INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN ECONOMICS & MANAGEMENT SCIENCES

OPEN ACCESS JOURNAL

Vol 14, Issue 3, (2025) E-ISSN: 2226-3624

The Impact of Japan's Aging Population on its Macroeconomics

Fan Yu[1], Roziana Baharin[2]

[1,2]Faculty of Economics and Management, Univerisiti Kebangsaan, Malaysia, 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia

To Link this Article: http://dx.doi.org/10.6007/IJAREMS/v14-i3/25421 DOI:10.6007/IJAREMS/v14-i3/25421

Published Online: 05 July 2025

Abstract

Japan's economy has become characterised by population ageing, with the country being designated a super-aged society as early as 2006 (Ministry of Health, Labour and Welfare, 2023). This demographic shift carries profound implications for significant macroeconomic variables, ranging from the demographic trend itself to the effects on an ageing population.This study analyses how changes in the age distribution of the population affect Japan's real GDP, inflation, fiscal balance, unemployment rate, domestic saving and domestic investment over the long run. The analysis attempts to quantify the connections and identify the underlying mechanisms causing the economic adjustments related to ageing demographics using annual data from 1993 to 2023.

Keywords: Domestic Saving, Domestic Investment, Unemployment Rate, Inflation Rate, Real GDP

Introduction

Globally, population ageing has become a social problem of increasing seriousness, especially in many industrialised countries. With falling birth rates and rising life expectancy, the proportion of the elderly population continues to rise worldwide. According to the United Nations Population Fund (UNFPA), the global population aged 60 and above surpassed one billion in 2020, and it is projected that by 2050, this demographic will reach nearly two billion, constituting approximately 22% of the world's total population.This phenomenon is particularly pronounced in developed countries, where the ageing population is exerting significant pressure on economic structures and social security systems. The World Health Organization (WHO) has similarly identified population aging as a key trend with the potential to influence the economic, social, and cultural landscapes of various countries.A notable instance of this phenomenon is observed in East Asia, where countries such as China, South Korea, and Japan are confronted with the challenge of a rapidly aging population.According to United Nations projections, by 2025, the population aged 60 and above in East Asia is expected to account for approximately 28% of the total population. This tendency is especially evident in Japan. In recent years, the rate and extent of population ageing in Japan has surpassed that of other countries.

China has both the highest population and the most obvious demographic ageing issues of any country. In 2020, the elderly population (aged 60 and above) in China was 18.1% of the total population, equivalent to approximately 250 million people (National Bureau of Statistics of China, 2021). It is projected that this figure will rise to 25% of the total population by 2030, a consequence of China's accelerated aging trajectory, which has been further exacerbated by the sustained decline in birth rates and the attendant rise in the average age of the population. This growth rate is among the fastest observed across the globe. This phenomenon is associated with a number of economic challenges, including a decline in the labour force, shifts in consumption patterns, and pressure on the social security system.For instance, China's manufacturing and service sectors are beginning to experience the impact of a labour shortage.A similar situation is being witnessed in South Korea, another East Asian country dealing with significant ageing issues. According to the Korea National Statistics Office (KNSO), the proportion of the South Korean population aged 60 years and over reached 16.5% in 2020 and it is predicted that this figure will rise considerably during the next few years (KNSO, 2022). The South Korean government has predicted that by 2025, more than 20% of the population will be old and by 2050 this will increase to approximately 40% (MSIP, 2022). This increase can be attributed to two key factors; the low birth rate and the ageing population. South Korea is experiencing a low birth rate, leading to a declining birth total and increasing the average age of the population.

Japan's population ageing issue is more severe than that of China and South Korea, and it has attracted international attention.In 2016, the elderly population (those 60 and older) constituted 26.7% of Japan's total population, according to figures from the Cabinet Office of Japan's Statistics Bureau. Projections indicate that the elderly population will increase to nearly 40% of the total by 2050, emphasising the magnitude of this demographic shift (Cabinet Office, 2016).Japan's ageing demographic is not only significant in global context – with one in two citizens falling within this bracket – but it also holds the particular status of having the fastest ageing population among developed countries, as highlighted in a 2014 report by The Economist (The Economist, 2014). The phenomenon of Japan's ageing population is characterised by not only the rise in the elderly demographic, but also considerable transformations in its population structure.The decline in the workforce of younger demographics has a direct impact on productivity and the stability of the labour market. Furthermore, Japan's economic growth has been subject to considerable pressure from variables such as shifts in consumer patterns and the increase in labour costs. Following a protracted period of low birth rates, the demographic dividend that Japan once enjoyed is gradually being lost, and the risk of economic growth slowing down is increasing. The Japanese government is currently dealing with a series of complex issues, including the question of how to maintain the operation of the social security system, how to deal with the increase in social pension costs, and how to address labor shortages.

