Long-term Projections of the World Economy*

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Abstract

This paper surveys long-term projections of global GDP per capita and presents our own projections through 2050 using a multi-country-multi-sector general equilibrium model (G-Cubed). Existing studies generally agree that global GDP per capita growth will continue to slow in the coming decades, driven by several global challenges such as rapid population ageing, slower technological progress, weaker capital investment, and stagnating educational attainment. Projections tend to be consistent for advanced economies, but vary considerably for developing regions, highlighting the importance of alternative methodologies and assumptions, as well as inherent long-term uncertainty. While existing studies rely on neoclassical models with an aggregate production sector, the G-Cubed model takes a disaggregated approach to projecting productivity and output that accounts for dynamic interactions between sectors and across economies. Our projections incorporate the impacts of three fundamental factors: productivity growth, population ageing, and climate change. Productivity growth in advanced economies is expected to slow, but artificial intelligence could counteract the decline and serve as an engine for sustained growth. Population ageing in most advanced economies will continue to constrain labour supply, potentially reducing GDP per capita through changes in age structure. Climate change poses challenges to economic growth through multiple channels, with moderate quantitative impacts by mid-century. The extent to which developing regions can boost productivity, leverage demographic advantages, and navigate climate change will depend on policy choices, as well as governance and institutional improvements. Finally, the paper discusses the implications of geopolitical fragmentation, government debt, and public infrastructure on economic growth.

Keywords: economic growth, long-term projections, productivity growth, population ageing, climate change, artificial intelligence, geopolitical fragmentation, government debt

JEL Classifications: O40, O33, C53, C68

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1 Introduction

Long-term GDP per capita growth is vital to improving the standards of living over lifetimes and across generations. Global GDP per capita has tripled since 1960, which has significantly improved economic well-being worldwide and lifted hundreds of millions of people out of poverty. Although most countries experienced positive economic growth for decades, their growth momentum varied significantly. Over the past six decades, GDP per capita increased nearly 10 times in upper-middle-income countries, about 4.5 times in lower-middle-income countries, and 4 times in high-income countries, while remaining largely stagnant in low-income countries.[1] There are numerous studies investigating economic growth drivers and particularly economic convergence and divergence between developing and advanced economies (Johnson and Papageorgiou 2020).

Looking into the future, whether advanced economies can sustain their economic growth, and whether low-income countries can catch up with advanced economies are intriguing and critical questions. Also, economic growth projections are fundamental to private business investment and public policy design. There is an extensive and well-developed literature concerned with methodologies for projecting economic growth over short time horizons. Over long horizons, however, where the goal is to quantify the implications of social-economic scenarios, the literature is limited. With the emergence of some global long-term issues such as energy transition, climate change, population ageing and soaring public debt, the time horizon over which projections are required has been stretched dramatically.

The goal of this paper is two-fold. First, we survey studies of long-term projections of GDP per capita, building on an earlier review by Stegman and McKibbin (2013) of previous long-term projections. We extend their survey by incorporating the studies of long-term projections conducted

[1] These growth rates are calculated using GDP per capita in constant US dollars based on market exchange rates, with data sourced from the World Bank World Development Indicators. GDP per capita measured in purchasing power parity shows similar growth trends and regional heterogeneity. Income classifications follow the World Bank definitions of income status by GNI per capita in 2024.

in the last decade. This paper discusses key issues that have emerged or intensified in the last decade concerning long-term economic growth, such as automation technology, population ageing, climate change, geopolitical fragmentation, fiscal sustainability, and public infrastructure. Second, we conduct our long-term projections of GDP per capita up to 2050 based on a global dynamic general equilibrium model (G-Cubed) with detailed country and sector disaggregation (McKibbin and Wilcoxen 1999, 2013). Our projections examine the long-term impacts of technology-driven productivity growth, population ageing, and climate change, as they are widely recognized as key drivers of long-term economic growth globally.

There appears to be some general agreement over the methodology of long-term projections across the studies. Essentially, the models combine neoclassical growth theory with additional assumptions, including technology convergence, to generate projections of model inputs. Despite the agreement over the general methodology, the projections vary considerably, particularly for developing regions over long-time horizons, highlighting the importance of alternative methodologies and assumptions. While existing studies rely on neoclassical models with an aggregate production sector, the G-Cubed model takes a disaggregated approach to projecting productivity and output that accounts for dynamic interactions between sectors and across economies. The survey presented here also highlights the fundamental difference in projections of economic growth over short-time and long-time horizons. The former are essentially forecasts and generally based on time series models, while the latter are undertaken to model scenarios and are generally driven by theoretical model assumptions.

The distinction between short-term projections aimed at forecasting the future and long-term projections that attempt to quantify scenarios is critical. Over short-time horizons, empirical trends and behaviour dominate, and forecasts can be, and frequently are, judged against actual outcomes. Over long-time horizons, the objective is more complex. Projections represent an attempt to quantify given scenarios and alternative methodologies and assumptions can produce highly variable results. In addition, there is inevitable subjective judgment in the interpretation of scenarios and in the assignment of likelihood and relevance. Therefore, it is fundamental that long-term economic projections are accompanied by clear and transparent descriptions of scenarios as well as the assumptions and methodologies that underlie the scenarios and their quantification.

When the projection horizon extends over decades, a high degree of uncertainty is associated not only with the underlying model and its parameterisation but also with the specification and evolution of the key drivers of economic growth. The more distant into the future, the more pervasive the uncertainty. The need to construct and quantify scenario assumptions regarding technological advances and social and political change complicates the projection of long-term economic growth considerably.

The projections collected from the literature are described as baseline projections. The assumptions underlying the projections are conservative with respect to major technological breakthroughs, socio-political change and innovative policy implementations. It is likely that over the projection period such shocks will occur, but their nature is so uncertain that it is difficult to justify their inclusion in projection exercises. Furthermore, a conservative approach allows projections to function as a basis from which alternative policies can be considered and evaluated. Projected variables are unlikely to match observed outcomes over long horizons, and relevance and usefulness must be subjectively judged with reference to the policy question under consideration. If the intention is to inform economic decision making, then success may be considered, not with reference to the accuracy of the projections, but with reference to the appropriateness of the policy decisions based upon them.

The remainder of this paper is organised as follows. Section 2 provides an overview of the key drivers of economic growth, and discusses the methodologies for modelling long-term economic growth. Section 3 reviews specific studies from the past decade on long-term projections of GDP per capita, focusing on their approaches and assumptions. Section 4 introduces the G-Cubed model used in this paper and presents the projection results. Section 5 compares our projections with other studies, and highlights key insights. Section 6 discusses additional factors that can influence economic growth but are not explicitly modelled in this paper. Section 7 concludes.

2 Projection methodology

This section examines the key drivers of economic growth, and broadly discusses the methodologies for modelling long-term economic growth. The section is divided into two parts. The first part discusses domestic drivers of economic growth, which play dominant roles in economic growth. The second part discusses external drivers of economic growth in open economies, especially in the form of catch-up or convergence across countries.

2.1 Domestic growth drivers

The most common approach to long-term economic projections is based on neoclassical growth models, such as the Solow-Swan model (Solow 1956; Swan 1956) and the Ramsey-Cass-Koopmans model (Ramsey 1928; Cass 1965; Koopmans 1965). Neoclassical models use an aggregate production function with capital and labour as two production factors. On the demand side, consumption and investment are assumed to be fixed fractions of output in the Solow-Swan model, whereas in the Ramsey-Cass-Koopmans model, consumption is endogenously determined to achieve a smooth path that maximizes lifetime utility. Those models characterize the dynamics of physical capital over time while assuming that labour and technology are exogenous.

Physical capital

The theory underlying neoclassical growth models provides a path for an economy as it converges to its steady state. The further an economy is from its steady state, the faster it grows. This is due to diminishing returns to capital. If all economies shared the same steady-state characteristics, then relatively poor countries, with low levels of capital and output per worker, would grow faster than relatively rich countries, and convergence in the absolute sense would occur. However, if countries differ in their respective steady state characteristics , then the convergence force applies only in a conditional sense. The growth rate tends to be high if GDP per capita is low in relation to its long-term or steady-state position. Neoclassical growth theory therefore predicts convergence of an economy to its own individual steady state. Under conditional convergence, poorer countries will only grow faster than rich countries if they are further below their respective steady states.

Labour force

Labour supply is exogenously determined, depending on the size of labour force and participation and employment rates. Population dynamics are driven by fertility and mortality changes. Fertility rates have been declining globally since the post-WWII baby booms, despite variations across countries and regions. Declining fertility, combined with increasing longevity, has driven an unprecedented process of population ageing , eventually leading to shrinking working-age population. In addition to labour quantity, labour quality or human capital, which encompasses knowledge, skills and health, is essential for economic growth. Labour quality is often associated with education attainment. Also, individual productivity follows a hump-shaped pattern over the life cycle, peaking in middle age before declining. The age-specific productivity pattern implies that population ageing reduces aggregate labour productivity at the national level. Additionally, some studies consider urbanization to project economic growth. This internal migration is important for labour supply, income convergence and economic growth in developing countries. International population migration is more subject to political restrictions.

Technological progress

Technological progress is vital to sustainable economic growth in the long run. It is important for all countries but especially relevant for the technological frontier (usually advanced economies especially the United States) since developing countries can often imitate the technologies at the frontier. GDP per capita growth in the United States has remained stable at around 2% per year for the past 150 years. The development of new general purpose technologies every few decades may explain this long-term growth stability (Jones 2023). While productivity has slowed in the United States and globally over the past two decades, artificial intelligence (AI) holds promise as a key driver for future economic growth.

Public infrastructure

Public infrastructure, especially in relation to transport, utilities, information and communication, and education, plays a crucial role in long-term economic growth (Agénor 2013). In particular, in low- and middle-income countries, inadequate public infrastructure is often viewed as a key impediment to economic growth and development (Devadas and Pennings 2018). Public infrastructure complements private capital to advance economic growth through several channels: improve productivity, facilitate trade, stimulate private investment, provide better public services, etc (Romp and de Haan 2007; OECD 2009; Agénor 2013). Despite its importance, public infrastructure is often missing in growth models.

Environmental sustainability

There have been long-standing discussions about the relationship between environmental sustainability and economic growth. For example, Meadows et al. (1972) argue that if growth trends in population, industrialization, resource use and pollution continue unchanged, the world would reach and overshoot the carrying capacity of the planet within the 21th century. But early growth models often focus solely on capital and labour as production factors without considering the environmental impacts of production activities. With increasing awareness of fossil fuel related air pollution and climate change, more and more studies incorporate energy as another input to investigate the interaction between economic growth and environmental sustainability, with a particular focus on climate change in recent years.

Policies and institutions

Economic policies and broader institutions are important for economic growth in the long run, especially in developing countries. Particularly, fiscal sustainability and monetary stability create a stable macroeconomic environment conducive to investment, consumption and international trade. Strong institutions, including effective governance, property rights enforcement and reliable legal systems, are essential to private investment and innovation. Empirically, low-income countries failed to converge with advanced economies in income levels over the long period after WWII. A large strand of theoretical and empirical work argue that income disparities between poor and rich countries are attributed to differences in the quality of institutions (Acemoglu et al. 2005; Acemoglu and Robinson 2012; Lloyd and Lee 2018).

2.2 Catch-up across countries

The neoclassical growth theory provides a framework for convergence to individual steady states but not for convergence of steady states across countries. This distinction is fundamental to the use of convergence assumptions. Projection studies often impose an assumption that economies converge towards each other (or a frontier economy) in one or more variables, which is often referred to as economic catch-up. To remain consistent with standard neoclassical growth theory, projections need to make an additional assumption that either economies share the same steady-state characteristics and the convergence of economies to their individual steady states corresponds to the convergence of economies to each other; or economies converge to individual steady states that, in turn, converge to each other.

The first assumption posits that all regions under consideration are converging to the same steady state, so steady-state convergence and economic catch-up are equivalent. Empirical evidence on GDP per capita convergence suggests that while subsets of regions such as OECD countries appear to share steady-state characteristics, this assumption does not hold across the broad set of regions. Johnson and Papageorgiou (2020) reviews studies on economic convergence and conclude that: (1) there is a broad consensus of no evidence supporting absolute convergence in cross-country per capita incomes; (2) the process of growth and of convergence is not smooth but rather start and stop, and is characterized by significant country heterogeneity; (3) several mechanisms of divergence and convergence are concurrently at work across countries in different stages of development process; (4) except a few Asian countries that exhibited transformational growth, most of the economic achievements in developing economies have resulted from removing inefficiencies, especially in governance and political institutions.

The second assumption above suggests that the steady-state characteristics of regions are heterogeneous but converge towards each other over time. In neoclassical growth models, steady-state characteristics are explicit, but models could encompass a range of characteristics relating to preferences and technologies. The use of the second assumption requires the development of a theoretical model of steady-state convergence and is complicated by our limited understanding of the determinants of steady states and their evolution over time, particularly for developing economies.

Catch-up in technological progress

In standard neoclassical growth theory, the fundamental driver of steady-state or long-term growth is exogenous technological progress. Technology is usually introduced with a constant and homogeneous growth specification, but empirical evidence suggests that both the growth rate and the level of technology vary across countries and over time. For projection exercises, an alternative specification is a convergence model of technological progress based on technology transfer, diffusion and adoption. This type of model has support in both the empirical and theoretical literature. All models surveyed in this paper assume some form of convergence in technology or total factor productivity (TFP). Projections of TFP and other key inputs determine the projected levels and growth rates of GDP per capita through an aggregate production function.

Catch-up with institutional challenges

Low-income countries failed to catch up with advanced economies in GDP per capita over the past half century, which is closely linked to institutional barriers. These barriers not only impede domestic growth drivers such as investment in human capital, infrastructure and innovation, but also slow the pace of catch-up with the productivity frontier by limiting integration into the global economy and hindering the adoption and imitation of new technologies.

Catch-up amid globalization and fragmentation

Since WWII, globalization has significantly shaped the global economy, fostering economic convergence through international trade, foreign direct investment, and global value chains. Globalization has entered a new phase in the last several decades due to advances in information technology, which enable the movement of ideas and services across borders at unprecedented speeds and scales (Baldwin 2016). Some developing countries started to catch up with developed countries as they integrated into global value chains. Information technology allows firms in low-cost regions to connect with global markets, contributing to income convergence. However, rapid globalization has been significantly reversed since the US-China trade war and technological decoupling in 2018, followed by the Covid-19 pandemic, Russia's invasion of Ukraine, the Middle East conflicts, and global policies from Trump's second presidential term.

