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ORIGINAL RESEARCH

Exploring the Dynamics of the Elderly Population and Economic Growth: A Comparative Analysis Across Continents

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Abstract
This paper explores the cause-and-effect relationship between the elderly population and global economic growth, focusing on different continents. A panel dataset spanning from 1961 to 2020 is utilized, with Gross Domestic Product (GDP) serving as the key measure for economic growth, represented as the percentage change in annual GDP. The study specifically centers on individuals aged 65 and above as a percentage of the total population. The analysis employs a Panel Granger causality test to assess the impact of the elderly population on economic growth. The results reveal a unidirectional Granger causality for Africa and Oceania, suggesting a one-way influence from the elderly population to economic growth. Conversely, instances of bidirectional Granger causality are identified for Asia, Europe, North America, and South America, indicating a mutual influence between the elderly population and economic growth during the study period. The study concludes that an endogenous relationship between economic growth and the elderly population emerges, but notably, this relationship becomes apparent only after an economy has completed its transition in economic development. This implies that the dynamics of the elderly population and economic growth are interlinked, with the nature of their interaction becoming more pronounced in the later stages of economic development.

Keywords Economic growth · Elderly population · Continents · Panel vector autoregression

1 Introduction

The connection between the ageing population and economic growth has been a subject of debate among scholars. Irrespective of the pace of economic expansion, the population and its demographic changes exert a stimulating impact on the overall process of economic development. According to Pham and Vo (2019), diverse age brackets display varying levels of productivity and financial necessities, while global governments and experts are keenly interested in understanding how these differences influence economic growth.

Extended author information available on the last page of the article

As evidenced by the latest World Bank report on the world Ageing Population Statement, high ageing populations over 65 is projected for the Asia Pacific region (The World Bank, 2021). While a decade ago, this may not have been a pressing issue for the ageing elderly population—but over time, the globalised economy, urbanisation and migration have caused a stir where currently, the issue is much felt. Yang et al. (2021) pointed out that during early 2000, the ageing elderly population did not have much concern or probably was unaware of ageing with dignity. This has been the case, especially with a high level of a support system of close relatives and children, predominantly in countries such as China and India, with the highest ageing populations in the world. With the change in lifestyles and related decisions, the world is now at a crisis point in handling more than 1.4 billion adults above 65 (Yang et al., 2021).

Sidlo et al. (2020) emphasised different viewpoints on the ageing population and the economic and social development of the world. Here, one distinctive element is the notion that the elderly men and women need to be taken care of since they do not substantially contribute to a country's economy and social development. Also, Sidlo et al. (2020) highlighted that the Westernised scenario of an ageing population living in assisted healthcare facilities may have also contributed to such biased notions. Some scholars unveiled another perspective. Maity and Sinha (2020) and Mitra and Abedin (2020) proved that, particularly in countries such as China, India, and Thailand, which have strong Confucian values ingrained, the elderly have a high stake in economic participation even after their prime years. The key reason for such considerations to go amiss is that most of these elderly population activities stem tend to occur within an informal economy and are hence not considered formal economic activities.

Within the rising ageing population globally, a country needs to identify its importance, i.e. whether it is somewhat a detrimental component or an engaging driver for economic and social growth (Yang et al., 2021). Thus, the conservative viewpoints often state that the ageing population can inherently be used wisely as assets to empower and engage the younger population, create and establish personal bonds, and act as advisories. In contrast, the liberal views focus on the elderly as a liability (Maity & Sinha, 2020). But such aims cannot be discussed and diffused without proper claim, and hence more systemised and statistical analysis of the available data needs to be brought on. In light of the above, an empirical study on this subject is significant. Therefore, the current study objective is to examine the Granger causality between the elderly population and economic growth based on continents. Hence, the panel Vector Autoregression (PVAR) model and the Granger causality test are used for analytical purposes.

As explained before, this research determines the direction of causality between the senior population and the economies of countries globally. The gross domestic product (GDP) gives a snapshot of the size of a country's economy, as well as its growth rate and direction. The GDP can be estimated from three different perspectives: expenditure, output, or income, and it can be adjusted for inflation and population to provide a complete picture of economic performance. The elderly population is defined as those aged 65 and above. These statistics have a wide range of implications for government and private retirement related planning, medical, education spending and overall economic success.

As a result, this study differs from previous research and adds to the literature in three areas. No prior research study targetting the global arena has been undertaken in the subject. According to the information available to experts, this study will be the first of its kind to be conducted with reliable data on a global scale. The causality patterns between the elderly population and the economy may alter between nations with varying levels of economic growth, given the broad country sample included in the analysis. Accordingly, the countries in the sample were grouped into six continents: Africa, Asia, Europe, Oceania, North America, and South America.

Examining the impact of ageing populations on GDP at a continent-wise level offers a more detailed insight into the intricate connections, enabling targeted policy interventions, improved resource planning, and informed decision-making globally and regionally. Specifically, variations in ageing trends across continents necessitate a nuanced approach. Some continents witness rapid ageing due to declining birth rates and increased life expectancy, while others maintain younger populations (Lee & Mason, 2010). This continent-wise analysis aids in comprehending these disparities, facilitating tailored policies to address specific challenges in each region. The economic ramifications of ageing populations also differ significantly among continents. Some may grapple with a pronounced economic burden due to a higher proportion of elderly individuals, affecting labour markets, pension systems, and healthcare costs. In contrast, others may exhibit more resilient economies owing to effective policies or unique demographic structures. Moreover, the implications for policy are noteworthy (Bloom et al., 2010). A continent-wise analysis enables the identification of best practices and lessons learned from regions successfully navigating challenges linked to an ageing population. Policymakers can leverage insights from these successful strategies, adapting them to their distinct demographic and economic contexts. In the context of global economic interdependence, understanding the dynamics of ageing and GDP on a continental scale is paramount. Economic challenges in one continent can send ripple effects across others through trade, investment, and other economic linkages. Analysing ageing at a continental level contributes to a more comprehensive global economic outlook. Resource allocation also benefits from continent-wise analysis. Governments and organizations can anticipate future demands on social services, healthcare, and pension systems, facilitating efficient resource allocation and long-term planning for the sustainability of social and economic systems.

Secondly, in an effort to encompass the characteristics of the elderly population, this study utilizes both an extended sample period dataset and specific datasets—namely, the World Bank Indicators (WBI) datasets—to examine the causal effects between the elderly population and economic development. The researchers delve into the causal relationship between the ageing population and economic growth over a span of 60 years, aiming to bridge existing information gaps. Additionally, the study underscores key implications derived from its findings, offering valuable insights to decision-makers in government, healthcare, and policymaking sectors.

The subsequent sections of the paper are organized as follows: Sect. 2 provides an in-depth analysis of empirical research and a literature review concerning the correlation between population ageing and economic growth. Section 3 elucidates the data and methodology employed in the study. Section 4 presents the empirical findings and their interpretations. The study concludes in Sect. 5.

2 Literature Review

This study referred to past literature over a 60-year period between 1960 and 2020. An increase in life expectancy has benefitted societies in many ways. It has been connected to increasing levels of income, among other benefits. This section discusses the relationship between elderly populations and economic growth globally, examining factors such as changing demographics and their impact on economic growth, the most widely used research methods, concepts, indexes, policy implications, and future research areas.