Japan's ageing population exerts a substantial influence on various economic factors, including consumption, savings and investment behaviour at the household level, as well as the country's broader macroeconomic variables. The financial strain on the social security system and the increase in health and retirement costs due to ageing have become significant factors in the Japanese government's policy adjustments. According to a 2015 study by Bloom et al. the ageing population exerts significant pressure on Japan's economic growth, inflation, fiscal deficit, investment rate, domestic savings rate, and other economic variables.While

China, South Korea, and Japan are confronted with challenges posed by population ageing, the pace at which these countries are undergoing this transformation differs considerably. While China and South Korea have already identified the challenges related to population ageing, Japan is currently experiencing the most severe population ageing.China's population is projected to reach its peak and transition into a pronounced ageing period by 2030. Due to a substantially lower birth rate compared to other developed nations, South Korea's ageing process commenced later than other nations, but it is anticipated to accelerate in the forthcoming decades.

Japan and other East Asian countries are implementing measures to address the demographic challenges posed by an ageing population. These measures consist of the following: the implementation of a delayed retirement age, the promotion of labor market reforms, the encouragement of childbirth, and the strengthening of immigration policies. Moreover, technological progress and digital transformation are regarded as potential solutions to mitigate labor shortages. For instance, Japan is promoting robotics and artificial intelligence to replace some labor-intensive jobs and address the issue of declining productivity caused by aging.

The issue of population aging has become a significant challenge that cannot be disregarded on a global scale, particularly in Asian countries. To this end, governments must formulate practical policies to mitigate the adverse effects of ageing and ensure sustainable economic growth and stable social development.

Literature review

A substantial body of literature has examined the impact of population ageing on Japan's macroeconomy from both theoretical and empirical standpoints. These studies primarily concentrate on how population ageing affects the operating mechanism of Japan's economy through macroeconomic variables such as the savings rate, investment rate, real GDP growth, inflation, fiscal balance and unemployment rate.

The impacts of population ageing on Japan's macroeconomy can be summarised as follows: an increase in the elderly population leads to a significant decline in the savings rate (negative correlation), resulting in a reduction in domestic investment (negative correlation), which in turn affects real GDP growth (negative correlation).The effect of ageing on inflation varies across different industries. While it may result in price increases in sectors such as medical care and elder care (positive correlation), ageing has a more pronounced effect on lowering overall inflation due to a decline in consumer demand (negative correlation).Aging has also contributed to higher fiscal deficits and social security spending, creating pressure on the fiscal balance (negative connection).A decrease in the labour force may initially result in a lower total unemployment rate (positive correlation), but developing industries may experience an increase in technological unemployment (negative correlation). The dynamics between these variables are intricate, which engenders challenges in achieving long-term economic progress and necessitates continuous evaluation and policy response.

Modigliani's (1966) life cycle hypothesis posits that an individual's propensity for saving is cyclically contingent on their life stage. It asserts that as individuals transition through different phases of life, their saving habits undergo a shift, leading to a decline in their savings