3 Projection studies

This section reviews the studies of long-term projections of GDP per capita conducted in the last decade. We collect the studies from various sources including international organisations, government agencies, academia, research institutes, and private sectors. We primarily focus on global studies but also include some country studies for major economies. Each projection covers at least 10 years and goes beyond 2030. Table 1 presents global studies, each of which covers major or all economies of the world in their projections. The columns, from left to right, represent study number, reference, representative institutions, year of publication, projection end year, geographic coverage, modelling approach and conversion factor. The start year of each projection is typically the most recent year with historical data prior to the publication year, and is omitted from the table. The country column (Coun.) indicates the number of countries or regions in each study. Some studies cover the global economy which is disaggregated into multiple countries and regions. The approach column indicates the type of methodology, including neoclassical growth models, computable general equilibrium (CGE) models, overlapping generation (OLG) models, macro-econometric models (Macro-econ), and econometric models. The conversion column (Conv.) shows the conversion factor used to standardize GDP into a common unit for cross-country comparison, using either market exchange rates (MER) or purchasing power parity rates (PPP). The table is organised by approach and further sorted in ascending order by year.

Table 1: Long-term economic projections of the global economy

No.	Study	Institution	Year	Period	Coun.	Approach	Conv.
G1	Au-Yeung et al.	Australian Treasury	2013	2050	155	Neoclassical	PPP
G2	PwC	PwC	2017	2050	32	Neoclassical	PPP
G3	Cuaresma	IIASA	2017	2100	144	Neoclassical	PPP
G4	Dellink et al.	OECD-EG	2017	2100	184	Neoclassical	PPP
G5	Leimbach et al.	PIK	2017	2100	32	Neoclassical	PPP
G6	Alestra et al.	Bank of France	2020	2100	28	Neoclassical	PPP
G7	JCER	JCER	2020	2060	65	Neoclassical	MER
G8	Fontagné et al.	CEPII	2022	2050	170	Neoclassical	MER
G9	Goldman Sachs	Goldman Sachs	2022	2075	104	Neoclassical	MER
G10	Pennings and Loayza	World Bank	2022	-	-	Neoclassical	PPP
G11	Lee and Song	Korea University	2023	2070	6	Neoclassical	PPP
G12	Guillemette & Chateau	OECD-LG	2023	2060	48	Neoclassical	PPP
G13	Conference Board	Conference Board	2024	2039	77	Neoclassical	MER
G14	Lunsford and West	US Fed and UW	2021	2070	23	Econometric	PPP
G15	Müller et al.	Princeton & Harvard	2022	2100	113	Econometric	PPP
G16	Benzell et al.	Boston University	2023	2050	17	OLG	PPP
G17	Chateau et al.	OECD-EL	2023	2050	18	CGE	PPP
G18	Chen et al.	MIT	2022	2050	18	CGE	PPP
G19	Oxford Economics	Oxford Economics	2024	2050	203	Macro-econ	PPP
G20	US EIA	US EIA	2023	2050	16	Macro-econ	PPP
G21	USDA	USDA	2024	2034	40	Macro-econ	MER
G22	IEA	IEA	2024	2050	10	Macro-econ	PPP

Notes: The institutions of the three OECD studies are distinguished by their respective model names: Energy-Growth model (EG), Long-term Growth model (LG), and ENV-Linkages model (EL). Pennings and Loayza (2022) provide a growth model but the model is applied to individual countries in separate studies.

The above global studies include major economies. There are also some projection studies for individual economies. Tables 2 present studies on the United States, with several sourced from US government agencies. Table 3 presents studies on China, sourced from research institutions and universities.

Table 2: Long-term economic projections of the United States

No.	Study	Institution	Year	Period	Approach
USA1	Müller and Watson	Princeton University	2016	2015-2090	Econometric
USA2	US CBO	US CBO	2023	2024-2054	Unavailable
USA3	US EIA	US EIA	2023	2024-2050	Macro-econometric
USA4	US OMB	US OMB	2023	2023-2033	Unavailable
USA5	S&P Global Insights	S&P	2023	2023-2053	Unavailable
USA6	US SSA	US SSA	2024	2024-2098	Macro-econometric

Table 3: Long-term economic projections of China

No.	Study	Institution	Year	Period	Approach
CHN1	Barro	Harvard University	2016	2015-2035	Neoclassical
CHN2	Higgins	US FRB	2020	2018-2038	Neoclassical
CHN3	Wang	Peking University	2020	2015-2050	Neoclassical
CHN4	Sasaki et al.	Bank of Japan	2021	2020-2035	Neoclassical
CHN5	Peschel and Liu	ADB	2022	2020-2040	Neoclassical

Next, we are going to discuss the above studies in technical details, organised into two groups in terms of methodology: neoclassical and alternative approaches.

3.1 Neoclassical approach

The most common approach to long-term projections is based on standard neoclassical models with an aggregate production function. A standard production function with constant returns to scale is specified as

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

where Y is output, K is physical capital, L is labour, A is TFP, α is the output elasticity of capital, and t is the time subscript, with the country subscript omitted for simplicity. TFP measures the efficiency with which inputs combine to produce output, and can be interpreted as technological progress.[2] The above production function can be augmented by incorporating human capital as

[2]Technology can be introduced into the production function in different ways. It is (1) Hicks-neutral if it improves the productivity of labour and capital proportionally, such as $Y = AF(A, L)$; (2) Harrod-neutral if it is labour augmenting, such as $Y = F(K, AL)$; and (3) Solow-neutral if it is capital augmenting, such as $Y = F(AK, L)$. In the standard Cobb-Douglas specification, these specifications are equivalent.

follows:

$$Y_t = A_t K_t^{\alpha} (H_t L_t)^{1-\alpha} \tag{2}$$

where H is human capital. Therefore, GDP per capita can be derived as follows:

$$y_t = \frac{Y_t}{P_t} = A_t (k_t)^{\alpha} H_t^{1-\alpha} \frac{L_t}{P_t} \tag{3}$$

where $k_t = K_t/L_t$ represents capital intensity. The projection of GDP per capita depends on the projections of labour, physical capital, human capital and TFP. The last term L_t/P_t depends on the age structure, labour participation rates, and unemployment rates. Unemployment rates are difficult to project in the long term and are often not given much consideration.

Labour assumptions

Population projections are typically sourced from the United Nations World Population Prospects. The working-age population is commonly used as a proxy for the potential labour force. Some studies also consider participation and employment rates. Goldman Sachs (2022) assume that the employment rate increases linearly with the working-age population ratio, based on the expectation that people extend their labour force participation as life expectancy and health outcomes improve. Fontagné et al. (2022) applies the participation rates by gender and age group estimated by the International Labour Organization. Guillemette and Chateau (2023) project employment rates using a cohort approach that accounts for generational trends, such as rising female employment rates, but also structural changes such as higher educational attainment. Potential employment changes stem from cohort employment propensities and demographic shifts.

Human capital is often measured based on educational attainment of the working age population, typically represented by average schooling years. Its growth is projected by extrapolating historical trends and assuming convergence to either a frontier economy or a world average. These projections are then translated into human capital based on estimated returns to education. For example, PwC (2017) projects that schooling years rise over time in each country at rates derived by extrapolating forward from trends over the past two decades, and then estimates human capital based on schooling years and assumed returns to schooling.

Deriving labour force growth rates from working-age populations implicitly assumes uniform productivity across age groups, but individual productivity typically follows a hump-shaped pattern. Benzell et al. (2023) allow age-specific productivity in an overlapping generation model, which better captures the growth of the aggregate effective labour force in the context of population ageing.

Capital assumptions

Physical capital accumulates through investment but gradually depreciates over time. Neoclassical models suggest that investment converges to the steady-state level. Some studies assume some form of convergence in the investment-output ratio over time, while others project investment based on savings which are modelled as a function of population age structure and other economic variables.

Au-Yeung et al. (2013) does not directly address investment but estimates the convergence rate for GDP per worker using historical data. PwC (2017) assumes that the initial investment-to-GDP ratios gradually converge toward the average long-term investment-to-GDP ratio across countries. This assumption reflects the view that the very low investment-to-GDP ratios in African countries will continue to increase, while the very high investment-to-GDP ratios in Asian emerging economies will tend to decline with declining marginal returns on investment over time. Alestra et al. (2022) assumes that the long-term capital-to-GDP ratio remains constant, and investment depends negatively on the relative investment price which in turn depends on technological progress. Guillemette and Chateau (2023) distinguishes between public and private investment, assuming that the public-investment-GDP ratio gradually returns to its 2015-2025 average and the private-investment-GDP ratio is modelled as a function of the long-term real interest rate and trend growth rates of labour efficiency and employment. The assumptions ensure that the long-term capital-to-

GDP ratio is stable. Goldman Sachs (2022) assumes that investment depends on recent investment and the current population dependency ratio, allowing for systematic differences across countries and time. Fontagné et al. (2022) project investment as a function of domestic savings, where savings depends on the population age structure and the gap of GDP per capita with respect to the frontier economy. Lee and Song (2023) also project investment based on domestic savings which depends on lagged GDP per capita and population age structure. Conference Board (2024) also projects investment as a function of domestic savings and a set of other variables.

Productivity assumptions

There are different definitions of productivity in the literature. Labour productivity is typically defined as output (GDP) per worker or per capita. Total factor productivity (TFP), as mentioned above, measures the efficiency with which all inputs are used in production, and is typically calculated as a residual after accounting for capital and labour contributions. Labour-augmenting productivity measures the efficiency of labour, often driven by advancements in skills, education, and technology that directly make labour more productive. The distinction of Hicks, Harrod and Solow types of technologies (see footnote 2) indicates that labour-augmenting productivity is equivalent to TFP in Cobb-Douglas production functions, but differ in more general production setups such as in the G-Cubed model.

In whatever definition, productivity growth is often linked to technological progress or technical change. Technological progress is the fundamental source of labour productivity growth and it is exogenous in neoclassical growth models. The studies collected here assume some form of convergence in technological progress across countries. Generally, technological progress is driven by two processes: the speed of technological progress in innovating economies and the speed of technology diffusion and adoption in those economies that are lagging behind. Convergence models assume that the growth rate of technology in lagging economies with a large technology gap can exceed the rate of innovation at the frontier, subject to the ability of lagging economies to adopt the available technology. That is, the growth rate of technology is determined by the long-term growth rate of technology at the frontier (typically the United States) and a convergence variable based on the technology gap.

Au-Yeung et al. (2013) assumes that countries converge at different rates toward their respective steady states (conditional convergence). The study assumes that US labour productivity grows at 1.7%, and identifies 66 countries in their steady state, as their productivity levels relative to the United States remained roughly constant over the past two decades. These countries are assumed to grow at the same rate as the United States. For other 89 countries, steady-state productivity levels relative to the United States are determined by their relative levels of a global competitiveness index. PwC (2017) assumes that US TFP grows at 1.5%. The convergence model starts with heterogeneous catch-up rates across countries. The catch-up rates converge towards 1.5 percent in the long run. Goldman Sachs (2022) assumes that the growth rate of TFP is determined by three factors: TFP growth in the frontier economy; a convergence variable based on respective gaps in GDP per capita relative to the frontier (absolute convergence); GDP per capita growth relative to the frontier over the last decade (momentum contribution). The last component allows countries to be rewarded or penalized based on their recent productivity performance. The process of convergence is therefore modelled as a combination of potentials and conditions. Convergence rates are heterogeneous across countries and across time. Alestra et al. (2022) models TFP as a function of energy prices, investment prices, schooling years and employment rates. Energy prices are included to account for the effects of climate change and climate policy on economic growth. Conference Board (2024) estimates TFP as a function of a set of variables based on historical data, and then projects future TFP based on the projections of those variables including schooling yeas, life expectancy, corruption, R&D, etc. Lee and Song (2023) assume that technological progress is endogenously determined by the quantity and quality of labour and the stock of technology, in the spirit of endogenous economic growth models. JCER (2020) distinguishes between tangible and intangible capital, and further assumes that TFP growth is driven by intangible capital, openness of digital services, and political stability. The study highlights that developing countries have greater potential for productivity catch-up by adopting technologies from advanced economies.

Extension with energy input

An aggregate approach to economic projections has limitations, particularly when energy and emissions are of concern. The above standard production function can be augmented to explicitly account for energy as a production factor:

$$Y_t = \left[\left(A_t K_t^{\alpha} L_t^{1-\alpha} \right)^{\rho} + (B_t E_t)^{\rho} \right]^{1/\rho} \tag{4}$$

where E is an energy input, B is energy productivity, $1/(1-\rho)$ is the elasticity of substitution between the capital-labour composite and the energy input. Energy consumption projections are based on energy prices. Firm maximizing profit implies

$$Y_t = \left[1 - \left(\frac{p_t}{B_t} \right)^{\rho/(\rho-1)} \right]^{-1/\rho} A_t K_t^{\alpha} L_t^{1-\alpha} \tag{5}$$

where p_t is the real price of energy.

Several studies follow this approach. Fontagné et al. (2022) take oil prices as exogenously given, sourced from the US EIA projection. The model includes two TFP terms: one for capital and labour, and the other for energy. The growth of capital-labour TFP is determined by a convergence model where human capital drives growth directly, through an innovation effect, and indirectly, through an imitation or technology transfer effect. The growth of energy TFP is determined by a dual channel convergence model where distance from the energy productivity frontier affects the growth rate positively and distance from the development frontier affects the growth rate negatively. The empirical evidence supports a U-shaped relationship between economic development and energy productivity. Guillemette and Chateau (2023) also incorporates energy as an additional production factor. They project labour efficiency growth as the sum of an absolute convergence component and a momentum component. The absolute convergence component depends on the remaining distance to US labour efficiency. The initial momentum component is calculated as a residual given the estimated trend labour efficiency growth and that projected by absolute convergence. This momentum component is then assumed to gradually taper off, eventually leaving absolute convergence the sole driver of trend labour growth. In the long run, trend labour efficiency growth in all countries converges to an assumed exogenous rate of global technological progress (1% per annum) at a convergence rate of 2.4%. Pennings and Loayza (2022) extends the standard production function by incorporating natural resources, beyond just energy, suited for modelling long-term growth in resource-rich countries. Commodity shocks, whether through price fluctuations or changes in resource quantities, influence long-term economic growth by directly affecting income and indirectly changing investment. Since a large share of resource income typically accrues to the government, the extent to which price booms drive investment depends on the fiscal rule.

Extension with disaggregated capital

The standard production function includes an aggregate stock of physical capital. Two studies break physical capital into different categories. Devadas and Pennings (2018) distinguish capital into private and public capital to highlight the role of public capital, and extend the above standard model as follows.

$$Y_t = A_t \left(\frac{\theta_t K_t^G}{\left(K_t^P\right)^{\tau}} \right)^{\phi} \left(K_t^P\right)^{\alpha} L_t^{1-\alpha} \tag{6}$$

where K^P and K^G represent private and public capital respectively. θ measures the efficiency or quality of public capital, ϕ measures the elasticity of output to efficient public capital, and τ

captures whether public capital is subject to congestion effects.