2.1 Middle East & Africa

The most striking benefits have been observed in Middle Eastern nations, with (McKinsey Global Institute, 2015) stating that Middle Eastern countries, including the United Arab Emirates, Saudi Arabia, and Kuwait, have experienced a significant reduction in population ageing influence. According to Abeywardhana (2019), the low economic impact of these Middle Eastern countries is because 70% of their population consists of expats on temporary work permits, and the impact of a tightly controlled family value system—particularly among migrant workers from South Asia.

Further to the above, the elderly receive excellent health care and family support—and on top of this, the additional government funding has shown to be quite useful. These improvements in caring for the elderly, however, are mostly centred in the Middle East, and statistics from other third-world countries, such as Chad, Niger, and South Africa, have not been extensively described and analysed. The existing body of literature addressing the connection between the elderly population and economic growth in Africa is constrained by the scarcity of dependable data. However, as Abeywardhana (2019) notes, many nations, which rely heavily on informal economies, lack a defined retirement age and require people to perform to an enterprise or care for their households until they are physically unable to do so.

It is noteworthy that according to Sidlo et al. (2020), elders in the majority of African tribes play a significant role in information and knowledge transfer, as well as in the teaching of the young—and are therefore productive and well paid. As a result, evaluating how population ageing has influenced their growth cycle over time is a substantial challenge in a community influenced by tribal culture.

2.2 Asia

Asian perspectives on the ageing population are diverse (Akram, 2016) and show a different perspective. Ageing is considered a normal aspect of the human cycle; as such, elders are frequently perceived to achieve the peak of human life. As a result, these values spill over on Asia's ageing population and economic growth. Especially in China, India, and Thailand, the elderly prefer to work far into their retirement years, emphasising entrepreneurial endeavours later in life. Specifically, Abeywardhana (2019) noted that these nations hold strong religious beliefs and hence place a premium on treating elders properly and maintaining a strong work ethic in their later years. As a result, this has been mostly seen through their perspective on the ageing population. Additionally, Mamun et al. (2020) indicate that both short- and

long-term economic growth has been negatively impacted in countries since a considerable proportion of disposable income has to be directed for elderly care. However, the most significant component is that systemised subsidies and care for the elderly are often significantly cheaper, having a minimal burden on the government. Furthermore, individual households are responsible for the ageing population in their immediate region, which has a negative effect on the disposable incomes of these households while catering to the elderly. Increase in disposable income means more savings. Moreover, Akram (2016) stated that, in contrast to Europeans and other industrialised continents, Asian families have a high wealth accumulation and savings rate, which is reflected in the latter stages of care for the ageing population. Specifically, this results in a significantly greater generational wealth accumulation and may be employed in a later context (Horioka et al., 2018).

Jayawardhana et al. (2023a) underscore the growing prevalence of ageing populations in Asia and its potential ramifications on economic growth. The study investigates the correlation between the elderly demographic and economic growth in the Asian context, offering valuable perspectives on the efficacy of governmental policies. Results indicate an adverse influence of the elderly population on economic growth in the majority of the examined countries, underscoring the necessity for policymakers to institute measures that motivate the elderly to actively contribute to national economies or propose initiatives that encourage such participation.

2.3 Europe

As far as continent-level research on the ageing population is concerned, Europe as a continent has tended to bear the burden of the high level of the ageing population (Yang et al., 2021). This scenario has disproportionately and adversely affected Scandinavian nations due to their older population and low fertility rates (McKinsey Global Institute, 2015). Thus, the ageing population has directly impacted economic development in both the short and long run. In the medium term, government subsidies for the elderly must be raised to enhance the life quality of the people aged 55–64 by offering chances for social security, lifelong learning, preventative health programs, and work prospects (United Nations, 2022). As a result, the additional burden on public resources can have a negative effect on the economy in the long run. Additionally, when it comes to short-term health and other problems of the elderly, the burden on young families results in lost productivity.

As evidenced by statistics, Europe bears the heaviest burden of the ageing population. As McKinsey Global Institute (2015) explained, with protestant values at the forefront of these countries, work is a primary means of purpose for Europeans. Thus, when they are no longer needed and their contribution is not recognised, their health rapidly declines, increasing the economy's burden. However, as explained previously under this subsection, Scandinavian nations, in particular, have experienced a rise in the elderly population at the expense of health care subsidies.

2.4 Oceania

Oceania-related research has tended to be scarce in the existing literature and accessible publications, except for a few studies focussing on New Zealand and Australia. Thus,

within these two nations, (Uddin et al., 2016) noted that the ageing population has tended to increase over the last decade, starting in 2010 and that subsidies for elderly care in terms of health and assisted living have also grown (Horioka et al., 2018). According to Yang et al. (2021), this has had a negative effect on the economy's overall effect due to the growing population and diversity difficulties, including aborigines and other indigenous populations. The WBI reported to United Nations (2022), that the Australian government has a disproportionate influence on aboriginal parties through subsidy, when combined with the effect of providing to an ageing population, has had a considerable negative impact on the country's economy. The World Bank cited in United Nations (2022), showed that the Australian government tends to have a very heavy impact form subsiding for the aboriginal parties and therefore this compounded with the effect of catering to the ageing population has significantly created a negative impact upon the economy of the country.Thus, this was visible in the several varied taxes levied on the country, the majority of which targetted the highest earnings. According to the McKinsey Global Institute (2015), more than 20% of service sectors in Oceania are geared toward the elderly, including providing assisted living, help, and care packages to the aged. The major effect of ageing is that these populations tend to lose their innate value-driven work ethic, resulting in a rapid loss in health. Mitra and Abedin (2020) found out that with many children travelling to various cities and towns—particularly in rural areas of Australia—there are several concerns regarding the elderly population's lack of savings, which has an inherently negative effect on the economy.

Thus, Uddin et al. (2016) observed the Granger Causality tests indicate that there is no noteworthy short-term connection between the variables—dependency ratio, savings rate, and real GDP—in Australia, except for a unidirectional link between the dependency ratio and GDP per capita. Similar to the findings in the earlier study on the continent, it is observed that the ageing population exerts a substantial adverse influence on Australia's real GDP and economic growth.

2.5 North America

As a region that houses more than 7% of the world's population, Northern America has a strong interest for economic growth and population growth (United Nations, 2022). Various studies on the ageing population's influence on the country have been performed, emphasising the long and short term effects on economic growth. The United Nations (2022) noted that North America's ageing population—particularly in the United States (US)—is more susceptible to a variety of illnesses than any other continent. This region has over 30% of the population suffering from hereditary diseases such as cancer, gestational and heart problems, and other inflammatory or autoimmune diseases. While there has been no explicit examination of continent-wide care for the elderly, the Canadian government, in particular, has spent heavily on medical costs and facilities, age-friendly infrastructures, and subsidies (Atkins, 2016). Thus, both in the short and long term, these result in massive fiscal losses for the government, since it subsidises the elderly who are not productive; it also increases the reliance on care to a much higher level (Abeywardhana, 2019). As Mamun et al. (2020) proved, the strain on adult, middle-aged children caring for elderly parents has increased dramatically in the past, most likely following the pandemic, and therefore has been substantiated by the causation link evaluation. Accordingly, this is because

many young children have chosen to return to live with their parents, which results in a high level of parent–child reliance.