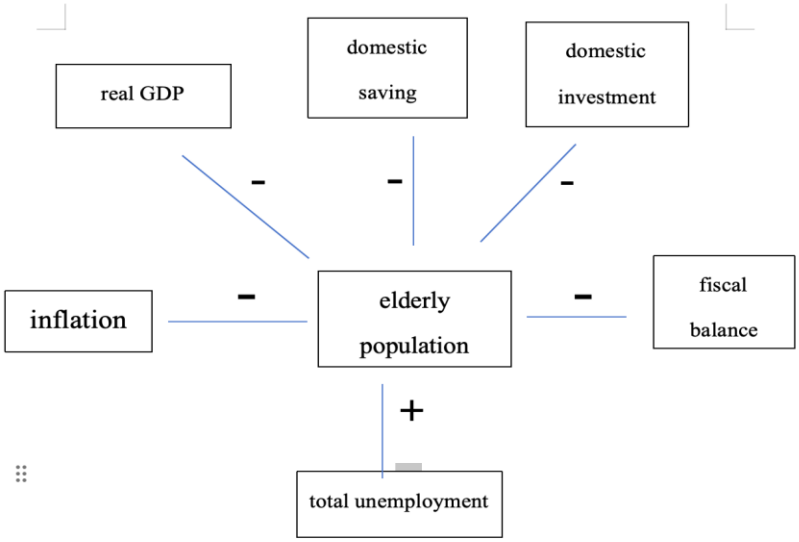
rate as they age. This phenomenon, according to the theory, exerts a significant influence on the accumulation of capital and the propensity for investment. Empirical evidence has substantiated the validity of this hypothesis in the Japanese context. Horioka's (2010) analysis highlighted a substantial decline in domestic savings in Japan, attributable to the nation's ageing population.Specifically, Horioka's regression study demonstrated that the savings rate experiences a decline of approximately 0.2 percentage points for every 1 percentage point increase in the ageing rate. This decline in savings has also been accompanied by a decline in domestic investment, resulting in a shortage of capital supply, which has further impacted Japan's capital formation and long-term economic growth.In relation to real GDP and inflation, Okun's Law (1962), proposed by Okun, posits a negative correlation between unemployment and output. However, Japan's aging population has altered this relationship to a certain extent. On the one hand, the aging population has been shown to lead to a decline in the labour force, thereby directly reducing the potential for real GDP growth (Yashiro, 1997). However, shifts in productivity and consumer demand have also been demonstrated to indirectly affect inflation.According to Anderson et al. (2014), the aging population has a tendency to lower aggregate demand, which in turn lowers the inflation rate. However, it should be noted that structural inflation may be caused by higher spending in specific areas, such as healthcare and pensions.

In relation to the fiscal balance, Yashiro (1997) demonstrated that as the population ages, the Japanese government's social security expenditure (particularly pension and medical spending) has increased substantially, resulting in heightened fiscal deficit pressure. According to data from the Japanese Ministry of Finance, between 2015 and 2020, the proportion of public spending related to aging in total spending increased from 22% to 28%. This phenomenon indicates that the demographic shift associated with aging poses not only a direct threat to fiscal balance, but also has the potential to influence long-term economic growth through the accumulation of debt.

Aging is associated with a decline in the total labor force, which can precipitate structural unemployment issues due to a disconnection between labor market demand and supply structures, particularly in sectors requiring a high level of technological innovation. According to Ogawa & Retherford (1993), Japan's ageing labour force is more likely to be employed in traditional sectors and less able to adapt to new ones, which could raise the country's risk of technological unemployment.

The extant literature demonstrates that Japan's ageing population exerts a multifaceted and intricate influence on its macroeconomic variables, with the factors in question exhibiting potential for interaction in intricate ways. To illustrate this point, a decline in the savings rate may precipitate a decrease in investment, which in turn could impede real GDP growth. Concurrently, an enhancement in the fiscal deficit has the capacity to exacerbate the slowdown in economic growth by impacting the efficiency of government expenditure and the investment patterns of the private sector. It is commonly acknowledged that dynamic models are useful instruments for examining intricate economic linkages. Economic modelling techniques including overlapping generations (OLG) models and dynamic stochastic general equilibrium (DSGE) are frequently used by researchers to examine the long-term impacts of population ageing (Fujii & Ihori, 2001). In conclusion, Japan’s macroeconomic response to population aging is shaped by multiple interrelated factors, rather than being determined by

a single variable. This study aims to examine how key macroeconomic variables interact in an aging society and how these interactions influence Japan's long-term economic stability.