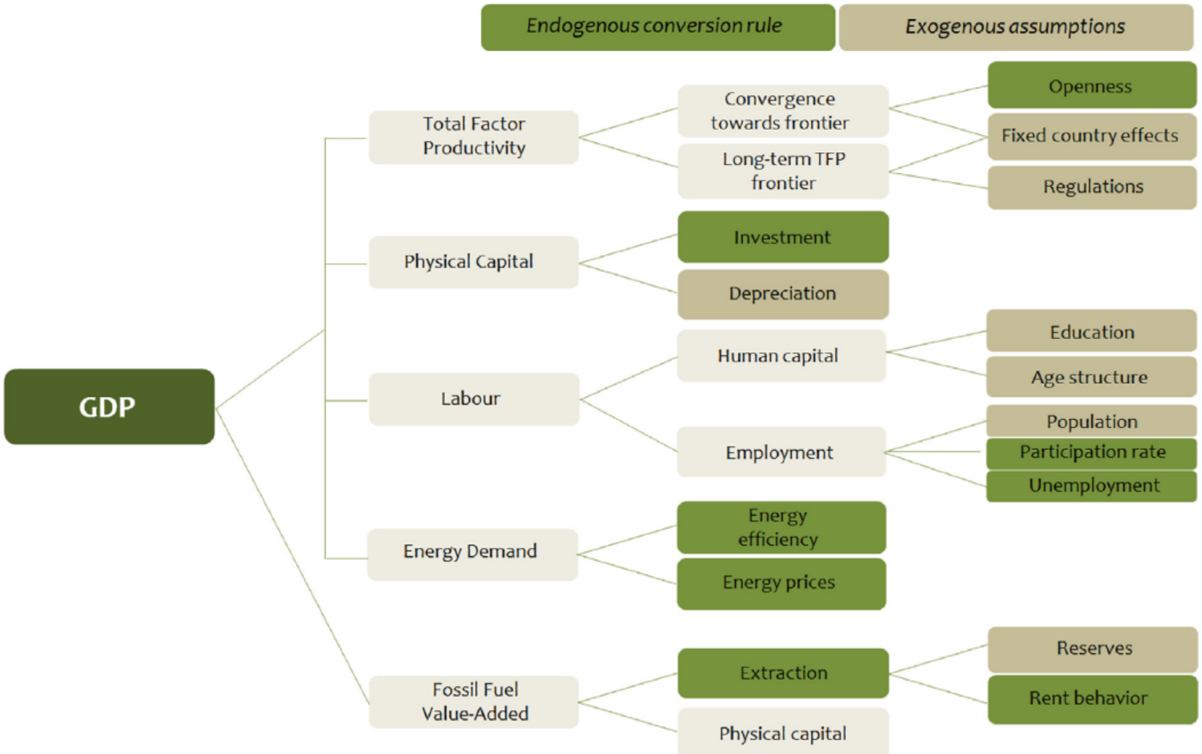
On the other hand, JCER (2020) emphasize the growing importance of intangible assets as a key driver of future economic growth in an increasingly digitalized world. The study separates (private) capital into tangible and intangible capital as follows.

$$Y_t = A_t K_t^{\alpha} D_t^{\beta} L_t^{1-\alpha-\beta} \tag{7}$$

where K and D represents tangible and non-tangible (digital) capital respectively. Future tangible capital investment is assumed to decrease as the share of manufacturing value-added declines and the share of old populations grows, while intangible capital investment is assumed to increase with higher income levels.

The neoclassical approach to long-term economic projections can be visually summarised in the following diagram drawn from Dellink et al. (2017). Although the studies differ from each other, the diagram captures common elements (plus an extension of energy). Additional extensions, including different types of capital, enhance the realism of economic models but also increase their complexity. This reflects the trade-off between the simplicity of modelling approaches and the complexity of the economic reality, which will be further discussed later.

Figure 1: Economic growth projection in the neoclassical approach



Conversion factors

Cross-country economic projections require GDP (or GDP per capita) to be converted into a common unit. Market exchange rates (MER) and purchasing power parity rates (PPP) are commonly used to facilitate cross-country comparison. GDP at PPP is a better indicator of living standards and output volumes, as PPP adjustments eliminate price differences between countries. Price levels tend to be lower in less developed economies, reflecting differences in economic development. Thus, in general, developing economies tend to be much larger using PPP than MER.

Most studies convert GDP per capita using PPP, while several use MER. MER-based projections typically assume that market exchange rates will appreciate over time in developing economies, gradually converging toward PPP rates. This assumption is based on the Balassa–Samuelson effect

(Balassa 1964; Samuelson 1964), which suggests that as emerging economies develop, their prices will increase towards the levels in advanced countries due to some combination of nominal exchange rate appreciation and/or higher price inflation. As prices increase, real currency appreciation occurs in the long run, resulting in the convergence of GDP at PPP and MER. More specifically, JCER (2020) adjusts market exchange rates over time based on an empirical estimate that a 10% increase in relative per capita GDP leads to a 3.5% real appreciation of the exchange rate. Similarly, Goldman Sachs (2022) models real exchange rate appreciation as a function of relative per capita GDP, but also assumes that the pace of adjustment depends on the gap between MER and PPP. Fontagné et al. (2022) assume that real exchange rate appreciation is driven by aggregate TFP and energy productivity catch-up. Conference Board (2024) borrows real exchange rate projections from the IMF World Economic Outlook and the OECD Economic Outlook.

3.2 Alternative approaches

In addition to the standard neoclassical approach, there are other approaches that are used for long-term economic projections or analyses.

Overlapping generation models

Benzell et al. (2023) build an overlapping generation general equilibrium model to project economic growth, with a particular focus on the role of future demographic change. The model assumes an aggregate production function consisting capital, labour and energy, which is similar to the neoclassical model with energy. On the demand side, households make intertemporal consumption decisions based on lifetime wealth, and investment is endogenously determined by the capital market. The study considers three scenarios of catch-up rates for labour productivity: two scenarios based on regression models (Müller et al. 2022) and one scenario calculated based on recent data from 1997-2017. The catch-up rates differ significantly across scenarios, and hence output growth rates also differ.

Multi-sector general equilibrium models

The neoclassical growth approach allows for linkages between country growth through the catch-up channel with the global frontier, but it does not allow for performance in non-frontier countries to affect performance in other countries. The linkages between countries are captured in open-economy general equilibrium models through international trade and/or international capital flows. Also, an aggregate approach in neoclassical models (even with energy) does not allow interactions between sectors and thus economic structural change.

There are numerous dynamic computable general equilibrium (CGE) models that generate economic projections in their baseline scenarios although the nature and purpose of these projections differ from standard economic projections. These models are typically recursively dynamic in the sense that they solve equilibrium in each period sequentially and link these periods through state variables, enabling dynamic analysis over time. Sectors within each economy are connected through input-output linkages. For example, Chateau et al. (2023) use the OECD ENV-Linkages model, a recursively dynamic CGE model, to evaluate the effects of European climate policies, where GDP projections in the baseline are calibrated to those of Guillemette and Chateau (2023) mentioned above. Chen et al. 2022 develops a recursively dynamic CGE model (EPPA) and also calibrates their baseline GDP projections to those of Guillemette and Chateau (2023).

The G-Cubed model falls into this category, but differs from typical CGE models in that the model is intertemporally dynamic and solves all periods simultaneously, which is a key feature of dynamic general equilibrium (DGE) models. The model will be discussed separately in the next section.

Integrated assessment models

Integrated assessment models (IAM), a dominant framework for analysing energy and climate issues, contain long-term economic growth. However, their economic projections are often exogenously aligned with external projections. For instance, the International Institute for Applied Systems Analysis (Riahi et al. 2017) provides a database for GDP (and GDP per capita) up to 2100 in various social-economic and environmental scenarios based on a set of IAM models. However, those projections are calibrated to those from several neoclassical models developed by the Organization for Economic Cooperation and Development (OECD) (Dellink et al. (2017)), the International Institute for Applied Systems Analysis (IIASA, Cuaresma (2017)) and the Potsdam Institute for Climate Impact Research (PIK, Leimbach et al. (2017)). The three studies project GDP (and GDP per capita) based on harmonized assumptions for the interpretation of various social-economic storylines in terms of the main drivers of economic growth. The scenarios typically pair social-economic scenarios, represented by Shared Socioeconomic Pathways (SSP) with environmental scenarios, represented by Representative Concentration Pathways (RCP).

The above three studies are based on neoclassical models but differ in some assumptions. Leimbach et al. (2017) follows the above standard production function, and Cuaresma (2017) introduce labour heterogeneity by differentiating labour by education levels and age group (younger and older workers), while Dellink et al. (2017) incorporate energy as an additional input. They all use the working-age population for the potential labour force, and then account for participation rates and human capital based on education. In terms of productivity, Leimbach et al. (2017) assume that TFP growth depends on three factors: the distance to the technology frontier, the stock of human capital (technological innovation), and the interaction between income per capita and the ratio of population with education to total population (technological adoption). Cuaresma (2017) models TFP as function of four components: TFP growth for the technological leader, short-term dynamics based on empirically derived initial TFP growth rate, convergence rate for catching-up with the technological leader in the long run, and transition time between historically dominated TFP growth and convergence-based long-term TFP growth. The study assumes a medium long-term

TFP growth rate for the technological frontier of 0.7% per year (SSP1, SSP2, and SSP4). Dellink et al. (2017) models TFP growth as a combination of two elements: countries gradually converge towards their long-term TFP frontier; the long-term TFP frontier shifts over time. As the long term TFP frontier is country-specific, all countries will grow through both channels. More technologically advanced countries are closer to their frontier and, ceteris paribus, grow less rapidly than countries which are less technologically advanced. The speed of convergence towards the frontier is influenced by fixed country effects reflecting a wide variety of country-specific factors, and an international trade openness.

Macro-econometric models

Macro-econometric models contain behavioural equations that characterize the relationships among variables, but their behavioural equations are based on observed economic patterns rather than microeconomic foundations. More specifically, behavioural equations capture historical empirical regularities, such as the consumption function relating consumption to income, without explicitly deriving them from individual optimization behaviour based on microeconomic theory.

Oxford Economics (2025) provides macroeconomic projections up to 2050 based on a macro-econometric model (Global Economic Model), where macroeconomic behavioural equations are estimated from historical data without a microeconomic foundation. The projection of USDA (2024) is based on S&P Global Insights and Oxford Economics. Similarly, the projection of US EIA (2023) also relies on Oxford Economics. The projection of IEA (2024) is consistent with the assessments from the IMF and Oxford Economics in the short to medium term. Over the long term, the growth in each region is assumed to converge to an annual long-term rate which depends on demographic and productivity trends, macroeconomic conditions, and the pace of technological change. Further technical details for these studies are not publicly available.

Econometric models

Time-series econometric models are typically used for short-term projections. However, several studies extend time-series models to make long-term projections using long-term historical data. Müller and Watson (2016) develop a statistical method for long-term forecasts of time-series variables using 1945-2014 quarterly data and 1901-2014 annual data respectively, and project average growth rates for US GDP per capita and other variables up to 75 years. Müller et al. (2022) estimate catch-up rates of GDP per capita in both uni-variate and multivariate auto-regressive models based on data of 113 countries from 1900-2017 and then project country-specific GDP per capita up to 2100. Lunsford and West (2021) evaluate out-of-sample forecasts for up to 50 years for key macroeconomic variables including GDP per capita growth. These studies underscore the challenges of achieving accurate long-term macroeconomic forecasts and suggest the need for a diversified approach when making long-term projections. The challenges arise from potential shifts in underlying trends, structural breaks, or changes in external factors over extended periods.

4 Projection in G-Cubed

This section presents the G-Cubed model that is used to project long-term growth of the global economy. We first introduce the methodology and then present key data input, including population age structure, age-specific labour productivity, and sectoral TFP. The design of projection scenarios is discussed in the end.

4.1 Method

Liu and McKibbin (2022) develop a variant of the G-Cubed model of McKibbin and Wilcoxen (1999, 2013) containing eighteen countries and regions (hereafter referred to as countries or regions interchangeably). Table 4 lists all regions, including six advanced economies, eight developing regions in Asia, and four developing regions outside of Asia. Among the residual regions, the

Rest of Advanced Economies includes Canada and New Zealand; the Rest of Asia comprises South Asia (excluding India), Hong Kong, Taiwan, Singapore, Mongolia, and other Asian countries not classified elsewhere; and the Rest of the World primarily represents Eastern Europe (including Russia and Turkey) and Central Asia.

Table 4: G-Cubed countries and regions

Groups	Codes	Regions
Advanced Economies	USA	United States
	JPN	Japan
	EUW	Western Europe
	AUS	Australia
	KOR	Korea
	ADV	Rest of Advanced Economies
Developing Asia	CHN	China
	IDN	Indonesia
	THA	Thailand
	MYS	Malaysia
	IND	India
	PHL	Philippines
	VNM	Vietnam
	ROA	Rest of Asia
Other Developing Regions	LAM	Latin America
	AFR	Sub-Saharan Africa
	MEN	Middle East and North Africa
	ROW	Rest of the World

Each economy is further disaggregated into six sectors, as outlined below. These sectors are interconnected through input-output linkages, with data sourced from the GTAP 10 database (Aguiar et al. 2016). The 65 sectors in the GTAP database are aggregated into the six sectors of the G-Cubed model.

Table 5: G-Cubed sectors

Groups	Number	Sector
Primary sectors	1	Energy
	2	Mining
	3	Agriculture
Manufacturing sectors	4	Durable Manufacturing
	5	Non-Durable Manufacturing
Services sector	6	Services

We highlight some important characteristics of the model that describe short-term dynamics and long-term equilibrium in the model. Households are heterogeneous, with one group making decisions using forward-looking expectations and the other following simple rules of thumb. They are subject to an intertemporal budget constraint. Firms are heterogeneous, with one group making decisions using forward-looking expectations and the other following simple rules of thumb. Firms are modelled separately within each sector. They are subject to an intertemporal budget constraint. The labour market features sticky nominal wages that adjust through time. The mechanisms for adjustment are specific to each country, given different labour contracting laws and regulations. The labour market clears with firms hiring until the marginal product of labour equals the real wage in each sector, with excess labour joining unemployed workers. In turn, nominal wages adjust to clear the labour market in the long run. Short-run unemployment rises or falls in response to aggregate demand and structural supply shocks. Government budget deficits accumulate into government debt. An intertemporal budget constraint applies to governments, which means that long-term equilibrium in stock variables occurs slowly over time through changes in asset prices. That is, interest rates adjust to equilibrate government fiscal positions. In the model used for this paper, government spending is exogenous, and government deficit is endogenous. The fiscal rule imposing fiscal sustainability is a lump sum tax on households that equals the change in the interest servicing costs. This implies that fiscal deficits can permanently change but the stock of debt to GDP will eventually stabilize at a new higher or lower level. Central banks set short-term nominal interest rates to target their macroeconomic mandates, such as inflation, unemployment or the exchange rate. Long-run inflation rates are anchored while allowing for short-term fluctuations through monetary rules, such as the Henderson-McKibbin-Taylor monetary rule (Henderson and McKibbin 1993; Taylor 1993). Countries are linked through international trade and capital flows. An intertemporal budget constraint also applies to countries, so current account deficits accumulate into foreign debt. Real exchange rates adjust to equilibrate the balance of payments.

