Journal of Economic Studies, Vol. 17 (2), pp. 243-258, (Special issue), Articles of the 22nd Annual Conference of Saudi Economic Association, September 10-11, 2025, University of Business and Technology (UBT), Jeddah, Saudi Arabia

DOI: 10.33948/ESJ-KSU-17-2-6

Aging Population and Economic Growth in Saudi Arabia: Evidence from ARDL Approach

Bashier A. Al-Abdulrazag [(1)] *Talal H. Alsabhan* [(2)]

(Received: Aug 15, 2024 – Accepted for publication: Oct 20, 2024)

Abstract: Globally, there is a significant debate on the Aging population matter among the researchers and government authorities, however, its adverse impacts, specifically economic impacts, are a controversial issue. This paper intends to assess the long and short run impacts of population aging on the economic growth of Kingdom of Saudi Arabia (KSA). Using annul data for the period 1981-2021 and applying the "Autoregressive Distributed Lag (ARDL)" framework, we show that population again is indeed detrimental for the long run growth performance of KSA. On the other hand, age dependency has impacted the growth performance positively. Moreover, human capital and domestic investment have positively impacted economic growth which is consistent with prior theoretical and empirical literature. Furthermore, inflation rate has negatively influenced economic growth while trade openness has not had the desirable significant impact on economic growth. Moreover, the short run analysis shows that economic growth positively responds to changes in trade and domestic investment and negatively to changes in inflation rate. Finally, the causality analysis displayed several one-way and two-way causal relationships among the variables including the bidirectionality between population aging and economic growth. Our results have important policy implications for the policymakers of the economy of KSA.

Keywords: Ageing population, Saudi Arabia, Economic Growth, NARDL, Cointegration
JEL classification: J10; O11, C72; C91, D63, J11.

الشيخوخة السكانية والنمو الاقتصادي في المملكة العربية السعودية: دليل من منهجية ARDL

أ.د. بشير أحمد العبدرزاق [(1)] *د.طلال حمد السبهان* [(2)]

(قُدّم للنشر: 15 أغسطس، 2024م – وقُبل للنشر: 20 أكتوبر، 2024م)

المستخلص: عالميًا، هناك جدل كبير حول مسألة شيخوخة السكان بين الباحثين والسلطات الحكومية، ومع ذلك، فإن آثارها السلبية، وخاصة الآثار الاقتصادية، تُعتبر قضية مثيرة للجدل. تهدف هذه الورقة إلى تقييم الآثار القصيرة والطويلة المدى لشيخوخة السكان على النمو الاقتصادي في المملكة العربية السعودية. باستخدام بيانات سنوية للفترة من 1981 إلى 2021 وتطبيق إطار "نموذج الانحدار الذاتي وفترات الإبطاء(ARDL) " ، نُظهر أن شيخوخة السكان تُعتبر ضارة بالفعل لأداء النمو على المدى الطويل في المملكة. من ناحية أخرى، كان للاعتماد على العمر تأثير إيجابي على أداء النمو. علاوة على ذلك، كان لرأس المال البشري والاستثمار المحلي تأثير إيجابي على النمو الاقتصادي، وهو ما يتماشى مع الأدبيات النظرية والتجريبية السابقة. بالإضافة إلى ذلك، أثر معدل التضخم سلبًا على النمو الاقتصادي، في حين أن الانفتاح التجاري لم يكن له التأثير الكبير المرغوب على النمو الاقتصادي. كما تُظهر التحليلات على المدى القصير أن النمو الاقتصادي يستجيب إيجابيًا للتغيرات في التجارة والاستثمار المحلي وسلبًا للتغيرات في معدل التضخم. أخيرًا، عرض تحليل السببية العديد من العلاقات السببية ذات الاتجاه الواحد والاتجاهين بين المتغيرات، بما في ذلك العلاقة ثنائية الاتجاه بين شيخوخة السكان والنمو الاقتصادي. وتقدم نتائجنا دلالات سياسية مهمة لصانعي السياسات في اقتصاد المملكة العربية السعودية.

الكلمات المفتاحية: شيخوخة السكان، المملكة العربية السعودية، النمو الاقتصادي، نموذج الانحدار الذاتي وفترات الابطاء، التكامل المشترك.

(1): *Professor, Department of Economics, College of Business Administration, King Saud University, Saudi Arabia. Email: basheerf@yahoo.com.*

(2): *Assistant Professor, Department of Economics, College of Business Administration, King Saud University, Saudi Arabia. Email: talsabhan@ksu.edu.sa.*

(1) *أستاذ، قسم الاقتصاد، كلية إدارة الأعمال، جامعة الملك سعود، المملكة العربية السعودية.*

(2) *) أستاذ مساعد، قسم الاقتصاد، كلية إدارة الأعمال، جامعة الملك سعود، المملكة العربية السعودية.*

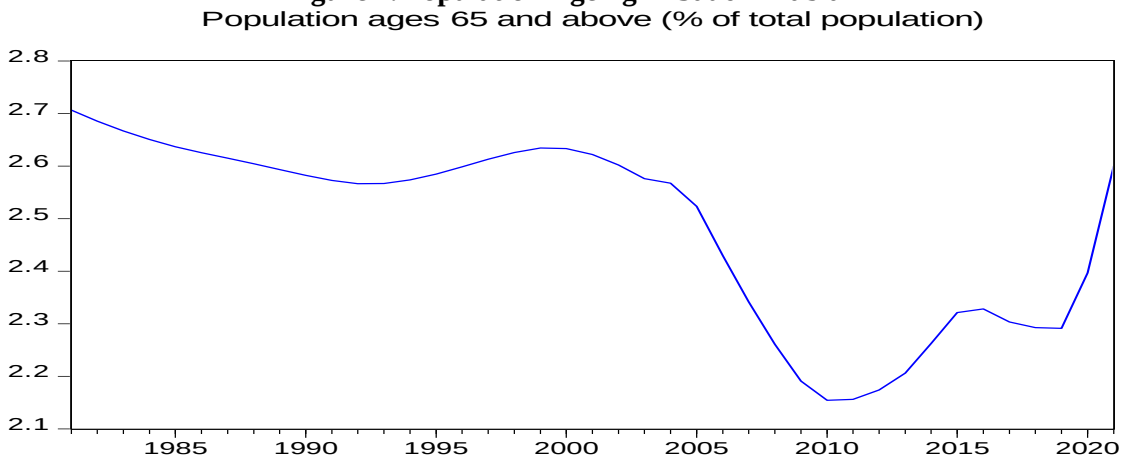
1 - Introduction

The global economy is experiencing an aging population phenomenon in recent times. According to Ismail et al. (2021) population aging is defined as "the increase in number and percentage of older population aged 60 years and above, and at the same time, decreasing in number and percentage of the young population aged 15 yr old and below". According to the World Health Organization (WHO), the ageing society is defined as "one where more than 7% of the population is in the aged of 65 years or above, an aged society as one in which this age group accounts for more than 14% of the total population, and a hyper-aged society as one wherein this rate is greater than 20%". Currently, the world population is around 8 billion people and most of the economies are suffering from the aging population. Several factors could be responsible for the ageing population problem. Bloom et al. (2010) commented that the increase life expectancy, falling fertility rates and variation in birth and death rates have significantly changes the global age structure. The aging population has several adverse consequences as the aged population is relatively less productive compared to the younger population. The recent research of Maestas et al. (2023) highlighted that each 10 percent increase in the population in the age bracket of 60 plus population will decrease income per person by 5.5 percent. Lee and Shin (2021) identified six distinct channels by which population aging impacts the growth performance of the economy. Therefore, the aging population phenomena has created serious concerns among the policymakers and government authorities worldwide.