Theoretical framework

The present study focuses on population aging, analysing its multiple impacts on the Japanese economy from a macroeconomic perspective, and constructing an analytical framework based on multiple classical economic theories.Firstly, the Life Cycle Hypothesis provides a theoretical basis for studying changes in savings and investment rates, pointing out that individual savings behaviour varies with different stages of the life cycle, and that aging will lead to a decline in the overall savings rate, thereby affecting capital accumulation and investment (Modigliani, 1966). Secondly, Okun's Law lends support to the negative impact of labour force reduction on real GDP growth. Simultaneously, this paper explores the multifarious effects of ageing on economic growth, taking into account the impact of ageing on labour productivity and consumer demand. Thirdly, the dual effects of aging on inflation are analysed in combination with the AD-AS Model. This analysis explores the contradictory effects of reduced demand, leading to a decline in inflation, and price increases in aging-related industries, leading to structural inflation (Anderson et al., 2014). Furthermore, utilising the Overlapping Generations Model (OLG) and Dynamic Stochastic General Equilibrium Model (DSGE), this study investigates the manner in which ageing amplifies fiscal deficit pressures and economic growth slowdowns by impacting savings, investment and fiscal expenditure. Finally, combined with labor market theory, this paper analyses how aging leads to structural unemployment, especially in the context of the difficulty of older workers in technology-intensive industries to adapt to emerging technologies, and further has a complex impact on the unemployment rate (Ogawa & Retherford, 1993). Utilising a comprehensive combination of theoretical frameworks, this paper aims to unravel the intricate dynamic interplay between Japan's population ageing and macroeconomic variables, thereby providing a foundation for the formulation of policies to address the challenges posed by ageing.

$$S = \alpha - \beta A$$

S: Domestic savings rate, which represents the proportion of household and corporate savings to GDP.

A: Aging rate, usually measured by the proportion of people aged 60 and above to the total population
α：The theoretical benchmark savings rate represents the average savings rate when it is not affected by aging.
β：The intensity of the negative impact of aging on the savings rate, reflecting the sensitivity of savings to changes in the aging rate。

In this context, the life cycle theory is crucial in understanding how the ageing population affects the domestic savings rate. According to the hypothesis, people save more money while they are employed and then use that money after they retire.Thus, the savings rate is directly impacted by an increase in the ageing rate (A), showing a general downward trend. The older population's savings capacity is generally low because their income sources are primarily concentrated in pensions or fixed asset returns, and they have been seen to spend their previous savings rather than save new ones.Changes in the population's composition have resulted in a decline in the proportion of the working-age population, and as fewer people are in this high-saving stage, the savings rate has also declined. According to empirical research by Horioka, the savings rate may decrease by roughly 0.2 percentage points for every percentage point increase in the ageing rate. Concurrently, the quality of the social security system exerts a significant influence on the savings rate. A flawless pension system mitigates residents' demand for savings, whereas an imperfect system prompts households to augment their savings in anticipation of economic uncertainty. Income level, interest rate and consumption propensity (C/Y) are also key influencing factors: higher income levels or interest rates usually promote savings, while the high consumption propensity of the elderly population for medical and elderly care services further compresses the savings space, thereby exacerbating the decline in the savings rate.

$$I = \gamma S$$

I: Domestic investment rate, reflecting the proportion of domestic fixed capital formation to GDP.
S: Domestic savings rate
λ: The efficiency coefficient of investment and savings conversion, which is affected by the degree of capital market openness and cross-border capital mobility

As domestic savings represent the primary source of investment funds, the savings rate (S) exerts a pivotal influence on investment levels. The impact of population ageing on capital supply is a pivotal factor that shapes the correlation between savings and investment. The decline in capital availability, consequent to an ageing population, results in a reduction in the savings rate and, by extension, a decline in investment. This decline in capital availability, in turn, further restricts capital accumulation, thereby impeding economic growth. Japan's experience highlights that the impact of declining savings on investment is particularly pronounced in ageing societies. In addition to savings, the rate of return on capital (r), the investment environment, foreign capital inflows (F), and capital market openness also influence investment. The role of foreign direct investment (FDI) and other cross-border capital flows is twofold: they can help address investment shortfalls when domestic savings are insufficient, and they can also encourage investment when favourable conditions and higher returns on capital are in place. In closed economies, investment is contingent on

domestic savings (λ ≈ 1), whereas in open economies, foreign capital inflows can help offset the effects of declining savings on investment (λ < 1). However, the phenomenon of ageing populations has the potential to contribute to diminished capital returns, thereby reducing businesses' propensity to invest. Concurrently, demographic shifts may precipitate investments in automation and artificial intelligence to compensate for labor shortages. The overall impact of international capital on alleviating financial constraints is contingent upon the degree of market openness and the associated risks.

