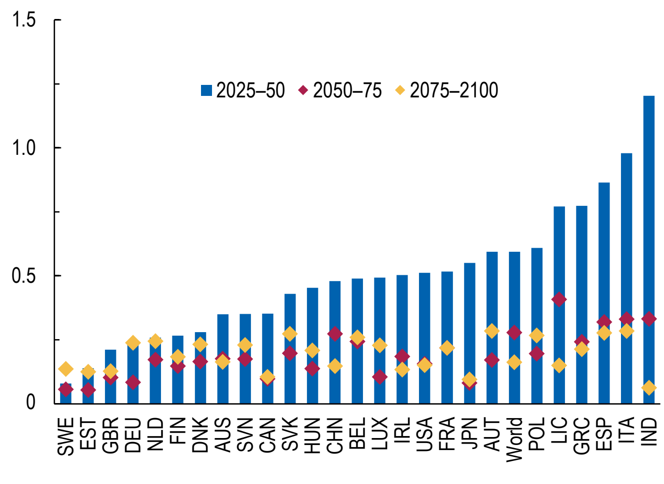
retirement age of 2 years over the next 20 years. The actual increase in the median economy over 2002–22 was about 2.6 years.

While reforms to induce higher effective retirement ages in standard defined-benefit system may involve changes to replacement rates, the model assumes replacement rates remain unchanged for simplicity.

Closing labor force participation gaps. Under this scenario, the country-specific female labor force participation rate is assumed to gradually increase such that the initial gender participation gaps are reduced by three-fourths by 2040. The data on labor force participation rate come from the International Labour Organization (ILO) modelled estimates series. This scenario stipulates a median rise of 4.7 (10.6) percentage points in female labor force participation by 2040 for women in the age group 25–54 (55–64) compared to an actual median increase of 7.1 (30.8) percentage points over the period 2000–24.

Under this policy scenario, India experiences the most substantial gains, followed by Greece, Italy, Japan, and the *LIC bloc*. In India, reducing the gender gap by three-fourths among individuals aged 55–64 would lead to a 37 percent increase in effective labor supply in that age group, while an equivalent gap reduction in the 25–54 age group would yield a 33 percent increase. Across all countries in the model, narrowing gender participation gaps would generate the largest boost in female labor supply among those aged 55–64.

Online Annex Figure 2.3.3. Average GDP Growth Rate, Combined-Policy Scenario
(Deviation from the baseline scenario, percentage points)



Source: IMF staff calculations.
Note: The bars and diamonds denote annual averages over the reported periods. The values for “World” denote averages for the economies included in the model. Data labels in the figure use International Organization for Standardization (ISO) country codes. LIC = bloc of low-income countries.

Combined labor policies. The combined impact of the three policies—improving health to close the gap with the frontier, increasing effective retirement age in line with rising life expectancy, and enhancing female labor force participation—could significantly boost global growth over the next 25 years for most countries (Online Annex Figure 2.3.3). In contrast, countries with small initial health disparities and gender participation gaps would derive lower gains.

Fiscal space. Labor supply policies create fiscal space for governments as they increase the labor supply and improve the old-age dependency ratio relative to the baseline. These fiscal gains can be utilized to lower the labor tax rate, increase the income replacement rate for retirees, or increase spending on other programs. Most model scenarios assume that the fiscal dividends from reforms are allocated equally among these three objectives such that the government maintains a constant debt-to-GDP ratio going forward. These gains are quantified in Figure 2.14 in the main text. This is considered additional fiscal space in the sense that the government may also choose to consolidate its primary deficit by the same amount and lower debt-to-GDP over time (see below). Since the magnitude of these gains changes over the transition period, Figure 2.14 reports the average gain over 2025-2100. More specifically, the average additional fiscal space due to the policies over the period t_1 to t_2 is computed as follows:

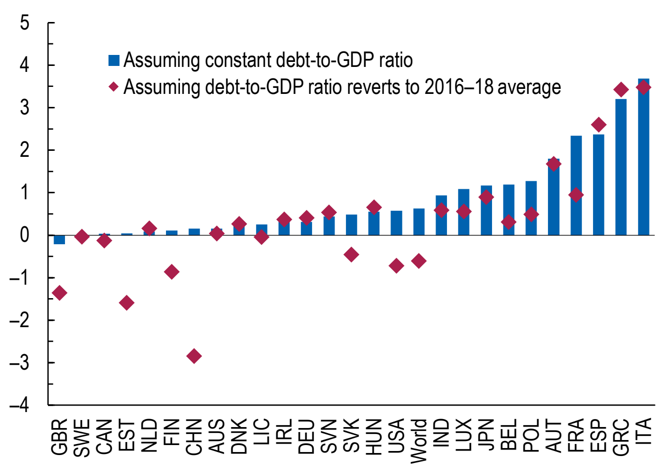
$$Fiscal\ space^{pol}_{j,t_1-to-t_2} = \frac{1}{(t_2 - t_1)} \sum_{t=t_1}^{t_2} \left[\left(\frac{Tr^{pol}_t + G^{pol}_t - T^{pol}_t}{GDP^{pol}_t} \right) - \left(\frac{Tr^{base}_t + G^{base}_t - T^{base}_t}{GDP^{base}_t} \right) \right]$$

where *pol* and *base* denote policy and baseline scenarios, respectively; *j* denotes country; *t* denotes year; *T* denotes labor tax revenues, *Tr* denotes transfers to retirees, and G denotes other government spending.