The ageing population constitutes a matter of concern at all levels related to the expected adverse impacts on key economic variables. For instance, population ageing adversely impacts growth performance, savings, investment, consumption, labor markets and transfer payments. However, empirical research on the consequences of an ageing population on economic growth is still a controversial subject among researchers due to diverse empirical findings reported in the literature. In general, some researchers have concluded that ageing population adversely affects economic growth (Park and Son, 2021; Mohd et al., 2021; Rahman et al., 2020; Wen-Hsin et al., 2019; Abeywardhana, 2019; Moradi & Nilgun, 2020; Tach & Duc, 2021; Valeriy et al., 2019). Another strand of applied research concluded that ageing population positively affects economic growth **(**Moradi & Nilgun, 2020; Rahman et al., 2020**)**. Moreover, researchers argue that the negative relation between the two variables is a result of labor supply shortage and the slowdown of productivity (Park and Son, 2021; Hsu et al., 2019; Miri et al., 2019; Mamun et al., 2020; Ademola, 2018; Mikiko, 2015; Moradi and Nilgun, 2020; Wen-Hsin et al., 2019). Futagami and Nakajima (2001) rightly pointed out that it is indeed not necessary that population aging decelerate economic growth. It seems that the research studies on the linkages between population ageing and economic growth are yet to reach an acceptable conclusion. It implies that extensive research is indeed needed to establish an explicit relationship between population aging and economic growth. Particularly, in the context of resource-rich economy of Saudi Arabia (KSA, hereafter), research evidence on the linkages between population aging and economic growth are indeed scarce. While it is a fact that KSA is going through age transformation period and hence it is of significant importance to quantity the exact impacts of population aging on economic growth.

Like all other economies, the problem of population ageing has become a serious concern in KSA in recent years. Ageing population has created significant concerns among the authorities of the KSA economy as it may create hurdles to achieve the targets of the vision 2023. The percentage of aged population "(population ages 65 and above (% of total population)" was 2.706 percent in 1981. Over the years, the aged population has declined, and it reached to the lowest point in 2011. However, since 2011, an upward trend is observed in the aged population. The observed increase in the aged population has created serious concerns among the authorities of KSA as the aged population has numerous undesirable repercussions. An overview of population ageing is provided in the following Figure 1.

Figure 1. Population Ageing in Saudi Arabia



The main motivations for pursing this study, taking Saudi Arabia as a case study, are in two folds. Firstly, this topic is highly essential as the empirical investigation on this matter is relatively scarce in the ageing population-growth nexus in the literature (Rahman et al., 2020), and especially in the KSA. While it is a fact that KSA economy is going through demographic transformation including population aging as demonstrated by recent research (Salam, 2023). Secondly, it focuses on the KSA because Saudi government is pursuing an ambitious economic plan to achieve high economic growth rates over the coming period (2030 Vision). The vision 2023 is indeed a comprehensive plan for the transformation of KSA economy and hence all sectors are expected to play a dominant role to push the KSA economy in the right direction.

This study applies the ARDL model to annual time series data for the 1981-2021 period to examine the short-run and long-run relationships between ageing population and economic growth in response to within the endogens growth model framework developed by (Romer, 1990). The motivation for the current study stems from the lack of research on the KSA economy with respect to the impact of population ageing on economic growth. In addition, the findings are expected to provide the KSA government and the policymakers with a clear understanding of the impacts and consequence of the ageing population on the Saudi economy. Thereby, it helps them to prioritize the areas for improvement for future economic growth. Therefore, the research hypothesis is that the ageing population has a negative impact on economic growth in KSA. Besides, population ageing is also responsible for several socioeconomic issues as well in addition to its adverse consequences on the overall growth performance of economies.

This research contributes to literature in three ways. Firstly, it contributes to the ageing-growth literature, which is relatively scarce in KSA. Secondly, we apply the advanced cointegration testing of "autoregressive distributed lag (ARDL)" to assess both the short run and long run influence of population ageing on economic growth. Thirdly, our study is interested in uncovering the direction of relationship between population aging and economic growth as prior literature is silent on the issue of causality. To the best of our knowledge, no study has investigated the asymmetric relationship between ageing population and economic growth in KSA. Our results would have significant policy implications for the authorities of KSA.

The organization of the article is as follows. Section 2 presents theoretical and empirical literature. Section 3 includes model derivation, data and methodology. Section 4 includes results and discussions. The causality findings are reported in the penultimate section. Section 5 presents concluding remarks and implications of the research.

2.0 Review of theoretical and Empirical Literature

2.1 Theoretical Background

Based on the argument of the economic theory, an ageing population is expected to hinder the economic process in the economy. In his lifecycle hypothesis (LCH), Modigliani and Brumberg (1954) showed a support to the notion that aging population can have a negative impact on the

performance of the economy, and hence, economic growth. The theme of the LCH is that population tends to save at early stages of their working life. This behavior would increase the national saving, and indirectly through investment activities economic growth. However, as the population ages over time, and some relative proportion of the population reaches their retirement age and their incomes fall, then according to LCH, there will be a reduction in aggregate national savings.

On the hand, Solow's growth theory indicates that as population is ageing, it becomes relatively difficult for the economy to sustain stable or steady state economic growth. In addition, the theory argues that only when population structure is constant, the steady state growth can be achieved. However, this condition, with an ageing population, is relatively out of reach, since the population structure is varying over time. Hence, Solow's growth theory predicts that ageing population negatively impacted economic growth (Mohd et al., 2021).

Another explanation of the impact of ageing population, is the Malthusian catastrophe theorem, which describes that the population growth exceeds the required needs to survive. The bottom line of his theory is that population tends to grow at a faster rate than the human needs, such as the basis needs. In addition, it argued that poverty will prevail because the growth in agricultural resources is outweighed by the uncontrolled population growth.

A new strand of economic theory known as endogenous growth theory led by Romer (1986) asserted that population growth is a vital factor for long-term economic growth. This argument is based on the idea that larger (populated) countries are expected to have highly skilled and professional people and large size markets for competitive and innovative firms. In addition, Romer (1988) pointed out that the low rate of both mortality and fertility would lead to population ageing while leaving the population size constant.

The endogenous growth model (Lucas, 1988; Romer, 1986) emphasized the vital role of labor. Physical capital and human capital in sustaining economic growth. These factors are seen to be main determinants of productivity growth and in turn economic growth. Nevertheless, aging population increase and the reduction in fertility rate hinder economic growth through the decrease in the quality of labor force. The forces behind such an outcome lies in the notion that ageing population increases the burden of working-age population (Rahman et al, 2020).