$$\triangle Y = \phi \Delta L + \psi K + \epsilon$$

ΔY: Real GDP rate
ΔL: Labor force growth rate, reflecting the rate of change of the working-age population
K: Capital stock, which depends on domestic investment and capital depreciation rate
ϵ：Other factors (technological progress, policies, etc.)
ϕ：Marginal productivity of labor
ψ：Marginal productivity of capital

According to production functions (such as the Cobb-Douglas production function), GDP growth depends on the input of labor and capital. The actual GDP growth rate is driven by the labor growth rate (L) and capital accumulation (K). Aging significantly reduces the working-age population, thereby reducing the potential economic growth rate. Aging reduces the growth rate of the working-age population (L < 0), while reduced savings inhibit capital accumulation (K). Capital accumulation depends on savings and investment, and a decline in the savings rate may limit capital growth. Technological progress (T) is a key factor in improving productivity. Technological progress may partially offset the negative impact of a reduced labor force. Government policies and the external economic environment (such as global trade conditions) also have a direct impact on economic growth. But in the long run, the shortage of labor and capital will weaken the potential for economic growth.

$$\pi = \boldsymbol{\lambda}(\boldsymbol{AD} - \boldsymbol{AS}) + \boldsymbol{\eta Ps}$$

π：Inflation rate.
AD: Total demand, mainly composed of consumption, investment, government spending and net exports.
AS：Total supply, reflecting the output capacity of the economy.
Ps：Prices of specific industries (such as medical care and pensions)
λ：The sensitivity coefficient of demand-supply differences to prices.
η：The transmission effect of price increases in specific industries on overall inflation

The inflation rate is influenced by the equilibrium between aggregate demand (AD) and aggregate supply (AS), both of which are significantly affected by population aging. On the demand side, aging results in a reduced share of the working-age population, thereby diminishing overall economic dynamism and lowering consumption levels, particularly for non-essential goods among the elderly. This reduction in aggregate demand exerts downward pressure on inflation. However, increased demand for healthcare and eldercare services can lead to price increases in these sectors, contributing to structural inflation. These shifts in consumption patterns complicate the overall inflation dynamics.On the supply side, the

shrinking labor force due to aging directly impairs production capacity and efficiency, potentially slowing or reducing the growth of aggregate supply (AS). Labor shortages may also elevate wage costs, leading to cost-push inflation. Additionally, lower savings and investment rates slow capital accumulation, further constraining production expansion and limiting aggregate supply growth. The role of monetary policy in regulating inflation cannot be overlooked. In an aging context, governments might adopt expansionary monetary policies to boost economic activity, with increased money supply typically raising inflation. However, aging can reduce the velocity of money circulation, thereby diminishing the effectiveness of such policies. Moreover, fluctuations in international markets, such as changes in imported raw material and energy prices, can influence the overall price level through cost inputs. In summary, the impact of aging on inflation hinges on the relative magnitude of supply and demand shifts. If the decline in total demand outpaces the weakening of supply, inflation may continue to fall. Conversely, if structural and cost-push inflation factors dominate, the inflation rate may rise.

FB = T - (G + Ea) ， Ea = kA

FB: Fiscal balance
T：tax revenue.
G：basic public expenditure
Ea: expenditures related to aging
k: unit cost of expenditures related to aging (e.g. pensions, health care)

