Effect of population aging and economic growth: evidence from the largest 15 countries

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Abstract

Purpose – Since the 1990s, the pace of population aging has accelerated significantly, sparking concerns about its potential negative effects on economic growth. This study aims to shed some light on the impact of aging on economic growth.

Design/methodology/approach – To mitigate the risk of aggregation bias while capturing broader trends, this study examines the impact of aging on economic growth through the 15 largest global economies from 1991 to 2023. Both autoregressive distributed lag (ARDL) method and generalized method of moments (GMM) were employed for analysis.

Findings – The findings indicate that the relationship between population aging and economic growth varies across countries, highlighting the role of country-specific factors in shaping this dynamic. While concerns persist that an aging population may impede economic growth, our analysis does not find strong evidence of a consistent negative correlation. This suggests that the economic impact of demographic shifts is complex and may be mitigated by factors such as technological advancements and policy responses. From the stability test results, the long-term relationship remains stable for most of the countries analyzed.

Originality/value – To the best of our knowledge, this is the first study to examine the effects of aging on economic growth across the 15 largest global economies. Our findings on the impact of aging on economic growth diverge from many previous studies, suggesting a more balanced perspective that underscores the potential for sustainable economic performance even in aging societies.

Keywords Aging, Growth, ARDL, GMM, Country

Paper type Research paper

1. Introduction

The global aging trend is one of the most significant demographic shifts of the 21st century, marked by rising life expectancy, declining birth rates, and an increasing proportion of older individuals in both developed and developing countries. As highlighted in Li *et al*. (2007), “We are aging – not just as individuals or communities, but as a world. In 2006, nearly 500 million people worldwide were 65 and older. By 2030, that number is projected to rise to 1 billion - 1 in every 8 of the earth’s inhabitants. Notably, the most rapid growth in the 65-and-older population is occurring in developing countries, which are expected to see an increase of 140% by 2030.”

This demographic shift presents a variety of economic, social, and healthcare challenges. In particular, aging populations have drawn considerable attention due to the substantial obstacles they pose to sustained economic growth. The purpose of this study is to analyze the effects of population aging on economic growth across the world’s 15 largest economies.

JEL Classification — J11, J14, 047

Data availability statement: All original data used in this study are publicly available from the World Bank. Specifically; the original data on GDP per capita were obtained from https://data.worldbank.org/indicator/NY.GDP.PCAP.CD; the original data on GDP at PPP were obtained from https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD; the original data on Labor Force were obtained from https://data.worldbank.org/indicator/SL.TLF.TOTL.IN and the original data on % of population ages 65 and older relative to the total population obtained from https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS

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By focusing on these major economies, this study aims to offer valuable insights into how aging populations influence individual economic performance as well as overall global economic trends.

As of 2022, the 15 largest economies by Gross Domestic Product (GDP) are: the United States (US), China, Japan, Germany, India, the United Kingdom (UK), France, Russia, Canada, Italy, Brazil, Australia, South Korea, Mexico, and Spain. Most of these countries are considered developed economies, characterized by high income levels, advanced infrastructure, and industrialization. However, Brazil, China, India, and Mexico are typically classified as developing economies due to their lower per capita income and differing stages of economic development. Russia occupies a unique position, with some classifying it as a developing economy due to its low GDP and lower living standards compared to developed countries, while others argue that its economic capabilities and condition merit its classification as a developed nation.

Each of these countries follows distinct development paths, influenced by their unique historical, political, and economic contexts. This diversity results in varying approaches to economic growth, policy frameworks, and responses to global challenges such as aging populations.

To clearly illustrate economic growth among the 15 countries, we present GDP per capita data in current US dollars across Figures 1–3. Each figure also includes the global average GDP per capita for comparison. We chose not to display all 15 countries in a single figure to maintain readability. Figure 1 illustrates the GDP per capita for the top 5 largest economies, while Figure 2 presents the data for the next 5, and Figure 3 displays the GDP per capita for the remaining 5. This breakdown allows for a more nuanced comparison between the different economies, highlighting variations in economic development across the world's largest nations. The data, covering the period from 1980 to 2023, is sourced from the World Bank.

From Figures 1–3, our analysis reveals that most developed countries, such as the UK, France, Canada, and Italy, exhibit relatively similar patterns of GDP per capita growth. However, these patterns differ significantly from those observed in the US, Japan, and other developing countries examined, which demonstrate distinct growth trajectories. These variations reflect differences in economic policies, structural conditions, and external influences. Such disparities underscore the diverse economic dynamics among the largest global economies, with some such as China maintaining relatively stable growth paths while others experiencing more volatile economic performance. The GDP per capita of all the developed countries examined is currently well above the world average. In contrast, the GDP

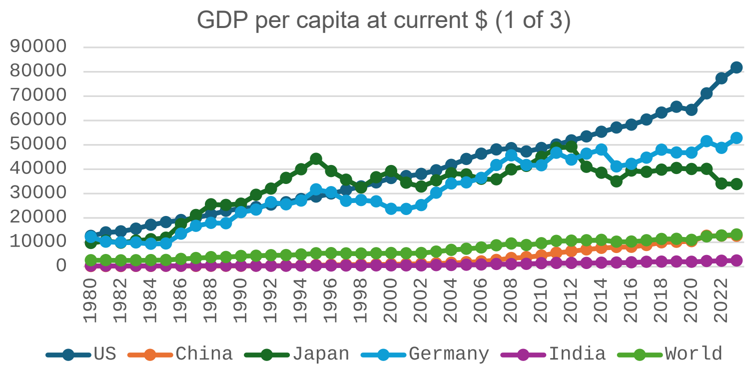

Figure 1. GDP per capita at current US dollars for US, China, Japan, Germany, and India. Source: Created by author