Hock and Weil (2012) pointed out that Northern America has seen a significant shift in attitudes related to elderly care. As a result, the immediate effects are still notnoticeable within the context. However, this also indicates that, with the average spending in Northern America being far greater than the global average, the burden on economies to support the elderly would further increase, having a considerable influence on economies.

Approximately one-third of the overall impact of population ageing on economic growth is manifested through alterations in employment per capita, while the remaining two-thirds are attributed to changes in output per hour worked. This indicates that the consequences of population ageing extend to both the quantity and quality of the labour supply. The ageing trajectory of the U.S. population has been nearly continuous over the past century, and this trend is anticipated to persist. The current scenario of population ageing stems from a significant reduction in the birth rate during the 1960s, marking the conclusion of the Baby Boom, coupled with an ongoing decrease in mortality rates among specific population groups. This demographic transition carries significant implications for the economy, influencing the size and composition of the labour force, as well as the demand for goods and services (Maestas et al., 2023).

2.6 South America

From a historical perspective, a few updates were reported in South America as comprehensive research. However, these updates have been included in other mixed continental studies, notably in Brazil, Chile, and Puerto Rico. These countries' frequently rising economies have a far more limited view of the ageing population. Besides, these countries have a favourable perception of the older population and make liberal use of their experience (Sidlo et al., 2020). Yang et al. (2021) noted that while a decline in labour force participation is inevitable for these nations—given the majority of these countries have high labour-intensive sectors—the broader contribution to child raising, household tasks, and community building is much more approachable. However, when the long term impact of the elderly population on South American countries is considered, it is not treated as a concern regardless of its negative effects. Primarily, as Maity and Sinha (2020) observed, these countries have extremely extended family values, where ageing is viewed positively within the family. Thus, the elderly have above-the average activity levels and extended participation in informal activities such as farming, child rearing, and babysitting, allowing the more abled members to work and participate in formal economic activism.

Given the scarcity of resources in these nations and the impending influence of population expansion on economic growth, the mixed outcomes may be characterised positively and negatively.

2.7 All Countries

Conflicting opinions can be observed when the overall global impact of the ageing population is considered. The world's population is ageing rapidly, while the fertility rate has declined notably in various regions (McKinsey Global Institute, 2015). As a result, this imposes a broken link to global production economies, where labour will

necessarily be scarce. Therefore, the issue is susceptible to escalating to a much bigger magnitude in the future. However, the United Nations (2022) stated that nations such as India and China have a stable rate of child birth, and hence the problem of the future labour force is manageable. Using the panel co-integration and causality approaches, Mahmoudinia et al. (2020) demonstrated a lasting connection between the variables under consideration, namely GDP growth and capital stock. Over an extended period, the population exhibits a positive and statistically significant impact on economic growth. However, in terms of the world's population expansion, the United Nations (2022) claimed that it would inevitably negatively influence countries' economic growth by delayaing the progression of the economic activities.

This segment explored the correlation between the elderly population and economic growth across diverse countries, aiming to juxtapose empirical evidence from African, Asian, European, North American, Oceania, and South American nations. The examination delved into the shifting demographics and fiscal complexities of these countries, scrutinizing the impact of the ageing demographic on economic progress. Theoretical foundations, research methodologies encompassing models, indexes, concepts, policy ramifications, and potential avenues for future studies were comprehensively considered. In Asia, a giant issue prevails with an ageing population, which currently hinders the continent's economic growth. China, in particular, is expected to undergo economic decline as a result of its ageing population. An identical situation exists on the European and American continents. As a result, appropriate steps are needed to rectify the issue. In comparison to other continents, Africa, on the other

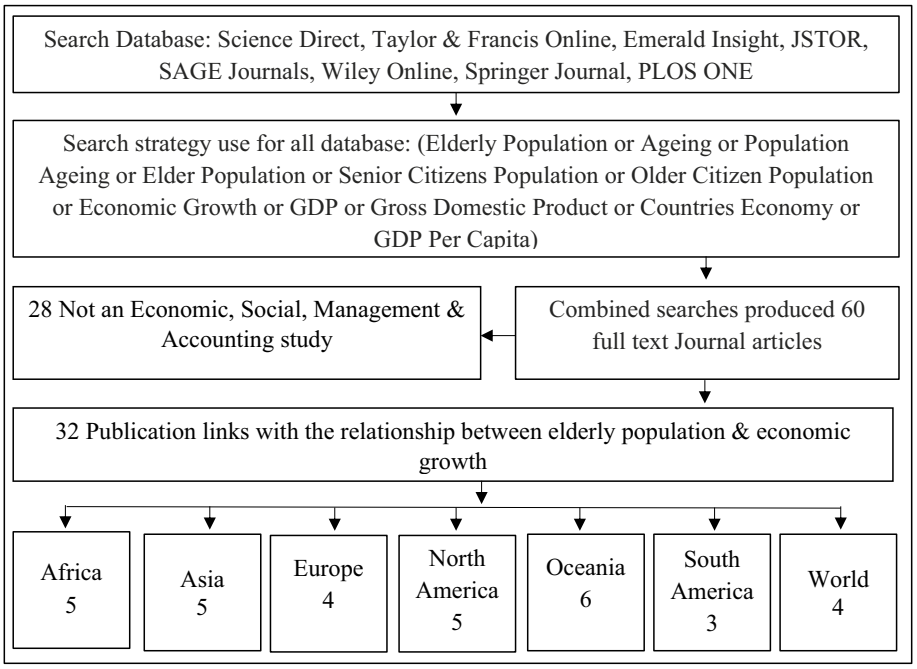

Fig. 1 Search strategy and classification of publication. Source: Authors' illustrations

hand, has a younger population. Thus, with appropriate and timely policies are in place, countries will be geared to reap the optimum economic advantage from the existing population.

Nagarajan et al. (2016) pointed out that the influence of ageing populations on economic growth can vary based on the diverse policies and institutions existing in different nations. For instance, countries possessing more extensive pension systems might encounter more pronounced adverse impacts on economic growth as a result of ageing populations. Conversely, nations with more adaptable labour markets and policies promoting immigration may be more adept at alleviating the detrimental effects of an ageing population on economic growth. In general, the existing literature emphasizes the importance for policymakers to carefully assess the potential consequences of ageing populations on economic growth and to implement strategies that can effectively mitigate these effects.

The relationship between the elderly population and economic growth has been a subject of considerable scholarly inquiry, with diverse perspectives emerging from the existing literature. A seminal work by Bloom et al. (2010) establishes a positive correlation between an ageing population and economic growth, arguing that older individuals contribute to productivity by leveraging experience and knowledge. However, contrasting this viewpoint, Lee and Mason (2017) contend that an increasingly elderly demographic may strain healthcare and pension systems, potentially impeding economic growth. This dichotomy highlights the complexity of the issue, requiring a nuanced understanding of various factors.

Moreover, studies such as those by Lee and Lee (2019) have explored the impact of the elderly population on consumer behavior and market dynamics. They posit that the silver economy, driven by the purchasing power of older individuals, can stimulate economic growth through increased demand for specific goods and services tailored to this demographic. In contrast, Bloom et al. (2021) caution against overlooking the potential negative consequences, emphasizing that the economic benefits of an ageing population are contingent upon effective policy responses addressing healthcare, employment, and social welfare.

