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Demographic Change and Long-Term Economic Growth Path in Asia

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Abstract

This study analyzes Asia's economic prospects over the next half-century, focusing on demographic changes. To project the GDP and per capita GDP growth rates for the five major Asian countries and the United States (US) until 2070, an endogenous growth model is used where physical and human capital accumulation, technological progress, and substitution between physical capital and labor are important determinants of the long-term growth rate. The simulation results show that while the declining labor force growth and an aging population have a long-term negative impact on economic growth, they will not predetermine the future of Asian economies. Highlighted is the importance of promoting technological innovation as well as investment in physical and human capital to sustain strong growth in Asian economies. China's average annual GDP growth is expected to decline to between 1.5% and 2.4% during 2051–2070, subject to scenarios. China's higher growth trajectory could approach about 85% of the US PPP-adjusted per capita GDP by 2070. India is projected to surpass the US in PPP-adjusted GDP by 2050 and China by 2070.

Keywords

Asia, demographic changes, economic growth, human capital, technological progress

JEL Classification

J11, J24, O33, O41, O53

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Demographic Change and Long-Term Economic Growth Path in Asia[a]

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ABSTRACT

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I. INTRODUCTION

Asia has made dramatic economic progress over the past 50 years, making it the largest and most dynamic region in the world. Asian countries including Japan, South Korea, China, India, and others have achieved impressive growth, closing the gap with advanced economies, and showing an increase in per capita GDP.

With 60% of the world population, Asia accounts for about 40% of the world's Gross Domestic Product (GDP) measured in purchasing power parity (PPP) (Figure 1). It is home to five of the world's 10 most populous countries: China, India, Indonesia, Pakistan, and Bangladesh.[1] Moreover, China, Japan, India, and South Korea are the current major economic powers. China is already the world's largest economy, surpassing the United States (US) in terms of the size of GDP based on PPP (Figure 1).[2]

Asia's strong economic growth has narrowed the gap with advanced economies. The per capita GDP of Japan, Singapore, and South Korea have risen rapidly, approaching that of the US. China, India, and Indonesia have followed a similar trajectory (Figure 2). China has rapidly caught up with the US in terms of per capita GDP based on PPP, increasing from a mere 2.4% of that of the US in 1980 to 28.3% in 2022. Over the same period, India's per capita GDP increased from 4.2% of that of the US to 11.0%.[3]

However, the question is whether the Asian economies can continue this path of rapid growth. While many expect Asia's growth to continue over the next few decades, a major challenge that could hamper the region's economic growth potential is rapid demographic changes. Specifically, China, Japan, and South Korea are already experiencing the impact of population aging and declining birthrate, as both could reverse the demographic dividends that have supported strong regional growth over the past five decades.

This study aims to analyze Asia's economic prospects over the next half-century, considering

[1] Please refer to the latest UN Population Division estimates (https://www.worldometers.info/world-population/population-by-country/)
[2] In terms of market exchange rates, China is the second-largest country, accounting for 18% of the world's GDP in 2022, compared to the US GDP of 25%.
[3] According to the IMF estimates, China's per capita GDP, measured by PPP-adjusted current international dollars, increased from 307 USD in 1980 to 18,093 USD in 2022, while India's per capita GDP increased from 532 USD to 7,048 USD during the same period.

that the impact of demographic change. According to the literature (Barro and Sala-i-Martin, 2004; Weil, 2014), the impact of demographic change on the growth potential of an economy is multi-faceted. Population aging and a declining birthrate have a direct impact on production due to a shrinking labor force. Moreover, demographic changes can also affect physical capital accumulation and technological development. Decline in labor force reduces productivity of physical capital. Consequently, firms can reduce physical capital investment. Investment in technological innovation can also decrease due to the shrinking market size alongside a decreasing population. On the contrary, declining labor force can have positive effects on physical capital accumulation and technological development, and thereby output growth. In the neoclassical growth model, lower labor force growth leads to a higher physical capital-labor ratio, resulting in a positive impact on output growth per worker. In addition, as the labor force declines, firms may consider increasing their investment in physical capital and technological development to replace labor shortage. As in theory, the impact of population on economic growth is ambiguous even in empirical studies. Some studies indicate a positive relationship between population and economic growth (Kremer, 1993; Bloom and Williamson, 1998), while others demonstrate the negative effect of population growth or fertility rate on economic growth (Barro and Lee, 2015).

To forecast the GDP and per capita GDP growth rates for major Asian countries up to 2070, this study employs a growth model that considers population growth, physical capital accumulation, technological progress, and human capital accumulation. In this model, physical capital accumulation and the rate of technological progress are endogenously determined by the values of various parameters for the equations of production, investment (saving), and technological innovation, along with the projected trajectory of population growth. Additionally, in our model, human capital accumulation is a crucial factor for enhancing labor quality that compensates for declining labor quantity.

Based on the growth model, we demonstrate how GDP and per capita GDP growth rates for major Asian countries including China, Japan, India, Indonesia, and South Korea will develop until 2070. As of 2021, these five economies account for about 84% of Asia's GDP measured in PPP. A few studies used the endogenous growth model explicitly when constructing long-term growth projections. While some international organizations and global investment banks provide long-term GDP projections for both the Asian and global economies (The Organization for Economic Cooperation and Development [OECD], 2021; Daly et al., 2022), their forecasts are primarily based on a simple growth accounting framework and not on an integrated endogenous growth framework. We attempt to address this gap and contribute to the literature by adopting a more integrated approach to projecting economic growth in Asia.

By estimating a system of simultaneous equations of GDP growth factors, the model improves internal consistency and presents a more reasonable and accurate projection. Specifically, this model helps us to obtain a more accurate estimate of the impact of demographic change on the future growth of Asian economies. Based on the unfavorable demographic outlook, one might believe that the future of Asian economies is bleak. However, this is not necessarily the case. Our model shows that the equilibrium of economic growth rate is not determined proportionally to the rate of population or labor force growth. Other key factors, such as physical and human capital accumulation and technological progress also play an important role in determining the growth rate. The overall impact of demographic change on GDP growth must consider the impact on investment in physical and human capital accumulation and technological development.

This study assesses the impact of demographic changes on Asian economies and provides accurate estimates of their growth potential, based on a growth model. Notably, our projections until 2070 are subject to risks and uncertainties, including economic crises, natural disasters, military conflicts, and major external shocks. Additionally, this study assumes that economic policies or institutions will remain unchanged, except for those explicitly considered in our analysis, although it is unlikely that this assumption will hold true. Policies and unexpected shocks can deviate actual growth from the potential growth path projected by the model, either exceeding or dipping below the projection. Therefore, our findings must be interpreted with caution.

This study also contributes to the literature debating the role of Asia in the global economy and geopolitical structure. The rise in Asia's economic power, especially China, has influenced the global economic and geopolitical landscape over the past five decades. It is an important question whether China and the region can sustain the strong economic growth and emerge as a major player on the global stage, transforming the global governance structure, over the next few decades. This study provides growth projections for Asian economies and the US and presents how Asia will fare relative to the US. This will provide understanding on how the global balance of power will change in the upcoming decades.

Section II briefly describes demographic changes and prospects in Asia. Section III explores to what extent the growth potential will be affected by the demographic reversal in major Asian economies using a growth accounting methodology. Section IV describes an endogenous growth model, and Section V reports the results of projections for major Asian economies and the US. Section VI concludes.

II. DEMOGRAPHIC CHANGE AND PROSPECTS IN ASIA

Asia's demographic changes have been dynamic and rapid. Following World War II (WWII), the region witnessed a rapid improvement in the birth rate, leading to an accelerated pace in population growth. When the baby boom generation that was born around WWII and reached the age of 15 years and older, Asia experienced the advantageous expansion of its working-age population, commonly referred to as the population dividend. This abundant labor is one of the contributing factors that support the region's rapid growth.

However, alongside other structural challenges, the Asian economy now confronts significant demographic challenges arising from a rapidly aging population, shrinking workforce, coupled with a declining birth rate. These demographic shifts pose profound implications for the region's social and economic landscape.

Nevertheless, the pattern and the pace of demographic change within Asia differ by country, as demonstrated in Figures 3–5.[4] Specifically, Figures 3–5 present the trends and perspectives of total population size and the share and growth rate of the working-age population for the five selected Asian countries and the US from 1980 to 2070, based on the United Nations'(UN) world population prospects 2022.

East Asian economies, including China and South Korea, seem to follow Japan in terms of the demographic trajectory. Japan is the world's most rapidly aging society, where the elderly aged over 65 years currently account for 29.8% of the population, almost doubling from 15.0% in

[4] We use data sourced from the UN World Population Prospects 2022 (UN DESA, 2022). This dataset contains population estimates and projections over a 150-year period for 237 countries or areas worldwide. Projections are available for the period from 2022 to 2101. We use the medium scenario projection that assumes medium changes in future levels of fertility, mortality, and international migration. For further details, please refer to UN DESA (2022).

1995. The country's total population has been shrinking since 2012. It is expected to decrease from 123.95 million in 2022 to 89.14 million in 2070, as demonstrated in Figure 2. The share of the working-age population aged 15–64 years has been declining rapidly from 69.8% in 1992 to 58.5% in 2022 and is expected to reach 50.4% in 2070, as presented in Figure 3. The working-age population growth rate is likely to continue negative over the period with an average of -0.17% in 2020–2030 to -1.14% in 2060–2070 (Figure 5).

South Korea's total population began declining in 2020. According to UN estimates, South Korea's total population is expected to decrease from 51.82 million in 2022 to 35.92 million in 2070, as presented in Figure 3. It is projected that the share of population aged 65 years and over is expected to increase continuously from 17.5% of the population in 2022 to 46.5% in 2070. The share of the working-age population aged 15–64 years will shrink by 25.4 percentage points (%p) between 2022 (70.9%) and 2070 (45.5%). The working-age population growth rate is expected to drop from an average of 0.53% in 2010–2020 to -1.02% in 2020–2030 and continue to decline to -1.96% in 2060–2070 (Figure 7).

Similar to Japan and South Korea, China is also facing an aging population and a simultaneous decline in birth rates amid its rapid catch-up. In terms of population size, China has reached its peak of around 1,425.89 million in 2021, and it is expected to reverse its increasing demographic path, as demonstrated in Figure 3. The total population is expected to decline to 1,085.29 million in 2070. The share of the working-age population aged 15–64 years has been declining from 72.8% in 2010 to 69.0% in 2022 and is expected to further decline to 53.5% in 2070, as presented in Figure 4. The proportion of population aged 65 years and over is expected to increase, reaching 44.2% by 2070, which is nearly tripling from 13.7% in 2022. The growth rate of working-age population is expected to decline from an average of -0.64% in 2020–2030 to -0.92% in 2060–2070 (Figure 5).

The population landscape in India and Indonesia is quite different, compared to the three East Asian countries mentioned earlier. Both countries are expected to experience an increasing population size. The population size in India is estimated around 1,417.17 million in 2022 and it is expected to reach around 1,696.98 million in 2063. This is also supported by its strong working-age population, which accounted for 67.8% in 2021. The share of the working-age population is expected to grow to around 68.9% over the next ten years and decline to 61.2% in 2070, which is still higher than the three East Asian countries. The share of population aged

65 years and above was minimal at around 6.8% in 2021 and is expected to constantly increase to 23.2% in 2070. These figures are still much lower than the three East Asian countries. India's working-age population is expected to grow by an average of 0.86% in 2020–2030, as demonstrated in Figure 5. Yet, it is likely to decline in the 2050s and will be -0.28 on average in 2060–2070.

The population growth rate for Indonesia would be modest. The current population of 273.75 million in 2021 is expected to peak in 2060 at around 319.42 million and begin decreasing to 317.72 million in 2070. The working-age population amounted to 67.7% in 2021 and is expected to increase until the late 2020s. However, its share will begin decreasing from 2030 onward around 68.5% to 64.0%, which is higher than the three East Asian countries and India. The elderly population was about 6.8% of the total population in 2021 and is expected to increase to 18.9% in 2070, which is the lowest among the five Asian countries.

III. DEMOGRAPHIC REVERSAL AND CHANGE IN GROWTH POTENTIAL: WHAT DOES GROWTH ACCOUNTING PREDICT?

A shrinking labor force is a potential threat to the sustained growth of Asian economies that are already losing economic vitality. The shrinking workforce will likely reverse the demographic dividends that supported the region's strong growth. Applying Solow's growth accounting technique, we can assess the role of the labor force in economic growth. Growth accounting is a methodology that is used for decomposing the growth rate of the total output of an economy into the contribution of four productive components including growth in physical capital stock, labor force, human capital per worker, and total factor productivity (TFP) growth, which reflects technological progress and economic efficiency.

This approach is applied to decompose output growth rates in the six selected economies including China, Japan, India, Indonesia, South Korea, and the US during 2010–2019. Data on GDP are gathered from the IMF's latest version of economic outlook database (IMF, 2022), while data on physical capital stock, human capital, and labor share are collected from the Penn-World Table (PWT) 10.1 (Feenstra et al., 2015). As for the number of workers, we use data on the working-age population sourced from the UN (2022), considering that sources available for cross-country labor force or employee data are less reliable than those for the working-age population.[5]

Table 1 presents a summary of the growth accounting estimates for six selected economies over the period, 2010–2019. Among them, China, India, and Indonesia exhibited higher GDP growth rates compared to Japan, South Korea, and the US. China achieved an annual average GDP growth rate of 7.67% during this period, with physical capital accumulation contributing most to GDP growth at 4.6%p (about 60%).[6] Total factor productivity (TFP) growth contributed 2.4%p (31.7%) of GDP growth. Labor contribution to GDP was merely at around 0.1%p (1.1%), and human capital contribution was about 0.6%p (7.7%).

India and Indonesia maintained high investment rates throughout their catch-up process. During the sample period, India achieved an annual average GDP growth rate of 6.94%, while Indonesia achieved 5.43%. For both countries, physical capital and TFP were the two major factors that contributed towards their GDP growth in the recent decade, whereas growth in labor contributed positively—0.9%p (12.9%) in India and 0.6%p (11.4%) in Indonesia. Compared to the other factors, human capital made the smallest contribution to their GDP growth.

During the same sample period from 2010 to 2019, South Korea's annual GDP growth rate was 3.3%. The accumulation of physical capital contributed highest toward GDP growth, accounting for 1.8%p (54%), whereas TFP growth contributed 0.7% p (22.3%) to GDP growth. The contribution of human capital and labor to GDP growth were about 0.5%p (14%) and 0.3%p (10%), respectively.

Japan's annual GDP growth was at around 1.2%, which is the lowest among the six selected economies, whereby TFP contributed 1.4%p to GDP growth, while physical capital and human capital contributed about 0.2%p each to GDP growth. Decline in labor contributed negatively

[5] If the working age population declines, the labor force is expected to decrease accordingly. However, to calculate the labor force more accurately as the total number of employed persons, changes in the demographic structure by age, sex, and education level, and changes in the employment rate for each group must be considered. For example, women's labor force participation and employment rates deepen the labor force. In addition, the total number of employed people varies based on the employment rate of the elderly aged 65–79 years. The employment rate of the elderly is on the rise in Korea, increasing from 37.6% in 2015 to 43.9% in 2022 (Statistics Korea, 2022).