The impact of population ageing on fiscal balance is profound and complex, affecting both government expenditure and revenue. From an expenditure perspective, an ageing population gives rise to the necessity for increased public expenditure on pensions, healthcare, and long-term care, thereby exerting pressure on public finances and potentially diminishing the capacity for investment in infrastructure, education, and technology. The combination of a rising number of pension recipients and a diminishing workforce contributing to social security further exacerbates the fiscal imbalance. Conversely, a declining working-age population has the effect of reducing the tax base and slowing economic growth, which in turn affects key revenue sources such as income tax and value-added tax. Furthermore, changing consumption patterns among the elderly, who tend to spend on low-tax or tax-exempt goods and services, further weaken tax growth potential. In order to address this widening fiscal deficit, governments often resort to financing through debt, a measure which increases long-term fiscal risks and interest payments. Rising debt levels may lead to credit rating downgrades, resulting in increased borrowing costs and limiting the government's capacity to implement countercyclical policies during periods of economic downturns. The implementation of policy measures can serve to mitigate these challenges. One such measure is the elevation of the retirement age, a strategy that has been demonstrated to expand the labour force and alleviate pension pressures (OECD, 2022). Additionally, the reform of the social security system, including the introduction of tiered pensions or the promotion of private retirement plans, has been shown to reduce fiscal burdens (OECD, 2022). Adjusting tax policies, such as increasing tax rates for high-income individuals or introducing new taxes like a carbon tax, can also strengthen revenue. Furthermore, strategies to stimulate economic growth, such as the attraction of foreign investment, the fostering of innovation, and the enhancement of productivity, can serve to

offset the impact of a diminishing labour force. Furthermore, the relaxation of immigration policies to attract skilled young workers has the potential to expand the tax base and slow down demographic shifts, thereby buying time to stabilize public finances. Overall, the fiscal impact of aging is multidimensional, requiring a balanced approach that combines expenditure control, revenue enhancement, and economic growth strategies.

$$U = Us + Ut \ , \quad Us = \omega(Ld - Ls)$$

U：total unemployment rate
Us: structural unemployment rate
Ut: technical unemployment rate
Ld: labor demand
Ls: labor supply
ω: labor market adjustment coefficient

The change in unemployment rate is determined by the gap between supply and demand in the labor market (Ld - Ls). The impact of population aging on the unemployment rate is dual and complex. Aging usually reduces the labor supply (Ls), which may ease the pressure of overall unemployment rate under certain conditions. However, this process may also cause structural unemployment and technical unemployment, which has become an important challenge for the labor market. First, aging significantly reduces the working-age population, especially in traditional manufacturing and some labor-intensive industries, which may lead to labor shortages and cause the unemployment rate to decline in these industries. However, this supply reduction may not be fully matched with the industry distribution and skill structure of labor demand. With the acceleration of technological progress, the widespread application of automation and artificial intelligence has significantly improved labor productivity, but it has also caused technical unemployment (Ut), especially in areas that rely on repetitive or low-skilled labor. Jobs in traditional manufacturing and some basic service industries may be replaced by machines, and low-skilled workers face a greater risk of unemployment. Secondly, the industrial restructuring brought about by aging may aggravate the unemployment problem. The expansion of the service industry has become an important trend in an aging society, but it has put pressure on employment in traditional manufacturing. In addition, the older workforce is relatively weak in learning and adapting to new technologies, which makes this group less competitive in technology-intensive jobs and increases the risk of structural unemployment (US). The lack of matching between skills and market demand may also increase unemployment, especially against the backdrop of accelerated aging and faster industrial adjustment.

Methodology and Data

	ADF Test			PP Test		
	Level	**1st differenced**	**2nd differenced**	**Level**	**1st differenced**	**2nd differenced**
Gross domestic saving (GDS)	0.076	0.2251***	0.8318***	0.076	0.2251***	0.8318***
Real GDP (rGDP)	0.0367	0.7541***	0.7479***	0.0367	0.7541***	0.7479***
Inflation	0.2585*	0.6561***	0.7784***	0.2585*	0.6561***	0.6874***
Unemployment rate	0.1463	0.861**	0.7958***	0.2740	0.8692**	0.8849***
Old population	0.1307	0.6544	0.4712***	0.0000	0.6349	0.7196
Worked age population	0.6900	0.2923	0.8116***	0.8585	0.2923	0.8116***
Young age population	0.0000	0.2140	0.5620	0.0011*	0.0018**	0.5620
CSD	0.0161*	0.9079***	0.9161***	0.0161*	0.9079***	0.9161***
GFC	0.053	0.4769***	0.9226***	0.053	0.4769***	0.9226***

Notes: *, **, *** indicate statistical significance at 10 %, 5% and 1% levels, respectively.