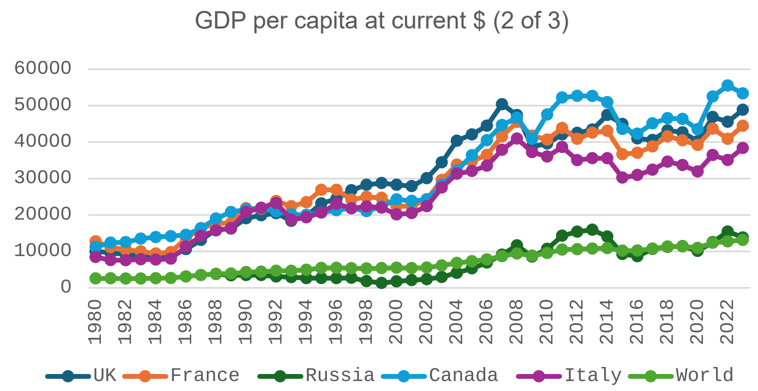

Figure 2. GDP per capita at current US dollar for UK, France, Russia, Canada, and Italy. Source: Created by author

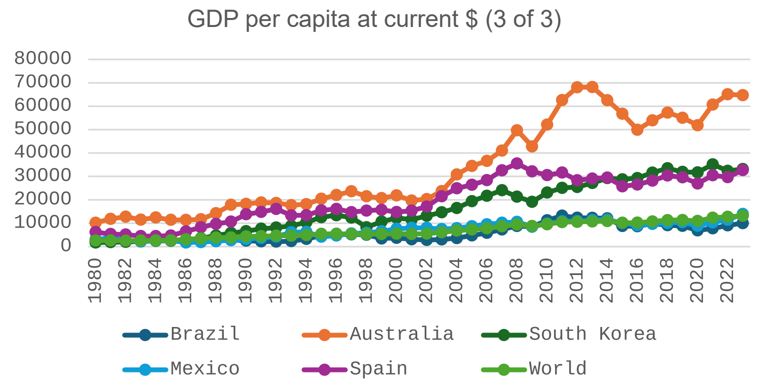

Figure 3. GDP per capita at current US dollars for Brazil, Australia, South Korea, Mexico, and Spain. Source: Created by author

per capita of the three developing countries – China, Brazil, and Mexico – now hovers around the world average, while India's GDP per capita remains below it. Russia's current GDP per capita is also approximately at the world average.

To gain a better understanding of aging trends in these 15 countries, we present data on the percentage of the population aged 65 and older relative to the total population in Figures 4 through 6, spanning from 1980 to 2023 and sourced from the World Bank. Similarly, to ensure readability, we opted not to display all 15 countries in a single figure. Each figure also includes the global average for comparison. Figure 4 illustrates the percentage of the population aged 65 and older for the top 5 largest economies, while Figure 5 presents data for the next 5, and Figure 6 covers the remaining 5 economies.

Figures 4 through 6 demonstrate a steady increase in the percentage of the population aged 65 and older, both globally and across the 15 largest economies. However, the pace of aging varies among these countries. While some countries, such as Japan – which has the highest percentage of the population aged 65 and older – are experiencing rapid aging due to declining birth rates and increased life expectancy, others, like India and Mexico, are undergoing demographic changes at a much slower pace. Among the countries examined, India and Mexico are the only two where the proportion of the population aged 65 and older remains

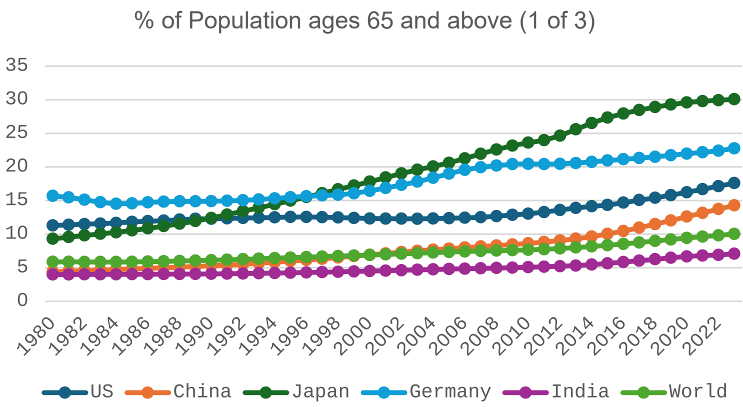

Figure 4. % of population ages 65 and above for US, China, Japan, Germany, and India. Source: Created by author

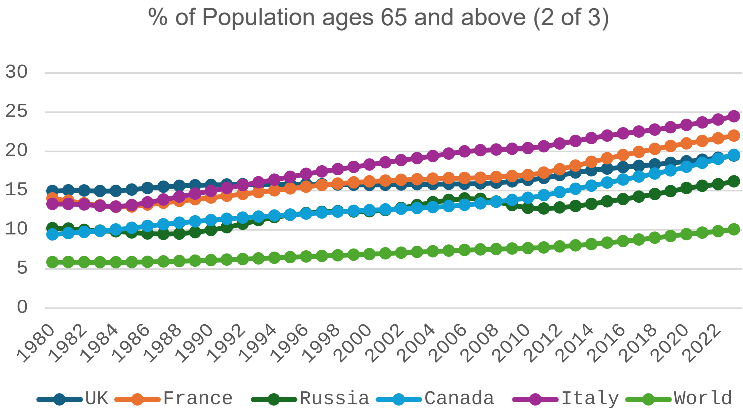

Figure 5. % of population ages 65 and above for UK, France, Russia, Canada, and Italy. Source: Created by author