An alternative exercise reported in Online Annex Figure 2.3.4 uses the same method to compute the fiscal space over 2025–40 but assuming that the fiscal dividends from the labor supply policies are also used to rebuild fiscal buffers—more precisely, to gradually reduce debt-to-GDP over 2030–40 toward its 2016–18 average, before the onset of the COVID-19 pandemic. The chart also reports, for comparison, the results when the debt-to-GDP ratio is assumed to remain stable (as in Figure 2.14 in the main text). The results show that for many of the model economies (e.g., Greece, Japan, Spain), the fiscal gains from reforms would be sufficient to rebuild fiscal buffers, with some remaining extra gains that could be deployed for additional critical spending. Others, such as China, the United Kingdom, and the United States, would require additional fiscal efforts (i.e. further consolidation in the primary balance) to bring debt-to-GDP back to pre-pandemic levels.

Online Annex Figure 2.3.4. Additional Fiscal Space over 2025–40, Combined-Policy Scenario

(Deviation from the baseline scenario, percent of GDP)

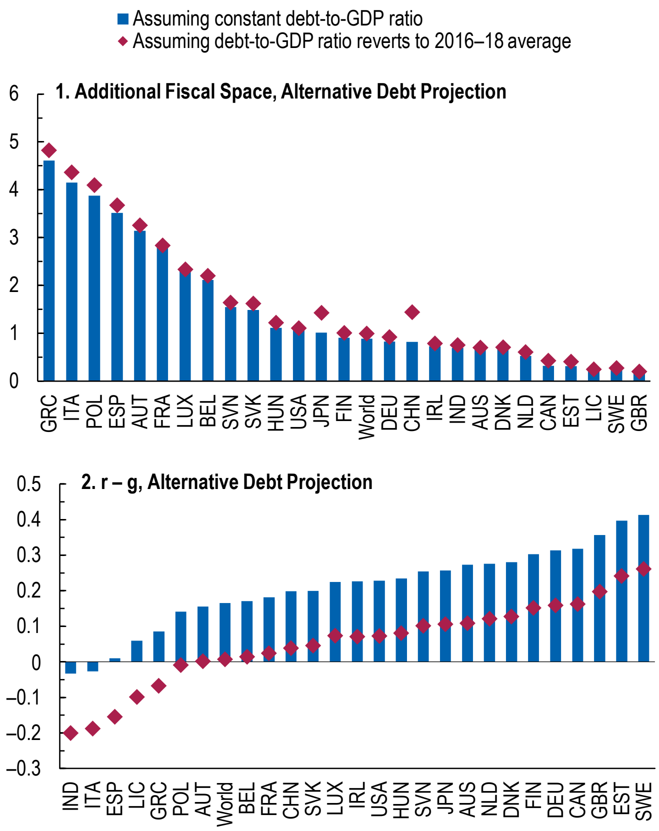


Source: IMF staff calculations.

Note: The figure shows the fiscal gains under the combined-policy scenario due to higher effective labor supply and improved old-age dependency ratio relative to the baseline. Because the magnitude of the gains varies over the transition, the figure reports the average gain over 2025–2040. The values for "World" denote averages for the economies included in the model. Data labels in the figure use International Organization for Standardization (ISO) country codes. LIC = bloc of low-income countries.

Online Annex Figure 2.3.5, panel 1, reports the additional fiscal space over a longer period, 2025–2100, with the alternative objectives for public debt, while panel 2 reports the same for *r–g*. The results indicate that the average additional fiscal space over 2025–2100 due to the combined labor policies is larger when countries are assumed to actively reduce their debt levels over 2030–40. That is, although this strategy may limit fiscal space in the short term (as seen in Online Annex Figure 2.3.4), reducing the level of debts leads to additional fiscal space over the long term. Panel 2 shows that average *r-g* over 2025–2100 would be lower for all model economies when the fiscal dividends from the labor supply policies are also used to rebuild buffers.