The results of the unit root test and their economic implicationsThe unit root test is a valuable tool for analysing the time series characteristics of research variables, providing a fundamental basis for the development of subsequent models. This paper employs the Augmented Dickey-Fuller test (ADF) and the Phillips-Perron test (PP) to systematically analyse the stationarity of each variable and its integral order. During the test, for the level value of the data series, when the data trend is obvious, the model containing the intercept and trend terms is used; for the difference series, only the intercept term is included. The selection of the lag period for the ADF test is based on the Modified Akaike Information Criterion (MAIC), while the PP test employs the Bartlett kernel function for spectrum estimation and determines the bandwidth through the Newey-West method (Banerjee, 1993). The unit root test results of the gross domestic saving rate (GDS) demonstrate that the unit root hypothesis can be rejected in terms of the level value, yet it succeeds in passing the ADF and PP tests following the implementation of the first-order difference, thereby indicating that the GDS is first-order difference stationary (I(1)). This outcome is consistent with the theoretical expectations of the Life-Cycle Hypothesis, reflecting that the savings rate is significantly influenced by the population age structure and economic cycle fluctuations. This finding provides a rationale for the non-stationary nature of the savings rate in the original time series.In contrast, the level value of real GDP (rGDP) passes the ADF and PP tests and demonstrates stationarity (I(0)), indicating a mean reversion characteristic consistent with

the long-term economic stability assumptions of classical economic theories, such as the Solow Growth Model. This further corroborates the robustness of real economic growth.

The level values of the inflation rate (Inflation) and the unemployment rate (Unemployment Rate) both show non-stationarity, but show stationarity after the first-order difference (I(1)). This shows that these variables are vulnerable to economic shocks and cyclical changes in the short term, but their differential stability reflects the characteristics of dynamic adjustment of variables.

The stability characteristics of population structure variables are diverse: the old population share (OLD) is second-order difference stable (I(2)), the working population share (WORKED) is first-order difference stable (I(1)), and the young population share (YOUNG) is stable in terms of level value (I(0)). This differentiated stability reflects the complex response mechanism of populations of different ages to economic fluctuations: the second-order stability of the old population reveals the profound impact of population transition on long-term economic trends, while the stability of the working population and the young population respectively explains their economic fluctuation properties in the short and medium term.

According to the unit root test results, the integral order of the research variable does not exceed one ($I \leq 1$), which lays the foundation for the subsequent construction of the autoregressive distributed lag (ARDL) model. However, the second-order difference in stationarity of the elderly population (I(2)) means that it cannot be cointegrated with macroeconomic variables (I(1)) in the same equilibrium relationship (see Banerjee et al., 1993). Therefore, when analyzing the relationship between the elderly population and macroeconomic variables such as the savings rate, the population structure variables need to be differentiated to match the characteristics of I(1).

The present study is inspired by the statistical basis of this research. Firstly, the long-term relationship between macroeconomic variables can only be associated with the rate of change of population age structure variables. For instance, the rate of change in the proportion of the elderly population (DOLD) not only explains the long-term downward trend in the savings rate, but also captures the dynamic impact of the acceleration or deceleration of the population aging process on savings fluctuations. The data diagram further corroborates this finding, highlighting a significant negative correlation between the rise in the aging proportion and the decline in the savings rate. However, it should be noted that conventional regression analysis, based exclusively on proportion levels, is inadequate in fully capturing this intricate relationship. The rate of change of the aging proportion (DOLD) is a more effective metric in reflecting the intricate impact of the aging process on fluctuations in savings. To clarify this point, consider the example of the 1970s, when an increase in DOLD was accompanied by a decline in the savings rate, and vice versa, with both stabilising in the early 1980s. By the mid-1980s, DOLD exhibited a substantial increase, and subsequently, the savings rate commenced a decline. This negative correlation persisted until approximately 2010, after which the two variables stabilized gradually.

Dependent variable is Old age population, ARDL (1,1,0,0,0,0)		
Critical values	**F - Statistics (6.517616)*** **	
	Lower Bound	Upper Bound
99%	4.537	6.37
95%	2.678	3.858
90%	3.125	4.608

This study applies the AutoRegressive Distributed Lag (ARDL) bounds test method to conduct a cointegration analysis on gross domestic saving (GDS) and its associated variables, with the objective of investigating the long-term relationship between the variables. In accordance with the theoretical framework proposed by Pesaran (2001), this study establishes the total savings rate as the dependent variable and conducts a cointegration test on the relevant macroeconomic and population age structure variables.