2.2 Empirical Literature

The potential impacts of population on major economic factors have attracted much attention of both policymakers and researchers in developing and developed countries, and specifically, economic growth. Accordingly, a huge body of theoretical models and applied research has been conducted to investigate the nexus relationship between ageing population and major economic factors, specifically, economic growth. However, the results were ambiguous, bouncing from negative to positive impacts due to various types of data employed, single country or group of countries. Additionally, research mainly relied on the linearity relationship assumption between ageing population and economic growth when applying various estimation methods to time series and panel data for single/multi-country levels (Moradi & Nilgun, 2020).

Related to the nature of such a relationship, two opposing views have been introduced, the pessimistic and optimistic. The pessimistic view advocates the negative impact of ageing population growth. Their argument based on the assumption that the increase in the share of old age group in population leads to a sharp reduction in the labor force and national saving rates of the country, thus, lessening the investment and national output (Thach & Duc, 2021). This view has been supported by the majority of the empirical work which concluded that ageing population negatively affect economic growth in a country (Mohd et al., 2021; Thach & Duc, 2021; Moradi and Nilgun, 2020; Rahman et al., 2020; Abeywardhana, 2019; Wen-Hsin et al., 2019; Acemoglu & Restrepo, 2017; Valeriy et al.,2019; Maestas et a., 2023). In this Regard, it has been argued that as ageing population increases, the consumption declines in current periods because people opt to save for future consumption. Consequently, consumption for durable goods, housing, and new products declines, which may exert a negative impact on economic growth. In addition, they argue that documented

that the responsiveness of growth towards population ageing is dependent on estimation methods (Nagarajan, Teixeira, and Silva 2016). Moreover, the view argues that ageing population increase causes a diversion of government public investment from infrastructure toward health care and public pension on the expense of development expenditures, especially, the elders are coming from professional and semi-professional (Nagarajan, Teixeira, & Silva, 2017; Teixeira et al., 2016; Acemoglu & Restrepo, 2017; Rahman et al., 2020). which in turn negatively affects capital accumulation and productivity growth (Ademola, 2018). For example, the transportation systems, public facilities, and housing areas may be changed consistently with the varying needs of the elderly who demand safe and clean environment (Rahman et al., 2020; Nagarajan et al., 2017).

Moreover, depending on the government's fiscal position, the government may resort to external substantial financial resources mainly to finance its infrastructure expenditure (Ramhan et al., 2020; Teixeira et al., 2017). In contrast to the pessimistic view, the optimistic view posits that a positive effect is associated with ageing population growth. Accordingly, the reduction in fertility rates and longevity would bring about a high savings where elders save more for their retirement. Thereby, provide more resources for investment which would boost investment in R&D which is a crucial engine for economic growth [Ademola, 2018]. Also, empirical research provides evidence on the positive or neutral impacts (Ismail et al., 2016; Tach & Duc, 2021, Blake and Mayhew 2006).

Some applied research goes deeply in investigating the impact of ageing populations on the various sources of economic growth. They attempted to explore the transmission channels through which the effects are transmitted to economic growth [1]. Focusing on 35 OECD countries, Lee & Kwanho (2021) focused on six transmission channels by which ageing population affect growth. Their empirical findings provide evidence about the negative consequences of both "higher old dependency ratio" and "old population share" on growth. They indicated that among all the six channels, lowering TFP accounts for the highest negative effect of population aging on growth. Recent research (Wen-Hsin et al. 2019) also supported the negative effect of population ageing on TFP.

Hsu et al. (2019) demonstrated that ageing population can affect economic growth through negatively affecting supply. Guo et al. (2016) using a mathematical representation of the consumption function, they derived a critical value as benchmark for the propensity to consume through which ageing population affects economic growth. They concluded that an ageing population could have positive and negative effects on EG depending on the value of MPC. If the marginal propensity to consume is greater than the critical value, then population ageing has an indirect negative impact on economic growth, whereas, if the MPC is less than the critical value, then ageing population positively affecting EG through the increase in per capita capital.

Capital formation due to affecting saving rates and leading to positively affect economic growth (Hsu et al., 2019). Recently, Hsu et al. (2019). give support to this argument. However, the previous empirical literature was criticized by assuming the relationship between economic growth and ageing population is linear one. Lee and Shin (2019) claimed that previous research assumed that relationship between population ageing, and economic growth is linear, however, he criticized this assumption which leads to incorrect impact of population ageing on economic growth. Their empirical findings demonstrate a negative nonlinear impact of ageing population (quadratic term) on economic growth of 142 countries for the period 1960-2014 using panel data analysis which supports his hypotheses.

From a policy perspective, a considerable body of research demonstrated that policy measures can mitigate the adverse negative impacts of population ageing on economic growth. Park and Son (2021) reported that the extent of population ageing effect varies among countries according to the classification of the income level. They argued that high- and middle-income countries are less affected by population ageing than low-income level countries. They advocate that due to the policy measures such high level of human capital formation and the engagement in high and advanced R&S technologies to mitigate the negative impacts of ageing population on growth.

[1] *For more detailed survey, see Nagarajan, R., Aurora, A.C. Teixeira, and Sandra, S. (2013)*

From the applied methodology side, the research methodology focused on the impact of Ageing population measures by various measures such as the old dependency ratio, the share of population aged above 65 years. While the GDP growth was utilized as proxy to economic growth. A strand of the applied studies investigates the nexus relationship between the two variables using the ARDL bounce test to cointegration, since it has some advantages over the other cointegration approaches and (Miri et al., 2019; Mohd et al., 2021; Moradi and Nilgun, 2020; Shairilizwan, 2020), or OLS estimation (Mikiko, 2015; Wen-Hsin et al. (2019) Valeriy et al. (2019). On the country-group level, the applied research utilized the panel data analyzes approaches to examine the nexus relation in developing and developed countries, the GMM approach (Thach et al., 2021; Rahman et al., 2020; Abeywardhana, 2019; Park and Son, 2021). Others applied the VECM approach (Ademola, 2018). Their findings provide evidence on the negative impact of an ageing population on economic growth. Thach et al. (2021) examined the effect of ageing populations on economic growth of developing countries over the period 1971-2015 by applying the panel quantile regression framework to account for the differences in the distribution of age groups.

Mikiko (2015) found that the old dependency has no effect on GDP when investigating the impact of ageing population on economic growth of Japan over the period 1975-2011 by using the OLS estimation approach. Miri et al. (2019) analyze the effect of age population structure on economic growth of Iran over the period 1987-2017 by applying the ARDL model. Their empirical findings revealed that aged population group over 64 years old negatively and significantly effect on economic growth in the long term. They concluded that the increase in the share of age population would slow down economic growth of Iran in the long run. They argued that ageing population reduces the marginal propensity to save, thus, causes a reduction in capital formation which in turn negatively affects economic growth.