The comparative literature thus underscores the need for a comprehensive approach to studying the relationship between the elderly population and economic growth. The divergent perspectives presented by (Bloom et al., 2010, 2021; Lee & Lee, 2019; Lee & Mason, 2017) underscore the multidimensional nature of this relationship, necessitating a nuanced research methodology that considers various contextual factors and policy implications. As the field advances, it becomes increasingly evident that a holistic understanding of the interplay between an ageing population and economic dynamics requires an integration of quantitative and qualitative research methods to capture the intricate nuances of this complex relationship.

3 Data and Methodology

3.1 Data

This study employed a quantitative approach, utilizing secondary data sourced from the WBI online database and employing panel data analysis. Economic growth was gauged through the per capita GDP growth rate, expressed as an annual percentage, using constant local currency for cross-comparisons. The elderly population was assessed by considering the percentage of individuals aged 65 and above in the total population. To ensure a comprehensive dataset, data were gathered annually spanning from 1961 to 2020. The analysis focused on 15 Asian, 14 European, 27 African, 3 Oceanian, 12 North American, and 13 South American countries, resulting in a total of 5,040 observations for the study. The

study examines 60 years of annual data from 84 countries, with one data point per country per year, for a total of 5040 observations.

3.2 Methodology

Several reputed electronic research databases, including Emerald, Science Direct, SAGE Premier, Wiley Online and reports were accessed for published literature in English. Figure 1 shows the pathway of the literature search.

This segment discloses the chosen research methodology, the data collection approach, and the economic model employed in this study. Various techniques for conducting Granger causality tests in panel data models exist (Granger, 1969). In this investigation, the current researchers utilized the methodology suggested by (Dumitrescu & Hurlin, 2012).

In this context, two variables, x and y, are regarded as covariance stationary and observed over T time periods and N cross-sectional units. Granger (1969) causality is defined as follows: the variable xi,t is considered a cause of yi,t if researchers can improve the prediction of yi,t by using all available information, compared to using information excluding xi,t for each individual i∈[1,N]. The Granger-causality model is assumed to be linear.

Granger causality serves as a method to explore causality between two variables in a panel time series. The concept of "causality" is linked to the idea of cause and effect, although it is not precisely identical. If the X variable Granger-causes Y, it implies that past values of X should contain information aiding in predicting Y. Consequently, a time-stationary Vector Autoregression (VAR) representation will be examined and applied to a panel dataset. The subsequent model is estimated for each cross-sectional unit i and time period t.

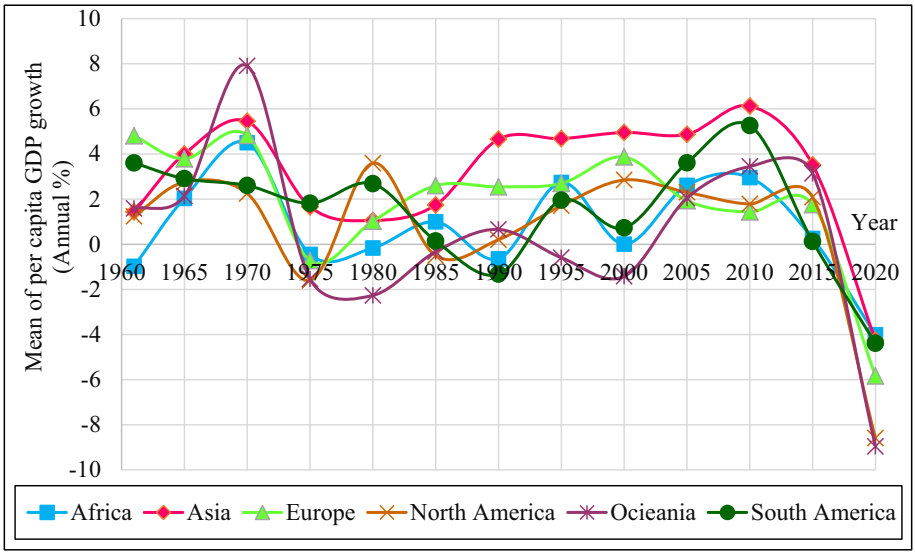

Fig. 2 Graphical display of mean of GDP growth (Annual %) that changes continuously over time. Source: Authors' illustrations based on world bank data

$$y_{i,t} = \sum_{k=1}^{p} \beta_k y_{i,t-k} + \sum_{k=0}^{p} \theta_k x_{i,t-k} + u_{i,t} \quad (1)$$

Here, u is normally distributed with $u_{i,t} = \alpha_i + \varepsilon_{i,t}$, p is the number of lags, and $\varepsilon_{i,t}$ are i.i.d. (0, σ^2). It is assumed that the autoregressive coefficients β_k and the regression coefficients θ_k's are constant for k ϵ [1, N].

In this context, u follows a normal distribution, where ui,t = αi + εi,t, p represents the number of lags, and εi,t are independent and identically distributed (i.i.d.) with a mean of 0 and variance of σ^2. It is presupposed that the autoregressive coefficients βk and the regression coefficients θk's remain constant for k ∈ [1, N

This research methodology is crafted to examine the causal relationship between the elderly population and the economies of various countries in the region. In essence, the study aims to ascertain whether the causality direction between the elderly population and a country's economy is bidirectional, unidirectional, or non causality.

To discern the Granger causality direction between the variables, a four-stage process is employed. Firstly, the Levin Lin Chu (LLC) unit root test is applied to investigate the stationary characteristics of the population aged 65 and above and per capita GDP, using panel data. If all variables demonstrate stationarity, the VAR model is employed for the subsequent phase of the linear Granger causality test. Subsequently, the PVARSOC technique is utilized to identify the optimal lag. Finally, the Granger causality test is conducted to establish the direction of causation between the variables.

Under the assumption that the Granger-causality model is a panel model, researchers will explore a Panel Vector Autoregression (PVAR) representation for the panel dataset.

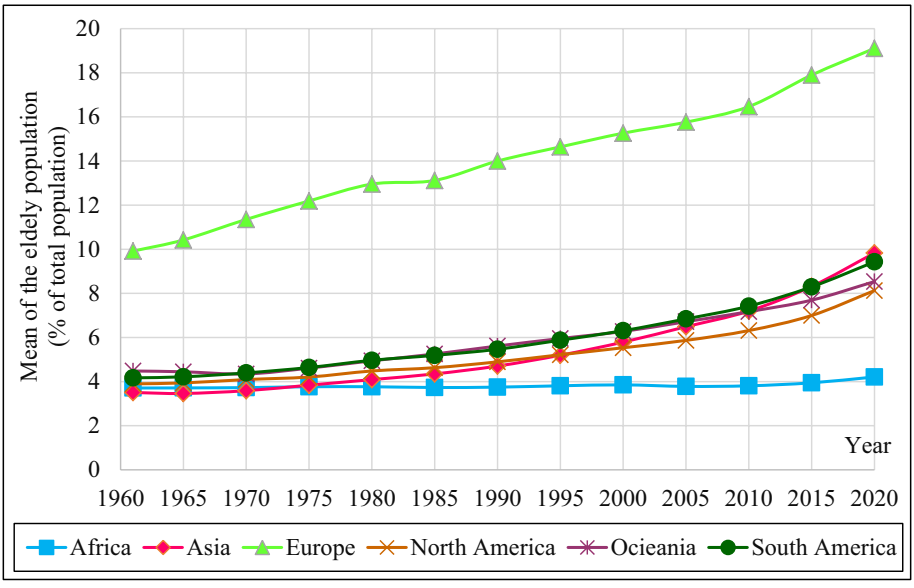

Fig. 3 Graphical display of mean of percentage of elderly population that changes continuously over time. Source: Authors' illustrations based on world bank data