[6] The reliability of Chinese growth data is controversial. The PWT 10.1 provides much lower estimates than the IMF or the World Bank, suggesting an annual average GDP growth of only 4.9% during the period from 2010 to 2019. According to the growth accounting results reported in the PWT 10.1, physical capital accumulation contributed the most toward GDP growth, accounting for 4.6%p (about 93%). Conversely, TFP growth had a negative contribution of -0.5%p (-9.5%) to GDP growth during this period.

-0.6%p to GDP growth.

The US economy achieved an annual average growth rate of 2.25% from 2010 to 2019. The largest contributor to GDP was TFP growth, accounting for 1.3%p (about 57%). Physical capital growth contributed 0.5%p (24%), while labor and human capital made smaller contributions of around 0.3%p (15%) and 0.1%p (4%), respectively.

Table 1 shows that labor force was not a major factor that affected economic growth directly in Asia over the past decade. In most countries, compared to labor force growth, physical and human capital accumulation and technological progress played a more significant role in economic growth.

We can also assess, based on the projected demographic changes, what would be the projected GDP growth rates of the six selected economies in the upcoming five decades between 2022 and 2070? Applying the growth accounting framework, we can estimate how much the change in working population growth directly affects GDP growth rates. We estimate the contribution of labor force growth to GDP growth rates over two periods, 2023–2050 and 2051–2070, assuming that the average labor share during the 2010–2019 period would remain unchanged.

Table 2 presents the results of our estimation. The change in GDP growth rates due to the working population growth rate is calculated by multiplying the average forecasted growth rate in the working population and the average labor share. The results show that demographic change will undermine growth across all the major Asian economies and the US over the next five decades.

As discussed in the Section II, the growth rate of the working-age population in China is projected to decline from 0.1% in 2010–2019 to -0.9% in 2023–2050 and -1.14% in 2051–2070. It is estimated that this demographic change alone will reduce China's average GDP growth rate by 0.6%p over the period 2023–2050 and by 0.8%p during 2051–2070 as compared to the growth rate over the period 2010–2019. This result, based on the growth accounting analysis, indicates that decline in the labor force will not solely reduce China's future growth potential significantly.

For India, the working-age population growth rate will reverse from 1.7% in 2010–2019 to 0.5% in 2023–2050 and -0.4% in 2051–2070. Consequently, due to this negative demographic change, India's average GDP growth rate is expected to reduce about 0.7%p in 2023–2050 and 1.1%p in 2051–2070 versus the growth rate observed during the period 2010–2019.

Similarly, Indonesia's working-age population growth rate is projected to decrease from 1.3% to 0.4% in 2023–2050 and further decline to -0.1% in 2051–2070. Consequently, demographic changes alone will have a negative impact on the average GDP growth rate, causing a decline of about 0.4%p in 2023–2050 and 0.7%p in 2051–2070, relative to the growth rate observed during 2010–2019.

Japan's working population growth will continue to decline from -1.0% in 2010–19 to -1.1% in 2023–2050, with a slight increase to -0.9% in 2051–2070. These demographic changes alone will result in an average GDP growth rate decrease of 0.1%p during the period 2023–2050 and an increase of 0.1%p in 2051–2070 versus the growth rate observed in 2010–2019.

South Korea will experience a sharp reversal in the working-age population growth, shifting from 0.7% in 2010–19 to -1.5% in 2023–2050 and -1.9% in 2051–2070. It is estimated that demographic change alone will reduce the average GDP growth rate by about 1.1%p in 2023–2050 and by about 1.3%p in 2051–2070 versus the growth rate observed during the period 2010–2019.

In the US, the working-age population growth will decline from 0.6% in 2010–2019 to 0.1% in 2023–2050 and -0.1% in 2051–2070. Owing to this negative demographic change, The US' average GDP growth rate will be reduced by about 0.2%p in 2023–2050 and 0.4%p in 2051–2070 relative the growth rate observed from 2010 to 2019.

These estimates of labor contribution to GDP, based on the growth accounting approach, are informative. However, the equilibrium economic growth rate will not change in proportion to the change in the contribution of labor force to the GDP growth rate calculated by the growth accounting technique. Other important growth factors, such as physical and human capital accumulation and technological progress, also play a vital role in determining the growth rate, as they can be affected by changes in the labor force. Physical capital accumulation tends to slow down with a lower labor force growth rate because a smaller labor force declines the average productivity of physical capital per labor. By contrast, physical capital accumulation can grow rapidly when labor force growth rate is lower, depending on the characteristic of the production function, that is, the extent to which physical capital substitutes for labor.[7]

According to Romer's (1990) endogenous technological progress model, a large population or market size increases the profitability of technological innovation, leading to a higher rate of technological progress. Conversely, Jones (1995) posits that the rate of technological progress is determined by the population growth rate, not population size. Recent studies also suggest that the population (labor force) growth rate plays a pivotal role in shaping the market entry strategies of new firms (Hopenhayn et al., 2022). In contrast to these models, Acemoglu's (2002, 2008) theory of directed technological change suggests that a population decline can stimulate technological progress and capital accumulation. Faced with a shrinking labor force, firms may increase investments in physical and human capital and develop labor-saving technologies, to compensate. This shift can lead to the development of more capital- and technology-intensive industries.

IV. AN ENDOGENOUS GROWTH MODEL

To assess the overall growth effect of demographic change, we present a growth model in which physical capital accumulation and the rate of technological progress are endogenously determined. We assume that physical capital accumulation and the rate of technological progress are determined based on a given population growth path. The values of various parameters, including the characteristics of the production function, are also assumed. The model considers the impact of labor force change on capital accumulation and technological progress and the impact of population age structure change on the saving rate. Additionally, human capital accumulation, which improves labor quality, is endogenously determined.

The standard growth model, such as the neoclassical growth model described by Barro and Sala-i-Martin (2004), suggests the "conditional convergence of income," in which a country with a low level of initial income per capita relative to its long-run or steady-state level of potential income per capita will tend to grow faster than a country that is already approaching

[7] In the case of the constant elasticity of substitution (CES) production function with the elasticity of substitution between labor and physical capital greater than 1, if the labor force growth rate is lower, the growth rates of physical capital per labor and output per labor are higher. As capital accumulates, the average product of capital per labor converges to a positive value that decreases with the labor growth rate (Barro and Sala-i-Martin, 2004).

its potential, if other conditions such as population (labor force) growth, saving rate, and technological progress, remain constant. This is attributable to the fact that physical and human capital levels in lower-income countries are far away from their long-run levels, and thus lower-income countries can accumulate capital more quickly than advanced economies. A country with a significant gap would be able to initiate a rapid catching-up process through higher rates of physical and human capital accumulation, owing to better rates of return on investment. This model implies that India, with its lower per capita GDP, has the potential of growing faster than China or the US. However, a low-income economy's growth rates will decline as it increases per capita income, approaching its long run level.

In the neoclassical growth model, various external environments and policy variables will affect growth rates by changing the steady-state level of output per worker or the steady-state growth rate. The important determinants of steady-state output per capita include population growth and saving rate. A higher rate of population growth will lead to less capital being available per worker, thus lowering the steady-state level of output per worker. This leads to a lower output per worker growth rate over the transition period to the steady-state level. Conversely, a higher saving rate increases the steady-state level of output per worker, resulting in a higher growth rate of output per worker during the transition period. Technological progress, which is assumed to be exogenous in this model, determines the long-run growth rate of output per worker in the steady state.

We have extended the standard neoclassical growth model by adding the endogenous determination of technological progress. Countries innovate modern technologies by investing in research and development (R&D) (Romer, 1986). Additionally, developing countries adopt technology imitation from technologically advanced economies to narrow their technology gap and accelerate technological diffusion (Nelson and Phelps, 1966).

We also factor in the fact that workers encompass diverse levels of human capital (quality of labor). Human capital accumulation happens through education and job experience and training. Human capital is a crucial factor contributing to economic growth (Lucas, 1988; Barro and Lee, 2013, 2015). Improvement in human capital will affect the growth rate by changing the steady-state level of physical capital per worker or output per worker. Human capital growth can also directly change the growth rate of output per worker.

In the model economy, the production function of an economy is defined as follows:

$$Y_t = F(K_t, A_t h_t L_t), \tag{1}$$

where Y_t is total production, K_t and L_t represent physical capital and labor respectively, A_t represents the level of technology, and h_t denotes human capital per capita. The neoclassical production function follows the law of diminishing marginal product. We assume labor-augmenting technological progress.

We assume the following CES production function:

$$Y_t = \left[\alpha K_t^{\rho} + (1-\alpha)\big((1-u)h_t L_t A_t\big)^{\rho}\right]^{1/\rho},\ 0 < \alpha < 1,\ \rho < 1, \tag{2}$$

where α is a value between 0 and 1, and it indicates the degree to which physical capital contributes to the production of final goods. ρ is a substitution parameter between labor and physical capital and takes a value of $\rho < 1$. ρ determines the elasticity of substitution between physical capital and effective labor, σ. That is, $\sigma = 1/(1-\rho)$. The elasticity of substitution σ represents the degree to which labor and capital are substituted for changes in the relative prices of capital and labor. If $\sigma > 1$, when the relative price of physical capital and labor changes, the input ratio of physical capital and labor experience a relatively large change compared to their price change. The model economy invests a certain fixed portion, $0 < u < 1$, of the total labor force (including human capital) in human capital accumulation, and the remaining $1-u$ in production.

The population growth rate is assumed to equal the labor force growth rate. We assume that labor force, measured by the working age population (those aged 15–64 years), will grow based on UN (2022) population projections that assume medium changes in future levels of fertility, mortality, and international migration, as displayed in Figure 5. The population growth rate n_t changes every period but is assumed to be constant in the long-run equilibrium.

$$\dot{L_t} \equiv \frac{dL_t}{dt} = n_t L_t \Leftrightarrow L_t = L_0 e^{n_t t}, \lim_{t\to\infty} n_t = n^{ss} \tag{3}$$

The growth of human capital per capita h is determined by the investment in human capital accumulation and the efficiency parameter.

$$\dot{h_t} = B(uh_t)^{\varepsilon}, B > 0\ , \varepsilon \le 1 \tag{4}$$

Here, B is an efficiency parameter that determines how quickly human capital increases with the same amount of human capital investment. The parameter ε represents the effect of the size of the accumulated human capital stock, which has a positive spillover effect on the growth rate of human capital. On one hand, if $0< \varepsilon \leq 1$, the size of accumulated human capital stock has a positive impact on the human capital growth rate. On the other, if $\varepsilon < 0$, it becomes more difficult for human capital to grow because the accumulated human capital stock increases. This difficulty can be observed in the challenge of improving the average educational attainment of workers over time.

Physical capital accumulates over time responding to the change in returns to physical capital investment, given the country-specific investment rate (s_t) and depreciation rate (δ). The growth rate of K is derived from

$$\dot{K}_t = s_t Y_t - \delta K_t \tag{5}$$

In the Solow-type neoclassical growth model, the saving rate is exogenously given and constant, $0 \leq s \leq 1$. In the neoclassical growth model with consumer optimization, households can choose their consumption and saving to maximize their lifetime utility. The representative consumer optimization model indicates that the saving rate is a complex function of preference parameters and lifetime income. Conversely, the life cycle model indicates that the demographic structure determines the saving rate. The old-age dependency ratio, which is the ratio of population aged 65 years or above the working-age population, has a negative impact on the saving rate, as the elderly only consume savings that they have accumulated in the past. Similarly, the youth dependency ratio, which is the ratio of the population aged 14 years or younger to the workforce, also has a negative impact on the saving rate, as children tend to consume without income. Several empirical studies show that the income variable and the old-age and youth dependency ratios determine the saving rate (Horioka and Terada-Hagiwara, 2012; Grigoli, Herman, and Schmidt-Hebbel, 2018). Following the abovementioned studies, we consider that saving rates depend on the change in per capita income and old-age and youth dependency ratios.

$$s_t = s(\tfrac{Y_t}{L_t}, \text{old} - \text{ age}, \text{ youth}, \dots) \tag{6}$$

where aged is the age dependency ratio and youth is the youth dependency ratio.

The formula (5), combined with the production function, can be rewritten for the growth rate of physical capital per capita as follows.

$$\frac{(K_t \dot{/} L_t)}{(K_t/L_t)} = s_t \left(\frac{Y_t}{K_t}\right) - (n_t + \delta) = s_t \left[\alpha + (1-\alpha)\left(\frac{K_t}{(A_t(1-u)h_t L_t)}\right)^{-\rho}\right]^{1/\rho} - (n_t + \delta) \tag{7}$$

Consider the case where the amount of per capita physical capital increases. The greater the elasticity of substitution (i.e., the closer the value of ρ is to zero), the higher the growth rate of physical capital per person. This is because the average productivity of physical capital $\left(\frac{Y_t}{K_t}\right)$ is higher with the higher value of substitution elasticity at the same capital-labor ratio. When the elasticity of substitution among factors of production is high, physical capital can substitute for scarce labor.

We consider countries that acquire new technologies either by innovating them or by adapting from countries at the frontier of technological development. Technological progress equation is assumed as follows:

$$\dot{A_t} = \psi_x (L_t h_t)^{\lambda} A_t^{\varphi}, 0 \ \leq \lambda \leq 1, \varphi \leq 1 \tag{8}$$

In the above equation, advancement in technology (knowledge) is determined by the size of the total labor force (including both labor quantity and quality) and the stock of technology (knowledge). ψ_x is an efficiency parameter of country x.

In the endogenous technological change model, technological progress is determined by the population of the economy (Romer, 1990). The size of the profit that a company can obtain from technological innovation depends on the market size, and population size is a key factor that determines the market size. Also, the larger the population, with a higher level of human capital, the greater the pool of workers who can improve their knowledge and generate ideas through learning-by-doing and externalities. The parameter λ determines the proliferation of new ideas associated with the increase in population through market size or learning-by-doing effects. λ is assumed between zero and one (Jones, 1995).

The parameter φ represents the influence of the technology stock on new technology development. If $\varphi > 0$, the accumulated technology supports new technology development, corroborating Isaac Newton's famous statement "…standing on the shoulders of giants". If

$\varphi < 0$, it indicates that technologies are more developed, and the more difficult it is to develop new technologies. Bloom et al. (2020) show that the spillover effect of existing technologies on innovation is negative in advanced countries, implying that it is becoming difficult to find new ideas.