The model is solved from 2018, with forward-looking variables adjusted so that the model solution for 2018 replicates the data for 2018. To generate a baseline for the future, key inputs include exogenous projections of age-specific population growth and sectoral labour-augmenting productivity growth. The dynamics of endogenous variables are driven by the growth of labour force and productivity.

4.2 Population

Population data are sourced from the United Nations World Population Prospects 2024 (the medium variant). The database includes annual population projections by age, extending to 2100, for 237 countries, which are then aggregated into the G-Cubed regions. Table 6 presents the population share for each region out of the global population from 2020 to 2050. Advanced economies are experiencing steady declines in the shares of the global population. Among developing regions, China's population share is shrinking substantially, while India maintains a stable population share. Southeast Asia and Latin America exhibit mixed trends, with some countries experiencing slight declines while others remain stable. Africa stands out as the key driver of global population growth, with its share rising significantly.

Table 6: Population share by region (%)

Region	2020	2030	2040	2050
USA	4.30	4.15	4.03	3.94
JPN	1.60	1.40	1.22	1.09
EUW	5.55	5.17	4.80	4.49
AUS	0.33	0.33	0.33	0.34
KOR	0.66	0.60	0.53	0.47
ADV	0.55	0.55	0.54	0.53
CHN	18.08	16.32	14.63	13.04
IDN	17.78	17.80	17.68	17.38
THA	3.48	3.45	3.40	3.32
MYS	1.42	1.42	1.41	1.39
IND	1.24	1.22	1.18	1.14
PHL	0.91	0.83	0.76	0.69
VNM	0.43	0.44	0.45	0.46
ROA	8.10	8.42	8.78	9.10
LAM	8.19	8.02	7.81	7.55
AFR	14.84	17.36	19.94	22.54
MEN	6.09	6.58	6.92	7.23
ROW	6.43	5.96	5.59	5.32

Table 7 presents the age structure of each region from 2020 to 2050. The age structure is represented by the share of youth (below 15 years old), the share of the working-age population (15-64 years old), and the share of the elderly (above 65 years old). The global age structure is shifting dramatically, with advanced economies ageing rapidly. Among developing regions, China and Southeast Asia are also experiencing significant ageing. In contrast, South Asia and Africa continue to sustain a relatively young workforce, positioning them as key drivers of global labour force growth in the coming decades.

Table 7: Age Structure by Region (%)

	2020			2030			2040			2050		
Region	Y	W	E	Y	W	E	Y	W	E	Y	W	E
USA	18.39	65.54	16.07	16.26	63.37	20.37	15.94	62.03	22.04	15.91	60.98	23.11
JPN	12.22	58.86	28.92	10.39	58.47	31.14	10.42	54.23	35.35	11.25	51.27	37.48
EUW	15.42	64.02	20.56	13.73	61.83	24.44	13.07	58.79	28.14	13.54	56.63	29.83
AUS	18.56	65.10	16.34	16.88	63.29	19.82	15.86	61.84	22.30	15.71	60.44	23.85
KOR	12.11	72.06	15.82	8.43	66.50	25.06	7.73	58.44	33.83	7.83	52.49	39.68
ADV	16.24	66.05	17.71	14.65	63.15	22.20	13.87	61.91	24.22	13.66	60.86	25.48
CHN	17.95	69.40	12.65	12.14	69.52	18.34	9.38	64.01	26.62	9.94	59.14	30.92
IDN	26.35	67.24	6.42	22.39	69.06	8.56	19.93	68.87	11.19	17.79	67.53	14.68
THA	25.83	67.56	6.61	22.43	68.61	8.97	20.49	67.39	12.12	19.18	65.68	15.14
MYS	30.68	64.59	4.73	23.83	69.33	6.84	21.17	70.03	8.80	19.62	69.22	11.15
IND	24.39	68.04	7.57	19.95	68.26	11.79	17.58	66.67	15.75	16.96	63.04	20.01
PHL	16.17	70.93	12.90	12.88	67.71	19.41	11.81	62.62	25.57	11.51	58.92	29.57
VNM	23.96	69.31	6.72	18.98	71.49	9.53	17.03	70.57	12.40	16.16	67.02	16.82
ROA	31.50	62.54	5.95	28.77	63.75	7.48	26.26	64.78	8.95	24.06	65.11	10.83
LAM	23.90	67.27	8.83	20.38	67.76	11.86	18.11	66.69	15.19	16.59	64.52	18.89
AFR	41.97	54.94	3.08	38.70	57.85	3.44	35.38	60.61	4.01	32.08	63.01	4.92
MEN	30.47	64.38	5.15	26.56	66.68	6.76	24.01	67.03	8.97	22.45	65.60	11.94
ROW	20.42	66.28	13.30	18.40	65.22	16.39	16.78	64.72	18.50	17.30	61.33	21.37

Notes: Y, W and E denote the youth, the working age population, and the elderly respectively.

4.3 Age-income profile

Individuals in each region are assumed to exhibit an identical hump-shaped age-productivity profile. The National Transfer Account (NTA) database provides age-specific labour income data for about 70 countries, including 15 in Asia, for various years spanning from 2002 to 2019. We assume that age-income profiles remain unchanged in the future. To map age-income profiles from NTA regions to G-Cubed regions, we use data from the largest economy with available data in each region as a representative for the region. This approach is supported by the strong similarity of age-income profiles among several large economies within each region. Further details can be found in Fry-McKibbin et al. (2025).

4.4 Sectoral productivity

For labour-augmenting productivity, we use a catch-up model in which sectoral productivity in each region converges toward the corresponding sector in the frontier region. The process is driven by three components: productivity growth in the frontier region, initial productivity levels across sectors and regions, and catch-up rates. We take the United States as the frontier region unless otherwise specified and assume that all sectors in the United States grow at a constant rate of 1.4% every year in the future (US CBO 2023).

The initial productivity levels by sector are calculated based on the 2023 Groningen productivity database, which provides sectoral labour productivity data for 12 sectors across 84 countries in 2017, measured in local currency. Sectoral productivity is measured by value added per worker in each sector. We map those countries and sectors to the G-Cubed model. The database also provides market exchange rates and sector-level purchasing power parity for cross-country comparison. We use market exchange rates to convert local currency to US dollars for more tradable sectors (mining, agriculture, manufacturing) and use purchasing power parity for less tradable sectors (utilities and services).

We normalize the initial productivity levels in all sectors in the United States to 100. This assumes that the US economic structure is stable on a balanced growth path and the productivity differences across sectors will remain unchanged into the future. We then calculate relative productivity levels by sector for all other regions. Table 8 presents the relative levels of productivity by sector by country. The United States is the frontier in all sectors, except for Australia, which outperforms in mining and agriculture. Developing Asia is far behind the frontier in the manufacturing sector and even more so in agriculture. In contrast, their productivity gaps in less tradable sectors (energy utilities and services) are much smaller. Other developing regions have similar productivity gaps to developing Asia in manufacturing and agriculture. They have, on average, relatively higher productivity in the mining sector because mining productivity is highly dependent on the abundance of mineral resources, and those regions are more resource-rich than developing Asia. The initial productivity gaps between the United States and other regions drive productivity catch-up of other regions, which implies that regions behind the United States would grow faster than the United States.

Table 8: Sectoral productivity levels in 2017

Regions	Energy	Mining	Agriculture	Manufacturing	Services
USA	100.00	100.00	100.00	100.00	100.00
JPN	48.22	14.47	26.44	59.03	74.72
EUW	25.69	89.57	50.17	56.82	97.21
AUS	31.64	123.87	126.19	52.59	82.38
KOR	84.96	21.88	27.21	55.71	97.12
ADV	85.04	87.15	93.48	55.88	84.27
CHN	54.06	10.76	5.45	12.85	60.29
IDN	25.39	13.35	4.22	6.88	78.06
THA	55.94	42.00	3.88	11.76	66.88
MYS	94.84	70.03	20.18	16.23	92.32
IND	47.19	5.26	2.52	3.97	41.49
PHL	25.29	3.11	3.53	10.07	22.02
VNM	30.54	18.89	1.90	2.14	43.32
ROA	37.86	8.99	2.39	8.12	47.03
LAM	35.33	38.95	10.91	18.11	49.40
AFR	58.82	12.59	1.86	3.39	26.53
MEN	46.28	54.07	5.33	10.23	49.38
ROW	32.77	23.32	7.36	13.30	80.24

4.5 Projection scenarios

Our projections involve three fundamental factors: demographic change, productivity growth, and climate change. There are potentially many scenarios, but we select several representative scenarios that can provide key insights.

Baseline

In our baseline, we incorporate demographic change described above, and assume that US labour productivity increases by 1.4% every year (US CBO 2023). In general, we assume that non-US regions catch up with the United States by sector, so regions behind the United States would generally grow faster than the United States. But we customize this catch-up approach to account for the differences between countries and sectors. We distinguish advanced and developing economies, and also resource and non-resource sectors.

For advanced economies, we assume no productivity catch-up with the United States. Among advanced economies, Japan's productivity in agriculture is 26% of the United States, although Japan highly integrates advanced technology and machinery into agriculture. It's far from the frontier, but there is not much space for further improvement, given the constraint in land size. Therefore, we assume no catch-up in resource sectors between non-US advanced economies and the United States. In addition to Japan, Korea and Europe are also constrained by natural endowments. Australia is abundant in natural resources and already has higher productivity in mining and agricultural sectors than the United States. The rest of the advanced economies, Canada and New Zealand, are also abundant in natural resources, and their productivity levels in resource sectors are close to the United States. With zero catch-up rates, the productivity in each resource sector grows at 1.4% every year in all advanced economies. Advanced economies share similar institutions and governance frameworks and have been closely integrated in the last several decades. Thus, we assume that advanced economies are all in their own steady states and do not catch up with the frontier in non-resource sectors. The productivity gaps can be attributed to fundamental heterogeneities in natural, geographic, cultural, and institutional differences. The productivity levels in services are already close to each other, and the productivity in manufacturing is also relatively high at about 50% in all other advanced economies.

For developing regions, most countries are significantly constrained by land size. Even China, despite its large size, has significantly less arable land than the United States. The productivity in agriculture in all developing Asian countries (except Malaysia) is about 5% or below relative to the

United States. For developing Asia, it is reasonable to assume Japan rather than the United States as the productivity frontier for agriculture. In addition to land, developing Asian countries are not comparable with the United States in terms of the abundance of minerals. Other developing regions in the world are abundant in natural endowments and have relatively high productivity in energy and mining sectors but also low productivity in agriculture. In contrast to resource sectors, non-resource sectors (manufacturing and services) depend more on labour and capital with less constraints of natural endowments. This implies that the productivity of manufacturing and services can potentially reach the frontier level. The current productivity levels in manufacturing are much lower in developing regions than in advanced economies particularly the United States.

We calibrate the catch-up rates in labour productivity among developing regions such that their GDP growth rates in the baseline over the period of 2018-2024 are roughly consistent with their historical growth performance. More specifically, the catch-up rates are set at 2% for China, at 1% in 2025 with an annual incremental of 0.1% up to 2% for India, Indonesia and Vietnam, at 1% for Thailand and Philippines, and zero for Malaysia and the rest of Asia. The catch-up rates in other developing regions are set at zero.

Demographic change

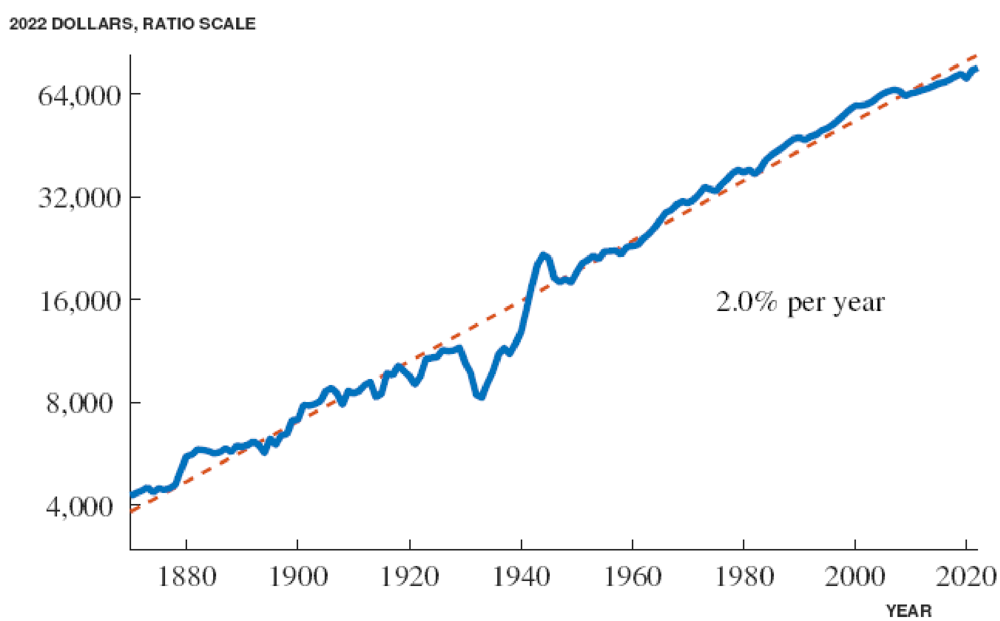
The above baseline includes the impacts of future demographic change. To separate the demographic impacts, we simulate a scenario where demographics remains stationary from 2024 onward, ceteris paribus. That is, population size and age structure do not change from 2024 onward. The differences in the results relative to the baseline capture the impacts of demographic change.

Productivity change

This scenario provides an illustration of rapid productivity growth. Figure 2, drawn from Jones (2023), presents US GDP per capita over the past 150 years, suggesting an average annual growth rate of 2%. An emerging strand of research seeks to estimate the impacts of AI on productivity.

Hornstein (2024) indicates that the development of AI could potentially increase productivity from less than 1% to 20% over the next 10 years, corresponding to annual growth rates of 0.1 to 2.0%. Suppose AI boosts US productivity by 0.1% in 2025, increasing by 0.1 percentage points annually until 2030, and then remains flat at 2.0% until 2050, before declining by 0.1% annually to the baseline. This brings US productivity back to its long-term average productivity growth at 2% over the next two decades or so. All other regions are assumed to benefit from AI-driven productivity growth at the same rates as the United States. However, there will certainly be heterogeneity across regions. The impacts will depend on the diffusion, investment, and regulation of AI technology among regions. Despite heterogeneity, this design provides an upper bound for potential productivity gains in other regions given the frontier productivity gains from AI development.