Mohd et al., (2021) examined the impact of ageing population on economic growth in Malaysia for the period 1981-2019 employing the ARDL bounds testing approach to cointegration. Their findings revealed a significant negative impact of ageing population on economic growth in Malaysia. As for physical capital, Human capital, and labor force, the empirical findings showed positive impacts on economic growth. Moradi and Nilgun (2020) examined the short-run and long-run impacts of ageing population on economic in Turkey for 1978-2018 period by applying the ARDL model. The empirical findings showed that population aging has a negative short-run or long-run effects on Turkey's economic growth. Rahman et al. (2020) investigated the effect of ageing population in 32 countries of upper-middle income countries for the period 199-2018 by applying system GMM. The empirical findings revealed a negative impact of ageing population on EG in these countries. Shairilizwan (2020) investigated the linkage between economic growth and ageing in Malaysia for the period 1990 to 2017 by applying the ARDL bounds test to cointegration. She pointed out that the ageing measured as the people over 55 years old. Abeywardhana (2019) examined the impact of ageing population economic growth in South Asia by means of descriptive analysis. The analytical results revealed that economic growth (GDP) depends on ageing structure, that ageing population has a negative impact on economic growth.

Hsu et al. (2019) attempted to link ageing to saving, investment and growth by analyzing data of Japan. The outcome provides some policy implication to mitigate the negative effect of ageing population such as child welfare programs, promote R&D, and increase expenditure on HC investment because it improves labor quality and productivity, and among others. Wen-Hsin et al. (2019) examined the impact of ageing population and workforce on economic growth in Taiwan using quarterly data from 1981–2017 by applying the ordinary Least Squares Method (OLS). The empirical findings revealed a significant positive impact of workforce on the rate of economic growth, the old-age dependency ratio has a significantly negative effect, and human capital has positive effect on total factor productivity (TFP) growth.

Ademola (2018) applied the VECM framework to assess the linkages between ageing and growth of Nigeria over the period 1975-2015 using ARDL. The outcome indicated that the elderly population is detrimental for growth. Moreover, he argues that expanding the retirement age and increasing expenditure on human capital investment would cure the problem. Valeriy et al. (2019) also assessed the influence of ageing on growth of Ukraine over the period 2000-2017 by applying

the linear regression. Their analysis confirmed the positive influence of ageing on economic growth and labor productivity.

Moreover, Mamun et al. (2020) explored the short and long-run consequences of ageing population on growth of Bangladesh for the period 1972-2015. Their results endorsed that population ageing improves growth. Therefore, they argued that the elderly population does not hinder EG of Bangladesh provided that per capita capital formation exceeds per capita ageing population. Park and Son (2021) attempted to assess the threshold influence of aging population on growth by utilizing a sample of 98 economies. The empirical findings estimated the ageing population threshold lies between 10.1% and 10.9%, which beyond that ageing population negatively affects EG of middle-income countries.

3.0 Econometric Model, Data and Methodology

3.1 Econometric Modeling

The paper is aimed at assessing the role of population aging on the growth performance. However, the growth process of economies responds to several factors other than population aging. For instance, human capital and physical capital are the main factors of growth performance as evident from prior research studies as well as theoretical literature. Following the previous research (Mohd et al., 2021; Rahman et al., 2020' Shairilizwan, 2020; Moradi & Nilgun, 2020; Lee and Kwanho, 2021) the study's economic model specification is constructed based on the Romer's endogenous theory which emphasizes the significance of the human capital as a vital determinant factor of economic growth. Similarly, Similarly, physical capital in the form of domestic investment also matters for economic performance. It is also a fact that open economies perform better as compared to closed economies (Dollar, 1992, Edwards, 1998). The following function form is specified for analysis.

$$y_t = f(popag^{\alpha}, popdpr^{b}, edu^{c}, inv^{d}, open^{e}, inf^{f}) \qquad (1)$$

where (Y_t) is the "growth of per capita GDP" ($POPAG^{\alpha}$) is an exogenous variable representing the aging population. The control variables include dependency ratio ($POPDPH^{b}$), human capital (EDU^{c}), domestic investment (INV^{d}), openness to trade ($OPEN^{e}$) and inflation rate (INF^{f}). The "ratio of the gross capital formation to GDP" is a proxy physical capital investment (Brida, Gómez, & Seijas, 2017). We transform equation1using logarithms transformation to the estimable form to address the non-linearities among the variables as shown by expression 2.

$$lny_t = \beta_0 + \beta_1 lnpopag_t + \beta_2 lnpopdpr_t + \beta_3 lnedu_t + \beta_4 lninv_t + \beta_5 lnopen_t + \beta_6 inf_t + U_{i,t} \quad (2)$$

All data from 1981 to 2021 were acquired from the "World Development Indicator (WDI)" except the human capital index which is retrieved from the "Penn World Table (PWT)". In the appendix part, the study provides a complete description of variables used in the study.

3.2 Estimation Strategies

The suitable technique for dealing with time series data is to adopt the cointegration technique. The reason for using cointegration is that time series variables are not stationary due to their upward trend. Researchers have proposed several techniques of cointegration, among which the "Engle & Granger, 1987; Johansen & Juselius, 1990" got significant attention from researchers due to their significant benefits. However, the mentioned tests are only valid in case all variables share the same integration order. The same order of integration of variables may not be possible in applied research in most of the cases. Hence, the scope and application of the mentioned tests is limited. Pesaran et al. (2001) suggested a new and interesting approach called "Autoregressive Lag Model (ARDL)" which has some benefits.

$$lny_t=\beta_0+\sum_{i=1}^{n1}\beta_{1i}\Delta lny_{t-i}+\sum_{i=0}^{n2}\beta_{2i}\Delta lnpopag_{t-i}+\sum_{i=0}^{n3}\beta_{3i}\Delta lnpopdpr_{t-i}+\sum_{i=0}^{n4}\beta_{4i}\Delta lnedu_{t-i}+\sum_{i=0}^{n5}\beta_{5i}\Delta lninv_{t-i}+\sum_{i=0}^{n6}\beta_{6i}\Delta lnopen_{t-i}+\sum_{i=0}^{n7}\beta_{7i}\Delta inf_{t-i}+\theta_1 lny_{t-1}+\theta_2 lnpopag_{t-1}+\theta_3 lnpopdpr_{t-1}+\theta_4 lnedu_{t-1}+\theta_5 lninv_{t-1}+\theta_6 lnopen_{t-1}+\theta_7 inf_{t-1}+\varepsilon_t \quad (3)$$

Equation 3 is the ARDL form of equation 2. In equation 3, the unknown parameters "$(\beta_1-\beta_7)$" measures short run influence of independent variables on dependent variable. Likewise, the parameters "$(\theta_1-\theta_7)$" indicates the short run influence of independent variables on dependent variable. In the ARDL methodology, the presence of cointegration can be assessed by testing the "null hypothesis $(\theta_1=\theta_2=\theta_3=\theta_4=\theta_5=\theta_6=\theta_7=0)$" against the "alternative hypothesis $(\theta_1\neq\theta_2\neq\theta_3\neq\theta_4\neq\theta_5\neq\theta_6\neq\theta_7\neq 0)$". The F-test values will be compared with the values of Narayan (2005). Cointegration will be accepted if the value of the F-test is higher than the upper limit and vice versa. The second step in the ARDL methodology is to estimate the "error correction model (ECM)". The ECM model is useful as it highlights the adjustment speed and demonstrates the short run relationships. The ECM version of equation 3 is presented below.

$$lny_t=\beta_0+\sum_{i=1}^{n1}\beta_{1i}\Delta lny_{t-i}+\sum_{i=0}^{n2}\beta_{2i}\Delta lnpopag_{t-i}+\sum_{i=0}^{n3}\beta_{3i}\Delta lnpopdpr_{t-i}+\sum_{i=0}^{n4}\beta_{4i}\Delta lnedu_{t-i}+\sum_{i=0}^{n5}\beta_{5i}\Delta lninv_{t-i}+\sum_{i=0}^{n6}\beta_{6i}\Delta lnopen_{t-i}+\sum_{i=0}^{n7}\beta_{7i}\Delta inf_{t-i}+\theta_1 ECT_{t-1}+\varepsilon_t \quad (4)$$

In expression 4, the term (ECT) measures the speed of adjustment. Other variables measure the short run relationship. In the ideal situation, the term ECT should possess a negative with statistical significance.