In developing countries, technological progress is also driven by technological imitation. The key assumption is that it is less expensive for the follower country to imitate the technology than to reinvent the technology on its own. This cost of replicating technology is lower when the follower (country x)'s technology gap with the leading country (US) is wider. This technology imitation effect provokes the assumption that the efficiency parameter is higher in a low-income country.[8]

$$\psi_x = \varphi(\mathrm{A_x}),\ \varphi' < 0 \tag{9}$$

If the production function of (1) is differentiated by time (t), the growth accounting formula is obtained (Barro and Sala-i-Martin, 2004). The formula can be rewritten in per capita terms as follows.

$$\frac{(Y_t\dot{/}L_t)}{(Y_t/L_t)} = \alpha_K \frac{(K_t\dot{/}L_t)}{(K_t/L_t)} + (1-\alpha_K)\left(\frac{\dot{A_t}}{A_t} + \frac{\dot{h_t}}{h_t}\right), \tag{10}$$

where α_K and α_L indicate the contribution of physical capital (K) and technology-embodied labor (hLA) to total output, respectively. In the neoclassical production function with constant returns to scale, the sum of α_K and α_L is equal to 1. According to (10), the per capita GDP growth rate is determined by per capita physical capital and human capital growth rates and technological progress.

According to the model, population change alters the growth of per capita physical capital and technological progress. The change in the rate of technological progress and the rate of human capital accumulation has a direct impact on the per capita GDP growth.

[8] Alternatively, we can assume that $\psi_x = \psi_{US}\left(1 + c\left(\frac{A_{us}}{A_x}\right)\right),\ c^{'} < 0,\ c(1) = 0$.This equation implies that as the ratio of $\frac{A_{us}}{A_x}$ approaches 1, the cost of copying technology in country x approaches the cost of invention in the US.

V. GROWTH PROJECTIONS OF ASIAN ECONOMIES

A. Baseline Scenario

Consider an economic system composed of the equations in Section IV. Consistent with the growth model's parameter values and the country-specific initial values of economic conditions such as population growth, human capital growth, investment rate, and technological growth, we conduct simulations of the growth model to determine the GDP and per capita GDP of the five major Asian economies and the US by 2070. We analyze the balanced growth path in the transition to the steady state.

Parameter values

For the production function, we assume the depreciation rate for physical capital, $\delta = 0.05$ for all countries. Regarding the elasticity of substitution between capital and labor, we rely on recent studies, including cross-country (Mallick, 2012; Knobloch and Stöckl, 2020) and country-specific analysis, to determine the values for each country. According to Knobloch and Stöckl (2020), while most cross-country regressions indicate elasticity of substitution (σ) that is greater than one, values of σ vary widely among individual countries, with the majority estimates declining below one.

For the US, we set the substitution elasticity at 0.60, based on previous studies. Knobloch and Stöckl's (2020) meta-analysis indicates that most estimates for the elasticity of substitution between capital and labor in the US economy are within the range of 0.45 to 0.87. This range is also consistent with Herrendorf et al.'s (2015) estimates of 0.84 and 0.80 for the US economy and manufacturing sector, respectively. Karabarbounis and Neiman (2014) estimate an elasticity of 1.25 using industry-level data. However, the most recent study (Oberfield and Raval, 2021) estimates that the aggregate elasticity for the US manufacturing sector falls within the range of 0.5–0.7, considering substitution within plants and reallocation across plants.

Unlike the US, previous studies focusing on Asian countries are limited for reference. For China, we set the elasticity of substitution to be around 1.17, based on the recent studies. Although the cross-country analysis done by Mallick (2012) reports a substitution elasticity of around 0.52, recent studies, including those of Manu et al. (2018) and Berkowitz et al. (2017), suggest values above unity. Manu et al. (2018) provides an extensive discussion on the Chinese economy and obtain an estimate for the elasticity of substitution at around 1.17.

For India, we assume an elasticity of substitution of unity. Previous studies by Mallick (2012), Upender (2009), and Pohit et al. (2000) suggest a range of estimates between 0.52 and 1.4. Mallick's estimate at the aggregate level is around 0.52, while industry-cross section analyzes the estimate at around 1.28. Pohit et al. (2000) also find that most industries have estimates around unity.

In the case of Indonesia, we rely on Mallick (2012) as it is the only reference available to the best of our knowledge. This work estimated the elasticity of substitution at around 1.14.

For Japan, there are two contrasting estimates. The cross-country analysis done by Mallick (2012) reports a substitution elasticity of around 0.33, which is lower than that of the US However, a more recent study by Paul (2018) using Japanese industry/sector-level data between 1970–2012 finds that the elasticity substitution fluctuates around unity with an overall average of 0.91. Given that Mallick's estimate is too low, we refer to Paul (2018) for Japan.

Finally, for South Korea, we assume an elasticity of substitution around 1.18, based on the recent study done by Song (2021). The study also obtained weighted averages of 1.26 for the manufacturing and 1.12 for the service sectors when estimating the elasticity of substitution in 48 industries. Mallick (2012) estimated a substitution elasticity of around 1.44.

Note that the greater the elasticity of substitution, the higher the economic growth rate in the balanced growth path. As an economy has a high elasticity of substitution among production factors, it can maintain higher productivity of physical capital while substituting labor with physical capital. Therefore, it is possible to maintain a relatively high rate of increase in per capita physical capital and per capita production.

We estimate the reduced form of the saving equation (6) using the panel data of cross-country data for the six economies from 1980 to 2019.

$$Saving\ rate_{i,t} = \beta_0 + \beta_1 \log(GDPPC_{it}) + \beta_2 \log(GDPPC_{it})^2 + \beta_3 \text{Old} - \text{age} + \beta_4 \text{Youth} + \varepsilon_i + \theta_t + v_{i,t}\,, \qquad (6)'$$

where $Saving\ rate_{i,t}$ represents the real domestic saving rate in country i at time t; $\log(GDPPC_{it})$ is the log of real GDP per capita and $\log(GDPPC_{it})^2$ is its squared term. For $\log(GDPPC_{it})$ and its squared term, we use one-period lagged values. *Old-age* denotes the old-age dependency ratio, and *Youth* represents the youth dependency ratio. Table 3 shows our estimation results. We report country fixed effects models with and without year dummies.

The results are broadly consistent with those of previous studies. The coefficient of Old-age is negative and significant, as the life cycle model predicts. The coefficient of Youth is statistically insignificant. Turning to the GDP-related variables, the coefficient of Log (GDPPC) is positive and significant, with its square term being negative and significant, suggesting a nonlinear (concave) relationship with the domestic saving rate. Initially, the income level has a positive effect on the domestic saving rate, but the marginal effect of income on the saving rate decreases gradually.

We calibrate the human capital equation (4) to fit the historical data from 1980 to 2019 and obtain the parameter ε for individual countries.[9] Following this specification, the average human capital growth rates will decline gradually from the level of the average growth rate over 2015–2019 at different rates for individual countries. Our estimates of ε range from 0.1 for India to -6.3 for Indonesia. These values indicate that it becomes difficult for human capital to grow as the accumulated human capital stock increases.

We estimate the technological progress equation (8) to obtain the parameters' values. The empirical specification is derived by taking a logarithm of the equation.

$$log\ (\dot{A}/A)_{i,t} = \gamma_0 + \gamma_1 \log\left(h_{i,t}L_{i,t}\right) + \gamma_2 log\left(A_{i,t}\right) + \varepsilon_i + \theta_t + v_{i,t}\,, \qquad (8)'$$

where $(\dot{A}/A)_{i,t}$ is country *i*'s technology growth rate at year *t*.[10] The specification controls for country and year fixed effects.

The regression applies to a panel set of cross-country data for the six economies from 1980 to 2019. For estimation, we use one-period lagged values for $\log\left(h_{i,t}L_{i,t}\right)$ and $log\left(A_{i,t}\right)$. Table 4 shows our estimation results. We report country fixed effects models with and without year dummies. The coefficient γ_1 is positive and statistically significant, though marginally. The coefficient γ_2 is negative and statistically significant. The parameters λ and φ can be drawn from γ_1 and γ_2 , such as $\lambda = \gamma_1$ and $\varphi\ = 1 + \gamma_2$, respectively. So, the initial growth rate for technology decreases when the labor force declines and technology level increases over time.

[9] Estimation results will be available upon the request.

[10] We use the logarithm of the linear transformation of the dependent variable, log (0.171+ $(\dot{A}/A)_{i,t}$) to avoid the logarithm of negative values. The minimum value for the technology growth rate is -0.17 in the sample.

Based on the panel regression results, we set λ=0.165 and φ=0.737 as the values of the parameters in the technological progress equation.

The initial values for GDP growth are obtained from the IMF's World Economic Outlook Database, October 2022. The working-age population growth is obtained from the UN World Population Prospects 2022. Per capita GDP growth is calculated. The initial values of human capital growth, saving rate (measured by real domestic investment rate), technological growth, and the output share of physical capital are obtained from PWT 10.1. Technological growth is measured by TFP growth divided by labor share. We take the average of these variables from 2015–2019 to construct their initial values for individual countries.[11] Therefore, we assume that Asian countries will revert to their pre-pandemic equilibrium growth trajectory after recovering from the COVID-19 shock.

Projection results

A summary of our baseline projections for the selected countries—China, India, Indonesia, Japan, South Korea, and the US—is reported in Figure 6 and Tables 5−6. Figure 6 depicts the simulation results for the six economies, showing the population growth rate (working-age population), human capital growth, technological progress, saving rate, output per capita growth, and total output growth along the transition path approaching the steady-state in this model. Table 5 provides our projections for GDP and per capita GDP growth rates across three different periods—2010–2019, 2023–2050, and 2051–2070. The projection results in terms of GDP and per capita GDP are reported in Table 6 and illustrated in Figures 8–9.

The simulation results for China are presented in Figure 6a). The rate of technological progress is forecasted to decrease from its initial value of 2.7% to 2.0% by 2070. The saving rate is likely to start declining from its initial value of 47% to 29% by 2070. Our projections imply that China is experiencing a significant slowdown in potential GDP growth, declining from 7.7% in 2010–2019 to 3.9% in 2023–2050 and 1.3% in 2051–2070 (Table 5). This slowdown is driven by a decline in labor force growth, physical capital accumulation, and technological

[11] As discussed in Footnote 5, there is a difference in the GDP growth rate between the IMF and PWT 10.1 for China. According to the IMF database, the average annual GDP growth rate for China declined from 6.7% over the period 2015–2019 to 5.9% during 2015–2022. After considering the estimates from PWT 10.1 and the lower GDP growth rate in recent years, we have decided to set the initial value of China's average annual GDP growth rate at 6.0% with a reduced TFP growth rate.

growth, and this could result in China's potential growth rate declining well below that of India and Indonesia.

Despite the slower pace of the catch-up, it is projected that the Chinese economy will continue to narrow its per capita income gap with that of the US. By 2070, China will reach 114,844 USD and 76.2% of the US per capita income in constant 2017 PPP price (Table 6). However, in terms of GDP, it is projected to demonstrate continuous growth, exceeding the US over the next 50 years. In terms of per capita income, China is expected to overtake Japan by 2050 (Figure 8).

India's simulation results are illustrated in Figure 6b). India is expected to experience a gradual decline in the rate of technological progress from its initial value of 4.3% in 2015–2019 to 3.0% in 2070. In addition, the saving rate is expected to increase from 29%, the initial value during the 2015–2019 period, to 35% in 2046, but reverse course and decline to 29% in 2056. The GDP and GDP per capita growth rates of are expected to decrease significantly, reaching 3.2% and 3.8% in 2070, respectively. The average annual GDP growth rate for the period 2051–2070 is expected at 4.2%, and the GDP per capita growth rate at 4.5% (Table 5).

According to our projections, the potential GDP growth of the Indian economy is forecasted to decline from 6.9% in 2010–2019 to 6.2% in 2023–2050, and further decline to 4.2% during the period 2051–2070 (Table 5). This is because both the rate of return to physical capital investment and the speed of technological catch-up are lower. Nevertheless, the Indian economy is likely to have higher growth potential than the other selected countries, over the next 50 years. However, India's actual growth path may deviate from this projected potential growth path depending on the country's policies and unexpected shocks. If India can achieve its higher potential growth rate, then the Indian economy is likely to continue to narrow its per capita income GDP to other Asian countries and the US. By 2070, India will reach 78,371 USD, equivalent to 52% of the US per capita income in constant 2017 PPP price (Table 6). India can surpass the US in terms of GDP by 2050, attributable to its more favorable demographics and higher per capita GDP growth. India is also projected to overtake China in terms of GDP by 2070 (Figure 9).

Indonesia presents a similar growth trajectory, as demonstrated in Figure 6c). The Indonesian economy is projected to have an inverted u-shaped growth potential over the next 50 years—5.6%

in 2023–2050 and 3.3% in 2051–2070, relative to 5.4% in 2010–2019 (Table 5). With its higher potential growth rate, Indonesia is expected to undergo a process of catching up with China, Japan, and the US. By 2070, Indonesia's per capita income is expected to reach around 76,961 USD, accounting for about 51% of the US per capita income in constant 2017 PPP price (Table 6). By 2050, the Indonesia's GDP is likely to be nearly twice that of Japan (Figure 9).

Figure 6d) presents the simulation results for Japan. The rate of technological progress is expected to drop to 1.3% by 2070 from its initial value of 1.7%. The saving rate is expected to decline from its initial value of 25% to 17% in 2045, gradually declining to 14% by 2070. According to our projections, the Japanese economy will experience a declining growth potential. Its potential GDP growth is forecasted to decline from 1.2% in 2010–2019 to 0.5% in 2023–2050, and further to 0.1 in 2051–2070 (Table 5). Given these low growth rates, the Japanese economy will be unable to significantly narrow its per capital income gap with that of the US. By 2070, Japan's per capita income will reach 76,942 USD, which is about 51% of the US's per capita income in constant 2017 PPP price (Table 6).

The simulation results for South Korea are demonstrated in Figure 6e). The South Korean economy demonstrates a slow decline in the rate of technological progress from its initial value of 0.8% to 0.7% in 2070. Additionally, it will experience a considerable decrease in the saving rate, down from its initial value of 39.9% to 4.3% in 2070, and this is attributable to rapid population aging and per capita income increase. Our projections indicate that the South Korean economy will experience a rapid decline in GDP growth rate, declining from its initial value of 2.6% to -2.5% by 2070.

Similar to the Japanese economy, the South Korean economy is projected to face declining growth potentials. Its GDP growth rate is forecasted to decline from 3.3% in 2010–2019 to 0.5% in 2023–2050 and further to -1.9 % in 2051–2070 (Table 5). Similarly, its per capita GDP growth rate is also projected to decrease, albeit less steeply, from 2.8% in 2010–2019 to 2.0% in 2023–2050 and further to 0.01% in 2051–2070. Given these low growth rates, it is forecasted that the South Korean economy will not be able to continuously narrow its per capita income gap with that of the US over the next 50 years. By 2070, South Korea will reach 79,364 USD, which is equivalent to 53% of the US's per capita income in constant 2017 PPP price (Table 6).

Lastly, Figure 6f) presents the simulation results for the US. The rate of technological progress is projected to decline modestly from its initial value of 2.4% to 1.8% by 2070, and the saving rate shows a decline from its initial value of 18.6% to 7.4% by 2070. According to our projections (Tables 5 and 6), the US economy is forecasted to experience a modest decline in its growth potential from 2.3% in 2010–2019, to 2.1% in 2023–2050 and 1.6% in 2051–2070. By 2070, the US is estimated to reach 150,759 USD in constant 2017 PPP price.