Figure 2: US GDP per capita over past 150 years



Climate change

Roson and Sartori (2016) estimate six damage functions for chronic climate risks, including sea level rise, agricultural productivity, heat-related labour productivity, disease-related labour productivity, tourism flows, and household energy demand. The damage functions are estimated for these outcome variables as functions of temperature changes relative to the historical average temperature over the period of 1985-2005 for 140 countries and regions included in the GTAP 9 database. We use the damage functions for the first four chronic climate risks to project their impacts on labour productivity and TFP.

The damage function for sea level rise provides the percentage change of the land stock in response to a one-degree increase in temperature by year and country. The percentage loss in land is assumed to cause the same percentage loss in TFP in all sectors. The damage function for labour productivity via heat-related health impacts provides the percentage change in labour productivity in response to a one-degree increase in temperature due to changes in morbidity. The productivity loss due to morbidity is assumed to be temporary shocks, which are not persistent across years. Morbidity can result in temporary losses of labour productivity, but can also decrease labour productivity for long periods of time or even permanently (permanent diseases, injuries and disabilities), but we don't have good data to distinguish different levels of persistence. In addition to climate impacts on labour productivity due to changes in morbidity, we also consider climate impacts on labour productivity due to changes in mortality. Bosello et al. (2006) shows that the years of death are 12% of the years of life diseased. Mortality results in permanent productivity loss. So we assume the impacts of temperature change on labour productivity through mortality are 12% of those through morbidity.

World Bank (2024a) provides historical annual temperatures from 1950 and projected annual temperatures up to 2100 for 246 countries. The data of projected temperatures under different SSP scenarios are sourced from the Coupled Model Intercomparison Project (CMIP) which offers comprehensive climate model outputs used for IPCC assessments. The CMIP is a multi-model ensemble of over 100 climate models from various research groups to account for uncertainties and variability and produce more robust projections. The projected temperature data include four scenarios: SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5, which pair Shared Socioeconomic Pathways (SSPs) with Representative Concentration Pathways (RCPs). We choose SSP2-4.5 to illustrate the climate impacts in our model. SSP2-4.5 represents a scenario in which the world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns; global and national institutions work toward but make slow progress in achieving sustainable development goals; environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines.

We compute population-weighted averages to aggregate temperatures from 246 countries in the World Bank climate database into 140 regions in the GTAP 10 database. Given the projected temperatures for 140 regions, we then compute the damages of temperature changes (relative to the historical averages) by sector for 140 countries from 2018 to 2100 based on the four damage functions above. We further aggregate climate damages from 140 regions to 18 regions in the G-Cubed model. More specifically, we compute weighted percentage changes for land, agricultural productivity, labour productivity, using land value, agricultural output value, labour size as the respective weighting factors, which are sourced from the GTAP 10 database.

Our baseline projection is based on actual data from 2018, which we assume already reflects climate impacts up to that year. To construct a hypothetical no-climate-damage baseline for measuring the impacts of climate change, we need to remove the temperature shocks that have occurred since the 1985-2005 average temperatures. To achieve that, we introduce a counteracting shock that offsets the climate shock in 2024. This adjustment ensures that, when we simulate climate shocks starting in 2025, the new baseline is isolated from historical climate damage. For climate impacts beyond 2024, we calculate net climate shocks relative to the 2024 level. Consequently, the future climate impacts relative to the no-climate-damage baseline include the cumulative effects of climate change from the historical average temperatures up to 2024 plus additional changes from 2025 onward.

To summarise, we consider four scenarios: (S1) Stationary demographics; (S2) Demographic change; (S3) Rapid productivity growth; (S4) Climate change SSP2-4.5. For convenience, S2 is referred to as the baseline which includes the impacts of future demographic change and moderate productivity growth described above. All other scenarios are separately simulated on top of the baseline. The deviations of S1 from S2 capture the impacts of demographic change. The deviations of S3 and S4 from S2 represent the impacts of additional productivity growth driven by AI, and the impacts of the climate change scenario, respectively.

4.6 Projection results

Table 9 presents growth rates of GDP per capita in three years: 2030, 2040, and 2050. The differences between S2 and S1 capture the impacts of demographic change. Population ageing is expected to slow GDP per capita growth in advanced economies over the coming decades. The impacts are projected to be particularly strong in Western Europe, Japan, and Korea; however, the impacts will decline over time as those economies are already highly aged, resulting in slower ageing in the future.

In developing regions, the impacts of population ageing is more heterogeneous. In the medium run, some regions, such as India, Latin America, Africa, and Middle East, are expected to benefit from relatively young populations over the next decade. However, these demographic dividends will fade in the long run as population ageing will take hold in those economies as well. Meanwhile, other developing regions will face adverse impacts even in the medium run. China, in particular, is projected to experience the most significant negative impact of population ageing, with the impact increasing over time due to its rapidly ageing population.

The differences between S3 and S2 reflect the impacts of rapid productivity growth. By design, the development of AI improves TFP equally across all regions and sectors. So all regions would experience higher growth of GDP per capita. The impacts differ between some regions due to different linkages across sectors and regions.

Quantitatively, both population ageing and AI are expected to have significant impacts on the future growth of GDP per capita. The comparison between S3 and S1 reveals the net impact of population ageing and productivity growth. In our scenarios, the positive effects of AI offsets or even exceed the negative effects of population ageing in most regions, except in those experiencing rapid population ageing.

It is important to recognize the considerable uncertainty surrounding the impacts of AI on global economic growth. Factors such as the speed of AI advancements, the distribution of AI applications across sectors, the distribution of AI applications across countries, and the regulation of AI applications all contribute to the unpredictability of its effects. Only a few studies in our survey provide brief qualitative discussions on the potential impact of AI. While many studies explore the impacts of AI on productivity, they do not specifically focus on long-term economic growth. Our AI scenario is intended to serve as an illustrative case.

The differences between S4 and S2 capture the impacts of climate change represented by SSP2-4.5. Compared to the baseline, the impacts of climate change on GDP per capita growth by 2050 are modest for some countries and moderate in others, ranging from 0.01% to 0.17%. This suggests that by mid-century, the impacts of climate change will remain relatively small, compared to those of population ageing and AI. But in the very long term, climate change could become a greater concern in the second half of this century, while the impacts of population ageing and AI may gradually diminish after next several decades.

As a caveat, our estimation of climate impacts focuses on several key impact channels due to data limitations of other channels at the global level. Also, our analysis focuses only on chronic climate risks from gradual temperature changes and does not account for the impacts of extreme weather events due to data limitations. Therefore, our estimates may underestimate the full impacts of climate change.

Table 9: Annual growth of GDP per capita

	S1			S2			S3			S4		
Regions	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
USA	1.64	1.55	1.56	1.34	1.43	1.37	1.94	1.85	1.73	1.31	1.40	1.33
JPN	2.45	1.98	1.96	1.20	0.81	1.46	2.19	1.85	2.30	1.07	0.77	1.39
EUW	1.62	1.58	1.59	0.96	1.23	1.30	1.65	1.91	1.90	0.91	1.22	1.29
AUS	2.03	1.81	1.79	1.86	1.48	1.39	2.41	1.94	1.69	1.78	1.46	1.37
KOR	1.66	1.60	1.60	1.20	1.18	1.09	1.63	1.64	1.57	1.15	1.17	1.03
ADV	2.04	1.92	1.91	1.83	1.75	1.61	2.39	2.20	1.95	1.79	1.74	1.60
CHN	3.84	2.54	2.21	3.40	2.44	1.43	3.82	2.85	1.84	3.24	2.35	1.26
IDN	2.73	2.30	1.93	2.60	2.00	1.78	2.89	2.26	1.98	2.45	2.01	1.73
THA	3.23	2.47	2.19	2.83	2.26	2.15	3.26	2.64	2.47	2.71	2.21	2.01
MYS	1.59	1.66	1.63	1.84	1.26	0.95	2.30	1.68	1.32	1.77	1.22	0.85
IND	3.26	2.56	2.14	3.44	2.14	1.85	3.72	2.33	1.97	3.23	2.12	1.77
PHL	3.38	2.28	2.19	3.48	1.93	1.90	3.68	2.14	2.03	3.35	1.94	1.88
VNM	3.34	2.34	2.00	2.88	2.02	1.83	3.04	2.17	1.94	2.77	2.02	1.79
ROA	2.74	2.40	2.15	2.71	1.86	1.64	3.02	2.09	1.79	2.61	1.86	1.61
LAM	1.59	1.78	1.73	2.16	1.65	1.46	2.75	2.15	1.88	2.05	1.61	1.41
AFR	0.79	1.64	1.47	1.89	1.27	1.11	2.46	1.52	1.27	1.78	1.26	1.08
MEN	1.75	1.78	1.76	1.93	1.32	1.31	2.28	1.65	1.52	1.75	1.29	1.25
ROW	2.34	2.10	2.07	1.87	1.85	1.67	2.51	2.43	2.08	1.81	1.81	1.63

Table 10 presents average and total growth rates of GDP per capita over the period of 2025-2050 (inclusive). Population ageing is expected to have significant impacts on GDP per capita in some regions over the next 25 years. In regions such as Japan, Korea and Western Europe, population ageing could reduce total growth from 2025 to 2050 by half compared to the growth that would have been without population ageing. Australia's total growth is expected to experience a reduction of about one third, while the United States will be only modestly affected. Among developing regions, Asian countries will face adverse impacts of population ageing to varying degrees, with total growth declining by 10-20% in most cases. Latin America and Africa are expected to see slightly higher total growth while the Middle East and Eastern Europe will experience moderately lower total growth due to population ageing. On the other hand, AI could boost GDP per capita growth by 10-20% in most countries worldwide. This productivity enhancement has the potential to offset the negative effects of population ageing in most regions. Despite the uncertainty and the distribution of AI driven growth, its overall impact could help mitigate the challenge of ageing populations. In terms of climate change, its total impacts are negative in most regions, with losses of up to 10%, while the rest of advanced economies will see slight benefits.

Table 10: Average and total growth of GDP per capita over 2025-2050

	S1		S2		S3		S4	
Regions	Average	Total	Average	Total	Average	Total	Average	Total
USA	1.54	48.95	1.38	42.94	1.8	58.86	1.34	41.27
JPN	2.1	71.78	1.05	31.06	1.97	65.86	0.95	27.79
EUW	1.63	52.36	1.14	34.19	1.76	57.5	1.12	33.62
AUS	1.87	62.08	1.54	48.62	1.97	65.98	1.48	46.66
KOR	1.65	53.03	1.2	36.28	1.63	52.33	1.15	34.54
ADV	1.95	65.15	1.74	56.53	2.16	74.17	1.75	57.15
CHN	3.1	121.09	2.69	99.25	3.1	121.11	2.52	90.97
IDN	2.44	87.21	2.2	76.28	2.43	86.84	2.08	70.86
THA	2.69	99.33	2.44	87.38	2.81	105.34	2.26	78.58
MYS	1.58	50.48	1.43	44.69	1.84	60.62	1.27	38.86
IND	2.87	108.63	2.66	98.06	2.86	108.27	2.52	91.23
PHL	2.84	107.01	2.61	95.39	2.78	104.02	2.54	92
VNM	2.87	108.54	2.5	89.97	2.63	96.56	2.42	86.36
ROA	2.53	91.42	2.16	74.21	2.37	84.07	2.07	70.45
LAM	1.78	58.01	1.85	61.22	2.33	82.16	1.75	57.08
AFR	1.33	41.13	1.47	46.3	1.78	58.39	1.27	38.84
MEN	1.87	61.95	1.59	50.65	1.88	62.4	1.48	46.35
ROW	2.1	71.61	1.72	55.74	2.25	78.31	1.68	54.14

5 Comparison

This section compares all projections and derives some general insights. For consistency, we focus on the period from 2025 to 2050 although some studies start before 2025 and/or extend beyond 2050. We report average annual and cumulative growth rates over the period of 2025-2050. In terms of geographic coverage, we first present the global economy as a whole, and then select major advanced economies and developing economies, respectively. The projections of Scenario 2 in the G-Cubed model are used for comparison, as most other studies do not explicitly account for the impacts of AI and/or climate change. To provide context for future projections, we also present the historical average annual growth rates from 2000 to 2019 (excluding the Covid-19 period), using data from the World Bank World Development Indicators.

5.1 The global economy

Over the past two decades, productivity growth has slowed in many advanced economies and, to some extent, in developing economies, contributing to a slowdown in global economic growth. Table 12 presents projections of global GDP per capita growth from 2025 to 2050. The average annual growth rate ranges from 1.04% to 2.72%, with an average of 1.87%. The total growth rate ranges from about 30.77% to 100.92%, with an average of 63.43%. There is a broad consensus that global GDP per capita growth is expected to decelerate further compared to the last two decades. There are several global challenges, including rapid population ageing, slower technological progress, weaker capital investment, and stagnating educational attainment.

The projections from G-Cubed falls at the lower end of the spectrum, primarily due to our assumptions of catch-up rates in the baseline. We assume that only developing Asia will continue to catch up in productivity with the United States, following their historical performance in the last two decades. In contrast, non-US advanced economies are not expected to catch up with the United States, nor developing regions outside of Asia, reflecting their recent historical trends.

Most projections assume slower technological progress without accounting for the potential impacts of AI on productivity growth, given that dramatic advances in large-language models have only emerged in the last few years. A few projection studies briefly discuss the impact of AI qualitatively. Goldman Sachs (2022) argues that digital transformation, automation, and AI are likely to enhance productivity, but these gains may not fully offset demographic challenges in advanced economies. The G-Cubed results indicate that the gains from AI development could fully offset the impacts of demographic change in our productivity scenario. However, these impacts are highly uncertain, and depend on productivity assumptions. Jones (2023) highlights that AI has the greatest potential, among other factors, to increase future productivity.

5.2 Advanced economies

Table 13 presents projections of GDP per capita growth for advanced economies as a group. The region column lists the region names as specified in each study, allowing for variations in geographic coverage. High-income countries are generally equivalent to advanced economies, while the OECD group includes a small number of upper-middle-income countries in addition to high-income countries. The average annual growth rate ranges from 0.90% to 1.70%, with an average of 1.40%, closely aligning with the historical performance of 1.38% at MER and 1.50% at PPP. The total growth rate ranges from about 26.23% to 55.0%, with an average of 43.88%. Advanced economies are expected to slow down, primarily due to rapid population ageing and sluggish productivity growth. Projections for advanced economies exhibit relatively small variations, in contrast to much larger divergence for developing economies, as discussed in the next sub-section.