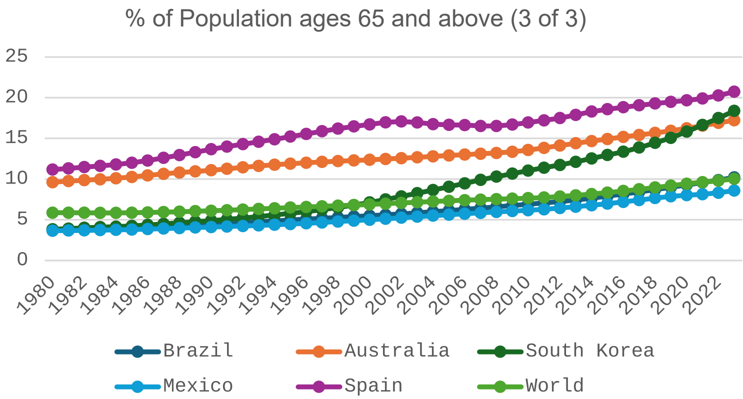

Figure 6. % of population ages 65 and above for Brazil, Australia, South Korea, Mexico, and Spain. Source: Created by author

below the global average as of 2023. Noticeably, in many of these economies, the acceleration of aging began around the 1990s, a period often regarded as when aging possibly started to impact economic growth. This raises the important question of how an aging population affects long-term economic growth.

In this context, examining the effects of aging on economic growth is both relevant and important. The remainder of the paper is organized as follows: Section 2 provides a brief overview of the existing recent literature on the relationship between aging and growth and elaborates on the rationale for focusing on the largest 15 economies. Section 3 introduces empirical models and estimation methods. Section 4 presents empirical results, and Section 5 offers concluding remarks and discussions.

2. Literature

The effects of aging on economic growth are rooted in well-established economic theories. The Neoclassical Growth Model suggests that long-term economic growth is primarily driven by capital accumulation, labor supply, and technological progress. According to the first Neoclassical Growth Model – Solow model, "economic growth was a direct result of population growth" (Roufagalas and Orlov, 2020). Then, as populations age, the resulting reduction in the labor force can hinder growth. Similarly, Demographic Dividend Theory suggests that economic growth is promoted when there is a large working-age population relative to dependents. In an aging society, a smaller proportion of workers support a larger group of retirees, increasing burdens of social security systems and leading to diminishing overall growth. Furthermore, the Secular Stagnation Hypothesis suggests that an aging population contributes to excess savings and reduced demand. Older populations tend to save more and consume less, which can suppress aggregate demand and slow investment. Additionally, a growing share of elderly dependents often results in higher public spending on healthcare, pensions, and social services, potentially causing fiscal imbalances. Without appropriate policy adjustments – such as raising the retirement age or reforming pension systems – these demographic shifts can further reduce economic growth by increasing the tax burden on a shrinking workforce.

On the other hand, several theories suggest that aging may not necessarily hinder economic growth. Endogenous Growth Theory emphasizes the importance of human capital, innovation, and knowledge accumulation. In this view, aging can have mixed effects: while a shrinking workforce might reduce innovation and entrepreneurship, older populations may also lead to higher capital accumulation per worker and facilitate a shift toward knowledge-based industries, thereby sustaining growth.

The Overlapping Generations Model highlights that an increase in the proportion of retirees raises the dependency ratio and can strain pension systems and public finances. However, the impact on growth largely depends on saving behavior. If older individuals maintain high savings and investment levels, then consequently growth may not suffer significantly.

More recently, advancements in automation, artificial intelligence (AI), and robotics have been argued to offset the negative effects of an aging population by boosting labor productivity. Countries with high capital intensity and robust technological infrastructure, such as the US, Japan, and Germany, may be able to sustain growth despite demographic shifts.

Additionally, some theories posit that immigration can counterbalance the negative effects of aging by replenishing the workforce. Open economies can also mitigate aging's impact by outsourcing labor-intensive activities or investing in markets with younger populations.

Previous studies have employed a variety of models and frequently relied on cross-country data spanning different time periods to examine the effects of population aging on economic growth. While most empirical research suggests that an aging population hampers economic growth, there is no consensus on how to measure population aging or on the extent of its effects. The diverse findings reflect varying theoretical perspectives on the impact of aging.

Studies support the notion that aging hampers economic growth include, but are not limited to, Emerson *et al*. (2024), Kotschy and Bloom (2023), Lai and Yip (2022), Maestas *et al*. (2023), and Park and Shin (2023). Both Kotschy and Bloom (2023) and Lai and Yip (2022) employ cross-country data. Emerson *et al*. (2024) analyze a panel of Organization for Economic Co-operation and Development (OECD) countries from 1975 to 2014 to estimate the relationship between the old-age dependency ratio (the population aged 65 and over relative to those aged 15 to 64) and secular growth over 10- and 20-year intervals. Their empirical findings reveal a clear negative impact of the old-age dependency ratio on economic growth, lending strong support to the demographic underpinnings of the secular stagnation hypothesis. Kotschy and Bloom (2023) analyze panel data from 145 countries to investigate the impact of demographic shifts in the working-age population on economic growth. They begin by assessing these effects within a standard empirical growth model using data from 1950 to 2015. Subsequently, they compare their findings with projected changes in population age structure to forecast economic growth from 2020 to 2050. Their research indicates that population aging is likely to slow economic growth. In the absence of aging effects, income per capita in OECD countries is projected to grow at an average rate of 2.5% annually from 2020 to 2050. However, when factoring in population aging, growth is expected to decelerate by 0.8% points based on retrospective measures of the working-age population, and by 0.4% points when using prospective measures. Hence, they argue "Expansions of labor supply due to improvements in functional capacity among older people can cushion much of this demographic drag." Lai and Yip (2022) investigate the impact of population aging on economic growth in 74 developing countries between 1990 and 2019. Using a static panel estimator, they analyze the relationship between population aging, labor force participation of older individuals, and economic growth. Their findings indicate a negative correlation between population aging and economic growth, but this effect is moderated by higher labor force participation among older workers. This suggests that the extent to which population aging affects economic growth depends largely on the participation rate of older individuals in the workforce.