The Panel Granger causality Test relies on certain assumptions for its validity. The time series data for each variable should be stationary. In the context of panel data, this assumption extends to both the cross-sectional and time dimensions. Panel unit root tests such as levin lin chu unit root test conducted in this study to ensure stationarity. The relationship between the variables should be linear. This means that the changes in the dependent variable are a constant proportion of the changes in the independent variable. The variables used in the analysis should be measured without error. Measurement errors can introduce bias and affect the accuracy of the test results. Ane there are No omitted variables, all relevant variables should be included in the model. Omitted variables can bias the results, especially when they are correlated with the included variables. It's important to note that violating these assumptions can affect the reliability and validity of the Panel Granger causality Test results.

4 Results and Discussion

The study's primary purpose is to examine the causal relationship between the elderly population and global economic growth utilising secondary data from a panel data set covering the period from 1961 to 2020. The research analysed 5,040 observations across the globe's six continents.

Table 3 in the Appendix presents the summary of descriptive statistics. Results show that among the countries covered in this study, Guyana on the South American had the highest GDP per capita growth rate, while Rwanda on the African continent had the lowest GDP per capita growth rate. Europe and Asian continents have above par GDP per capita growth rate when considering the global context. Also, a clear contrast of GDP per capita growth rate between countries in a continent is observed worldwide, as the coefficient of variation in GDP per capita growth rate is greater than one across all continents. Specifically, Japan on the Asian continent shows the largest elderly population as a percentage, while Niger on the African continent shows the lowest elderly population as a percentage.

Figure 2 illustrates GDP per capita of continents between 1961 and 2020. After 1965, GDP per capita growth rate has been fluctuating in all continents owing to the cyclical nature of economic growth. However, Asian continent was able to retain higher GDP per capita growth rate from 1985 to 2015. Furthermore, Europe was showing a similar trend but at a lower value than Asia. All the continents without an exception have gone to a recession towards 2020 due to the inevitable economic damages caused by covid 19 pandemic and resulting lockdowns.

Figure 3 shows the elderly population above 65 which continents over the 60 years from 1961 to 2020. Overall, the elderly population steadily increased during the 60 years in all continents. In general, the most significant increases in the elderly population are reported in Europe between 1961 and 2020. Asia, Oceania, North America and South America show similar gradual growths in their elderly population. Elderly population in Africa has remained almost constant since 1961.

Low fertility in Europe due to socio-economic factors such as changing gender roles, and the rising cost of living led to the relatively high increase in the proportion of elderly population over the past few decades.

Interesting insights can be drawn when Figs. 2 and 3 are considered. Even though the elderly population (% total) in Europe has increased at a relatively high rate, GDP per capita growth rate is quite similar to rest of the continents. On the other hand, GDP per capita

Table 1 Results of Granger Causality test

Panel granger causality test by groups of continents		
	DGDP → DDEPOP	DDEPOP → DGDP
Africa	9.239**	0.903
Europe	10.98 **	39.138 ***
	GDP → DDEPOP	DDEPOP → GDP
All Countries	32.601***	23.773***
Asia	13.53***	12.926***
North America	10.856**	13.825***
Oceania	6.925*	2.088
South America	22.734***	7.603*

Remarks: *, indicates significance at the 10% significance level,**, indicates significance at the 5% significance level,***, indicates significance at the 1% significance level. DDEPOP = second difference of elderly population; DGDP = first difference of GDP

Table 2 Granger causality test results by group of continents

Continent	Test	GDP-POP
All countries	LLC	two-way
Africa	LLC	one-way
Asia	LLC	two-way
Europe	LLC	two-way
Oceania	LLC	one-way
North America	LLC	two-way
South America	LLC	two-way

LLC = Levin-Lin-Chu test

fluctuated considerably for the rest of the continents, but the elderly population grew steadily. The volatility is high in GDP per capita when compared to that of the elderly population. Also, while cyclical variations are visible in Fig. 2, such variations are not visible in Fig. 3. The reason for these is probably due to no major disasters, wars or pandemics that caused high death rates and wiped out large populations between 1961 and 2020. The worst effects of the COVID pandemic came into effect after 2020. High life expectancy and technological advancements would have been major driving factors for the elderly population and GDP per capita growth.

4.1 Levin Lin Chu Unit Root Test

Preliminary to the Granger causality analysis, researchers test for stationarity of GDP and the elderly population. Accordingly, the LLC Unit Root Test created by Levin Lin Chu in 2002 is employed in the study. A panel unit root test is suggested for the null hypothesis of unit root against a homogeneous stationary hypothesis.

Table 4 in the Appendix reports the results of the panel unit root test suggested by LLC for the elderly population (% total) and real GDP per capita growth (% annual). In this test,

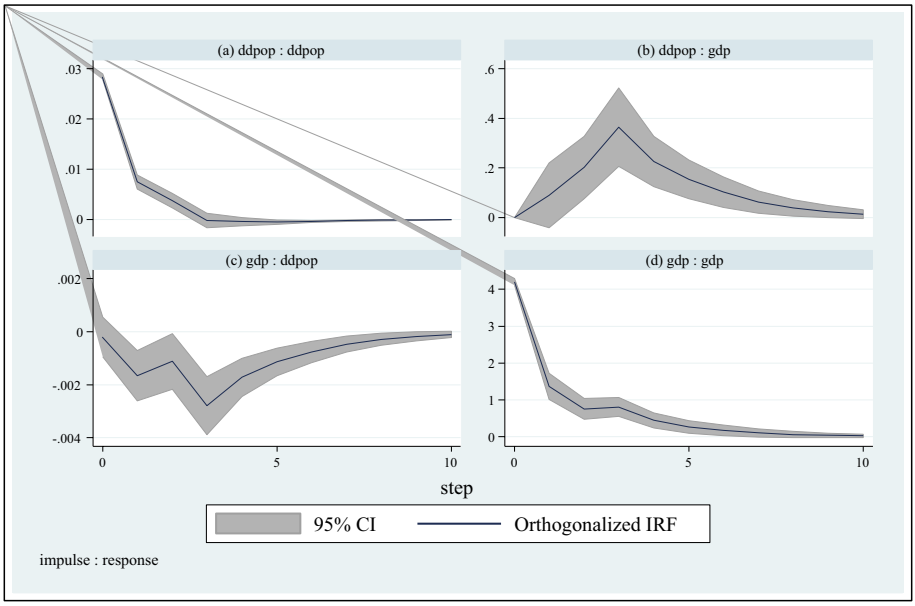

Fig. 4 Impulse response of the GDP and elderly population for all countries. Notes: dgdp = first difference of GDP; ddpop = second difference of elderly population. Source: Authors' illustrations based on STATA software

Panels contain unit root in the null hypothesis, while panels are stationary in the alternative hypothesis. In Stata statistical software, researchers first performed a LLC unit root test for GDP variables. The GDP variable was stationary at the first level for all continents. Then, researchers performed the elderly population variable test and found that all continents are unit roots at the first level. Africa and Europe became stationary at the first difference (DEPOP) of the elderly population. Other continents became stationary at the second difference (DDEPOP).