As the global productivity frontier, US productivity growth shapes not only its own economy but also the global economy. The United States maintained an average annual GDP per capita growth rate of 1.6% from 1990 to 2019, with 2.1% in the 1990s, 0.7% in the 2000s, and 1.7% in the 2010s. The growth is projected to decline in the future compared to the 2010s. Table 14 presents annual growth rates for the United States from all projections. The average annual growth rate ranges from 0.89% to 2.1%, with an average of 1.46%, compared to 1.7% in the 2010s. The total growth rate ranges from about 25.79% to 71.66%, with an average of 47.19%. US OMB (2024) projects productivity growth at 1.67% over the next decade, aligning closely with the rate in the 2010s. Over the longer term, US CBO (2023) projects that US productivity will grow at an average annual rate of 1.4% over the next three decades. The report attributes this slower growth to two key factors: capital accumulation will slow down because increased federal borrowing would reduce private investment; TFP will increase more slowly due to slower increase in educational attainment, declining federal investment, and climate change effects. Jones (2023) identifies several headwinds to sustaining future growth, including the increasing difficulty of transformative innovation, the potential decline in investment in intellectual property products, stagnation in educational attainment, and slowing population growth. On the positive side, the development of a new general-purpose technology every few decades may be the driver for stable growth over the past 150 years, suggesting that AI could be the engine for future sustained growth.

Most studies include Europe but vary in their geographic coverage such as entire Europe, the European Union, Western Europe, and the Euro zone. Table 15 presents annual growth rates for Europe, where geographic coverage is specified in the region column. The average annual growth rate ranges from 0.82% to 1.97%, with an average of 1.34%, which is consistent with the average growth rate in the European Union from 2000 to 2019. The total growth rate ranges from about 23.66% to 66.49%, with an average of 40.38%.

Japan has experienced similar low growth in GDP per capita as Europe (especially Western Europe) over the past two decades, driven by rapid population ageing and slower technological progress among other factors. The projections for future growth align with this historical performance. Table 16 presents growth rates for Japan. The average annual growth rate ranges from 0.38% to 1.82%, with an average of 1.21%, which is moderately higher than the historical growth rate of 0.72% from 2000 to 2019. The total growth rate ranges from 10.36% to 59.83%, with an average of 37.38%.

Some studies provide projections for small advanced economies individually, such as Canada, Australia, and Korea, which are presented in Tables 17, 18 and 19, respectively. Canada's projections are consistent, with annual growth rates ranging from 0.99% to 1.74%. The average growth rate across projections is 1.27%, closely aligning with its historical growth rate of 0.92%. Similarly, Australia's projections are closely clustered, with annual growth rates ranging from 0.9% to 1.62%. The average growth rate across projections is 1.25%, which is very close to its historical growth rate of 1.33%. In contrast, Korea's projections show greater variation, with annual growth rates ranging from 0.70% to 3.06%. The average growth rate across projections is 1.62%, approximately half of its historical growth rate of 3.36%, mainly attributed to rapid population ageing driven by extremely low fertility rates.

5.3 Developing economies

Compared to advanced economies, developing economies are projected to maintain stronger growth, although they will also slow down compared to the past several decades. Au-Yeung et al. (2013) project that emerging Asia will be the main driver of global economic growth, with productivity levels doubling in China and India by 2050 but minimal improvement in Latin America. PwC (2017) also projects that emerging economies will continue to drive global economic growth, leading to a significant shift in global economic power. Several major emerging economies including China, India, Indonesia, Brazil, and Mexico are expected to significantly increase their share of global GDP from around 35% to 50% by 2050, while the share of advanced economies will decline.

Table 20 presents growth rates for Asia, where geographic coverage is specified in the region column. We group the studies by sub-regions of Asia, including Asia Pacific (comprising East Asia, Southeast Asia and South Asia, including high-income countries), developing or emerging Asia (comprising East Asia, Southeast Asia and South Asia, excluding high-income Asian countries), Southeast Asia (or ASEAN), and South Asia. In general, developing Asia is projected to maintain strong growth, reflecting their strong performance over the past several decades.

Among developing Asia, China's economic growth remains a topic of significant global interest.

Table 21 presents projections for China. The average annual growth rate ranges from 1.41% to 6.08%, with an average of 3.40%, which is much lower than the historical rate of 8.4%. The total growth rate ranges from 43.75% to 364.36%, with an average of 140.62%. China's growth is widely projected to decline due to several factors: a rapidly ageing population; a shift from investment-driven to consumption-driven growth; and a slowdown in productivity catch-up as the technological gap with developed countries narrows. Dollar et al. (2020) provide an extensive examination of China's long-term economic strategy to achieve high-income status by mid-century, emphasizing that future growth depends on improving productivity and fostering innovation rather than relying on capital accumulation as in the past decades. In addition, structural, financial, and institutional reforms that promote market mechanisms and the rule of law are crucial for sustaining economic development. Lee and Song (2023) show that population ageing in Asian developing countries, particularly China, will have long-term negative impacts on economic growth. However, they also highlight the importance of promoting technological innovation and investment in physical and human capital. Meng (2023) argues that labour quality rather than labour quantity played a more significant role in driving China's past economic development, and emphasizes the need for further improvements in labour quality to sustain future economic growth amid an ageing population. JCER (2020) argues that China's restrictions on cross-border data flow would hinder productivity growth in a world where digital technologies are central to economic growth. The study also highlights that the economic outlook will depend on the trade environment, influenced by geopolitical dynamics between the United States and China.

India is another key focus of the studies. Table 22 presents India's growth rates. The average annual growth rate ranges from 1.42% to 7.04%, with an average of 4.29%, which is close to its strong performance of 5.07% in the past two decades. The total growth rate ranges from 44.42% to 486.41%, with an average of 210.73%. India is widely projected to be one of the fastest-growing economies, driven by its young population and significant potential for productivity catch-up. Benzell et al. (2023) project significant shifts in global economic power, with emerging economies, particularly China and India, gaining prominence. Along South Asia, Southeast Asia is also expected to grow fast. Table 23 presents the growth rates for Indonesia. The average annual growth rate ranges from 2.20% to 4.25%, with an average of 3.33%. The total growth rate ranges from 76.28% to 195.06%, with an average of 138.33%.

Table 24 presents the growth rates for Latin America as a group. The average annual growth rate ranges from 0.88% to 3.9%, with an average of 1.88%. The total growth rate ranges from 27.14% to 170.40%, with an average of 67.72%. Table 25 presents the growth rates for Mexico. The average annual growth rate ranges from 0.44% to 2.66%, with an average of 1.66%, in contrast with the historical rate of only 0.31%. The total growth rate ranges from 20.55% to 90.05%, with an average of 60.82%. Table 26 presents the growth rates for Brazil. The average annual growth rate ranges from 0.57% to 2.86%, with an average of 1.64%. The total growth rate ranges from 15.80% to 107.90%, with an average of 57.47%. Most studies project stronger growth for Latin America compared to their historical performances over the past two decades. Goldman Sachs (2022) argue that Latin American economies will accelerate in the future after a decade of significant underperformance relative to their convergence potential.

Table 27 presents projections for Eastern Europe and Central Asia. The projections that include Russia do not reflect the implications of the Russian invasion of Ukraine since 2022. The average annual growth rate ranges from 1.72% to 3.72%, with an average of 2.31%. The total growth rate ranges from 55.64% to 158.56%, with an average of 83.69%. The war will have significant long-term negative impacts on economic growth not only in Russia and Ukraine, but also across Eastern Europe and Central Asia, as well as the global economy. Trade patterns are undergoing permanently shifts, with countries reducing their reliance on and investment in Russian energy and markets. Both Russia and Ukraine will face severe labour shortage due to workforce losses and emigration. The region is significantly increasing military expenditures, diverting resources from social programs and infrastructure investment. Even after the war, prolonged geopolitical tensions will persist, exacerbating economic uncertainty and constraining regional cooperation.

Table 28 presents growth rates for Africa. In terms of geographic coverage, some studies focus on Sub-Saharan Africa, others include North Africa, while some projections group North Africa with the Middle East. The average annual growth rate ranges from 0.68% to 5.2%, with an average of 1.94%. The total growth rate ranges from 19.13% to 273.6%, with an average of 77.49%. The large variations across studies arise from different assumptions on Africa's ability to translate its population advantage into economic growth and achieve its productivity catch-up potential. Although Africa's productivity significantly lags behind the global productivity frontier, weak institutions and poor governance would continue to impede its progress in closing the productivity gap.

5.4 General remarks

Some general remarks follow from the comparisons of projections. There appears to be some general agreement on the methodology, with most studies standing on neoclassical models, despite various modifications. This preference arises from the simplicity and tractability of the neoclassical approach, which focuses on the supply side of the economy through an aggregate production function. However, the neoclassical approach overlooks some important elements such as linkages between sectors and economies. The G-Cubed model takes a disaggregated approach to projecting output and productivity, accounting for dynamic interactions between sectors and across economies.

Projections vary considerably for developing regions over long time horizons. The differences highlight the importance of alternative methodologies and assumptions. A key assumption concerns TFP growth. TFP growth remained relatively stable over the past several decades in advanced economies, while developing countries have much room for improvement. However, the pace of innovation in advanced economies and the speed at which developing countries catch up involve much uncertainty, particularly in relation to AI. A great deal of uncertainty arises from the investment, development, diffusion, application, and regulation of AI technology within individual countries and across national borders. While all projections emphasize the negative impacts of population ageing, our results suggest that these effects could be offset by productivity gains from AI technology. McKibbin and Triggs (2019) examine various productivity growth scenarios driven by technological advances and show a wide range of impacts on global economic growth.

More generally, long-term projections are inherently uncertain in relation to alternative methodologies and assumptions. To address such uncertainty, it is useful to explore alternative scenarios and test different parameter values as robustness checks. For example, Benzell et al. (2023) consider three scenarios of productivity catch-up. US EIA (2023) examines seven scenarios to account for uncertainty in relation to energy prices and carbon technology costs. Riahi et al. (2017) includes five SSP scenarios to address various social-economic uncertainties, along with multiple RCP scenarios to account for climate change uncertainties.

Model parameterization can be an issue for developing economies due to data limitation. The parameters of the production function are generally assumed to be constant over time, although some attempt has been made to account for changes over time in the convergence parameter related to modelling technical change. The high growth rates projected for developing economies are likely to change economic structure, which could, in turn, affect the relationships in the model. Such economic structural changes cannot be captured without dis-aggregating the economy into multiple sectors.

This paper reports only average annual growth rates over the projection horizon of each study, which masks the trends over the period. Most studies provide projections at five- to ten- year intervals, if not annually. Their time series growth rates reveal that GDP per capita growth slows over time, a trend driven by the assumption of productivity convergence.

Some studies make projections of GDP per capita using both market exchange rates and purchasing power parity. The two conversion approaches can lead to significant differences in the projections, particularly for developing economies. In general, projections using market exchange rates indicate slower growth for developing economies compared to advanced economies, whereas projections based on purchasing power parity suggest faster economic convergence between developing and advanced economies.

Several studies estimate the impacts of climate change, summarised in Table 11. Alestra et al. (2022) show that climate change will reduce global GDP by 1.86% by 2050 under a scenario with a temperature increase of 4.8 degrees by 2100 (consistent with SSP5-8.5). The damage is comparable to our estimated global GDP loss of 2.1% by 2050 under the SSP2-4.5 scenario. Fricko et al. (2017) provides estimates of global GDP losses from six IAMs. The results range from negligible to a loss of 1.47%, with an exceptional case of 0.5% GDP gains. These studies are related to the broader literature that examines the impacts of climate change on economic growth (Fernando et al. 2021). One strand of the literature estimates the impacts of climate change on economic variables, such as output and productivity, using historical data and econometric models. Another strand projects the economic impacts of future climate change under various scenarios in structural models, including the projection studies presented in the following table.

Table 11: Climate impacts on global GDP in 2050 (%)

Projection	Model	Type	Scenario	GDP loss
Alestra et al. (2022)	ACCL	Neoclassical	SSP5-8.5	1.86
Liu and McKibbin (2025)	G-Cubed	CGE-DGE	SSP2-4.5	2.10
Fricko et al. (2017)	AIM/CGE	IAM	SSP2-4.5	0.54
Fricko et al. (2017)	GCAM4	IAM	SSP2-4.5	-0.05
Fricko et al. (2017)	IMAGE	IAM	SSP2-4.5	0.00
Fricko et al. (2017)	MESSAGE-GLOBIOM	IAM	SSP2-4.5	0.20
Fricko et al. (2017)	REMIND-MAGPIE	IAM	SSP2-4.5	1.03
Fricko et al. (2017)	WITCH-GLOBIOM	IAM	SSP2-4.5	1.47

6 Discussion

We briefly discuss the potential implications of other factors on long-term economic growth, such as geopolitical risks, government debt, public infrastructure, and institutional quality.

6.1 Geopolitical fragmentation

Geopolitical fragmentation and conflicts can have far-reaching implications on long-term economic growth by disrupting international trade and investment flows, and global supply chains. Heightened geopolitical tensions would increase uncertainty and risk, thereby reducing investment and trade. Many studies examine the economic impacts of geopolitical fragmentation (e.g., Marijn et al. 2023 on trade restrictions; McKibbin and Noland 2025 on tariffs). While geopolitical risk can have strong impacts on economic growth, it is challenging to quantify its long-term impacts due to the inherent uncertainty of geopolitical dynamics over decades. Moreover, geopolitical relations span multiple dimensions (economic, political, technological, ideological, military, security, etc.), so their economic consequences depend on specific risks and/or opportunities. Generally speaking, the current shift of the global focus from economic integration to national security would reduce efficiency gains from economic specialization, competitiveness, and scale, all of which can adversely affect global economic output.

6.2 Government debt

Public debt has surged in many advanced and developing countries over the past decade, especially after the Covid-19 pandemic. Although quantitative studies on the impact of public debt on economic growth often yield mixed findings, there is a broad consensus that excessive debt harms economic growth in the long term. US CBO (2023) revises its long-term projection of US productivity downward from the past several decades, arguing that increased public debt in the United States would reduce private investment, thereby slowing capital accumulation and productivity growth. World Bank (2024d) shows that external debt levels of low- and middle-income countries increased to all-time high levels in 2023 and, coupled with elevated interest rates, posed challenging debt burdens for those countries. Many small and poor countries have underdeveloped domestic financial systems and limited access to global capital markets, making it challenging to carry debt and sustain heavy debt service burdens. As a result, these low-income countries face significant difficulties in achieving sustained economic growth in the long term.