There are several previous studies focusing on specific countries include, but are not limited to, Maestas *et al*. (2023) on the US, Kato (2022) on Japan, Wang and Conesa (2022) on China, Dai and Hatta (2021) on Japan, and Zhou and Li (2021) on China. Maestas *et al*. (2023) analyze data from US from 1980 to 2010 to estimate the impact of population aging on GDP per capita growth. Their findings indicate that a 10% increase in the share of the population aged 60 and older led to a 5.5% decline in per capita GDP. Approximately one-third of this decline was due to slower employment growth, while two-thirds resulted from reduced labor productivity. The study suggests that population aging reduced the US annual GDP per capita growth rate by 0.3% points during the 1980–2010 period.

These studies contribute to our understanding of the effect of aging on economic growth. Country-specific studies provide valuable insights into individual nations, while cross-country studies offer a broader perspective on the overall impact of aging. However, cross-country analyses may suffer from "Simpson's Paradox": a situation where a trend appears in different groups of data but disappears or reverses when the groups are combined. This is because the effects of aging on economic growth can differ significantly based on variations in labor resources and economic structures. As a result, a strong negative relationship in one country may be diluted by weaker or nonexistent relationships in others, or even offset by outliers. This variability may help explain why some studies choose to conduct a group of country-specific analyses rather than relying on cross-country data encompassing many nations. For instance, Park and Shin (2023) examine 12 Asian economies, while Emerson *et al*. (2024) and Lee and Shin (2021) focus on OECD countries. However, Emerson *et al*. (2024) and Lee and Shin (2021) rely on cross-country data for their analysis. The 12 countries analyzed by Park and Shin (2023) include Hong Kong, China; India; Indonesia; Malaysia; Pakistan; China; the Philippines; the Republic of Korea; Singapore; Taipei, China; Thailand; and Viet Nam – to project the impact of population aging on economic growth in developing Asia from 2021 to

2050. They assume that demographic changes influence growth through four key channels: per capita labor hours, total factor productivity, physical capital accumulation, and human capital accumulation. Their findings indicate that the demographic transition will significantly impede future growth across the region, though the impact will differ by economy.

Notably, a few studies indicate that empirical evidence does not consistently support a negative relationship between aging and economic growth. For example, Nicolini and Roig (2024), Seok and Kim (2024), Park *et al*. (2022) and Acemoglu and Restrepo (2017). Nicolini and Roig (2024) analyzed data from European Union (EU) countries spanning 2000 to 2020 to examine the potential impact of population aging on regional growth dynamics within the EU. Their findings suggest that population aging does not necessarily impede regional economic growth, especially when immigrant workers are able to fill labor market gaps left by retiring individuals and take on new roles arising from the increased demand for services – particularly in healthcare and daily support – driven by an aging population. Seok and Kim (2024) examine the impact of population aging on the relationship between exports and economic growth in Korea, utilizing the export-led growth hypothesis within an Autoregressive Distributed Lag (ARDL) framework and data spanning from 1990 to 2021. They find that population aging has a positive long-run effect on economic growth, suggesting that the human capital effect outweighs the adverse productivity effects associated with aging. They recommend two potential policy responses: promoting higher birth rates and encouraging immigration. Park *et al*. (2022) argues that the impact of population aging on economic growth remains uncertain. In their analysis of data from more than 170 countries, they find that a rising proportion of older individuals, combined with a shrinking working-age population, negatively affects economic growth. However, they also point out that improvements in life expectancy, labor productivity, and total factor productivity allow older age groups to contribute more positively to future growth. Additionally, increased automation helps mitigate the negative effects of aging by slowing the decline in productivity among older workers. Similarly, Acemoglu and Restrepo (2017) analyze cross-country data from 169 countries, followed by an in-depth examination of OECD nations between 1990 and 2015, and find no evidence of a negative relationship. They argue that "this counterintuitive finding may reflect the more rapid adoption of automation technologies in countries experiencing significant demographic shifts."

To avoid "Simpson's Paradox" of aggregation bias while still capturing broader trends, we have chosen to focus on a group of countries to study the impact of aging on growth. Unlike Park and Shin (2023), who selected a group of countries with some similarities, our study focuses on the top 15 largest economies in the world. To the best of our knowledge, this may be the first study to analyze the effects of aging on growth within this group. On one hand, these 15 countries differ significantly in their economic structures and backgrounds, meaning the impact of aging on growth may vary across them. On the other hand, as the largest economies globally, their economic developments not only affect their own nations but also have widespread implications for the rest of the world. This broader approach allows us to analyze the effect of aging on a diverse range of economies, providing a more comprehensive understanding of how aging impacts economic growth across both developed and developing nations.