4.2 Lag Length Criteria

The next step is to decide on the optimal lag length of the PVAR specification. To discover the optimal moments and model lag order, PVARSOC can be leveraged to calculate selection-order statistics. This PVAR Lag Selection Criteria table (Table 5 in the Appendix) presents results from the first-, second-, third-, fourth-, fifth-, sixth-, seventh-, eighth- and ninth order PVAR models using the first tenth lags of the endogenous variables as instruments.

The Hansen's J test is used to test over-identifying restrictions in a statistical model. The optimal lag length in the PVAR specification is determined based on Moment selection Akaike Information Criterion (MAIC), Moment selection Bayesian Information Criterion (MBIC), and Moment selection Hannan and Quinn Information Criterion (MQIC). The optimal lag length should be the one that minimizes the MBIC, MAIC, and MQIC

information criteria. When mixed results are obtained, the decision is based on the minimum value in the MAIC criterion (Serena & Perron, 2001).

According to Table 5 in the Appendix, selecting five lags for all countries, Africa, Asia, and South America continents lowers the MAIC criterion in our case. Further, the MAIC criterion is lower when select even lags for European continent. In the Oceania continent, the MBIC and the MQIC criteria are lower when selecting one lag, but the MAIC criterion are lower when selecting four lags.

4.3 Granger Causality Test

Researchers ran the Granger causality test based on six continents. These empirical results are reported in Table 1. Granger causality is a method to examine the causality between two variables in a panel time series. "Causality" is related to the cause-and-effect notion, although it is not exactly the same. Rather, it is a statistical concept which is based on prediction. If X variable's Granger causes Y, then past values of X should contain information that helps predict Y (Galappaththi et al., 2023; Granger, 1969; Jayawardhana et al., 2023b).

When GDP per capita (% annual) Granger causes elderly population (% total) and vice versa, this is known as bi-directional Granger causality. If only Granger causes another in a single direction, it is unidirectional Granger causality. If both the variables are independent, then there is no causality.

Table 2 additionally presents the outcomes of the Granger causality test. The hypothesis is rejected for full sample continent whether the causal effect is running from elderly population to real GDP per capita or vice versa. This finding indicates a unidirectional causal effect between the elderly population and economic development in the full sample continent. It means that the country's economy promotes the elderly population in Africa and Oceania. This finding is in line with Maity and Sinha (2020) who also found evidence of unidirectional causality between the elderly population and the country's economy. Nevertheless, as shown in Table 1, the results for Asia, Europe, North America and South America continents indicate Bi-directional effects between the elderly population and the country's economy.

Based on the Granger causality results obtained from this study, it can be concluded that certain changes in economic growth affect the decision making of the ageing population. The panel Granger causality test consists of the following two hypotheses:

H_0: Excluded variable does not Granger-cause Equation variable.

H_a: Excluded variable Granger-causes Equation variable.

Figure 4 demonstrates the impulse response of the gdp and ddpop with itself and with the other variable. The diagonal panels in Fig. 4a, d illustrate the impact of shocks to gdp and ddpop growth on the future values of their own growth. In Fig. 4a, ddpop have a standard deviation shocks in first and third phase associated with its own future values, and then the impact converges to zero gradually. In Fig. 4d, the gdp significantly responds to its own shock in the first phase and second phase. Following that, the impact steadily weakened and gradually converged to zero.

The off-diagonal panels of Fig. 4b, c show the effects of a growth shock in one variable on the path of growth in the other variable. In Fig. 4c, gdp has standard-deviation shock on ddpop shock in the first phase showing a significant negative impulse response and peaking in the second phase and again showing a shock in third phase, then the effect converged

smoothly to zero. In Fig. 4b ddpop significantly responds to gdp showing a significant positive impulse response and peaking in third phase and then the impact steadily weakened and gradually converged to zero.

As North America, Asia, South America, and Europe indicate a bidirectional causal effect between the elderlypopulation and economy in this study, in the previous literature, the governments have taken major steps towards indicating its effect. McKinsey Global Institute (2015) pointed out, in Australia and New Zealand, more than 20% of the service industries cater to the ageing population—starting with the provision of assisted living, aid and care packages delivered. However, in Oceania, elderly population does not Granger cause GDP per capita growth rate. Hence, such concern driven approach towards aged care indicates that while the statistical comprehension does not indicate a causal relationship, the societal concern is much higher. This is evident even with Yang et al. (2021) where it was proposed that the ageing population in Europe have a high level of concern in the Scandinavian countries economies in the long run. Particularly Nordic countries such as Norway and Sweden, with its egalitarian principles, will see much more concern in the coming years. As McKinsey Global Institute (2015) highlighted the effect is imminent in Europe, considering their lifestyle and also the differential approaches to taking care of the family. Mamun et al. (2020) asserted that in countries like Italy, the significant burden of the family can be quite lowered due to collectivism. This is much evident in most Asian countries—which can be a specific reason for the countries in Asia to show a lowered impact from the ageing population. In countries with the highest population such as China and India, the ageing population may not have an impact on the economy because of collectivism; even after retiring, the ageing population tends to take care of their young grandchildren and aid with agriculture.

According to the United Nations (2022), for the African and North American regions, 30% of the North American population tends to suffer from autoimmune and non-contagious diseases, which can significantly impact the economy, as in rising health care costs. The effect of this has been much higher considering the pandemic and its long-term effects. However, the Asian ageing population showed more resilience and therefore these statistics need to be included in the social and environmental variables among the limited variables. This is particularly for Asia and Europe, which record the highest longevity regions (Mamun et al., 2020).

For the African continent, GDP per capita is said to Granger cause elderly population with high statistical significance. This result suggests that high economic growth will increase the proportion of the elderly population. Fast growing economies in Africa may have led to high life expectancy resulting in a higher proportion of the elderly population(He & Li, 2020). On the other hand, the common belief that the high proportion of the elderly population hinders economic growth (Bloom et al., 2010) has been invalidated through this study. Reasonably, the burden of the elderly population on economic growth, particularly in the European & Oceania continents may have been veiled by the surge of migrant workers in the last few decades (Noja et al., 2018). Moreover, early action plans and proactive policy measures implemented by countries would have been instrumental in reducing the burden of the elderly population (United Nations, 1982). Overall, how the elderly are perceived, taken care of, regional beliefs and values etc., determine whether the elderly contribute to economic

growth in a respective country, whereas high healthcare costs by governments may not always lead to positive outcomes (as explained in developed countries).

However, even if the results show no Granger causality exists between GDP per capita and the elderly population for some continents, researchers cannot rule out the causality between the above mentioned two variables. But, future studies must consider potential mediator variables in the analysis.