B. Alternative Scenarios

We present additional projections for the GDP and per capita GDP growth rates for the five major Asian countries and the US under four alternative scenarios: 1) constant technological progress; 2) slower decline in saving rate; 3) constant human capital growth; 4) constant technological progress, slower decline in saving rate, and constant human capital growth.[12] To elaborate, in the first alternative scenario with constant technological progress, we assume that the rate of technological progress will not change over the next 50 years. In the second alternative scenario, we assume a slower decline in the saving rate. The saving rates for China, South Korea, Japan, and the US will decrease at half the pace of the baseline scenario over the next 50 years. Additionally, for India and Indonesia, their saving rates will decrease at half the pace of the baseline scenario after peaking in 2045 and 2034, respectively. In the third alternative scenario, we consider constant human capital growth, assuming that the rate of growth in human capital will remain constant over the next 50 years. The fourth alternative scenario combines the assumptions of all the previous scenarios.

The projection results are demonstrated in Figure 7. In most of the selected countries, in terms of the GDP growth rate, the alternative scenarios outperform the baseline scenario. As expected, by maintaining the initial rates of technological progress and human capital growth while implementing a slower decline in saving rate, the economy is poised to achieve higher GDP growth rates, surpassing those projected in the baseline scenario.

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[12] We can also consider an alternative scenario in which the value of substitution elasticity (σ) changes due to industry upgrading, improvements in labor quality, changes in production technology, and more. However, in an environment where technological innovations, such as artificial intelligence (AI), are occurring rapidly, predicting how the value of σ will change in the future becomes quite challenging. Nonetheless, to provide an example of assessing the impact of σ value changes for the Chinese economy, we have analyzed a scenario that assumes a gradual decline of σ to 0.9 (Japan's value) over the next ten years, followed by a further gradual decline to 0.6 (US value) from 2051 to 2060. The simulation results demonstrate that the annual GDP growth rates predicted in this alternative scenario are, on average, lower by about 0.7%p over the period from 2023 to 2050, and about 0.2%p over the period from 2050 and 2070 versus those in the benchmark scenario. Conversely, if the value of the substitution elasticity (σ) increases from its current value of 1.17 to 1.4, the growth rates are, on average, higher by about 0.7%p over the period from 2023 to 2050 and about 0.3%p over the period from 2050 and 2070 versus those in the benchmark scenario. The detailed estimation results will be available upon request.

In addition to those estimated under the baseline scenario, Table 5 reports the projections results under Scenario 4 where we assume a slower decline in the saving rate and both constant technological progress and human capital growth.

Based on our projections under this alternative scenario in Table 5, China's average annual GDP growth is estimated to decline to 2.5%, which is higher than the 1.3% estimated under the baseline scenario over the period of 2051 to 2070. Similarly, per capita GDP growth is projected at 3.9% during the same period, compared to the 2.7% estimated under the baseline scenario. Given these higher growth rates, the Chinese economy under this alternative scenario will continue to narrow its per capita income gap with that of the US at an accelerated pace compared to the baseline scenario. By 2070, China will reach 159,449 USD, which is 39% higher than the baseline scenario (Table 6). This presents about 85% of the US per capita income in constant 2017 PPP.

India’s average annual GDP growth is estimated to decrease to 5.3%, which is about 1.2%p higher than the baseline scenario over the period, 2051–2070 (Table 5). India’s per capita GDP growth is projected at 5.7% during the same period, surpassing the 4.5% estimated under the baseline scenario. By 2070, India will reach 109,436 USD, which is 40% higher than the baseline scenario (78,371 USD) and represents 40% of the US per capita income in constant 2017 PPP (Table 6). In addition, the size of India’s economy, in terms of real GDP, is projected to surpass that of the US by 2050 and China by 2070 (Figure 9).

Indonesia’s average annual GDP growth is estimated to decline to 3.9% over the period, 2051–2070, which is about 0.6%p higher than the baseline scenario. Similarly, per capita GDP growth is projected to be 4.0% during the same period, compared to the estimated 3.3% under the baseline scenario. Over the next 50 years, the Indonesian economy will show a similar per capita income trajectory with the Indian economy. As shown in Table 6, by 2070, Indonesia will reach a per capita income of 91,217 USD in constant 2017 PPP, which is 19% higher than the estimated 76,961 USD under the baseline scenario. It represents 48% of the US’s per capita income.

According to our projections under this alternative scenario in Table 5, Japan’s average annual GDP growth is estimated to decline to 0.8%, which is higher than the 0.1% estimated under the baseline scenario, over the period 2051–2070. Similarly, per capita GDP growth is projected at 1.6% during the same period versus the 1.0% estimated under the baseline scenario.

By 2070, Japan will reach a per capita income of 94,003 USD, which is 22% higher than the baseline scenario (Table 6). This represents 50% of the US's per capita income in constant 2017 PPP.

For South Korea, the average annual GDP growth is estimated to decrease to -0.3%, which is 1.6%p significantly higher than the baseline scenario of -1.9% over the period, 2051–2070 (Table 5). South Korea is projected to achieve 1.7% per capita GDP growth during the same period, which is 1.7%p higher than the baseline scenario. Under the alternative scenario, South Korea will likely reach a per capita income of 131,506 USD, about 66% higher than the baseline scenario (79,364 USD). This will considerably narrow its income gap with the US, as it will reach 66% of the US per capita income in constant 2017 PPP (Table 6).

As shown in Table 5, the US's average annual GDP growth is estimated to decrease to 2.3%, which is 0.7%p higher than the baseline scenario of 1.6% over the period 2051–2070. The US is projected to achieve 2.3% per capita GDP growth during the same period, which is also higher than the 1.6% estimated under the baseline scenario. With its modest growth rates, the US will maintain a higher per capita income among the selected economies over the next 50 years. By 2070, the US will reach an income per capita of 188,559 USD, which is 25% higher than the baseline scenario (150,759 USD).

Our simulation results with the baseline and alternative scenarios highlight that demographic change, specifically a declining working-age population, is not the only major factor influencing economic growth. This finding is consistent with our growth accounting results in Table 1. For example, China's rapid GDP growth rates from 2010 to 2019 are primarily attributed to physical capital accumulation and TFP growth, rather than labor force growth. Similarly, both the baseline and alternative simulation results in Table 5 imply that the significant decline in China's GDP growth rates over the next 50 years will largely be the outcome of physical capital accumulation and TFP growth. Additionally, for South Korea, when comparing the baseline and alternative simulation results, we observe that the pace of physical accumulation and technological progress can mitigate substantially the negative impact of a declining working-age population on per capita income growth.

In addition, both our simulation results discussed earlier indicate a significant slowdown in the growth rates of all five Asian economies, while the US is expected to maintain more consistent growth over the next 50 years. Consequently, the convergence of emerging Asian economies with the US in terms of per capita income is expected to continue, yet it is unlikely that the major Asian economies will match the US level of per capita GDP. Nevertheless, the overall Asian economy will sustain its significant expansion, primarily driven by China and India. China has already surpassed the US in terms of PPP-adjusted GDP and is projected to significantly close the gap with the US, even in terms of PPP-adjusted per capita GDP, over the next 50 years. India is also expected to surpass the US in terms of PPP-adjusted GDP in the late 2040s.

VI. CONCLUSION

This study presents an analysis of the economic prospects of the five major Asian countries and the US over the next 50 years, focusing on the impact of demographic changes. Our endogenous growth model suggests that population growth will not solely determine the equilibrium economic growth rate. In determining the growth rate, factors such as the accumulation of physical and human capital, technological progress, and the elasticity of substitution between physical capital and labor contribute substantially. The simulation results imply that the five Asian economies can improve their respective potential growth rates by replacing labor shortages with capital and technology, while simultaneously improving the quality of the labor force, promoting technological progress, and maintaining a high level of investment in physical capital.

To mitigate the adverse impact of population aging and a shirking workforce on the economic growth, Asian countries should adopt proactive and effective strategies. Primarily, enhancing the quantity and quality of the workforce is essential. The labor market should encourage greater participation of females and the elderly and encourage active migration flows. Furthermore, to accumulate human capital, it is necessary to improve the education system and implement training programs. The education system must address the challenges posed by rapidly changing industry structures and technologies. Strengthening lifelong education and skill training would be helpful in enhancing the productivity of workers, especially older employees.

Additionally, efforts should be made to foster technological innovation and physical capital accumulation by developing technological capabilities, infrastructure, and systems that match advanced countries. Asian countries also need to increase their returns on savings or investments. Implementing fiscal measures and enhancing pensions can be considered to improve national savings.

Asian economies, through effective policies and reforms, can experience higher growth and emerge as major global players, thus potentially transforming the global economic and geopolitical landscapes. This economic growth of these five Asian countries can foster increased cross-border exchanges and deepen trade and investment within the region, fueled by a growing middle class and industry upgrading. This increased interdependence within Asia presents opportunities for strong growth.

However, Asia's ascent also heightens geopolitical risks, both within the region and on a global scale. The willingness of major players to prioritize global peace and prosperity over their own national interests remains uncertain. The world witnessed the US–China trade tensions and technology rivalry, as well as geo-economic fragmentation. These events have had significant repercussions on Asia and the global economy. As Asian countries begin to gain influence on the regional and global stages, it is crucial for the major economies, including China, India, and the US, to work together to reduce conflicts and hostilities, while actively fostering cooperation and collaboration.

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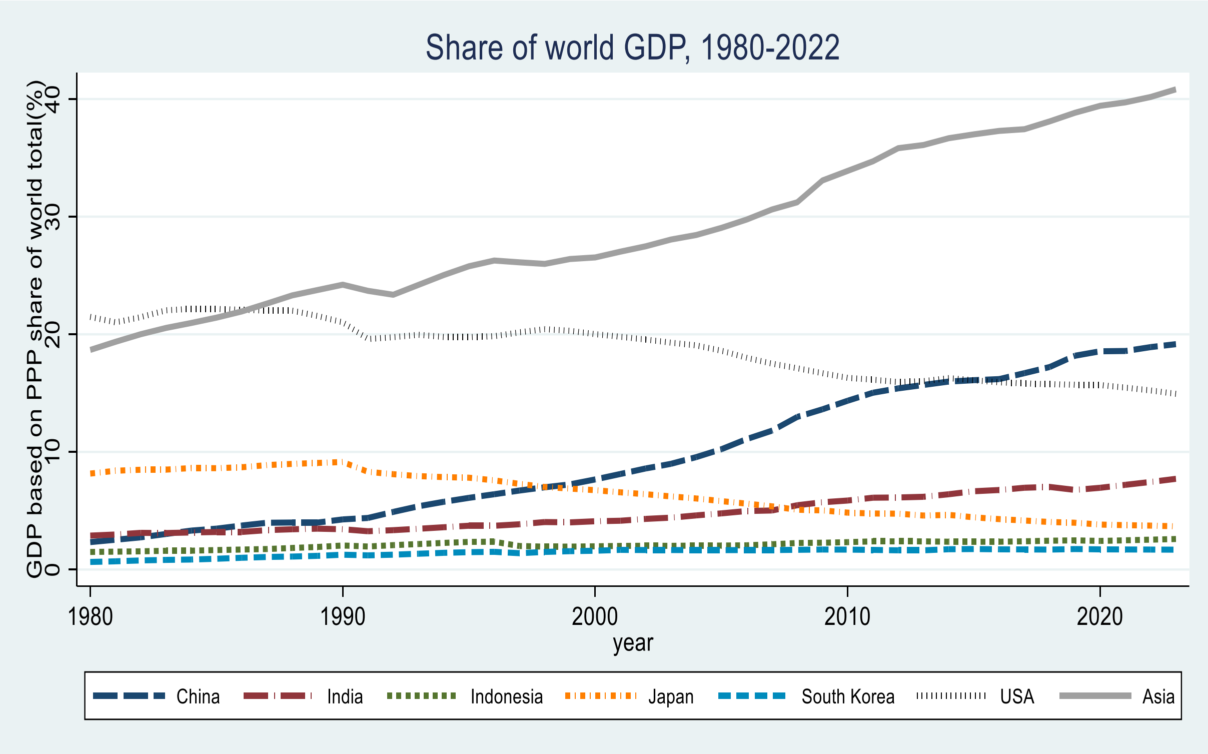
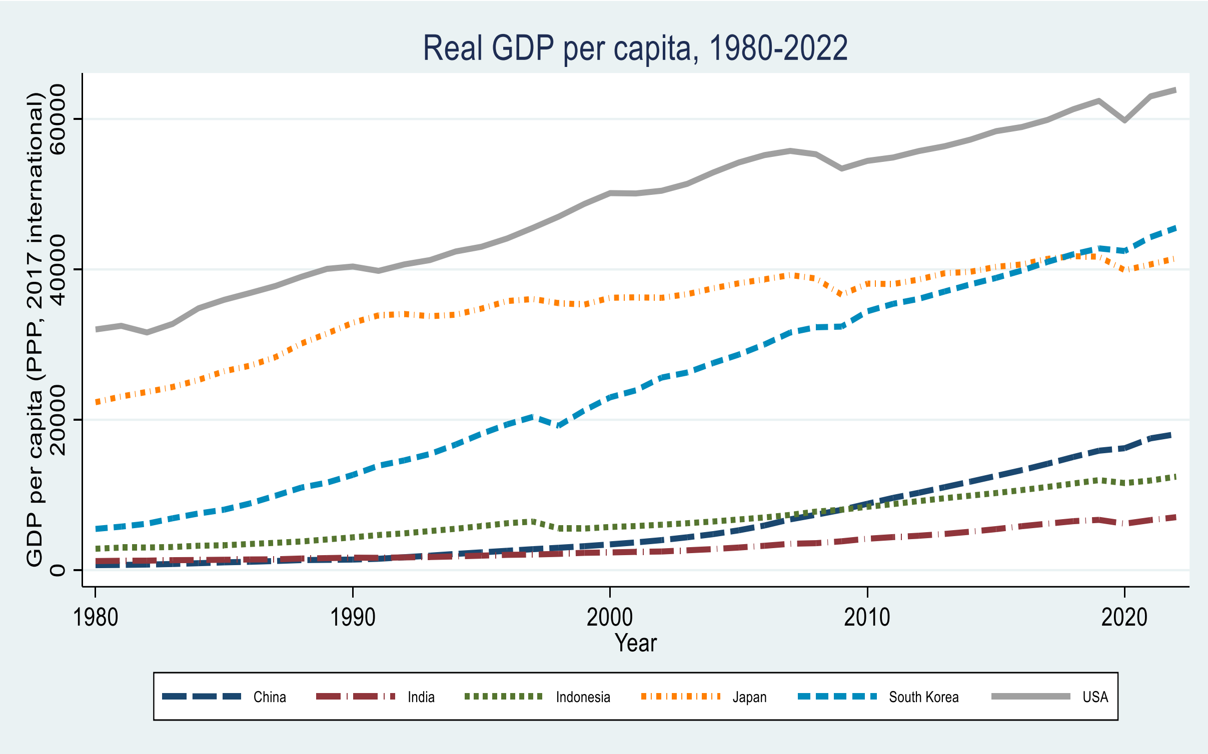
Figure 1: Trend of GDP Share in 1980~2022, Asia and Selected Economies (%)