6.3 Public infrastructure

Public infrastructure complements private capital to advance economic growth through various channels (Romp and de Haan 2007; OECD 2009). Pennings and Loayza (2022) introduce public capital (or public infrastructure) into an aggregate production function, thereby expanding the neoclassical approach by highlighting the role of public capital in economic output. World Bank (2024c) emphasizes the importance of public investment in developing economies in fostering growth, enhancing productivity, and reducing poverty. Their empirical analysis, based on panel data of 129 developing countries over the period 1980-2019, shows that, in developing countries with ample fiscal space and efficient government spending, increasing public investment by 1% of GDP can raise output by up to 1.6% over five years, crowding in private investment and driving long-term economic growth. However, while this finding highlights the positive role of public investment, it must be interpreted with caution in the current world with excessive debt. This linear relationship is less likely to hold in high-debt environments. Thus, there is an inherent trade-off between public investment and debt sustainability. To maximize the benefits of public infrastructure, developing economies must implement policy reforms to improve investment efficiency, strengthen governance, and optimize fiscal spending. In addition, global support through financial aid and technical assistance is essential for lower-income nations to achieve these objectives.

6.4 Governance and institutions

Long-term economic projections in neoclassical and other approaches rely on the assumption of productivity growth, which is typically treated as exogenous. On the other hand, the literature on endogenous growth often links productivity growth to policy (including R&D spending), governance and institutions. Income disparities between poor and rich countries are frequently attributed to differences in the quality of institutions (Lloyd and Lee 2018). Among the projection studies surveyed in this paper, Au-Yeung et al. (2013) assume conditional convergence and link a country's steady-state productivity to a range of indicators including institutional quality.

World Bank (2024b) highlights weak governance as a key challenge of low-income countries in achieving middle-income status, arguing that their long-term growth prospects hinge on improving institutional quality, public financial management, and investments in education and infrastructure. However, projecting the long-term evolution of governance and institutions is challenging due to the complex interplay of economic, political, social and technological factors.

7 Conclusion

As long-term economic challenges gain increasing importance, long-term economic projections are fundamental for guiding private business investment and informing public policy design and assessment. This paper reviews studies on long-term GDP per capita projections conducted over the last decade, highlighting key trends, methodologies, and findings.

There appears to be general agreement that neoclassical growth models are used for economic growth projections. Several global challenges are frequently highlighted in projection studies, including rapid population ageing, slower technological progress, declining capital investment, and stagnating educational attainment. Therefore, GDP per capita growth is expected to continue slowing in the coming decades in both advanced and emerging economies. Emerging economies will remain the primary drivers of global economic growth. The projections are generally consistent for advanced economies due to their mature economic systems, but vary considerably for developing regions over long time horizons. These variations underscore the importance of alternative methodologies and assumptions, especially in relation to productivity catch-up of developing countries.

Despite its simplicity and tractability, the neoclassical approach falls short in capturing the importance of structural change and sector-driven growth given it relies on an aggregate production sector. But structural change across sectors is likely to be important and relevant to a range of economic issues and policy questions. Therefore, this paper provides long-term projections based on a multi-country-multi-sector model. A sectoral approach may result in less convergence than is generally assumed at the aggregate level. While the baseline projections from the literature are broadly consistent with those from the G-Cubed model, the rich sectoral detail and international linkages built into G-Cubed are critically important when evaluating policy scenarios and shock responses.

It is useful to disentangle the impacts of different driving factors of long-term economic growth. Our projection aligns with the literature demonstrating the negative impacts of rapid population ageing and slower technological progress through conventional catch-up mechanisms assuming the frontier productivity growth continues to decelerate. However, most projections do not account for the potential implications of AI, as large-language models have only emerged in recent years. Our scenario of AI-driven productivity growth indicates that AI could offset the effects of population ageing. However, given its large uncertainty, this remains an area requiring further research as AI development continues to evolve and more data become available. Climate change, on the other hand, is expected to have, at most, moderate negative impacts by mid-century. In addition, factors such as geopolitical fragmentation, government debt, infrastructure investment, and institutional reform are important specific drivers of economic growth, all of which are closely related to productivity growth.

The methodologies for long-term projections of the world economy are not well developed and what is in the public domain is not completely transparent. There is a trade-off between the simplicity with respect to the projection approach and the complexity of modelling the global economy. The G-Cubed model provides an approach that focuses on the changing sectoral composition of the world economy and the role of endogenous consumption and investment decisions as well as international linkages.

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Appendix: Summary of projection studies

For comparison, we focus on the time period from 2025 to 2050 although some studies start before 2025 and/or extend beyond 2050. The average annual growth rates and total growth rates in all subsequent tables are calculated for the period of 2025-2050 (inclusive) unless some projections conclude before 2050. The period column indicates the end year of each projection. The bottom of each table presents the historical average annual growth rates from 2000 to 2019 (excluding the Covid-19 period), with data sourced from the World Bank World Development Indicators. Several studies only report GDP, so we use population data from the United Nations 2024 Population Prospects to calculate GDP per capita. Some studies explore alternative assumptions, and we use their reference projections.

Table 12: Projections of global GDP per capita growth

Study	Institution	Year	Period	Conversion	Average	Total
Au-Yeung et al.	AUS Treasury	2013	2050	PPP	1.70	54.96
Cuaresma	IIASA	2017	2050	PPP	1.85	61.25
Dellink et al.	OECD-EG	2017	2050	PPP	2.05	69.61
Leimbach et al.	PIK	2017	2050	PPP	2.29	80.21
Alestra et al.	Bank of France	2020	2050	PPP	1.04	30.77
JCER	JCER	2020	2050	MER	1.15	34.62
Goldman Sachs	Goldman Sachs	2022	2050	MER	2.72	100.92
Chen et al.	MIT	2022	2050	PPP	1.63	52.25
Müller et al.	Princeton & Harvard	2022	2050	PPP	2.05	69.49
Benzell et al.	Boston University	2023	2050	PPP	2.88	109.57
US EIA	US EIA	2023	2050	PPP	1.82	59.86
Conference Board	Conference Board	2024	2036	MER	1.75	-
USDA	USDA	2024	2034	MER	1.89	-
IEA	IEA	2024	2050	PPP	2.00	67.34
Oxford Economics	Oxford Economics	2024	2050	PPP	1.79	58.52
Liu and McKibbin	G-Cubed	2025	2050	MER	1.26	38.62
Average					1.87	63.43
2000-2019				MER	1.76	
2000-2019				PPP	2.24	

Table 13: Projections of GDP per capita growth in advanced economies

Study	Institution	Year	Region	Period	Conversion	Average	Total
Au-Yeung et al.	AUS Treasury	2013	Advanced	2050	PPP	1.56	49.69
Alestra et al.	Bank of France	2020	Advanced	2050	PPP	1.25	38.12
Goldman Sachs	Goldman Sachs	2022	Advanced	2050	MER	1.70	55.00
Müller et al.	Princeton & Harvard	2022	Advanced	2050	PPP	1.64	52.64
Conference Board	Conference Board	2024	Mature	2036	MER	1.31	-
Oxford Economics	Oxford Economics	2024	Advanced	2050	PPP	1.27	38.94
Liu and McKibbin	G-Cubed	2025	Advanced	2050	MER	1.35	41.67
Cuaresma	IIASA	2017	OECD	2050	PPP	1.61	51.48
Dellink et al.	OECD-EG	2017	OECD	2050	PPP	1.23	37.42
Leimbach et al.	PIK	2017	OECD	2050	PPP	1.26	38.48
JCER	JCER	2020	OECD	2050	MER	0.90	26.23
Müller et al.	Princeton & Harvard	2022	OECD	2050	PPP	1.69	54.61
Guillemette & Chateau	OECD-LG	2023	OECD	2050	PPP	1.48	46.52
Oxford Economics	Oxford Economics	2024	OECD	2050	PPP	1.29	39.65
Average						1.40	43.88
2000-2019			High-income		MER	1.38	
2000-2019			High-income		PPP	1.50	

Table 14: Projections of GDP per capita growth in the United States

Study	Institution	Year	Period	Conversion	Average	Total
Müller and Watson	Princeton Uni.	2016	2090	PPP	1.95	65.22
PwC	PwC	2017	2050	PPP	1.33	41.06
Cuaresma	IIASA	2017	2050	PPP	1.25	37.98
Dellink et al.	OECD-EG	2017	2050	PPP	0.89	25.79
Leimbach et al.	PIK	2017	2050	PPP	1.06	31.49
Alestra et al.	Bank of France	2020	2050	PPP	1.29	39.54
JCER	JCER	2020	2050	MER	0.95	27.87
Lunsford and West	US Fed and UW	2021	2045	LCU	1.70	55.00
Chen et al.	MIT	2022	2050	PPP	1.55	49.17
Goldman Sachs	Goldman Sachs	2022	2050	MER	1.37	42.44
Fontagné et al.	CEPII	2022	2050	MER	1.53	48.41
Benzell et al.	Boston University	2023	2050	PPP	1.88	62.49
US EIA	US EIA	2023	2050	PPP	1.59	51.01
Guillemette and Chateau	OECD-LG	2023	2050	PPP	1.11	33.18
Lee and Song	Korea University	2023	2050	PPP	1.92	63.96
US CBO	US CBO	2023	2050	LCU	1.40	43.54
S&P Global Insights	Global Insights	2023	2050	LCU	2.10	71.66
US OMB	OMB	2023	2033	LCU	1.67	-
US EIA	US EIA	2023	2050	PPP	1.58	50.21
Conference Board	Conference Board	2024	2036	MER	1.23	-
USDA	USDA	2024	2034	MER	1.22	-
US SSA	US SSA	2024	2050	LCU	1.63	52.25
IEA	IEA	2024	2050	PPP	1.50	47.27
Oxford Economics	Oxford Economics	2024	2050	PPP	1.45	45.38
Liu and McKibbin	G-Cubed	2025	2050	MER	1.38	42.94
Average					1.46	47.19
2000-2009					0.70	
2010-2019					1.68	
2000-2019					1.24	

Notes: LCU refers to local currency, as cross-country comparison is not involved.

Table 15: Projections of GDP per capita growth in Europe

Study	Institution	Year	Region	Period	Conversion	Average	Total
Conference Board	Conference Board	2024	Europe	2036	MER	1.27	-
Alestra et al.	Bank of France	2020	WE	2050	PPP	1.20	36.30
Benzell et al.	Benzell et al.	2023	WE	2050	PPP	1.13	33.89
US EIA	US EIA	2023	WE	2050	PPP	1.25	38.26
Oxford Economics	Oxford Economics	2024	WE	2050	PPP	1.06	31.54
Liu and McKibbin	G-Cubed	2025	WE	2050	MER	1.14	34.19
Chen et al.	MIT	2022	EU+	2050	PPP	1.47	46.14
JCER	JCER	2020	EU	2050	MER	0.82	23.66
USDA	USDA	2024	EU	2034	MER	1.62	-
IEA	IEA	2024	EU	2050	PPP	1.20	36.36
Cuaresma	IIASA	2017	EU15	2050	PPP	1.97	65.94
Dellink et al.	OECD-EG	2017	EU15	2050	PPP	1.28	39.19
Leimbach et al.	PIK	2017	EU15	2050	PPP	1.20	36.30
Au-Yeung et al.	AUS Treasury	2013	Euro Zone	2050	PPP	1.54	48.89
Goldman Sachs	Goldman Sachs	2022	Euro Zone	2050	MER	1.98	66.49
Müller et al.	Princeton & Harvard	2022	Euro Zone	2050	PPP	1.68	54.21
Guillemette and Chateau	OECD-LG	2023	Euro Zone	2050	PPP	1.37	42.30
Oxford Economics	Oxford Economics	2024	Euro Zone	2050	PPP	0.99	29.33
Average						1.34	41.44
2000-2019			Euro Zone		MER	0.95	
2000-2019			Euro Zone		PPP	0.94	
2000-2019			EU		MER	1.23	
2000-2019			EU		PPP	1.33	

Notes: WE: Western Europe; EU15: European Union member states that joined prior to 2004. EU+: European Union plus United Kingdom, Croatia, Norway, Switzerland, Iceland, and Liechtenstein.

Table 16: Projections of GDP per capita growth in Japan

Study	Institution	Year	Period	Conversion	Average	Total
PwC	PwC	2017	2050	PPP	1.55	49.01
Cuaresma	IIASA	2017	2050	PPP	1.12	33.59
Dellink et al.	OECD-EG	2017	2050	PPP	1.13	33.93
Leimbach et al.	PIK	2017	2050	PPP	1.04	30.87
Alestra et al.	Bank of France	2020	2050	PPP	0.64	17.99
JCER	JECR	2020	2050	MER	0.38	10.36
Goldman Sachs	Goldman Sachs	2022	2050	MER	1.40	43.54
Fontagné et al.	CEPII	2022	2050	MER	1.36	42.28
Chen et al.	MIT	2022	2050	PPP	1.82	59.83
US EIA	US EIA	2023	2050	PPP	0.82	23.75
Guillemette and Chateau	OECD-LG	2023	2050	PPP	1.67	53.82
Lee and Song	Korea University	2023	2050	PPP	1.53	48.56
Conference Board	Conference Board	2024	2036	MER	1.51	-
USDA	USDA	2024	2034	MER	1.40	-
IEA	IEA	2024	2050	PPP	1.40	43.54
Oxford Economics	Oxford Economics	2024	2050	PPP	0.68	19.12
Liu and McKibbin	G-Cubed	2025	2050	MER	1.05	31.06
Average					1.21	36.08
2000-2019					0.72	

Table 17: Projections of GDP per capita growth in Canada

Study	Institution	Year	Period	Conversion	Average	Total
PwC	PwC	2017	2050	PPP	1.32	40.56
Cuaresma	IIASA	2017	2050	PPP	1.35	41.89
Dellink et al.	OECD-EG	2017	2050	PPP	1.06	31.55
Leimbach et al.	PIK	2017	2050	PPP	1.29	39.60
Alestra et al.	Bank of France	2020	2050	PPP	1.22	36.90
JCER	JCER	2020	2050	MER	1.01	29.70
Fontagné et al.	CEPII	2022	2050	MER	1.06	31.64
Goldman Sachs	Goldman Sachs	2022	2050	MER	1.59	50.86
Chen et al.	MIT	2022	2050	PPP	1.60	51.28
Guillemette and Chateau	OECD-LG	2023	2050	PPP	1.22	37.23
US EIA	US EIA	2023	2050	PPP	0.99	29.28
USDA	USDA	2024	2034	MER	1.26	-
Oxford Economics	Oxford Economics	2024	2050	PPP	1.08	32.20
Liu and McKibbin	G-Cubed	2025	2050	MER	1.74	56.53
Average					1.27	39.17
2000-2019					0.92	