4.0 Estimation Results and Discussion

4.1 Unit root Results

In Table 1, the study reported the result of unit root which are acquired with the help of the "Augmented Dickey Fuller Test (ADF)". It is found that that at level, except inflation, all variables are non-stationary. However, at first difference, the issue of non-stationarity is resolved for all selected variables. The order of integration of variables selected for the study is not uniform. The diversity in integration order is the valid justification for employing the ARDL technique.

Table 1. Unit root findings

Variables	Level	Difference	Conclusion
lny_t	-1.033	-5.678***	I (1)
$lnpopag_t$	-1.714	-4.064***	I (1)
$lnpopdpr_t$	-1.367	-3.789**	I (1)
$lninv_t$	-2.243	-6.557***	I (1)
$lnedu_t$	-1.996	-4.193***	I (1)
inf_t	-3.603**	-9.256***	I (0)
$lnopen_t$	-1.832	-5.111***	I (1)

*"**Note**: The asterisk (***, **) indicates significance level at 1 and 5 percent level".*

4.2 Descriptive Analysis

The study has reported descriptives statistics in Table 2. The descriptives showed that the mean value of "GDP per capita" is 18824.28 "constant 2015 US$". KSA experienced the highest level of GDP per capita (33070.590) in 1981. Similarly, the lowest value of GDP per capita (15670.730) is recorded in 1987. Since then, the KSA has recorded a persistent increase in GDP per capita.

The age dependency "(Age dependency ratio, old (% of working-age population)" statistics show that on average 4.057 persons are dependent. The maximum (5.173) and minimum (3.131) values of age dependency are experienced by KSA in 1981 and 2013 respectively. On the other hand, the average value of population aging "(Population ages 65 and above (% of total population)" is 2.486 percent while its deviation is 0.173. The maximum and minimum values of population aging are observed in the years 1981 and 2010 respectively. Moreover, the human index takes a mean value

of 2.259 while its standard deviation is only 0.305. Finally, the maximum and minimum values of human capital index are witnessed in the years in 1981 and 2019 respectively.

As far as inflation is concerned, the descriptives indicated a mean value of 1.451 % while its standard deviation is only 2.647. The highest inflation of (9.879 %) is recorded in 2008 while the lowest inflation of (-3.203 %) is in 1987. Overall, the inflation statistics are an indication of improved macroeconomic stability as prices have remained stable during the study period. The investment statistics "(Gross fixed capital formation (% of GDP)" shows that average domestic investment in KSA is 21.647 % which is reasonable. The highest (29.356 %) and lowest value (17.308 %) of domestic investment have happened in 2015 and 1996 respectively. Finally, trade liberalization journey of KSA is remarkable as evident from the descriptives. The trade openness index "(Trade (% of GDP)" takes an average value of 72.325 % which is indeed remarkable. The highest value and lowest values of openness are observed by KSA in 2008 and 2020 respectively.

Table 2. Descriptive Statistics

Descriptives	y_t	$popdpr_t$	$popag_t$	edu_t	inf_t	inv_t	$open_t$
Mean	18824.28	4.057	2.486	2.259	1.451	21.647	72.325
Maximum	33070.59	5.173	2.706	2.713	9.870	29.356	96.102
Minimum	15670.73	3.131	2.154	1.737	-3.203	17.308	49.713
Std. Dev.	2869.481	0.662	0.173	0.305	2.647	2.940	11.767
Observations	41	41	41	41	41	41	41

4.3 ARDL Results

The cointegration results are shown in Table 3. The calculated F-test value is 5.387 which exceeds the upper limit in all significance levels. Therefore, we accept the alternative hypothesis and reject the null hypothesis which believes that variables are not cointegrated. Hence, the presence of cointegration is accepted among the variables.

Table 3. Cointegration Results

"Dependent Variable"	**Bound Test**	**Decision**
$lny_t/lnpopag_t, lnpopdpr_t, lnedu_t, lninv_t, lnopen_t, inf_t$	5.387***	"H_1 Accepted"
"Critical Level"	"I (0)"	"I (1)"
1%	2.88	3.99
5%	2.27	3.28
10%	1.99	2.94

4.4 Discussion on Long Run Results

The study presented the findings of long run relationships in Table 4. According to results, populating aging is indeed harmful for the long run growth of KSA. The Coefficient of population aging is negative as well significant. Therefore, population aging is posing a serious threat for the future growth of the KSA. Our results are supported by the recent research of Maestas et al. (2023) who highlighted that each 10 percent increase in population aging will decrease income per person by 5.5 percent. Therefore, the current aging population needs the attention of the policymakers of the KSA as it may disturb the set targets of the vision 2030. It would be a rational policy suggestion would be that the policymakers are to upgrade the industrial structure in order to escape the negative consequences of the aging population. Structural transformation in the industrial sector favoring the aging population would help the KSA economy to sustain the long run growth performance. On the other hand, age dependency is found to be impacting the growth process of KSA both positively and significantly. The coefficient of population dependency is positive as well as significant in the

estimation. It means that population dependency is playing a significant role in promoting the growth performance of KSA.

The results confirmed the positive and significant role of human capital in promoting the growth performance of KSA. The coefficient of human capital is positive and significant. Our results are aligned with the results of Dewan and Hussein (2001) and Barro (2003). Human capital is the main driver of growth and hence the authorities of Saudi Government must investment significantly in the education sector. An improved education sector would increase human capital due to which the growth performance would be improved enormously. The results further show that domestic investment has improved the growth performance of KSA, which is consistent with the theoretical and empirical literature. For instance, our results regarding the positive influence of domestic investment on economic growth are consistent with the findings of Barro (2003) who also endorsed a positive relationship between investment and growth.

Our results also showed that the inflation rate has deteriorated the economic performance of KSA. Inflation is harmful for the economy as it shakes the confidence of investors as well as consumers. Tahir and Azid (2015) also provided significant evidence about the adverse consequences of inflation and commented that it creates uncertainty in the economy due to which the confidence of stakeholders inversely impacted. Hence, their significant role in uplifting the growth process weakens. Finally, the impact of trade liberalization on the growth of KSA is positive and not significant. However, trade liberalization is important for the growth process (Dollar, 1992, Edwards, 1998. It means that the Saudi authorities need to take some aggressive steps towards liberalization of the economy. Increased liberalization would add to the growth process of KSA significantly.