Online Annex Figure 2.3.5. Additional Fiscal Space and r – g under Combined-Policy Scenario, Average over 2025–2100
(Deviation from the baseline scenario, percentage points)



Source: IMF staff calculations.
Note: The figure shows the fiscal gains under the combined-policy scenario due to higher effective labor supply and improved old-age dependency ratio relative to the baseline. Because the magnitude of the gains varies over the transition, the figure reports the average gain over 2025–2100. The values for “World” denote averages for the economies included in the model. Data labels in the figure use International Organization for Standardization (ISO) country codes. g = GDP growth rate; r = interest rate; LIC = bloc of low-income countries.

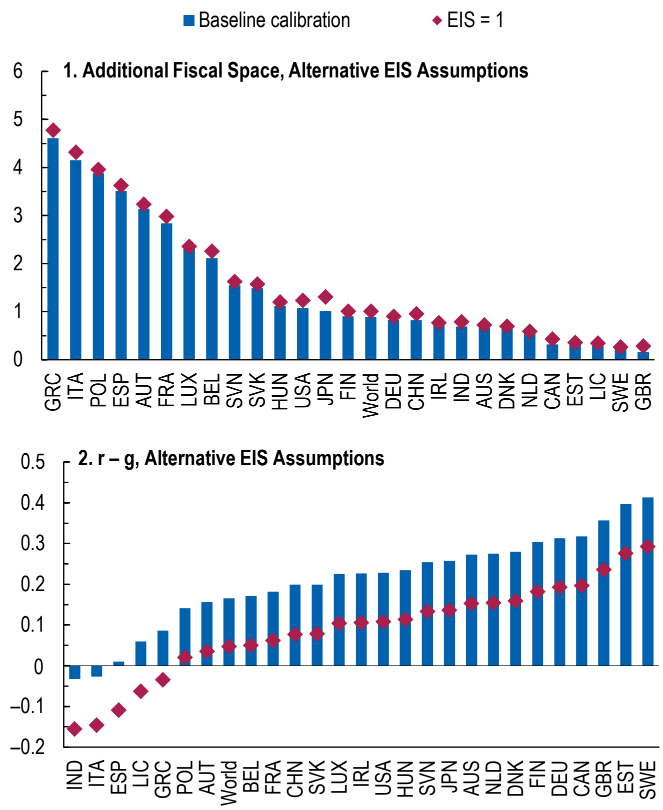
Details on modelling additional migration (Box 2.1). The exercise reported in Box 2.1 assumes doubling of annual migration flows of young individuals (aged 20 years old in the model economy) from the *LIC bloc* towards aging AEs over the long run. This additional annual flow is assumed to increase gradually, reaching the long-run level by 2040, when it would represent about one percent of the *LIC bloc*'s population aged 20–24. Since the additional migrants are young, they have lower productivity than prime-aged workers. For simplicity, the model assumes that these young migrants have zero net worth, thereby abstracting from any changes in net wealth due to migration.

Online Annex 2.3.3. Robustness Analyses

Sensitivity to elasticity of intertemporal substitution. The sensitivity of interest rates to growth-enhancing policies affects the extent to which *r-g* improves because of these policies. This sensitivity, in turn, depends on the model assumptions for the elasticity of intertemporal substitution (EIS). The baseline calibration assumes an EIS of 0.5, as in Auclert and others (2024). A counterfactual exercise is used to assess the effect of labor supply policies that boost growth (the combined policy scenario) under the assumption that EIS = 1, with other parameters recalibrated to match the same targets as in the baseline.

Online Annex Figure 2.3.6, Panels 1 and 2, show the additional fiscal space and *r-g* under the baseline and, respectively, under the alternative assumption for the EIS. With EIS = 1, consumption and savings respond more strongly to changes in interest rates. A given change in GDP growth (g) leads to a smaller change in the real interest rate (r) when EIS is higher. Consequently, *r-g* in the combined policy scenario is lower for every country in the model when EIS = 1 than in the baseline calibration (Panel 2 of Online Annex Figure 2.3.6). However, Panel 1 of Online Annex Figure 2.3.6 shows that the sensitivity of fiscal space to the elasticity of intertemporal substitution is relatively small.

Online Annex Figure 2.3.6. Additional Fiscal Space and r – g under Combined-Policy Scenario, Average over 2025–2100
(Deviation from the baseline scenario, percentage points)



Source: IMF staff calculations.
Note: Panel 1 shows the fiscal gains under the combined-policy scenario due to higher effective labor supply and improved old-age dependency ratio relative to the baseline. Because the magnitude of the gains varies over the transition, the figure reports the average gain over 2025–2100. In both panels, the blue bars show the differences under our baseline calibration in which the EIS is assumed to be 0.5, while the red diamonds represent the differences when the EIS is set to 1. The values for "World" denote averages for the economies included in the model. Data labels in the figure use International Organization for Standardization (ISO) country codes. g = GDP growth rate; r = interest rate; EIS = Elasticity of intertemporal substitution; LIC = bloc of low-income countries.

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