Table 18: Projections of GDP per capita growth in Australia

Study	Institution	Year	Region	Period	Conversion	Average	Total
PwC	PwC	2017	Australia	2050	PPP	1.32	40.60
Cuaresma	IIASA	2017	Australia	2050	PPP	1.42	44.15
Dellink et al.	OECD-EG	2017	Australia	2050	PPP	1.04	30.96
Alestra et al.	Bank of France	2020	Australia	2050	PPP	1.43	44.77
JCER	JCER	2020	Australia	2050	MER	1.04	30.87
Fontagné et al.	CEPII	2022	Australia	2050	MER	0.90	26.38
Goldman Sachs	Goldman Sachs	2022	Australia	2050	MER	1.51	47.65
USDA	USDA	2024	Australia	2034	MER	1.28	-
Oxford Economics	Oxford Economics	2024	Australia	2050	PPP	1.00	29.63
Liu and McKibbin	G-Cubed	2025	Australia	2050	MER	1.54	48.62
Leimbach et al.	PIK	2017	AUS-NZ	2050	PPP	1.17	35.47
Chen et al.	MIT	2022	AUS-NZ	2050	PPP	1.62	52.01
US EIA	US EIA	2023	AUS-NZ	2050	PPP	1.03	30.40
Average						1.25	38.18
2000-2019						1.33	

Table 19: Projections of GDP per capita growth in Korea

Study	Institution	Year	Period	Conversion	Average	Total
PwC	PwC	2017	2050	PPP	1.62	52.00
Cuaresma	IIASA	2017	2050	PPP	0.76	21.63
Dellink et al.	OECD-EG	2017	2050	PPP	2.04	69.03
Leimbach et al.	PIK	2017	2050	PPP	1.13	33.96
Alestra et al.	Bank of France	2020	2050	PPP	0.88	25.44
JCER	JCER	2020	2050	MER	0.70	19.88
Fontagné et al.	CEPII	2022	2050	MER	1.94	64.62
Goldman Sachs	Goldman Sachs	2022	2050	MER	2.53	91.30
Chen et al.	MIT	2022	2050	PPP	3.06	119.16
Lee and Song	Korea University	2023	2050	PPP	2.00	67.14
US EIA	US EIA	2023	2050	PPP	1.33	40.97
USDA	USDA	2024	2034	MER	1.81	-
Oxford Economics	Oxford Economics	2024	2050	PPP	1.69	54.73
Liu and McKibbin	G-Cubed	2025	2050	MER	1.20	36.28
Average					1.62	53.55
2000-2019					3.36	

Table 20: Projections of GDP per capita growth in Asia

Study	Institution	Year	Region	Period	Conversion	Average	Total
Au-Yeung et al.	AUS Treasury	2013	Asia Pacific	2050	PPP	2.56	92.87
Alestra et al.	Bank of France	2020	Asia Pacific	2050	PPP	1.36	42.04
US EIA	US EIA	2023	Asia Pacific	2050	PPP	2.89	109.92
Oxford Economics	Oxford Economics	2024	Asia Pacific	2050	PPP	2.97	114.25
IEA	IEA	2024	Asia Pacific	2050	PPP	3.00	115.66
Cuaresma	IIASA	2017	Developing Asia	2050	PPP	2.37	83.86
Dellink et al.	OECD-EG	2017	Developing Asia	2050	PPP	2.92	111.35
Leimbach et al.	PIK	2017	Developing Asia	2050	PPP	3.15	123.98
Müller et al.	Princeton & Harvard	2022	Developing Asia	2050	PPP	2.02	68.20
Goldman Sachs	Goldman Sachs	2022	Developing Asia	2050	MER	4.03	179.37
Oxford Economics	Oxford Economics	2024	Emerging Asia	2050	PPP	3.45	141.45
Liu and McKibbin	G-Cubed	2025	Developing Asia	2050	MER	2.25	78.13
Goldman Sachs	Goldman Sachs	2022	ASEAN	2050	MER	4.79	237.45
Müller et al.	Princeton & Harvard	2022	ASEAN	2050	PPP	1.98	66.49
USDA	USDA	2024	Southeast Asia	2034	MER	3.70	-
IEA	IEA	2024	Southeast Asia	2050	PPP	3.20	126.82
Oxford Economics	Oxford Economics	2024	Southeast Asia	2050	PPP	3.01	116.38
Benzell et al.	Boston University	2023	South Asia	2050	PPP	2.71	100.20
USDA	USDA	2024	South Asia	2034	MER	4.90	-
2000-2019			Developing Asia		MER	7.35	
2000-2019			Developing Asia		PPP	6.95	
2000-2019			South Asia		MER	4.63	
2000-2019			South Asia		PPP	4.67	

Notes: Asia Pacific: East Asia, Southeast Asia and South Asia, including high-income countries; Developing or emerging Asia: East Asia, Southeast Asia and South Asia, excluding high-income Asian countries; ASEAN: Association of Southeast Asian Nations.

Table 21: Projections of GDP per capita growth in China

Study	Institution	Year	Period	Conversion	Average	Total
Au-Yeung et al.	AUS Treasury	2013	2050	PPP	3.15	124.10
Barro	Barro	2016	2035	PPP	3.50	-
PwC	PwC	2017	2050	PPP	2.55	92.68
Cuaresma	IIASA	2017	2050	PPP	2.23	77.43
Dellink et al.	OECD-EG	2017	2050	PPP	2.87	108.69
Leimbach et al.	PIK	2017	2050	PPP	2.26	78.79
Alestra et al.	Bank of France	2020	2050	PPP	1.41	43.75
Higgins	US FRB	2020	2038	PPP	2.58	-
JCER	JCER	2020	2035	MER	2.06	69.92
Wang	Peking University	2020	2050	PPP	4.73	232.79
Sasaki et al.	Bank of Japan	2021	2035	PPP	4.80	-
Fontagné et al.	CEPII	2022	2050	MER	4.88	244.77
Goldman Sachs	Goldman Sachs	2022	2050	MER	3.39	137.93
Chen et al.	MIT	2022	2050	PPP	2.67	98.40
Peschel and Liu	ADB	2022	2040	PPP	3.37	-
Benzell et al.	Boston University	2023	2050	PPP	6.08	364.36
US EIA	US EIA	2023	2050	PPP	3.18	125.44
Guillemette and Chateau	OECD-LG	2023	2050	PPP	2.65	97.59
Lee and Song	Korea University	2023	2050	PPP	4.78	236.70
Conference Board	Conference Board	2024	2036	MER	4.36	-
USDA	USDA	2024	2034	MER	4.27	-
IEA	IEA	2024	2050	PPP	3.70	157.19
Oxford Economics	Oxford Economics	2024	2050	PPP	3.45	141.45
Liu and McKibbin	G-Cubed	2025	2050	MER	2.69	99.25
Average					3.40	140.62
2000-2019					8.40	

Table 22: Projections of GDP per capita growth in India

Study	Institution	Year	Period	Conversion	Average	Total
Au-Yeung et al.	AUS Treasury	2013	2050	PPP	3.82	164.82
PwC	PwC	2017	2050	PPP	3.56	148.35
Cuaresma	IIASA	2017	2050	PPP	3.06	119.07
Dellink et al.	OECD-EG	2017	2050	PPP	3.73	159.43
Leimbach et al.	PIK	2017	2050	PPP	4.22	192.80
Alestra et al.	Bank of France	2020	2050	PPP	1.42	44.42
JCER	JCER	2020	2050	MER	4.25	195.11
Fontagné et al.	CEPII	2022	2050	MER	7.04	486.41
Goldman Sachs	Goldman Sachs	2022	2050	MER	6.15	371.98
Chen et al.	MIT	2022	2050	PPP	3.90	170.40
Benzell et al.	Boston University	2023	2050	PPP	5.17	270.89
Conference Board	Conference Board	2024	2036	MER	3.83	-
US EIA	US EIA	2023	2050	PPP	4.26	195.74
Guillemette and Chateau	OECD-LG	2023	2050	PPP	4.13	186.40
Lee and Song	Korea University	2023	2050	PPP	5.59	311.33
USDA	USDA	2024	2034	MER	5.24	-
IEA	IEA	2024	2050	PPP	5.10	264.48
Oxford Economics	Oxford Economics	2024	2050	PPP	4.35	202.74
Liu and McKibbin	G-Cubed	2025	2050	MER	2.66	98.06
Average					4.29	210.73
2000-2019					5.07	

Table 23: Projections of GDP per capita growth in Indonesia

Study	Institution	Year	Period	Conversion	Average	Total
Cuaresma	IIASA	2017	2050	PPP	3.22	128.09
Dellink et al.	OECD-EG	2017	2050	PPP	3.83	165.80
Leimbach et al.	PIK	2017	2050	PPP	4.24	194.61
PwC	PwC	2017	2050	PPP	2.91	111.01
Fontagné et al.	CEPII	2022	2050	MER	3.49	144.02
Chen et al.	MIT	2022	2050	PPP	2.54	91.77
Lee and Song	Korea University	2023	2050	PPP	4.25	195.06
Liu and McKibbin	G-Cubed	2025	2050	MER	2.20	76.28
Average					3.33	138.33
2000-2019					4.00	

Table 24: Projections of GDP per capita growth in Latin America

Study	Institution	Year	Period	Conversion	Average	Total
Au-Yeung et al.	AUS Treasury	2013	2050	PPP	1.50	47.40
Cuaresma	IIASA	2017	2050	PPP	2.05	69.77
Dellink et al.	OECD-EG	2017	2050	PPP	2.20	76.36
Leimbach et al.	PIK	2017	2050	PPP	2.76	102.72
Alestra et al.	Bank of France	2020	2050	PPP	1.26	38.61
JCER	JCER	2020	2050	MER	0.90	26.23
Goldman Sachs	Goldman Sachs	2022	2050	MER	3.90	170.40
Chen et al.	MIT	2022	2050	PPP	2.50	90.03
Müller et al.	Princeton & Harvard	2022	2050	PPP	2.04	69.06
Benzell et al.	Boston University	2023	2050	PPP	0.93	27.14
Conference Board	Conference Board	2024	2036	MER	0.88	-
USDA	USDA	2024	2034	MER	2.34	-
IEA	IEA	2024	2050	PPP	1.90	63.13
Oxford Economics	Oxford Economics	2024	2050	PPP	1.25	38.26
Liu and McKibbin	G-Cubed	2025	2050	MER	1.85	61.22
Average					1.88	67.72
2000-2019				MER	1.29	
2000-2019				PPP	1.34	

Table 25: Projections of GDP per capita growth in Mexico

Study	Institution	Year	Period	Conversion	Average	Total
Au-Yeung et al.	AUS Treasury	2013	2050	PPP	1.50	47.30
US EIA	US EIA	2023	2050	PPP	1.33	41.12
Cuaresma	IIASA	2017	2050	PPP	2.26	78.91
Dellink et al.	OECD-EG	2017	2050	PPP	2.15	73.80
Leimbach et al.	PIK	2017	2050	PPP	2.50	90.05
Alestra et al.	Bank of France	2020	2050	PPP	1.26	38.63
Fontagné et al.	CEPII	2022	2050	MER	1.80	59.11
Chen et al.	MIT	2022	2050	PPP	2.66	97.87
Benzell et al.	Boston University	2023	2050	PPP	0.72	20.55
Conference Board	Conference Board	2024	2036	MER	0.44	-
Average					1.66	60.82
2000-2019					0.31	

Table 26: Projections of GDP per capita growth in Brazil

Study	Institution	Year	Period	Conversion	Average	Total
US EIA	US EIA	2023	2050	PPP	0.84	24.30
Au-Yeung et al.	AUS Treasury	2013	2050	PPP	2.18	75.00
Cuaresma	IIASA	2017	2050	PPP	2.06	69.85
Dellink et al.	OECD-EG	2017	2050	PPP	1.90	63.30
Leimbach et al.	PIK	2017	2050	PPP	2.86	107.90
Alestra et al.	Bank of France	2020	2050	PPP	1.28	39.35
Fontagné et al.	CEPII	2022	2050	MER	0.57	15.80
Chen et al.	MIT	2022	2050	PPP	2.75	102.69
Benzell et al.	Boston University	2023	2050	PPP	0.67	19.02
Conference Board	Conference Board	2024	2036	MER	1.24	-
Average					1.64	57.47
2000-2019					1.33	

Table 27: Projections of GDP per capita growth in Eastern Europe and Central Asia

Study	Institution	Year	Region	Period	Conversion	Average	Total
US EIA	US EIA	2023	EEU & Eurasia	2050	PPP	3.72	158.56
Cuaresma	IIASA	2017	EEU & FSU	2050	PPP	1.72	55.64
Dellink et al.	OECD-EG	2017	EEU & FSU	2050	PPP	2.39	84.72
Leimbach et al.	PIK	2017	EEU & FSU	2050	PPP	2.44	87.08
Alestra et al.	Bank of France	2020	EEU & CA	2050	PPP	1.43	44.48
Chen et al.	MIT	2022	EEU & CA	2050	PPP	2.80	104.95
Müller et al.	Princeton & Harvard	2022	Dev. Europe	2050	PPP	1.79	58.61
Benzell et al.	Boston University	2023	EEU	2050	PPP	2.77	103.40
Liu & McKibbin	G-Cubed	2025	EEU & CA	2050	MER	1.72	55.74
Average						2.31	83.69
2000-2019						1.33	

Notes: EEU: Eastern Europe; FSU: Former Soviet Union; CA: Central Asia; Dev. Europe: Developing Europe.

Table 28: Projections of GDP per capita growth in Africa

Study	Institution	Year	Region	Period	Conversion	Average	Total
Alestra et al.	Bank of France	2020	Africa	2050	PPP	1.27	38.77
JCER	JCER	2020	Africa	2050	MER	2.16	74.30
US EIA	US EIA	2023	Africa	2050	PPP	0.74	21.17
USDA	USDA	2024	Africa	2034	MER	1.54	-
IEA	IEA	2024	Africa	2050	PPP	2.0	67.34
Chen et al.	MIT	2022	Africa	2050	PPP	2.0	67.34
Cuaresma	IIASA	2017	ME & Africa	2050	PPP	2.3	80.62
Dellink et al.	OECD-EG	2017	ME & Africa	2050	PPP	2.6	94.91
Leimbach et al.	PIK	2017	ME & Africa	2050	PPP	3.04	117.74
Benzell et al.	Boston University	2023	MENA	2050	PPP	2.12	72.39
Conference Board	Conference Board	2024	MENA	2036	MER	0.89	-
Liu and McKibbin	G-Cubed	2025	MENA	2050	MER	1.59	50.65
Au-Yeung et al.	AUS Treasury	2013	SSA	2050	PPP	1.75	56.87
Goldman Sachs	Goldman Sachs	2022	SSA	2050	MER	5.2	273.60
Müller et al.	Princeton & Harvard	2022	SSA	2050	PPP	2.63	96.40
Benzell et al.	Boston University	2023	SSA	2050	PPP	1.88	62.27
Conference Board	Conference Board	2024	SSA	2036	MER	1.03	-
Oxford Economics	Oxford Economics	2024	SSA	2050	PPP	0.68	19.13
Liu and McKibbin	G-Cubed	2025	SSA	2050	MER	1.47	46.3
Average						1.94	77.49
2000-2019			SSA		MER	1.60	
2000-2019			SSA		PPP	1.71	

Notes: ME: Middle East; MENA: Middle East and North Africa; SSA: Sub-Saharan Africa.