Table 4. Long run Results

Variables	Coefficients	Standard Error
$lnpopag_t$	-7.569***	1.329
$lnpopdpr_t$	7.0001***	1.333
$lninv_t$	0.214*	0.122
$lnedu_t$	5.487***	1.087
$lnopen_t$	0.029	0.110
inf_t	-0.008*	0.004
Constant	-8.297351	2.329

"Note**: The asterisk (, *) indicates significance level at 1 and 10 percent level".*

4.5 Short Run Results

Table 5 includes the short run findings. The short run results showed that in the short run only investment and trade openness matter for achieving higher economic growth. Similarly, inflation rate is also detrimental for economic performance in the short run, the same as like the long run. Moreover, in short run, education is insignificant which means that education only matters in long run. Furthermore, in the short run, both population ageing and dependency ratios are also insignificant. Finally, the coefficient of ECT is (-0.09) which shows that adjustment from the short run towards the long run is 9 % per year.

Table 5. Short Run Results

Variables	Coefficients	Standard Error
$\Delta lnpopag_t$	-5.896	6.601
$\Delta lnpopdpr_t$	5.126	10.571
$\Delta lninv_t$	0.281*	0.154
$\Delta lnedu_t$	1.179	8.004
$\Delta lnopen_t$	0.287***	0.053
Δinf_t	-0.020***	0.002
ECT (-1)	-0.098***	0.007

*"**Note**: The asterisk (***, **) indicates significance level at 1 and 5 percent level".*

4.6 Diagnostic Testing

Diagnostics are shown in Table 6. The results show that no econometric issue is detected in the estimated model. The results confirmed that "serial correlation" and "heteroscedasticity" are absent. Moreover, the functional form is correct as confirmed by the "Ramsey test". Finally, the distribution is normal as evident from the "Jarque-Bera test".

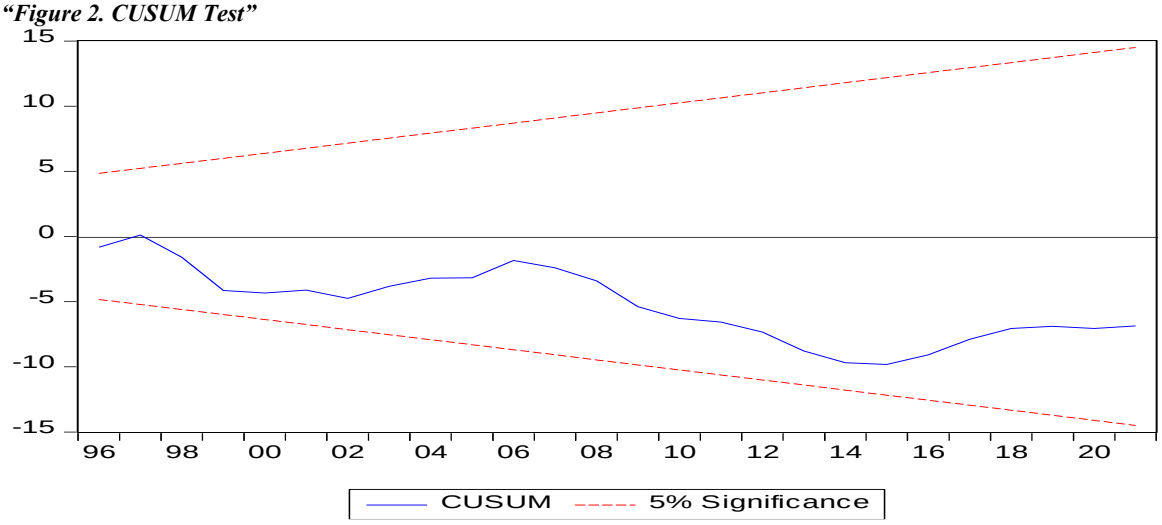
Table 6. Diagnostics

Tests	"Hypothesis"	"Test-Value + Prob."	"Decision"
"LM-Test"	"Ho: No serial correlation"	2.522 (0.125)	"No serial correlation"
"White-Test"	"Ho: No heteroscedasticity"	1.289 (0.323)	"No heteroscedasticity"
"Jarque-Bera Test"	"Ho: Data is normal"	3.268 (0.195)	"Normal distribution"
"Ramsey-Test"	"Ho: Correct functional form"	1.753 (0.218)	"Correct functional form"

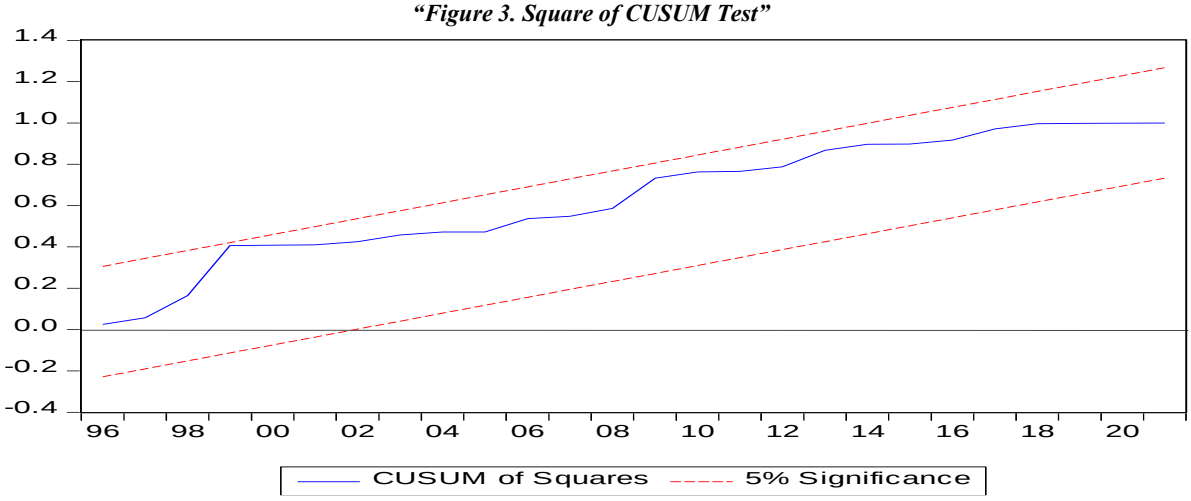
4.7 The Stability of Residuals

In this section, the study carried out the well know "CUSUM test" and the "Square of CUSUM test" for assessing the stability of error term. Figure 2 and Figure 3 provided below display the results. Both the mentioned figures have reflected the stability of the error term as the estimated lines are inside the critical limits. The stability of error term basically reflects the validity and reliability of results. Consequently, our findings could be used with confidence by the policymakers of KSA regarding improving economic growth amid the problem of population aging.

"Figure 2. CUSUM Test"



"Figure 3. Square of CUSUM Test"



5.0 Causality Findings

Causality findings are demonstrated in Table 7. The causality findings revealed several causal relationships both unilateral as well as bilateral. A two-way causal relationship is found between population aging and economic growth, education and economic growth and trade openness and investment rate. On the other several, we found that population dependency is linked with growth and inflation rate while economic growth is associated with investment rate in unilaterally manner.

Similarly, trade openness is causing a population dependency ratio while population aging is causing an inflation rate. Finally, the findings showed that trade openness is connected unilaterally with population aging while education is linked with inflation rate in a unilateral manner.