Notes: Asia comprises countries in the "emerging and developing Asia" group and six advanced economies, including Hong Kong SAR, Japan, South Korea, Macao SAR, Singapore, and Taiwan Province of China (https://www.imf.org/external/pubs/ft/weo/2022/02/weodata/groups.htm)

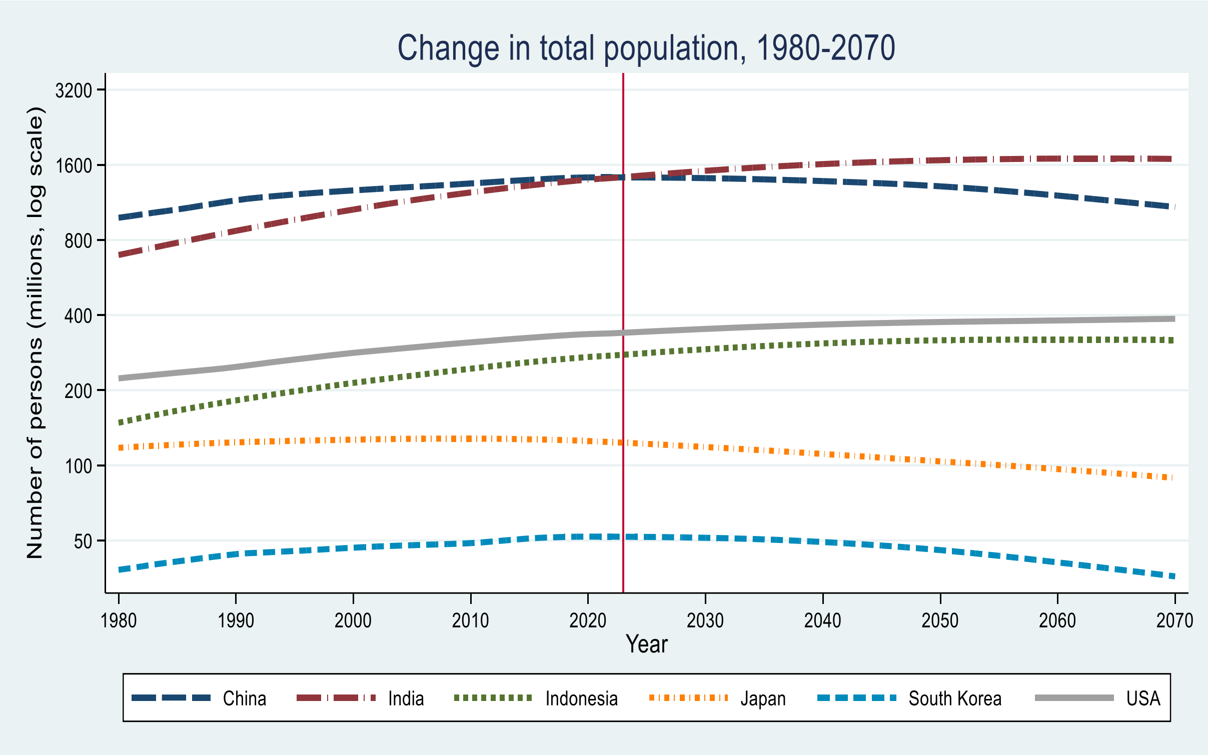
Source: International Monetary Fund's (IMF) World Economic Outlook Database: October 2022 (https://www.imf.org/en/Publications/WEO/weo-database/2022/October)

Figure 2: Per capita GDP (PPP) of selected economies, 1980–2022



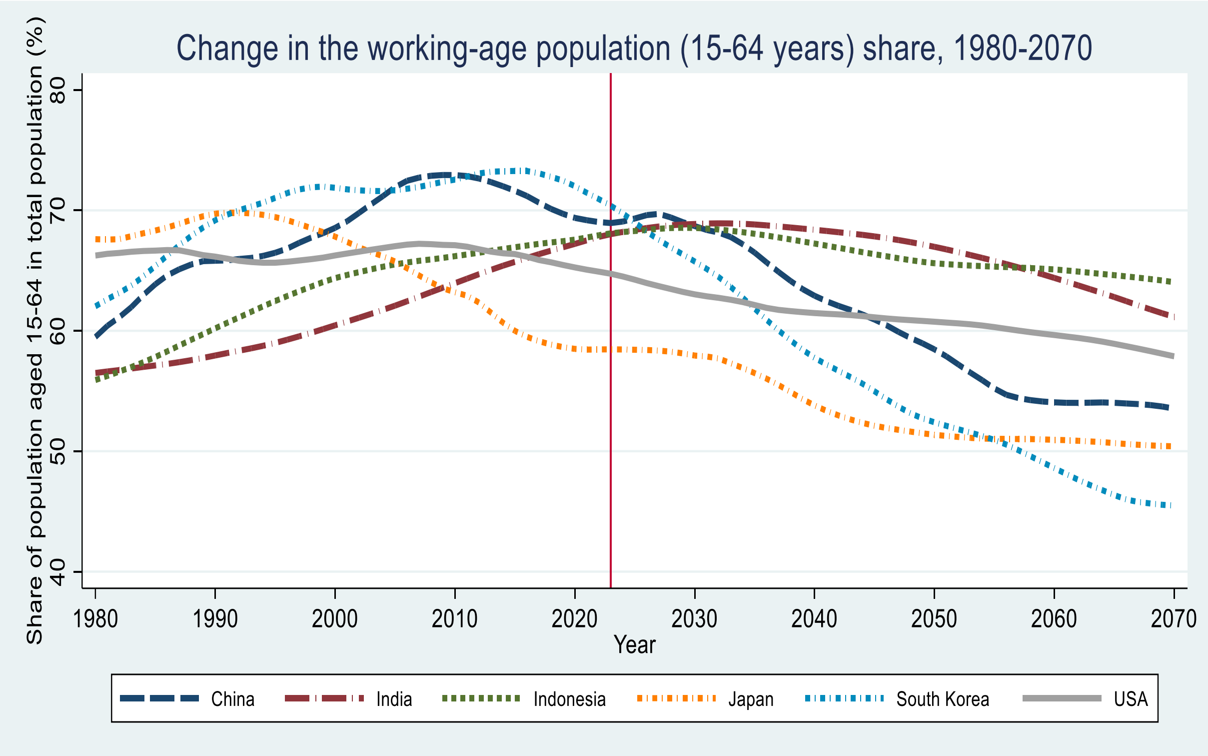
Source: IMF's World Economic Outlook Database: October 2022
(https://www.imf.org/en/Publications/WEO/weo-database/2022/October)

Figure 3: Trend and Projection of Total Population in 1980–2070, Selected Economies



Note: Forecasts are the United Nation's (UN) medium scenario projections.
Source: UN, *World Population Prospects 2022* (https://population.un.org/wpp/)

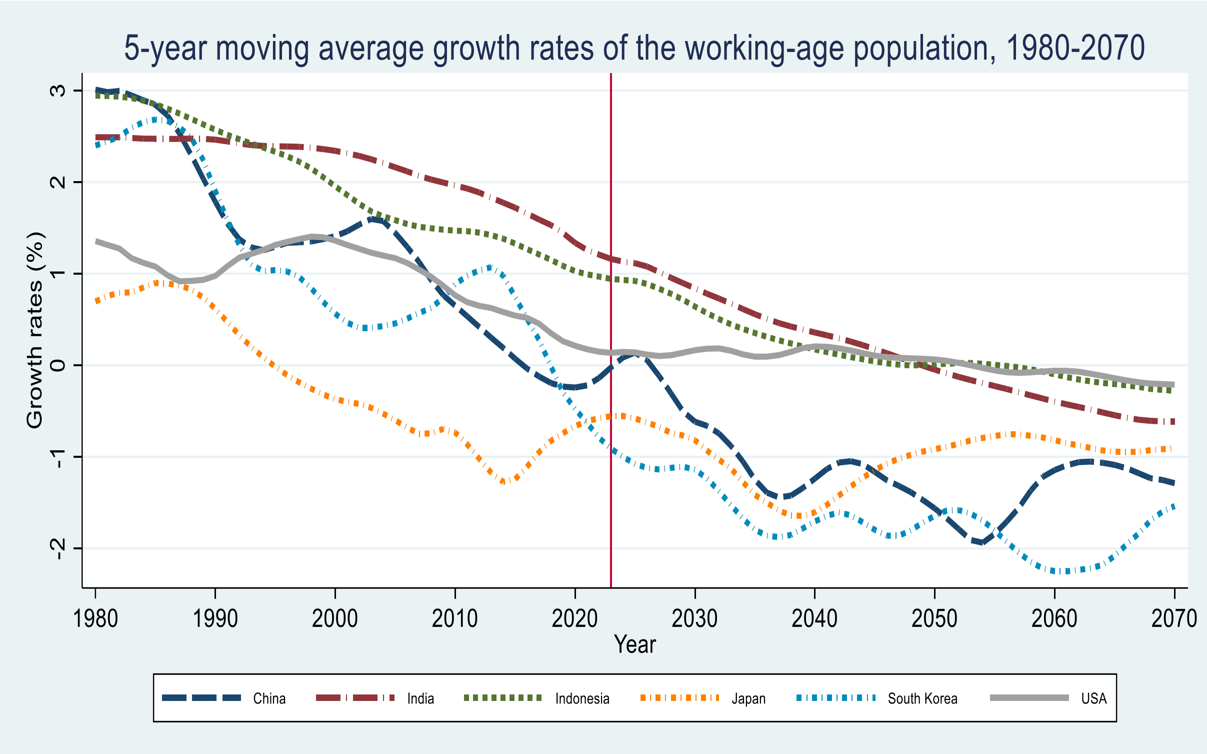
Figure 4: Trend and Projection of Share of Working-Age Population, 1980–2070



Note: Forecasts are the UN's medium scenario projections.

Source: UN, *World Population Prospects 2022* (https://population.un.org/wpp/)

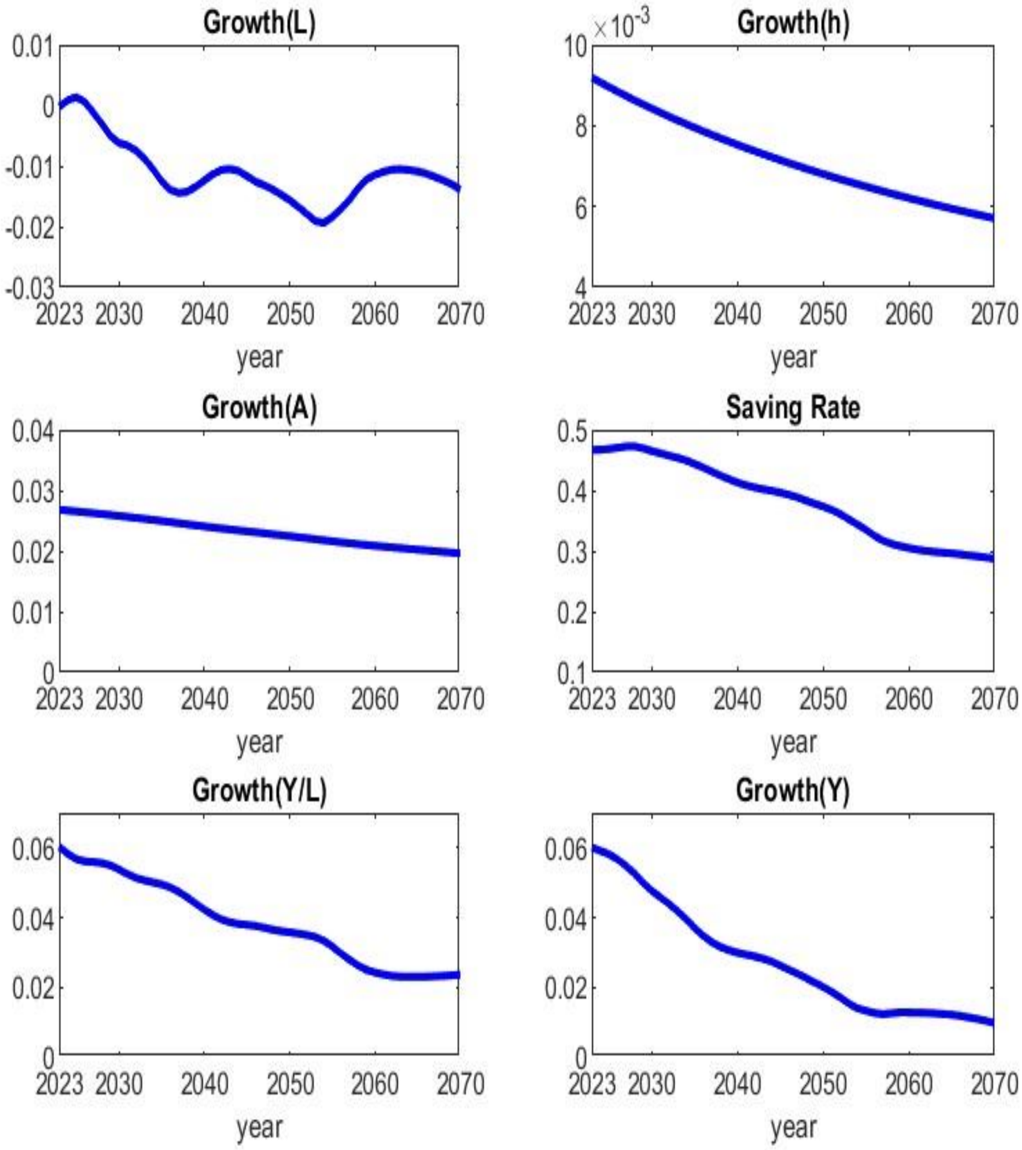
Figure 5: Trend and Projection of Growth Rates of Working-Age population, five–year moving average, 1980–2070