Thus the finding indicates that there is a uni-directional causal effect between the elderly population and economic development in the full sample continent, which creates an impact on the population and economic growth to be impacted by each other. Therefore in terms of utilising the results for further dissection, it is clear that the Asia, Europe, North America and South America continents indicate Bi-directional effects between the elderly population and the country's economy and will be a significant challenge to mitigate in future, as the economies are growing it can clearly make an impact on how the elderly care is perceived by the middle class population. Primarily the current economic changes observed in most of the countries on a post pandemic context, such as the ' adult children moving back with parents to reduce the costs', leaving grandchildren with the care of elderly parents and parents migrating to work, the rising inflation causing to stay as an extended family are some factors which needs to be considered in the larger arena (McKinsey Global Institute (2015). Therefore while there is an impact on the growth of the economy by the changes in the grath of the peiopaualation – sub socio ecocnomic faators can iimpact the trend in the future.

5 Conclusion

In this paper, researchers applied the Granger- causality approach to a panel data model, to determine the direction of causality between the elderly population and economic growth. The main purpose of this study was to identify the relationship between the ageing population and the economy. Although economics models have been used to study many aspects of the ageing population and the economy, limited efforts have been made to study the relationship between the ageing population and the economy using Granger causality. Therefore, this study provides a socio-economic benchmark for improving and examining the relationship between the ageing population and the economy. According to the information accessible to the authors, no research has been conducted analysing all continents across the world carrying out a cross comparison. As a result, one of this study's relevant empirical contributions is to illustrate the causation between the elderly population and the economy worldwide over a long period, such as six decades from 1961 to 2020.

As endogenous variables, researchers used GDP per capita and the elderly population. The LLC Unit root test was used to evaluate the stationarity of an endogenous variable, and the findings indicated that GDP is stationary in the first level for all continents. In contrast, the elderly population is stationary in the first differences for Africa and Europe and second difference for other continents. The present study's findings were evaluated using static panel data approaches such as the PVAR Model and the Panel Granger Causality test. The statistical findings of this study indicate a unidirectional causality relationship between the economy and the elderly population

in Africa and Oceania. There is bidirectional causal effect between the elderly population and the economy in Asia, Europe, North America and South America.

The study's conclusions on the causal relationship between the elderly population and the economy are critical for governments in these geographical regions to adopt legislation and regulations and make demographic policy decisions. This study contributes to the economic and demographic policy implications for continents, guiding them in their efforts to grow their economies.

Despite the fact that a large sample of data was employed, certain countries were ignored from the analysis of each continent based on GDP and elderly population parameters due to a lack of available data. For future investigations, the empirical analysis may be extended by country, taking into account the individual countries on each continent. Researchers developed the list of variables suitable for this case based on earlier research. However, further study may reveal that some variables are more significant and impactful than others. Future research may focus on variations between demographic and economic sub-indices to acquire a fuller knowledge of the many viewpoints on the global economy and the elderly population. Given that the data for this research was taken from 1960s towards 2020s, researchers must bear in mind that even the moderating variables might have changed along the this period. Nevertheless, future researches must carefully select major mediating variables such as spillover effects, technological advancements, educational level and other socio-economic trends for further analysis of the relationship between elderly population and economic growth regionwise. For an example, South Asian regions show a decline in extended families with growing popularity of nuclear families, urbanisation and enhance in educational levels (Yeung et al., 2018). Such factors can be useful in understanding relationship between elderly population and economic growth better.

To deepen the insights into the correlation between the elderly population and economic growth, researchers can conduct a temporal analysis by examining data spanning the last 30 years and contrasting it with the preceding three decades. This longitudinal approach can unveil significant shifts and patterns, offering a nuanced comprehension of the evolving dynamics between ageing populations and economic growth. For instance, an exploration of mortality rates during this period may unveil noteworthy variations, especially in developing nations, where advancements in healthcare, changes in lifestyle, and socioeconomic factors could have influenced elderly mortality (Crimmins et al., 2016). Furthermore, the widespread adoption of technology in recent decades may have implications for the economic contributions and well-being of the elderly, as technology can impact workforce participation, social connections, and access to services (Charness & Boot, 2009).

Additionally, a comparative examination of the past and present can provide insights into policy shifts and interventions directed at the elderly population. For example, the implementation and evolution of pension systems, healthcare policies, and social support structures might have shaped the economic consequences of an ageing demographic (Bloom et al., 2015). Analysing these changes can offer valuable insights into the efficacy of policies designed to address potential economic challenges linked to an ageing population. Moreover, a comparison of technology usage among the elderly across the two time periods could reveal changes in productivity, engagement in the labour market, and overall economic contributions. Understanding how technological progress has impacted the economic integration of the elderly can

guide the formulation of policies to harness potential benefits and address challenges associated with an ageing workforce (Anderson & Perrin, 2017). In summary, a thorough examination of findings from the last 30 years in contrast to the preceding three decades, covering mortality rates, technological advancements, and policy changes, has the potential to enrich the study on the relationship between the elderly population and economic growth, providing a more contextualized and dynamic understanding of this intricate interplay.

In terms of policy implications, the governments have taken initiatives in investing in the care of the elderly as per the previous literature. However, the findings indicated bi directional causal relationship between the elderly population and the economy in Asia, Europe, North America and South America. Henceforth, mainly regarding the policy implications, South East Asian countries and Oceania need to be revaluated as these nations have made significant investments for the elderly population. Also, as an overall policy discussion, the GDP is significantly affected by various micro and macroeconomic factors, which in turn can hinder the growth of the ageing population Thus, the countrywide demographic stance tends to be different and region wise these can vary. Especially in Asia and the Nordic, and in some countries such as Italy –the elderly productivity is much higher compared to that of other countries, as indicated by the literature review. Therefore, the governments will need to look at the macro and micro economic policy formulation prior to investigating the factors and the impact.

The policy implication regarding GDP and the ageing population has to be focussed on for the midterm to longterm, while adopting other key macroeconomic directions on the closer, more ground level than a strategic level. Because the policy levels tend to have a different impact based on the population in numbers, the distribution and even in the recent years regarding the economic impacts from the external market. Hence, such a larger context has to be considered when implementing policy changes.

The study results show uni directional Granger causality between GDP per capita and the elderly population for African and Oceania regions. Higher the GDP per capita, the higher the elderly population. From different viewpoints, the elderly population has been regarded as an asset and a liability. Nevertheless, with the advancement in medical sciences, a high percentage of healthy elders can contribute to the economy directly with their vast experience. Also, they can support the economy indirectly by rearing children. Above benefits could be reaped through improving GDP per capita because, according to the study, it granger cause with the elderly population. Therefore, the government can impose policy measures such as high investment in infrastructure, education, and appropriate tax rates for high GDP per capita, indirectly resulting in the elderly population growth.

There is a possibility that there can be Granger causality between the GDP per capita and elderly population in individual countries, as this study focussed on continent wide analysis only. As mentioned earlier, such insights could be drawn by extending this research to analyse respective countries in depth. Differences in the way elderly are treated, their cultural beliefs, quality of life and dependency can significantly impact on their degree of economic contribution in different regions. However, several general policy measures are available for implementation to encourage the elderly population to contribute more to the economy. Raising the compulsory retirement age, providing continuous professional development training for the elderly and involving them in advisory capacities are a few common measures. Policies to control the fertility level, such as incentives to delay childbearing (to lower fertility) and paid parental leave (to raise fertility), can be made to control the proportion of the elderly population in the future.

Appendix

See Tables 3, 4 and 5.