Table 7. Causality

"Hypothesis"	**Test-Value**	**Prob. Value**
$lnpopdpr_t$ to lny	19.3159***	9.E-05
lny to $lnpopdpr_t$	1.62235	0.2107
$lnpopag_t$ to lny	5.10613**	0.0298
lny to $lnpopag_t$	2.71594*	0.1078
$lnedu_t$ to lny	53.7934***	1.E-08
lny to $lnedu_t$	8.12724***	0.0071
$lninv_t$ to lny	1.67435	0.2037
lny to $lninv_t$	3.14362*	0.0845
inf_t to lny	0.08815	0.7682
lny to inf_t	1.82194	0.1853
$lnopen_t$ to lny	1.66603	0.2048
lny to $lnopen_t$	0.15033	0.7004
$lnpopag_t$ to $lnpopdpr_t$	0.98624	0.3271
$lnpopdpr_t$ to $lnpopag_t$	1.83336	0.1839
$lnedu_t$ to $lnpopdpr_t$	0.09377	0.7611
$lnpopdpr_t$ to $lnedu_t$	0.14865	0.7020
$lninv_t$ to $lnpopdpr_t$	0.12118	0.7297
$lnpopdpr_t$ to $lninv_t$	1.46839	0.2333
inf_t to $lnpopdpr_t$	2.46240	0.1251
$lnpopdpr_t$ to inf_t	3.62603*	0.0647
$lnopen_t$ to $lnpopdpr_t$	16.4514***	0.0002
$lnpopdpr_t$ to $lnopen_t$	0.11422	0.7373
$lnedu_t$ to $lnpopag_t$	1.06848	0.3080
$lnpopag_t$ to $lnedu_t$	0.23019	0.6342
$lninv_t$ to $lnpopag_t$	0.11037	0.7416
$lnpopag_t$ to $lninv_t$	2.18234	0.1481
inf_t to $lnpopag_t$	1.99431	0.1662
$lnpopag_t$ to inf_t	4.68498**	0.0370
$lnopen_t$ to $lnpopag_t$	19.6878***	8.E-05
$lnpopag_t$ to $lnopen_t$	0.32713	0.5708
$lninv_t$ to $lnedu_t$	0.37146	0.5459
$lnedu_t$ to $lninv_t$	0.68160	0.4143
inf_t to $lnedu_t$	1.02976	0.3168
$lnedu_t$ to inf_t	3.04951*	0.0891
$lnopen_t$ to $lnedu_t$	1.26567	0.2678
$lnedu_t$ to $lnopen_t$	7.5E-05	0.9931
inf_t to $lninv_t$	2.60680	0.1149
$lninv_t$ to inf_t	0.02779	0.8685
$lnopen_t$ to $lninv_t$	8.01884***	0.0074
$lninv_t$ to $lnopen_t$	3.55528*	0.0672
$lnopen_t$ to inf_t	0.79725	0.3777
inf_t to $lnopen_t$	1.14695	0.2911

6.0 Conclusions and Implications

6.1 Concluding Remarks

This study was intended to assess the role of population aging in the process of economic growth which has received relatively less attention in the context of KSA. The analysis carried out is based on the observations of KSA sourced from credible sources for the period 1981-2021. For the short run and long run impacts, the study employed the well-known ARDL modeling approach.

Our results have confirmed that population aging is a potential threat for the growth process of KSA. It is a fact that population aging harms the growth process as the efficiency of aged population is far less as compared to the younger population. On the other hand, our results underscore that dependency ratio is impacting the growth process positively and significantly. Furthermore, our results also demonstrated that human capital and investment are the main driving forces behind the growth of KSA in the long run. The inflation rate has negatively while trade openness has insignificantly impacted the growth performance. The short run analysis indicated the growth of KSA is dependent on trade openness and domestic investment. Finally, the causality analysis displayed several one-way and two-way causal relationships among the variables including the bidirectionality between population aging and economic growth.

6.2 Implications of Research

Following are the implications of our research study.

1) The results showed that population aging is responsible for the poor growth performance of KSA. This could be because the aged population is contributing relatively less to the growth process as compared to the younger population. Therefore, the older population need to be encouraged and motivated to enhance their contribution to the growth performance. Moreover, some necessary structural changes are required in the industrial sector to turn it favorable for the aged population.
2) Secondly, it is suggested the authorities of KSA should increase their investment both in physical capital and in human capital as both these factors have added to the growth performance positively. Increased human capital and the availability of physical capital would help the economy to achieve long run sustainable growth.
3) The inflation rate needs to be monitored as it is harmful for growth performance in the light of the acquired results. The statistics presented indicated that KSA has done well over the years in keeping the inflation rate at a reasonable limit.
4) The policy of trade liberalization needs to be executed in full speed in order to make it work for improvement in economic growth.

Appendix Section

Table 1 A. Variables and Sources

Variables	Definition	Source
y_t	"Economic growth (The growth rate of GDP per capita"	"WDI"
$popag_t$	"(Population ages 65 and above (% of total population)"	"WDI"
$popdpr_t$	"(Age dependency ratio, old (% of working-age population)"	"WDI"
inv_t	"Gross fixed capital formation as % of GDP"	"WDI"
edu_t	"Human Capital Index"	"PWT"
$open_t$	"Trade as % of GDP"	"WDI"
inf_t	"The growth rate of consumer price index"	"WDI"

References

Abeywardhana, D. K. Y. (2019). The impact of ageing population on economic growth in South Asia. *Asian Social Science, 15*(7), 70–76. https://doi.org/10.5539/ass.v15n7p70

Acemoglu, D., & Restrepo, P. (2017). Secular stagnation? The effect of aging on economic growth in the age of automation. *American Economic Review, 107*(5), 174–179. https://doi.org/10.2139/ssrn.2899142

Ademola, O. Y. (2018). Economic growth and population ageing in Nigeria: Innovation accounting techniques. *Journal of Sustainable Development, 11*(4), 190–200. https://doi.org/10.5539/jsd.v11n4p190

Barro, R. J. (2003). Determinants of economic growth in a panel of countries. *Annals of Economics and Finance, 4*(2), 231–274.

Blake, D., & Mayhew, L. (2006). On the sustainability of the UK state pension system in the light of population ageing and declining fertility. *The Economic Journal, 116*(512), F286–F305. https://doi.org/10.1111/j.1468-0297.2006.01086.x

Bloom, D. E., Canning, D., & Fink, G. (2010). *Population aging and economic growth. In M. Spence & D. Leipziger (Eds.), Globalization and growth* (pp. 297–328). World Bank.

Brida, J. G., Gómez, D. M., & Seijas, M. N. (2017). *Debt and growth: A non-parametric approach. Physica A: Statistical Mechanics and Its Applications,* 486, 883–894. https://doi.org/10.1016/j.physa.2017.05.052

Dewan, E., & Hussein, S. (2001). *Determinants of economic growth (Panel data approach). Economics Department, Reserve Bank of Fiji.*

Romer, P. M. (1990). *Endogenous technological change. Journal of political Economy*, 98(5, Part 2), S71-S102.