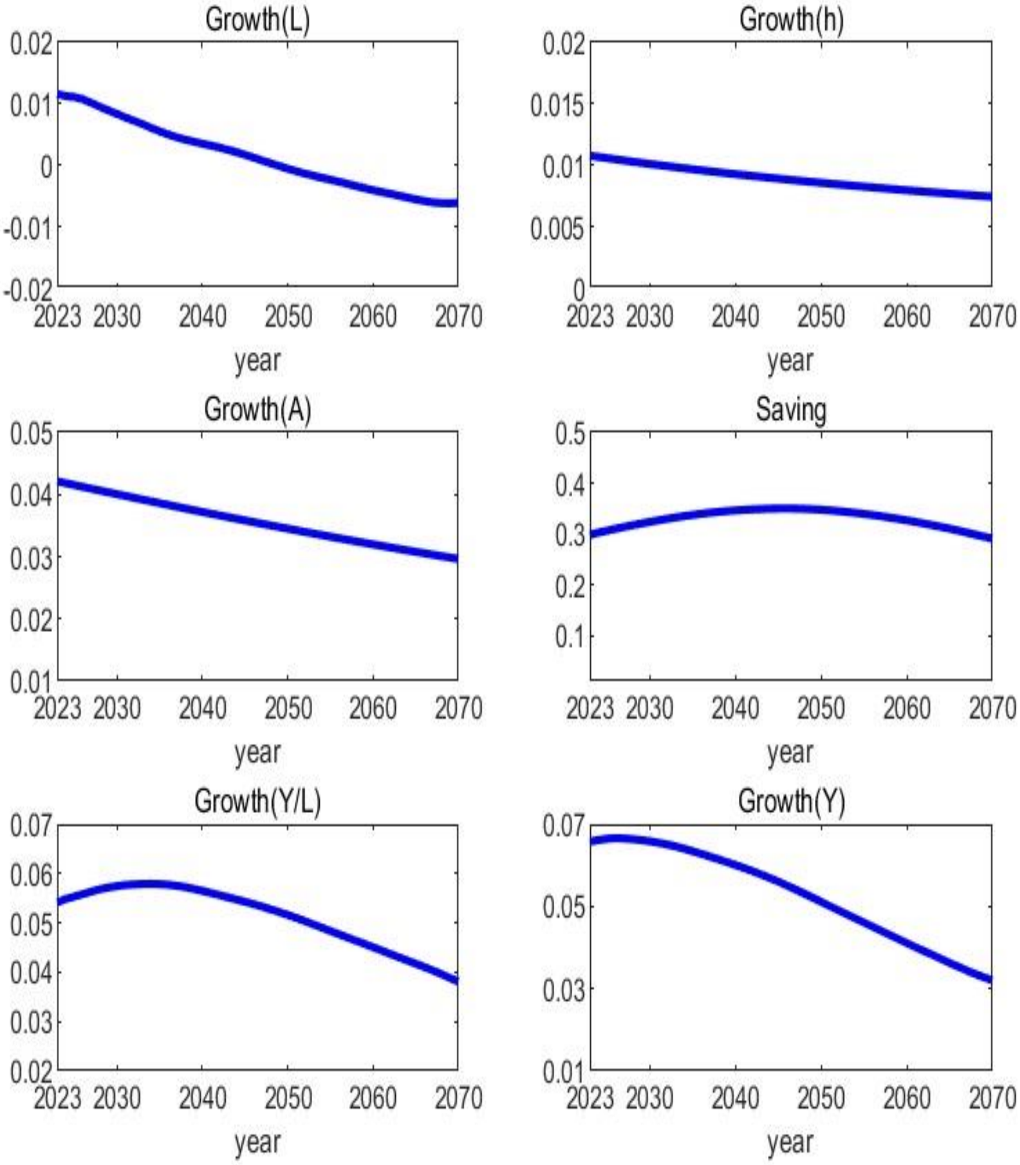
Note: Forecasts are the UN's medium scenario projections.
Source: UN, *World Population Prospects 2022* (https://population.un.org/wpp/)

Figure 6: Simulation Results from the Endogenous Growth Model

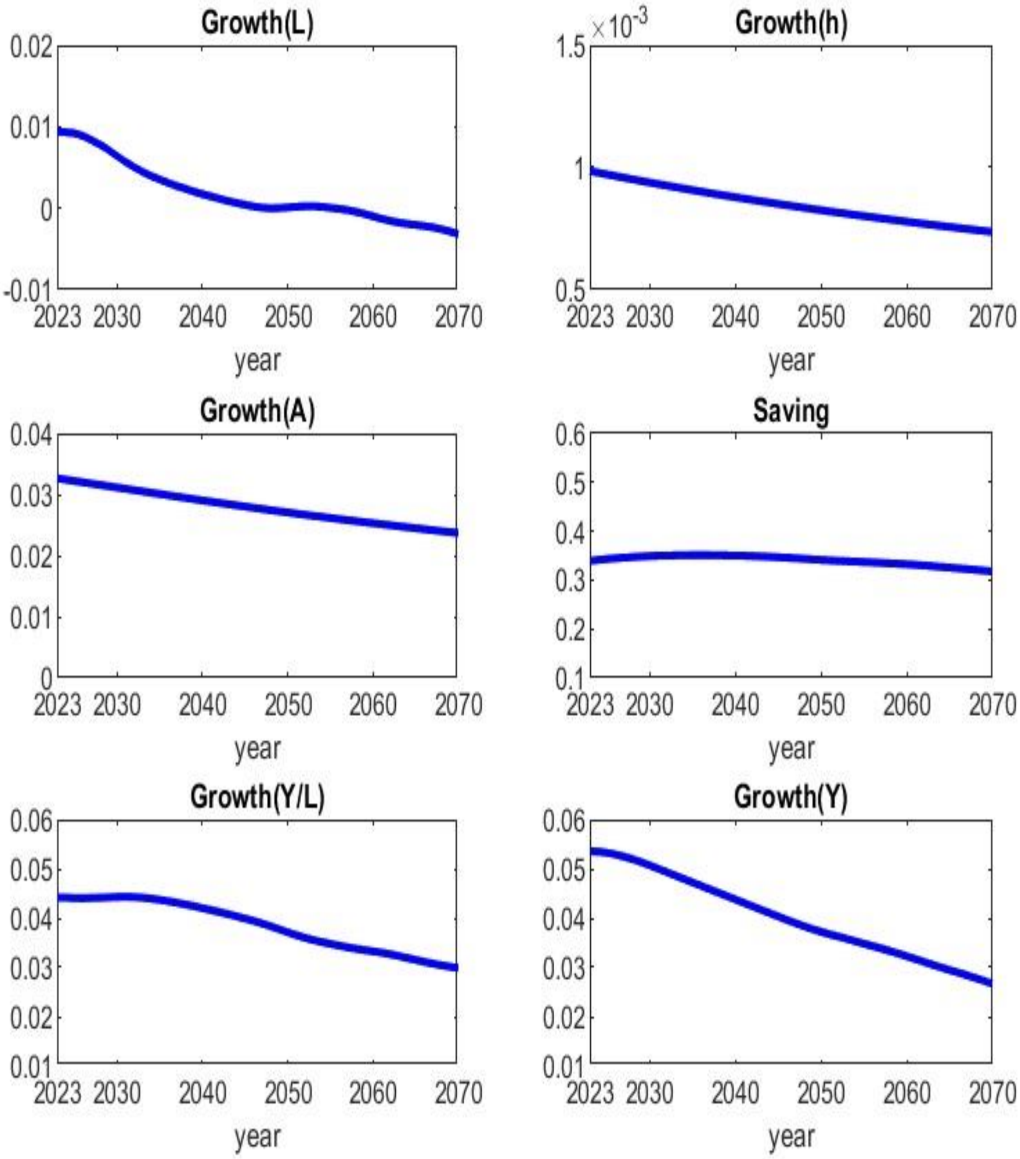
a) China



b) India

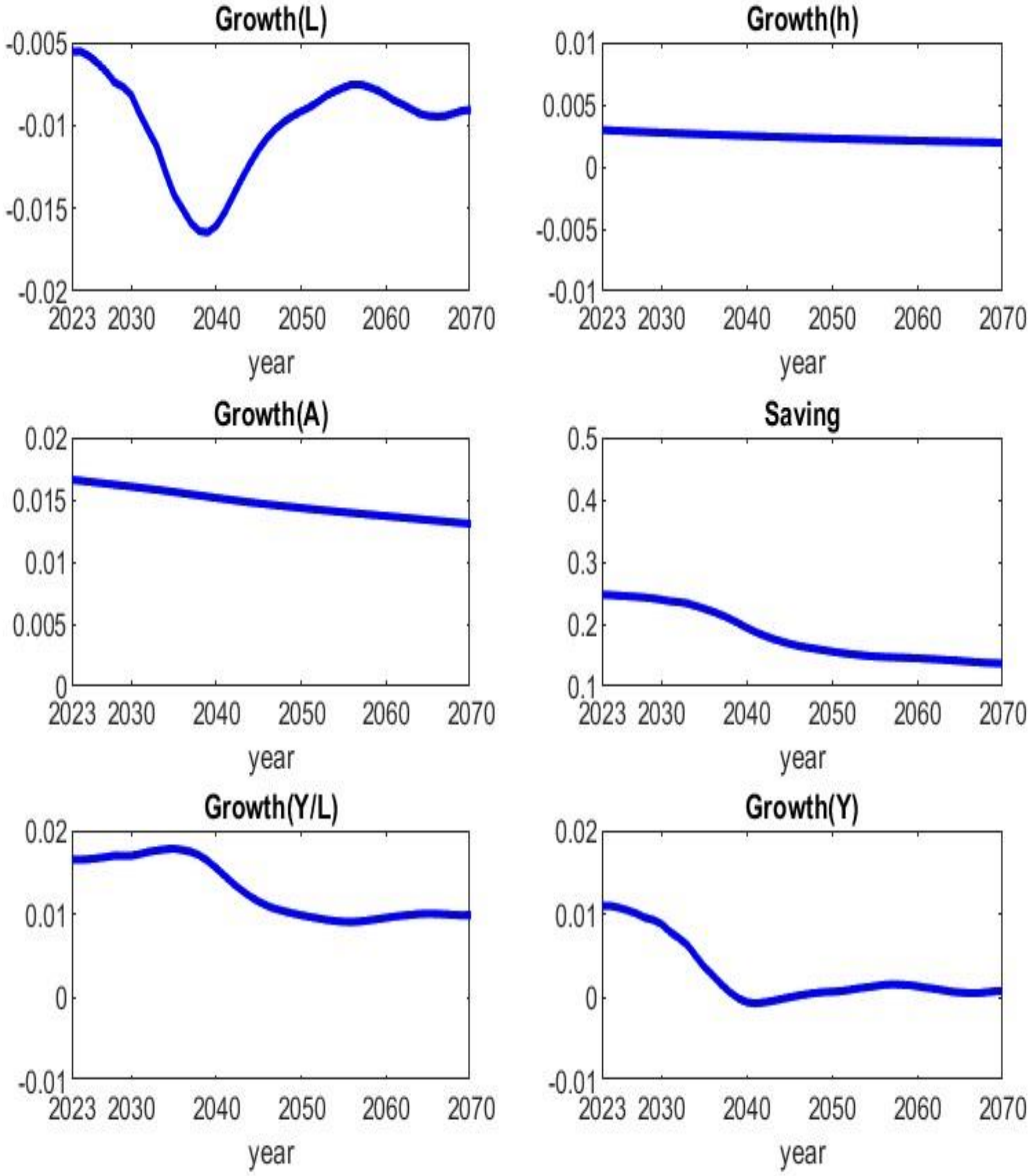

Growth(L)
0.02
0.01
0
-0.01
-0.02
2023 2030 2040 2050 2060 2070
year
Growth(h)
0.02
0.015
0.01
0.005
0
2023 2030 2040 2050 2060 2070
year
Growth(A)
0.05
0.04
0.03
0.02
0.01
2023 2030 2040 2050 2060 2070
year
Saving
0.5
0.4
0.3
0.2
0.1
2023 2030 2040 2050 2060 2070
year
Growth(Y/L)
0.07
0.06
0.05
0.04
0.03
0.02
2023 2030 2040 2050 2060 2070
year
Growth(Y)
0.07
0.05
0.03
0.01
2023 2030 2040 2050 2060 2070
year

c) Indonesia



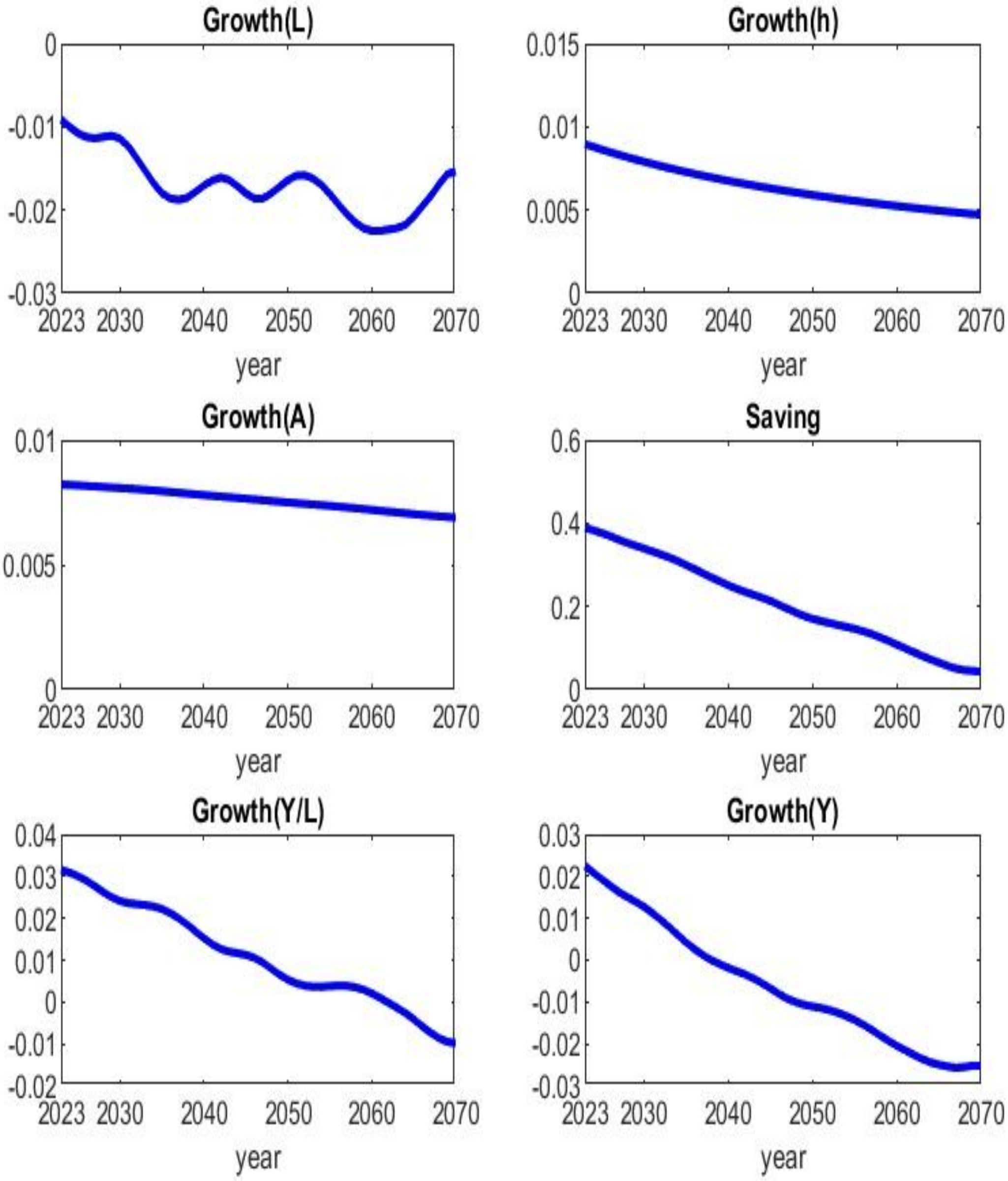
Growth(L)
0.02
0.01
0
-0.01
2023
2030
2040
2050
2060
2070
year
×10^-3
Growth(h)
1.5
1
0.5
Growth(A)
0.04
0.03
0.02
0.01
0
Saving
0.6
0.5
0.4
0.3
0.2
0.1
Growth(Y/L)
0.06
0.05
0.04
0.03
0.02
0.01
Growth(Y)