3. The model and method

GDP per capita is a widely utilized metric for evaluating a country's economic standard and growth trajectory. It is influenced by a myriad of interconnected factors, including human capital, physical capital, technological innovation, labor force dynamics, institutional frameworks, and government policies, among others. The focus of the current study is to examine how labor resources, particularly the aging population, impact economic growth. To comprehensively capture the determinants of GDP per capita, we incorporate not only the labor force and aging population but also GDP measured at Purchasing Power Parity (PPP) to account for other essential economic factors.

Let YP represent the country's GDP per capita, Y denote the country's GDP at PPP, L signify the labor force, while A denotes the aging population.

Given the uncertainty regarding the existence of a linear relationship between the dependent variable (YP) and the three determinants of interest (Y, L, and A), we adopt a Cobb-Douglas-type function. Specifically, the model is formulated as follows:

$$\mathrm{YP} = \beta \mathrm{Y}^{\mathrm{b}} \mathrm{L}^{\mathrm{c}} \mathrm{A}^{\mathrm{d}} \tag{1}$$

Take the logarithm of Equation (1), this gives us the following model for GDP per capita as a function of GDP at PPP, labor force, and the aging population:

$$LnYP_t = a + bLnY_t + cLnL_t + dLnA_t + \varepsilon_t \tag{2}$$

Here, $a = \ln\beta$. YP is measured in current US dollars, Y is quantified in billions of dollars, L is expressed in millions, and A indicates the percentage of the population aged 65 and older relative to the total population.

The Cobb-Douglas functional form is selected for its versatility in modeling potential non-linear relationships between the dependent variable and its determinants. This framework accommodates varying degrees of elasticity and interaction effects among variables, enabling a more comprehensive analysis of the factors influencing GDP per capita. Furthermore, the multiplicative structure of the Cobb-Douglas function simplifies the interpretation of elasticity coefficients, providing clear and actionable insights into the magnitude and direction of each determinant's impact on economic performance.

In Equation (2), the coefficients b, c, and d represent the elasticity of GDP per capita with respect to GDP at PPP, labor force, and aging population, respectively. A higher GDP at PPP is generally expected to result in a positive coefficient for Y, particularly if the increase in GDP at PPP is primarily driven by growth in GDP, which will increase GDP per capita. However, if other factors, such as a lower price level, play a significant role in boosting GDP at PPP, we may not observe a corresponding rise in GDP per capita, and the coefficient for Y could be non-positive. The relationship between the labor force and GDP per capita is less straightforward. If a larger labor force stems from population growth, it could lead to a decline in GDP per capita as the labor force expands. Conversely, if a growing labor force enhances production and contributes to higher GDP, GDP per capita would be expected to rise. Lastly, most people believe a higher proportion of older individuals in the population is associated with slower economic growth for the reasons explained earlier. Thus, the coefficient for the aging population is anticipated to be negative.

The ARDL method was selected for its ability to produce robust estimates, even with a relatively small number of observations. We followed Pesaran *et al*. (2001) and specified an ARDL version of the error-correction model in Equation (3) to carry out empirical analysis:

$$\begin{aligned}\Delta LnYP_t = \alpha &+ \sum_{j=1}^{n} \beta_j \Delta LnYP_{t-j} + \sum_{j=0}^{n} \gamma_j \Delta LnY_{t-j} + \sum_{j=0}^{n} \delta_j \Delta LnL_{t-j} + \sum_{j=0}^{n} \theta_j \Delta LnA_{t-j} \\ &+ \omega_1 LnYP_{t-1} + \omega_2 LnY_{t-1} + \omega_3 LnL_{t-1} + \omega_4 LnA_{t-1} + \mu_t \end{aligned} \tag{3}$$

One key advantage of the ARDL approach is that it does not require pre-testing for unit roots prior to estimation. Pesaran *et al*. (2001) provide two sets of critical values for testing cointegration. The upper bound assumes all variables are integrated of order one, while the lower bound assumes all variables are integrated of order zero. Cointegration is supported if the F-test statistic exceeds the upper bound critical value. If the *F*-test statistic is below the lower bound critical value, there is no cointegration. However, if the *F*-test statistic falls between the lower and upper bound critical values, the results are inconclusive. The optimal lags for each variable are determined using the Akaike Information Criterion (AIC). After selecting the optimal lags, the *F*-test is conducted to assess cointegration. Furthermore, cointegration is indicated when the error correction term derived from the short-run estimates is both negative and statistically significant.

As previously mentioned, each country has experienced significant acceleration of aging since around 1990 and we expect aging to be a long-term trend. Consequently, we are interested in assessing the stability of the models we estimate. To do so, we use the Cumulative Sum of Recursive Residuals (CUSUM) and the Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ) plots. The estimated long-run relationship is considered stable if, and only if, the CUSUM and CUSUMSQ plots remain within the 5% critical boundaries, represented by two straight lines.

Finally, acknowledging the potential for endogeneity, we substitute GDP at PPP with the lagged value of GDP per capita and utilize lagged regressors as instruments in estimation via the Generalized Method of Moments (GMM). We also conduct tests to assess the endogeneity of the regressors.

4. The empirical results

We aim to analyze the long-term effects of aging on economic growth, using annual data from 1991 to 2023 sourced from the World Bank. As mentioned earlier, the acceleration of aging began around the 1990s, a period widely recognized as when aging may have started to influence economic growth. Further, the year 1991 marks the first year that data on the percentage of the population aged 65 and older became available. 2023 is the most recent year for which all relevant variables are accessible. Due to the relatively small number of observations, we use the ARDL estimation method. Moreover, including too many lag variables in the model can significantly increase the risk of multicollinearity. This occurs because the lagged variables may be highly correlated with one another, leading to inflated standard errors, reduced model precision, and difficulties in accurately estimating the effects of the independent variables. Hence, we impose a maximum of two lags on the dependent variable and four lags on its regressors, with the model incorporating both a constant and a time trend. The results of the cointegration tests are summarized in Table 1.