Dollar, D. (1992). Outward-oriented developing economies really do grow more rapidly: Evidence from 95 LDCs, 1976–1985. *Economic Development and Cultural Change, 40*(3), 523–544. https://doi.org/10.1086/451959

Edwards, S. (1998). Openness, productivity and growth: What do we really know?. *The Economic Journal, 108*(447), 383–398. https://doi.org/10.1111/1468-0297.00293

Engle, R. F., & Granger, C. W. J. (1987). Cointegration and error correction representation: Estimation and testing. *Econometrica, 55*(2), 251–276. https://doi.org/10.2307/1913236

Futagami, K., & Nakajima, T. (2001). Population aging and economic growth. *Journal of Macroeconomics, 23*(1), 31–44. https://doi.org/10.1016/S0164-0704(01)00160-3

Guo, Z., Liu, L., & Liu, X. (2016). Population aging, marginal propensity to consume and economic growth. *Asian Economic and Financial Review, 6*(9), 534–546. https://doi.org/10.18488/journal.aefr/2016.6.9/102.9.534.546

Hsu, Y.-H., & Lo, H.-C. (2019). The impacts of population aging on saving, capital formation, and economic growth. *American Journal of Industrial and Business Management, 9*(12), 2231–2249. https://doi.org/10.4236/ajibm.2019.912148

Ismail, N., Rahman, H. S. W. H. A., Hamid, T. A. T. A., & Said, R. (2016). Aging and economic growth: Empirical analysis using autoregressive distributed lag approach. *Sains Malaysiana, 45*(9), 1345–1350.

Ismail, Z., Ahmad, W. I. W., Hamjah, S. H., & Astina, I. K. (2021). The impact of population ageing: A review. *Iranian Journal of Public Health, 50*(12), 2451–2466.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration with applications to the demand for money. *Oxford Bulletin of Economics and Statistics, 52*(2), 169–210. https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x

Lee, H.-H., & Shin, K. (2019). Nonlinear effects of population aging on economic growth. *Japan and the World Economy, 51*, 1–38. https://doi.org/10.1016/j.japwor.2019.100963

Lee, H.-H., & Shin, K. (2021). Decomposing effects of population aging on economic growth in OECD countries. *Asian Economic Papers, 20*(3), 1–25. https://doi.org/10.1162/asep_a_00839

Lucas, R. E., Jr. (1988). On the mechanics of economic development. *Journal of Monetary Economics, 22*(1), 3–42. https://doi.org/10.1016/0304-3932(88)90168-7

Mamun, S. A. K., Rahman, M. M., & Khanam, R. (2020). The relation between an ageing population and economic growth in Bangladesh: Evidence from an endogenous growth model. *Economic Analysis and Policy, 65*, 34–44. https://doi.org/10.1016/j.eap.2020.02.001

Mikiko, O. (2015). Population ageing and economic growth in Japan. *International Journal of Sociology and Social Policy, 35*(11/12), 841–863. https://doi.org/10.1108/IJSSP-02-2015-0018

Miri, N., Maddah, M., & Raghfar, H. (2019). Aging and economic growth [Persian]. *Iranian Journal of Ageing, 13*(Special Issue), 626–637. https://doi.org/10.32598/SIJA.13.Special-Issue.626

Modigliani, F., & Brumberg, R. (1954). *Utility analysis and the consumption function. In K. Kurihara (Ed.), Post-Keynesian economics* (pp. 151–170). Rutgers University Press.

Mohd, S. N. A., Ishak, A. A., & Selvaratnam, D. P. (2021). *Ageing population's impact on economic growth in Malaysia from 1981 to 2019: Evidence from an autoregressive distributed lag approach*. Frontiers in Public Health, 9, 731554. https://doi.org/10.3389/fpubh.2021.731554

Moradi, M., & Uslu, N. C. (2020). The impacts of population aging on Turkey's economic growth: An empirical analysis with ARDL model. *Journal of Business, Economics and Finance, 9*(4), 292–303. https://doi.org/10.17261/Pressacademia.2020.1325

Maestas, N., Mullen, K. J., & Powell, D. (2023). The effect of population aging on economic growth, the labor force, and productivity. *American Economic Journal: Macroeconomics, 15*(2), 306–332. https://doi.org/10.1257/mac.20170367

Nagarajan, R., Teixeira, A. A. C., & Silva, S. (2017). The impact of population ageing on economic growth: A bibliometric survey. *Singapore Economic Review, 62*(2), 275–296. https://doi.org/10.1142/S021759081550068X

Nagarajan, N. R., Teixeira, A. A. C., & Silva, S. T. (2016). The impact of an ageing population on economic growth: An exploratory review of the main mechanisms. *Analise Social, 51*(218), 4–35.

Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics, 37*(17), 1979–1990. https://doi.org/10.1080/00036840500278103

Pesaran, M. H., Shin, Y., & Smith, R. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289–326. https://doi.org/10.1002/jae.616

Park, H., & Son, J. C. (2021). Threshold effects of population aging on economic growth: A cross-country analysis. *The Singapore Economic Review*, 1–23. https://doi.org/10.1142/S0217590821500440

Rahman, N. H. A., Ismail, S., & Ridzuan, A. R. (2020). Ageing population and economic growth: An empirical investigation. *International Journal of Academic Research in Business and Social Sciences, 10*(5), 609–625. https://doi.org/10.6007/IJARBSS/v10-i5/7234

Romer, P. M. (1989). *Human capital and growth: Theory and evidence. NBER Working Paper No. 3173*. https://doi.org/10.3386/w3173

Salam, A. A. (2023). Ageing in Saudi Arabia: New dimensions and intervention strategies. *Scientific Reports, 13*(1), 4035. https://doi.org/10.1038/s41598-023-31276-1

Shairilizwan, T. (2020). Ageing population and economic growth: Evidence from Malaysia. *South Asian Journal of Social Studies and Economics, 7*(4), 11–18. https://doi.org/10.9734/SAJSSE/2020/v7i430196

Teixeira, A. A. C., Nagarajan, N. R., & Silva, S. T. (2017). The impact of ageing and the speed of ageing on the economic growth of least developed, emerging and developed countries, 1990–2013. *Review of Development Economics, 21*(3), 909–934. https://doi.org/10.1111/rode.12294

Tahir, M., & Azid, T. (2015). The relationship between international trade openness and economic growth in the developing economies: Some new dimensions. *Journal of Chinese Economic and Foreign Trade Studies, 8*(2), 123–139. https://doi.org/10.1108/JCEFTS-02-2014-0004

Thach, N., & Duc, H. (2021). Aging population and economic growth in developing countries: A quantile regression approach. *Emerging Markets Finance and Trade, 57*(7), 108–122. https://doi.org/10.1080/1540496X.2019.1698418

Valeriy, H., Mariya, S., & Svitlana, S. (2019). *Population aging and economic dynamics in Ukraine: Models of endogenous growth theory and empirical estimates of current challenges. Advances in Economics, Business and Management Research, 99,* 283–285. http://creativecommons.org/licenses/by-nc/4.0

Wen-Hsin, H., Yen-Ju, L., & Hsien-F., L. (2019). Impact of population and workforce aging on economic growth: Case study of Taiwan. *Sustainability, 11*(22), 6301. https://doi.org/10.3390/su11226301