Table 3 Summary of descriptive statistics for the key variables

Countries	Descriptive statistics	variables	
		GDP (% annual rate)	POP (% of total population)
All countries	Obs	5040	5040
	Mean	1.8941	6.4037
	SD	4.7426	4.6401
	Min	−47.5032	1.1938
	Max	42.7893	28.3973
Africa	Obs	1620	1620
	Mean	1.1315	3.8118
	SD	5.6572	2.3570
	Min	−47.5032	1.1938
	Max	37.5355	22.5545
Asia	Obs	900	900
	Mean	3.4255	5.3589
	SD	4.6217	3.5614
	Min	−29.9865	2.1400
	Max	21.9152	28.3973
Europe	Obs	840	840
	Mean	2.1893	14.1254
	SD	2.9862	3.7681
	Min	−11.2335	3.4797
	Max	13.6151	23.3019
North America	Obs	720	720
	Mean	1.5981	5.2117
	SD	4.3167	2.5785
	Min	−28.6474	2.4661
	Max	23.3782	20.8274
Oceania	Obs	180	180
	Mean	1.5792	5.8323
	SD	4.0976	4.1178
	Min	−19.6347	2.1466
	Max	15.5073	16.2131
South America	Obs	780	780
	Mean	1.7392	5.9088
	SD	4.4189	2.5699
	Min	−15.2682	2.9052
	Max	42.7893	15.0877

Table 4 Levin-Lin-Chu unit root test results

Levin-Lin-Chu Unit Root Test							
	All countries	Africa	Asia	Europe	North America	Oceania	South America
GDP	−17.70***	−19.12***	−7.27***	−4.25***	−5.76***	−3.49***	−2.86***
EPOP	12.5676	−0.4652	6.046	1.3384	11.8135	3.5522	10.2929
DEPOP	8.33	−2.36***	4.68	−2.55 ***	8.43	−0.88	7.65
DDEPOP	−27.29***	–	−9.63***	–	−6.93***	−7.03***	−12.57***

***Denote significance at 1%

Table 5 Panel VAR lag length criteria

Panel VAR Lag selection criteria						
	Lag	J	J Pvalue	MBIC	MAIC	MQIC
All countries	1	140.7410	0.0000	**−157.374***	68.7411	−11.4640
	2	131.4274	0.0000	−133.5630	67.4274	−3.8660
	3	125.1898	0.0000	−106.6770	69.1898	6.8080
	4	101.4675	0.0000	−97.2756	53.4675	−0.0025
	5	47.1930	0.0006	−118.4260	**7.193037***	**−37.3653***
	6	47.7042	0.0001	−84.7913	15.7042	−19.9425
	7	56.6646	0.0000	−42.7070	32.6646	5.9295
	8	48.3644	0.0000	−17.8833	32.3644	14.5411
	9	30.0155	0.0000	−3.1084	22.0155	13.1038
Africa	1	70.9273	0.0005	**−187.0861***	−1.0727	−70.8762
	2	50.3619	0.0206	−178.9833	−13.6381	**−75.68564***
	3	48.9237	0.0085	−151.7533	−7.0763	−61.3679
	4	34.6735	0.0734	−137.3354	−13.3265	−59.8621
	5	19.1629	0.5113	−124.1779	**−20.83712***	−59.6168
	6	13.4045	0.6430	−101.2682	−18.5956	−49.6193
	7	11.6890	0.4710	−74.3154	−12.3110	−35.5788
	8	8.2791	0.4067	−49.0573	−7.7209	−23.2328
	9	1.2284	0.8734	−27.4397	−6.7716	−14.5275
Asia	1	67.8985	0.0010	**−168.1966***	−4.1015	**−67.51306***
	2	66.3235	0.0003	−143.5388	2.3235	−54.0423
	3	41.3940	0.0494	−142.2356	−14.6060	−63.9261
	4	53.3348	0.0005	−104.0619	5.3348	−36.9396
	5	18.6066	0.5475	−112.5573	**−21.39337***	−56.6220
	6	14.7240	0.5449	−90.2072	−17.2760	−45.4589
	7	12.83787	0.3809346	−65.86051	−11.16213	−32.29931
	8	15.07052	0.0577887	−37.39506	−0.9294796	−15.02093
	9	12.69728	0.0128537	−13.53552	4.697276	−2.348451
Europe	1	142.8536	0.0000	−91.5157	70.8536	7.9703
	2	99.5074	0.0000	**−108.821***	35.5074	−20.3889
	3	80.7376	0.0000	−101.5500	24.7376	−24.1716
	4	73.1899	0.0000	−83.0563	25.1899	−16.7323
	5	49.5564	0.0003	−80.6487	9.5564	−25.3787
	6	15.2089	0.5094	−88.9552	−16.7911	**−44.7392***
	7	4.2535	0.9784	−73.8696	**−19.7465***	−40.7076
	8	8.2645	0.4081	−43.8175	−7.7355	−21.7095
	9	8.4164	0.0775	−17.6246	0.4164	−6.5706

Table 5 (continued)

Panel VAR Lag selection criteria						
	Lag	J	J Pvalue	MBIC	MAIC	MQIC
North America	1	29.6984	0.7615	**−198.364***	**−42.3016***	**−103.221***
	2	22.6986	0.8876	−180.0230	−41.3014	−95.4517
	3	18.9314	0.9002	−158.4500	−37.0686	−84.4501
	4	17.9040	0.8076	−134.1370	−30.0960	−70.7088
	5	10.8516	0.9500	−115.8500	−29.1484	−62.9924
	6	14.5016	0.5614	−86.8593	−17.4985	−44.5736
	7	22.2989	0.0343	−53.7217	−1.7011	−22.0074
	8	17.4329	0.0259	−33.2475	1.4329	−12.1047
	9	15.4575	0.0038	−9.8827	7.4575	0.6887
Oceana	1	32.7652	0.6232	**−145.39***	−39.2349	**−82.3727***
	2	24.5260	0.8248	−133.8340	−39.4740	−77.8188
	3	18.0685	0.9244	−120.4970	−37.9315	−71.4832
	4	7.9848	0.9991	−110.7850	**−40.0152***	−68.7738
	5	6.1443	0.9987	−92.8309	−33.8557	−57.8212
	6	6.9425	0.9744	−72.2376	−25.0575	−44.2299
	7	7.3436	0.8341	−52.0415	−16.6564	−31.0357
	8	5.1745	0.7388	−34.4156	−10.8255	−20.4117
	9	2.1584	0.7067	−17.6367	−5.8416	−10.6347
South America	1	54.8838	0.0228	**−176.06***	−17.1163	**−78.9394***
	2	48.0503	0.0340	−157.2330	−15.9497	−70.9036
	3	42.5294	0.0386	−137.0930	−13.4706	−61.5552
	4	34.7507	0.0722	−119.2120	−13.2493	−54.4647
	5	21.4583	0.3706	−106.8440	**−18.5417***	−52.8879
	6	21.8471	0.1482	−80.7945	−10.1529	−37.6299
	7	17.5093	0.1314	−59.4719	−6.4907	−27.0984
	8	9.9954	0.2653	−41.3254	−6.0046	−19.7431
	9	8.3757	0.0787	−17.2847	0.3757	−6.4935

MBIC = model/moment selection Bayesian information criterion; MAIC = model/moment selection Akaike information criterion; MQIC = model/moment selection Hannan and Quinn information criterion. *Denotes minimum values of MAIC, MBIC, MQIC

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