Table 1 shows that the 95% upper bound critical value is 4.01, while the 95% lower bound critical value is 5.07. Among the 15 countries examined, the *F*-test statistic at optimal lags exceeds the 95% upper bound in 12 cases, indicating the presence of cointegration among the variables. However, for France (3.34), Mexico (3.50), and the United States (3.04), the *F*-test statistics fall below the lower bound, suggesting no evidence of cointegration between GDP per capita and its regressors. Nevertheless, we proceed with ARDL estimates for error correction models. Table 1 reports both the coefficients of the error correction terms and their corresponding T-ratio probabilities. All error correction term coefficients are negative and statistically significant, supporting the presence of cointegration.

The long-run coefficient estimates are presented in Table 2. For the sake of brevity, we do not report the ARDL error correction model results or the short-run estimates here, but they are available upon request.

Table 2 shows that the GDP at PPP coefficient is positive for 10 of the 15 countries examined. However, for five countries (Canada, France, Japan, Mexico, and South Korea), the coefficient is not statistically significant. This result suggests that GDP per capita is generally positively associated with GDP at PPP.

As for the labor coefficient, it is negative and significant in 5 countries, positive and significant in 3 countries, and insignificant in 7 countries. Notably, among the four developing countries examined (Brazil, China, India, and Mexico), all labor coefficients are negative, with statistically significant values in Brazil, China, and India. It appears that in developing nations, a larger labor force is often a result of a larger population, which can lead to a decrease in GDP per capita as the labor force grows. In contrast, in developed countries, a larger labor force

Table 1. Cointegration test results from ARDL

Country	*F*-test at optimal lags	*F*-statistics 95% lower bound I(0)	*F*-statistics 95% higher bound I(1)	CointEq(−1)
Australia	5.68	4.01	5.07	−1.02 (0.00)***
Brazil	27.32	4.01	5.07	−0.62 (0.00)***
Canada	5.33	4.01	5.07	−0.70 (0.00)***
China	24.71	4.01	5.07	−1.51 (0.00)***
France	3.34	4.01	5.07	−0.53 (0.00)***
Germany	5.83	4.01	5.07	−0.91 (0.00)***
India	8.32	4.01	5.07	−1.76 (0.00)***
Italy	4.64	4.01	5.07	−0.36 (0.00)***
Japan	14.63	4.01	5.07	−1.31 (0.00)***
Mexico	3.50	4.01	5.07	−0.56 (0.00)***
Russia	6.87	4.01	5.07	−0.51 (0.00)***
South Korea	9.34	4.01	5.07	−0.73 (0.00)***
Spain	17.83	4.01	5.07	−1.38 (0.00)***
UK	6.31	4.01	5.07	−0.83 (0.00)***
US	3.04	4.01	5.07	−0.50 (0.00)***

Note(s): CointEq(−1) is the error correction term in the ARDL short-run estimates. The number inside the parenthesis is the probability of T-Ratio. *** indicates significance at 1%; **indicates significance at 5%, while * indicates significance at 10%
Source(s): Created by author

Table 2. Long-run estimation results from ARDL

Country	Optimal lags	Ln(Y)	Ln(L)	Ln(A)
Australia	(2, 1, 2, 2)	1.24 (0.09)*	9.72 (0.00)***	−5.91 (0.00)***
Brazil	(2, 0, 2, 3)	5.83 (0.00)***	−6.31 (0.01)***	−21.89 (0.00)***
Canada	(1, 1, 4, 4)	0.47 (0.60)	4.96 (0.15)	−1.66 (0.18)
China	(2, 3, 1, 4)	2.52 (0.00)***	−3.40 (0.00)***	−1.40 (0.02)**
France	(2, 0, 0, 0)	0.25 (0.79)	2.31 (0.63)	−2.76 (0.10)*
Germany	(2, 2, 4, 1)	2.63 (0.07)*	−1.66 (0.69)	3.03 (0.00)***
India	(2, 4, 0, 2)	5.06 (0.00)***	−1.74 (0.00)***	0.36 (0.38)
Italy	(1, 2, 3, 4)	8.37 (0.03)**	20.08 (0.02)**	3.73 (0.54)
Japan	(2, 4, 4, 3)	0.83 (0.16)	−7.70 (0.00)***	−0.85 (0.19)
Mexico	(1, 4, 4, 2)	2.03 (0.50)	−1.81 (0.79)	−0.72 (0.90)
Russia	(1, 4, 2, 4)	2.19 (0.01)***	15.46 (0.14)	13.05 (0.16)
South Korea	(2, 1, 4, 2)	−0.82 (0.49)	2.95 (0.58)	7.20 (0.03)**
Spain	(2, 0, 0, 0)	0.40 (0.02)**	1.26 (0.00)***	−2.76 (0.00)***
UK	(2, 4, 1, 2)	5.33 (0.04)*	3.01 (0.16)	0.74 (0.80)
US	(1, 4, 4, 4)	1.11 (0.00)***	−0.45 (0.02)**	0.15 (0.03)**

Note(s): The number inside the parenthesis is the probability of T-Ratio. *** indicates significance at 1%; **indicates significance at 5%, while * indicates significance at 10%
Source(s): Created by author

typically boosts production, increasing the potential for GDP growth. Consequently, labor force expansion does not necessarily result in a decline in GDP per capita.