d) Japan

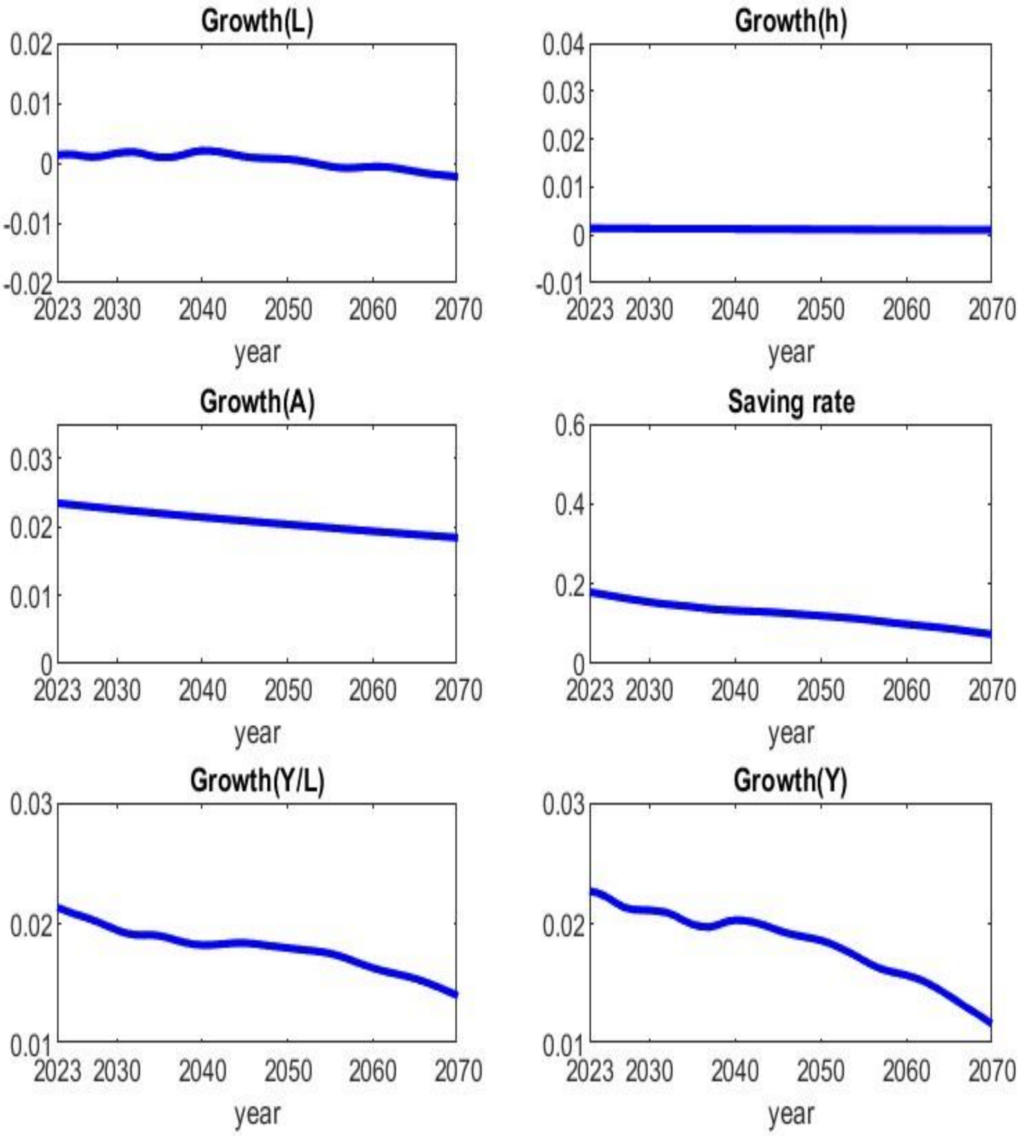


Growth(L)
-0.005
-0.01
-0.015
-0.02
2023 2030 2040 2050 2060 2070
year
Growth(h)
0.01
0.005
0
-0.005
-0.01
2023 2030 2040 2050 2060 2070
year
Growth(A)
0.02
0.015
0.01
0.005
0
2023 2030 2040 2050 2060 2070
year
Saving
0.5
0.4
0.3
0.2
0.1
2023 2030 2040 2050 2060 2070
year
Growth(Y/L)
0.02
0.01
0
-0.01
2023 2030 2040 2050 2060 2070
year
Growth(Y)
0.02
0.01
0
-0.01
2023 2030 2040 2050 2060 2070
year

e) South Korea



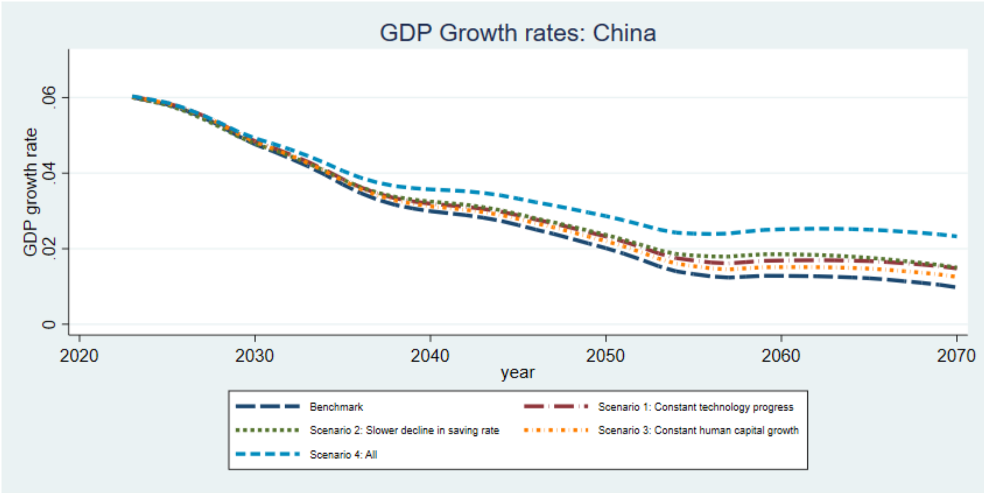
f) United States



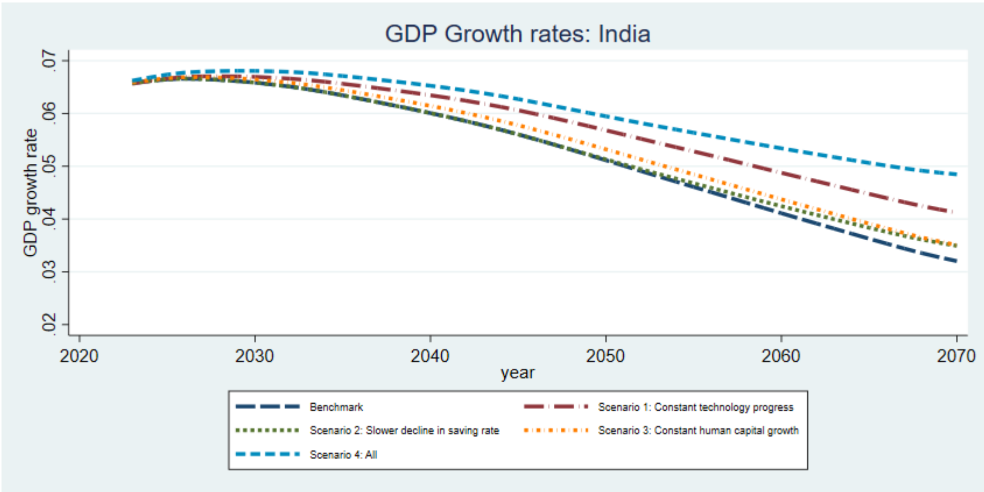
Notes*:* For simulation exercises, the initial values for GDP growth are obtained from the IMF's World Economic Outlook Database, October 2022. The working-age population growth is obtained from the UN World Population Prospects 2022. Per capita GDP growth is calculated. The initial values for human capital growth, saving rate (measured by real domestic investment rate), technological growth, and the output share of physical are obtained from the Penn-World Table (PWT) 10.1. Technological growth is measured by total factor productivity (TFP) growth divided by labor share.

Figure 7: Projections for GDP Growth with Alternative Scenarios

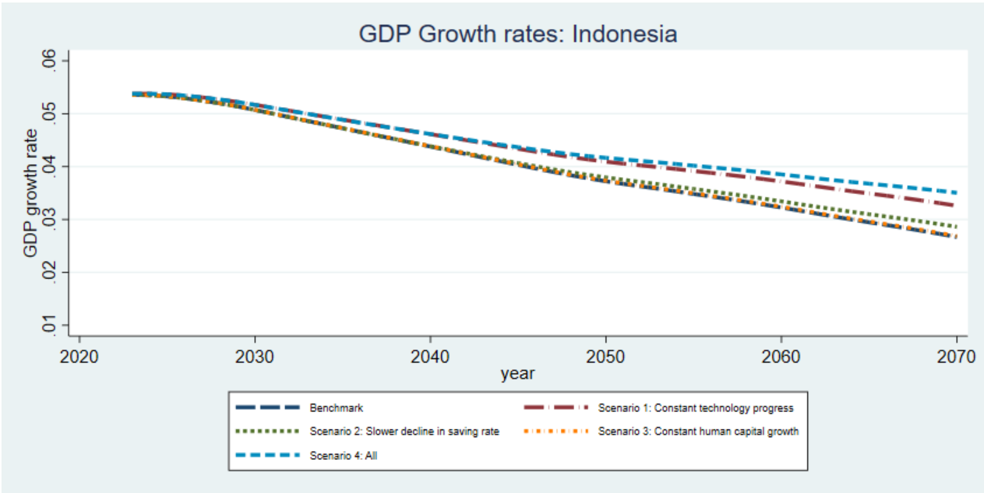
a) China



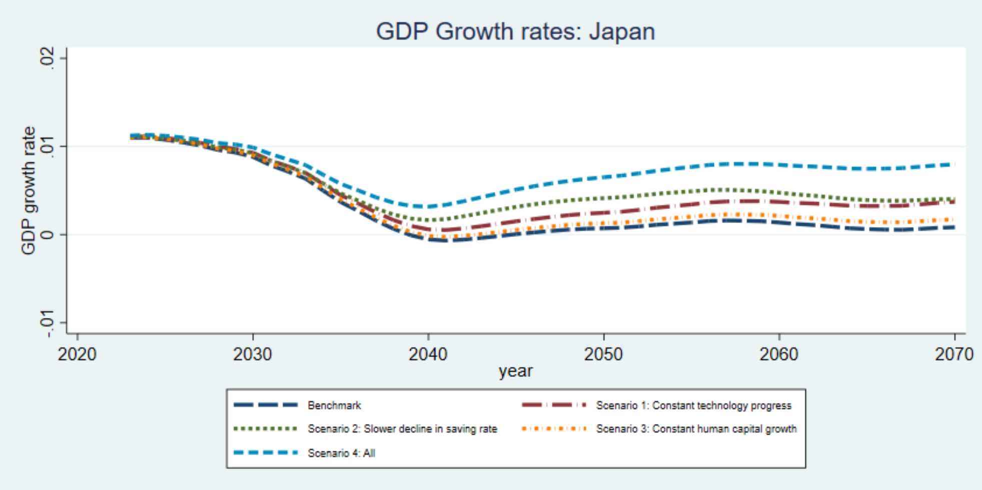
b) India



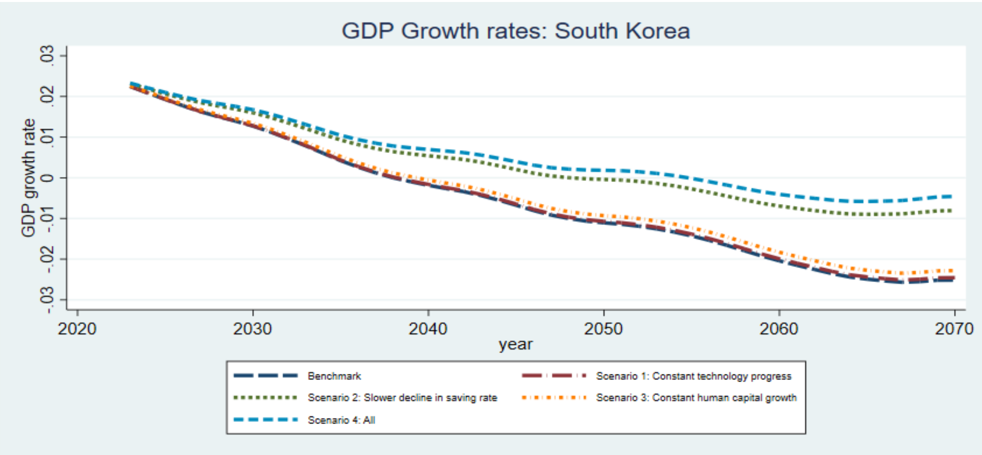
c) Indonesia



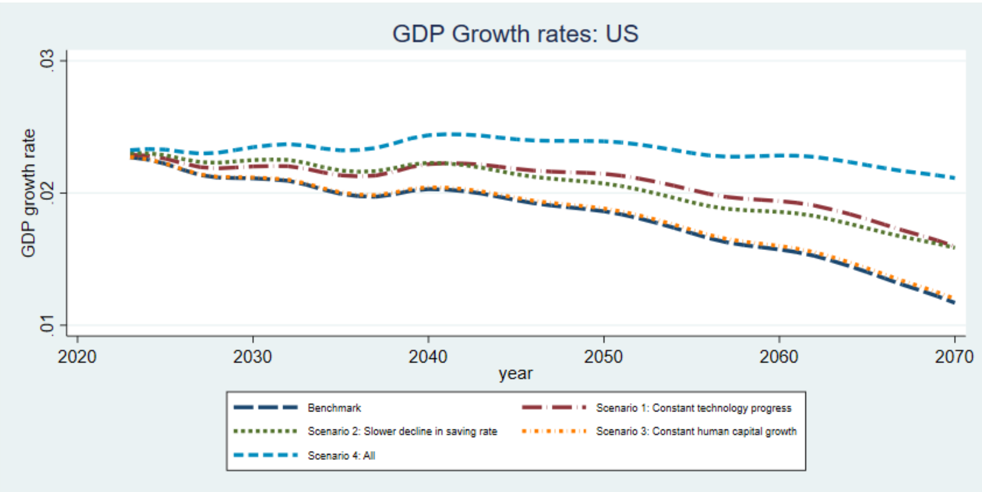
d) Japan



e) South Korea

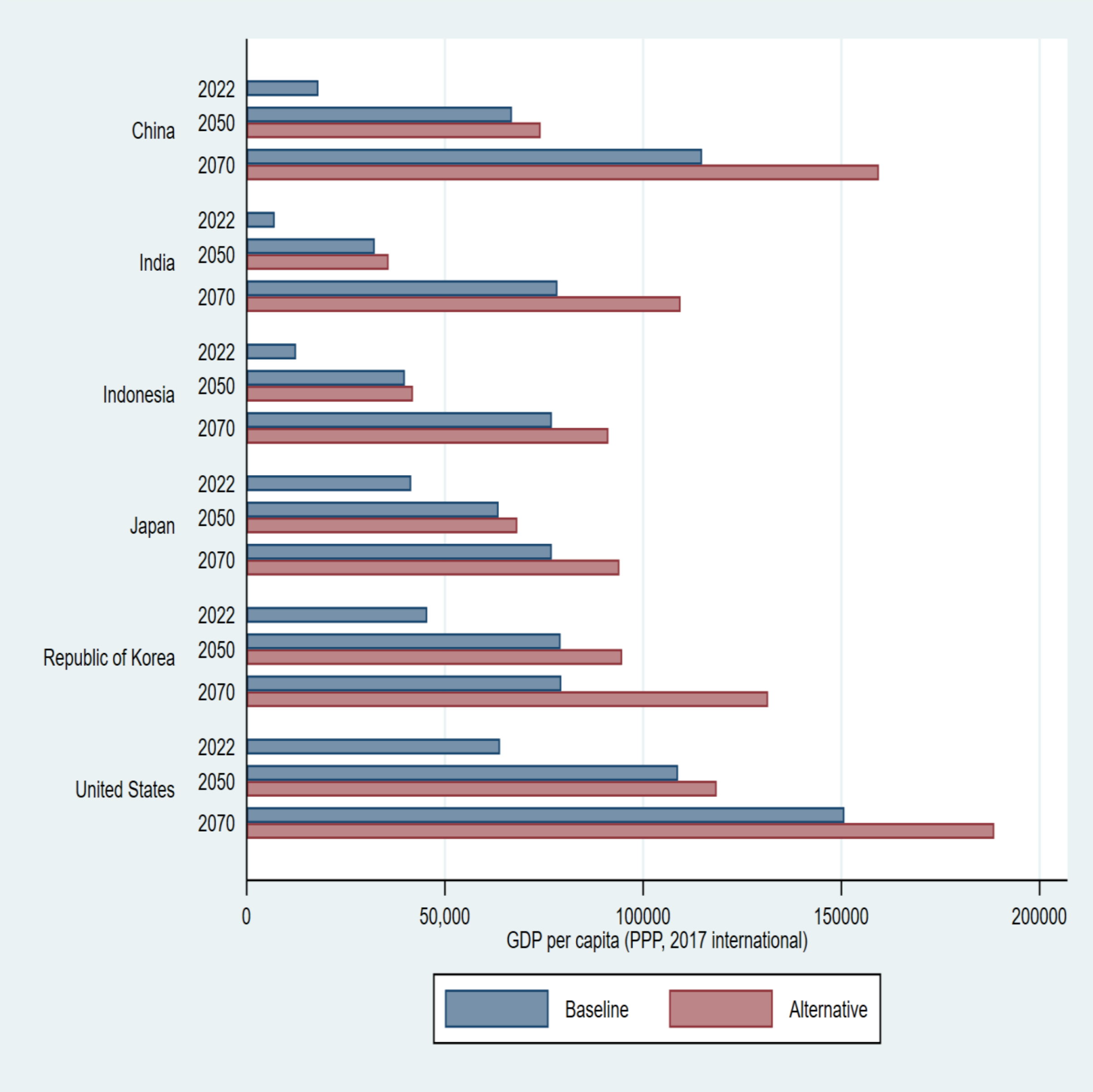


f) United States



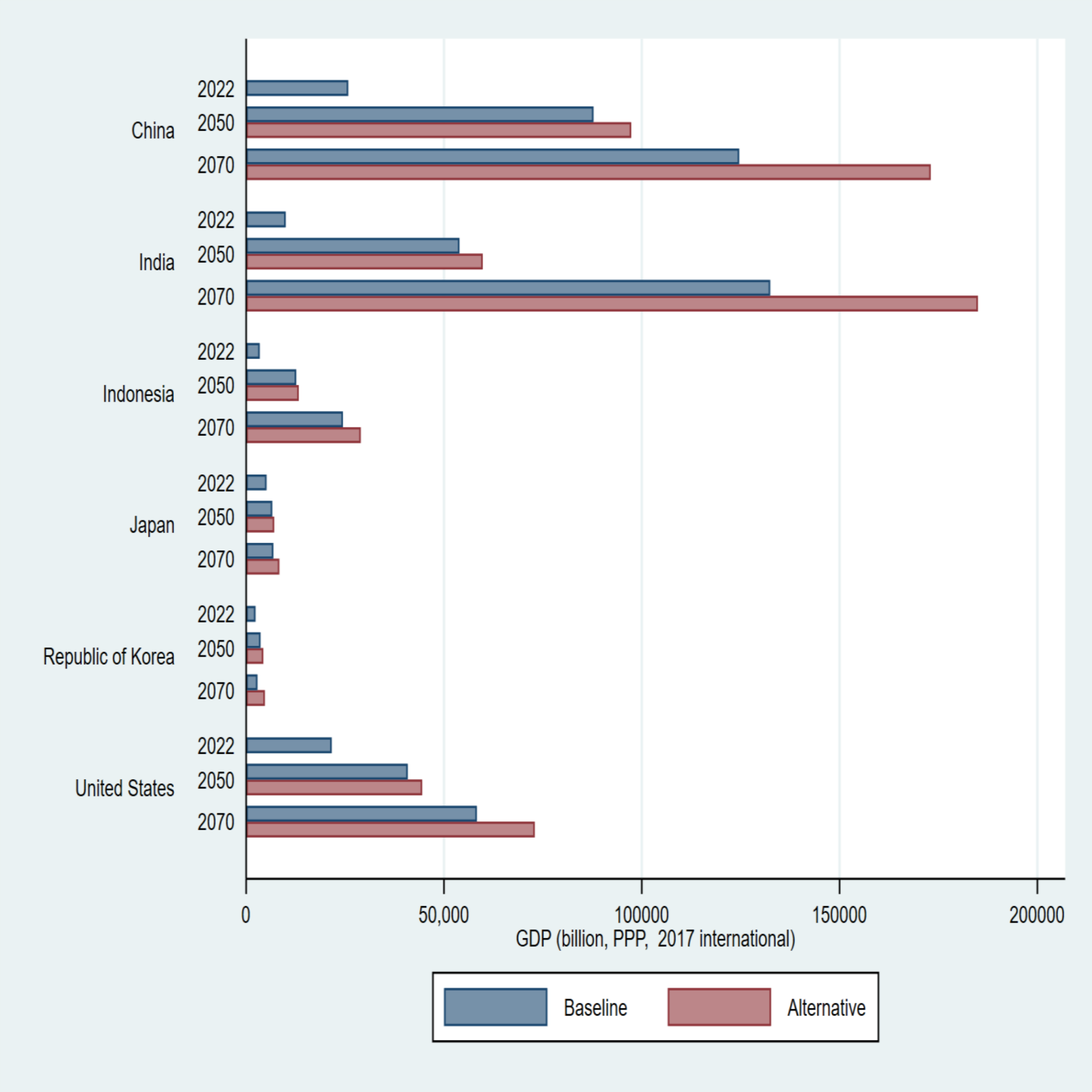
Notes: In addition to the baseline scenario depicted in Figure 5, three alternative scenarios are presented: 1) Constant technological progress; 2) Slower decline in saving rate; 3) Constant human capital growth; and 4) Constant technological progress, slower decline in savings rate, and constant human capital growth. Refer to explanations given in the text.

Figure 8: GDP Per Capita—actual in 2022 and projections in 2050 and 2070



Notes: Figure 8 provides projection results for PPP (Purchasing Power Parity)-adjusted real per capita GDP for the selected five Asian countries and the United States, subject to the baseline and alternative scenarios. Data on per capita GDP for the year of 2022 are sourced from the IMF. The per capita GDP projections for the baseline scenario are drawn from Figure 6. For an alternative scenario, per capita GDP projections are made under the assumption of constant saving rate and technological progress rate, which is the fourth alternative scenario in Figure 7.

Figure 9: Real GDP—actual in 2022 and projections in 2050 and 2070



Notes: Figure 9 provides the projection results for the purchasing power parity (PPP)-adjusted real GDP for the selected five Asian countries and the United States, subject to the baseline and alternative scenarios. Data on GDP for the year of 2022 are sourced from the IMF. For the baseline scenario, GDP projections are drawn from Figure 6. For an alternative scenario, GDP projections are made under the assumption of a constant saving rate and technological progress rate, which is the fourth alternative scenario in Figure 7.

Table 1. Growth Accounting for Selected Economies, 2010–2019

	GDP Growth Rate	Contribution from			
		Labor	Human Capital	Physical Capital	Total Factor Productivity
China	0.0767	0.0008	0.0059	0.0456	0.0243
	100%	*1.1%*	*7.7%*	*59.5%*	*31.7%*
India	0.0694	0.0090	0.0057	0.0339	0.0208
	100%	*12.9%*	*8.2%*	*48.8%*	*30.0%*
Indonesia	0.0543	0.0062	-0.0021	0.0328	0.0174
	100%%	*11.4%*	*-3.8%*	*60.3%*	*32.1%*
Japan	0.0121	-0.0056	0.0018	0.0019	0.0140
	100%	*-46.3%*	*14.9%*	*15.4%*	*116.0%*
South Korea	0.0333	0.0034	0.0047	0.0179	0.0074
	100%	*10.1%*	*14.0%*	*53.6%*	*22.3%*
USA	0.0225	0.0033	0.0010	0.0054	0.0128
	100%	*14.6%*	*4.4%*	*23.9%*	*57.1%*

Notes: Data on real GDP growth rates are sourced from the IMF's World Economic Outlook Database, October 2022. Data on physical capital stock, human capital, and labor share are collected from the PWT 10.1 (Feenstra et al., 2015). Data on the working-age population, obtained from the UN, are used as the labor input.

Table 2. Decline in GDP due to the Change in the Working-age Population Growth

	Growth rate in the working-age population			Change in the GDP growth due to the change in the working-age population growth	
	2010–19	2023–50	2051–70	Between 2023–50 and 2010–19	Between 2051–70 and 2010–19
China	0.001	-0.009	-0.014	-0.006	-0.009
India	0.017	0.005	-0.004	-0.006	-0.011
Indonesia	0.013	0.004	-0.001	-0.004	-0.007
Japan	-0.010	-0.011	-0.009	-0.001	0.001
South Korea	0.007	-0.015	-0.019	-0.011	-0.013
US	0.006	0.001	-0.001	-0.002	-0.004

Notes: The change in GDP growth rates due to changes in the working population growth rates are calculated assuming that the labor share remains unchanged throughout the period. Therefore, figures in the last two columns are computed by multiplying the difference between the average forecasted growth rate in the working population over the period 2023–2050 (or 2050–2070), and its average growth rate over the period 2010–2019 with the average labor share over the period 2010–2019.

Table 3. Equation for Saving Rate

	(1)	(2)
Log(GDPPC)	0.495**	0.485**
	(0.133)	(0.130)
Log(GDPPC)^2	-0.022**	-0.022**
	(0.008)	(0.008)
Old-age dependency ratio	-0.488***	-0.451***
	(0.057)	(0.111)
Youth dependency ratio	0.120	-0.012
	(0.278)	(0.252)
Constant	-2.330**	-2.231**
	(0.586)	(0.596)
Observations	234	234
R-squared	0.870	0.896
Country FE	Yes	Yes
Year FE	No	Yes

Notes: Table 3 reports pooled-OLS estimates of Equation (6)'. The dataset contains six selected economies, including China, India, Indonesia, Japan, Korea, and the United States from 1980 to 2019. The dependent variable is the real domestic saving rate. The independent variables include the log of real GDP per capita and its squared term, old-age dependency ratio (ratio of the population aged 65 years or older to the working-age population aged 15–64 years) and the youth dependency ratio (ratio of the population aged 14 years or younger to the working-age population aged 15–64 years). One-year lagged values for log ($GDPPC_{it-1}$) and its squared term are used. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 4. Equation for Growth Rate of Technology

	(1)	(3)
$\log(hL)$	0.165***	0.170***
	(0.039)	(0.027)
$log(A)$.	-0.263*	-0.255
	(0.115)	(0.130)
Constant	-2.800***	-2.831***
	(0.267)	(0.176)
Observations	234	234
R-squared	0.046	0.250
Country FE	Yes	Yes
Year FE	No	Yes

Notes: Table 4 reports the pooled-OLS estimates of Equation (8)'. The dataset contains six selected economies, including China, India, Indonesia, Japan, South Korea, and the United States from 1980 to 2019. The dependent variable denotes the growth rate of technology. The independent variables include the log of the total size of the total labor force (including both labor quantity L and quality h) and the log of the technology stock. One-year lagged values for the log of the total labor force size and the log of the stock of technology are used. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 5. Average GDP and per Capita GDP Growth Rates over Three Different Periods: 2010–2019, 2023–2050, and 2051–2070

	Actual data	Projection: Baseline scenario		Projection: Alternative scenario	
	2010–2019	2023–2050	2051–2070	2023–2050	2051–2070
A. GDP growth (%)					
China	7.669	3.934	1.346	4.319	2.508
India	6.939	6.172	4.170	6.562	5.382
Indonesia	5.431	4.663	3.240	4.848	3.863
Japan	1.207	0.452	0.104	0.712	0.755
South Korea	3.333	0.507	-1.913	1.160	-0.271
United States	2.251	2.054	1.567	2.367	2.270
B. Per capita GDP growth (%)					
China	6.831	4.783	2.741	5.168	3.904
India	5.545	5.585	4.535	5.976	5.747
Indonesia	3.985	4.250	3.340	4.435	3.963
Japan	1.298	1.534	0.962	1.794	1.614
South Korea	2.785	1.998	0.014	2.650	1.656
United States	1.559	1.919	1.645	2.232	2.348

Notes: For an alternative scenario, GDP projections are made under the assumption of a slower decline in the saving rate, constant technological progress rate, and constant human capital growth, which is the fourth alternative scenario.

Table 6. GDP and per capita GDP in 2023, 2050, and 2070

	Actual data	Projection: Baseline scenario		Projection: Alternative scenario	
	2022	2050	2070	2050	2070
A. GDP (billions; PPP; 2017 international $)					
China	25,800	87,794	124,638	97,321	173,048
India	9,988	53,925	132,465	59,790	184,973
Indonesia	3,427	12,655	24,452	13,299	28,981
Japan	5,142	6,593	6,858	7,083	8,379
South Korea	2,359	3,623	2,850	4,334	4,723
United States	21,613	40,840	58,314	44,495	72,936
B. Per capita GDP (PPP; 2017 international $)					
China	18,094	66,884	114,844	74,142	159,449
India	7,048	32,281	78,371	35,792	109,436
Indonesia	12,440	39,891	76,961	41,924	91,217
Japan	41,483	63,529	76,942	68,250	94,003
South Korea	45,529	79,164	79,364	94,688	131,506
United States	63,890	108,793	150,759	118,529	188,559

Notes: For an alternative scenario, the GDP projections are made under the assumption of a slower decline in the saving rate, constant technological progress rate, and constant human capital growth, which is the fourth alternative scenario.