The aging coefficient is negative and significant in 5 countries, positive and significant in 3 countries, and not significant in 7 of the 15 countries analyzed. This suggests that in approximately two-thirds of the major economies examined (10 out of 15 countries), there is no evidence that population aging negatively impacts economic growth. While this finding contradicts most previous studies, such as those by Kotschy and Bloom (2023), Lai and Yip (2022), and Park and Shin (2023), it aligns with the views of some researchers. For instance, Acemoglu and Restrepo (2017) contend that there is no inherent negative relationship between aging and economic growth, while Park *et al*. (2022) suggest that the impact of population aging on growth remains uncertain.

Germany, South Korea, and the US exhibit a positive and statistically significant aging coefficient, indicating that these countries might experience fewer adverse economic impacts from an aging population. Consistently ranking high on global innovation indexes, they benefit from substantial investments in research and development, strong educational systems, and robust infrastructures. These factors not only support technological advancement but also enhance productivity, enabling these nations to offset the typical challenges associated with demographic aging. Consequently, their commitment to innovation and high-quality human capital may serve as a buffer against the negative economic effects commonly linked to an aging workforce.

The relationship between aging populations and economic growth is inherently complex, and several unique characteristics of the US economy help mitigate the negative effects of an aging demographic. As the world's largest economy, the US leverages its leadership in advanced technologies such as automation and AI. These innovations enable higher productivity with fewer workers, helping to offset the economic challenges posed by a shrinking workforce. Additionally, many older adults in the US remain in the workforce longer, extending their productive years and contributing significant economic value. The US economy is increasingly knowledge-based, relying more on cognitive skills than on physical labor. In this environment, older workers bring valuable experience, expertise, and professional networks, which continue to enhance productivity. Immigration also plays a crucial role in counteracting demographic decline, as younger immigrants enter the labor force and help sustain economic growth. Government policies have further mitigated the economic impacts of an aging population. Adjustments to the retirement age, incentives to boost labor force participation among women and older adults, and investments in healthcare and support services have all contributed to reducing the economic burden of aging. Moreover, aging populations drive demand in specific sectors such as healthcare and leisure, spurring growth in these areas. This sectoral expansion helps offset some of the broader economic slowdown typically associated with aging demographics. While the effectiveness of these factors varies, collectively, they offer mechanisms to alleviate the potential negative impact of an aging population on economic growth. The US may serve as a compelling example of how thoughtful policies and innovation can reduce the economic effects of aging and sustain growth.

The results of the CUSUM and CUSUMQ stability tests are presented in Table 3. The estimated model is considered stable only if the CUSUM and CUSUMQ plots remain within the 5% critical boundaries, indicated by two straight lines. For brevity, we have only reported the summary of stability results here; however, the corresponding graphs are available upon request.

Table 3 shows that the long-run relationship between GDP per capita and its regressors is stable for most countries, with the exception of China, Japan, and the US. Future research could delve deeper into these three nations, given their status as some of the world's largest economies and the unique characteristics of their economic structures. Their prominence in global innovation and advanced technological development offers rich ground for further exploration, potentially yielding valuable insights into how large, diverse economies adapt to challenges such as an aging population.

Finally, to address potential endogeneity, we substitute GDP at PPP with the lagged value of GDP per capita and employ lagged value of regressors as instruments to carry out GMM estimation. Additionally, we conduct tests to evaluate the endogeneity of the regressors. The results are reported in Table 4.

Based on the regressor endogeneity tests, none of the J statistics are significant at the 5% level, indicating that the regressors can be treated as exogenous. Although the GMM estimation results for each country differ somewhat from the ARDL estimates, the overall

Table 3. The results of stability tests

Country	CUSUM	CUSUMQ
Australia	S	S
Brazil	S	S
Canada	S	S
China	S	NS
France	S	S
Germany	S	S
India	S	S
Italy	S	S
Japan	S	NS
Mexico	S	S
Russia	S	S
South Korea	S	S
Spain	S	S
UK	S	S
US	S	NS

Note(s): "S" denotes stability, while "NS" indicates instability
Source(s): Created by author

Table 4. Estimation results from GMM

Country	J-statistic	LnYP(−1)	Ln(L)	Ln(A)
Australia	5.51 (0.14)	0.48 (0.00)***	3.97 (0.00)***	−3.47 (0.00)***
Brazil	6.76 (0.08)*	0.71 (0.00)***	0.86 (0.30)	−0.16 (0.76)
Canada	4.65 (0.20)	0.60 (0.00)***	2.21 (0.00)***	−0.79 (0.00)***
China	5.17 (0.16)	0.95 (0.00)***	0.92 (0.14)	−0.05 (0.77)
France	2.69 (0.44)	0.46 (0.00)***	3.56 (0.00)***	−0.75 (0.03)**
Germany	5.58 (0.13)	0.43 (0.01)***	0.42 (0.66)	0.95 (0.01)***
India	2.11 (0.55)	0.88 (0.00)***	0.59 (0.10)	−0.10 (0.58)
Italy	4.07 (0.25)	0.77 (0.00)***	−1.73 (0.18)	1.01 (0.04)**
Japan	5.25 (0.15)	0.03 (0.85)	−2.90 (0.03)**	0.09 (0.28)
Mexico	3.75 (0.29)	−0.26 (0.76)	4.34 (0.25)	−2.37 (0.31)
Russia	2.65 (0.45)	0.59 (0.00)***	10.80 (0.01)***	1.61 (0.01)***
South Korea	2.25 (0.52)	0.26 (0.46)	−1.21 (0.60)	1.22 (0.20)
Spain	4.96 (0.17)	−0.32 (0.39)	3.45 (0.00)***	−0.93 (0.08)*
UK	1.36 (0.71)	0.72 (0.02)**	1.34 (0.46)	−0.65 (0.54)
US	5.22 (0.16)	0.98 (0.03)**	−0.13 (0.93)	0.15 (0.47)

Note(s): The number inside the parenthesis is the probability of J-statistic. *** indicates significance at 1%; **indicates significance at 5%, while * indicates significance at 10%
Source(s): Created by author

findings are consistent. The aging coefficient is mixed – negative and significant in three countries, positive and significant in three, and not significant in nine. Under the GMM framework, there is no evidence that aging hinders economic growth in 80% of the countries analyzed (12 out of 15), compared to two-thirds of the countries based on ARDL estimation.

5. Conclusion and discussion

The issues related to aging and its impact on economic growth are complex and multifaceted. As populations age, economies face several challenges and consequences, which can affect growth in both direct and indirect ways. In the meantime, today's technological innovation such as automation and AI, and longer life expectancy greatly impact productivity and shape the economy that we have not experienced before. This adds to the complexity of the effect of aging on economic growth.

In our study, we analyze the effects of aging on economic growth using data from 1991 to 2023, focusing on the 15 largest economies in the world. Our findings reveal that the impact of aging on economic growth varies significantly across countries. This variation suggests that while aging presents certain challenges to economic performance, its impact is influenced by country-specific factors such as technological advancements, labor market dynamics, government policies, and the ability of economies to adapt to demographic shifts.

While the estimation results for most countries from the ARDL and GMM methods are not exactly same, the overall findings on the impact of aging on economic growth remain largely consistent. Specifically, the ARDL estimation does not indicate significant negative effects of aging on growth in 10 out of 15 countries, while the GMM estimation yields similar results in 12 out of 15 countries. These findings provide strong evidence that aging may not necessarily hinder economic growth, a conclusion that contrasts with most previous studies. Possible explanations for this divergence, particularly in the case of the US, are discussed in the preceding section. Additionally, the long-term relationship between aging and economic growth remains stable across most of the countries examined.

As demonstrated by Aiginger (2005), labor market regulations significantly impact economic performance. Beyond the US, which we have previously discussed, countries such as Japan, Germany, Canada, and South Korea offer exemplary models. Japan, confronting one of the world's most rapidly aging populations, has emerged as a global leader in automation and robotics. The country invests heavily in technologies that bolster key industries such as manufacturing and healthcare, while also gradually opening its immigration channels for skilled workers to supplement its labor force. Germany actively promotes lifelong learning and skills development through a robust apprenticeship system and comprehensive vocational training programs. Additionally, it has reformed its immigration policies to attract highly qualified professionals, particularly in sectors facing labor shortages. Canada has long integrated immigration into its labor market strategy. By streamlining processes for skilled workers and investing in effective integration programs, Canada addresses demographic challenges and strengthens its workforce. The nation also emphasizes reskilling and upskilling initiatives to keep pace with technological advancements. Similarly, South Korea has enhanced workforce productivity by investing in both automation and education. The country supports research and development in automation technology and provides targeted training programs to help workers adapt to the evolving economic landscape.

Given the critical role of technological advancement and policy intervention in shaping economic outcomes, a key limitation of this study is the exclusion of these factors. Although the study focuses on demographic aging as a primary driver of growth dynamics and implicitly captures other influences through GDP at PPP and labor force variables, it does not explicitly account for the direct effects of innovation, automation, or productivity-enhancing technologies. These factors can substantially mitigate the economic impact of an aging population. Similarly, public policy measures – such as adjustments to the retirement age, immigration policies, and investments in education and healthcare – can substantially influence labor force participation and productivity, thereby modifying the link between demographic shifts and economic performance. By omitting these variables, the model may overstate the direct impact of aging or overlook important moderating mechanisms. Future research should incorporate indicators of technological progress and relevant policy variables, where available, to better isolate the net effects of aging and provide a more comprehensive understanding of the multifaceted drivers of long-term economic growth in aging societies.

Nevertheless, insights from this study – along with comparative experiences from other countries – can help policymakers identify effective strategies to mitigate the adverse impact of population aging on economic growth. A range of policy tools remains available to address these demographic challenges. First, they can incentivize technological adoption by offering tax credits, or low-interest loans to businesses that invest in automation and advanced technologies. Additionally, they can support programs that help workers transition into roles that complement automated systems rather than directly compete with them. Investing in research and development to tailor automation solutions for industries facing labor shortages due to aging is also essential. Second, government can promote immigration to attract younger, skilled immigrants to counter demographic imbalances and inject new talent into the labor market. Third, the government can extend workforce participation to encourage older workers to remain employed through raising the retirement age, offering flexible work arrangements, and providing incentives for delayed retirement. Fourth, policy makers can reform social systems through updating pension and healthcare systems to ensure long-term fiscal sustainability while adequately supporting an aging population. Finally, policy makers can adopt family-friendly policies that encourage higher fertility rates, including enhanced childcare support, comprehensive parental leave, and other benefits that help families balance work and life.

Our study adds valuable insights to the broader discussion on aging and economic growth, underscoring the nuanced and context-dependent nature of this relationship. While aging is frequently viewed as a constraint on growth, our findings suggest that its impact may not be as detrimental as traditionally assumed. In many cases, the effect is not negative because of factors such as a country's ability to promote productivity and labor force participation among older individuals, as well as targeted investments in productivity-enhancing sectors like technology and healthcare. These country-specific strategies reveal that aging populations, when supported by adaptive policies and innovations, may exert a more limited drag on growth. This perspective encourages a more balanced view, highlighting the potential for sustainable economic performance even within aging societies.

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