The findings reveal that the F statistic of the total savings rate (12.18) significantly surpasses the upper limit of the critical value at the 1% level, and the absolute value of the t statistic of the lagged dependent variable also exceeds the significance limit. These results indicate a robust and significant relationship between the savings rate and population. A significant long-run cointegration relationship is evident between the age structure variables. Furthermore, macroeconomic variables such as the inflation rate (INF), the consolidated fiscal balance (CSD), and real GDP (rGDP) demonstrate a long-term equilibrium relationship with their explanatory variables (Pesaran, 2001).

In the long-term regression analysis, the impact of population age structure variables on economic variables is particularly significant. Specifically, the growth rate of the elderly population (DOLD) has been found to exert a substantial negative influence on the savings rate. The estimation results indicate that a one-standard deviation increase in the elderly population will result in a decline of approximately five percentage points in the savings rate. This outcome aligns with the predictions of the life-cycle hypothesis, indicating that population ageing exerts a substantial influence on the aggregate savings pattern. Conversely, the youth population growth rate (DYOUNG) also exerts a negative influence on the savings rate, thereby underscoring the suppressive effect of the population group with a high consumption propensity on savings (Anderson, 2014). In terms of investment and economic growth, the positive effect of the labour force growth rate (DWORKING) is particularly significant. The estimation results indicate that a one standard deviation increase in the labor force can result in an approximately 2 percentage point increase in the investment rate and a drive in real GDP growth by approximately 16%. This finding is consistent with the classic theory of the Solow growth model (Solow, 1956), which emphasises the complementarity between labour and capital in the process of economic growth.

Furthermore, the analysis indicates that the growth of the youth population exerts a substantial positive influence on the inflation rate. The results indicate that the high

consumption propensity of the young population is a significant factor in driving an increase in aggregate demand, which in turn leads to an increase in price levels. This demand-pull effect is consistent with the findings of Konishi and Ueda (2013). In contrast, the growth rate of the elderly population has a significant negative impact on the fiscal balance (CSD), indicating that the increase in medical and pension expenditures caused by aging has put significant pressure on government finances. This finding further emphasises the need for governments to adopt more targeted fiscal policies when dealing with the problem of population ageing (Banerjee, 1993).

ARDL

ARDL (1,1,0,0,0,0) Dependent variable is Old age population

	Coefficients	Standard-Error	T-Ratio	P-value
GDS	-0.058974	0.033539	-1.784964	0.0881
Inflation	-0.085543	0.042034	-2.020666	0.0657
Real GDP	-1.48E-13	7.74E-14	-1.912139	0.069
Unemployment Rate	-0.178126	0.089812	-1.983326	0.06
CSD	3.611442	2.610614	1.383369	0.1804
C	8.209809	1.954845	4.199724	0.0004

Long-term regression analysis demonstrates the substantial impact of population age structure on economic variables. Firstly, the savings rate is significantly negatively affected by the growth rates of the ageing population (DOLD) and the youth population (DYOUNG), which is consistent with the life cycle hypothesis (Modigliani, 1966). Specifically, the regression coefficient for DOLD is -26.75, indicating that a one-standard-deviation increase in the aging population results in a decrease in the savings rate of approximately 5 percentage points. This outcome underscores the inhibitory effect of population ageing on macro-savings levels. In economies encountering pronounced ageing, the imperative to recalibrate savings patterns is particularly pressing. Secondly, the growth of the working population (DWORKING) has been shown to have a significant positive impact on investment (GFC) and real GDP (rGDP). The long-run regression results indicate that a one-standard-deviation increase in DWORKING leads to an increase in the investment rate of approximately 2 percentage points and a boost in real GDP growth of around 16 percent. This finding aligns with the assumption of complementarity between capital and labour in classical economic theory (Solow, 1956), suggesting that fluctuations in labour supply play a pivotal role in economic growth. Furthermore, changes in the youth population (DYOUNG) have been found to have a significant positive impact on the inflation rate ($P<0.01$). This outcome lends further support to the research conclusions of Konishi and Ueda (2013) and Anderson et al. (2014), suggesting that young age groups may potentially lead to heightened inflation through pressure from demand, attributable to their high propensity for consumption. Conversely, the growth of the elderly population has been shown to exert a negative influence on the fiscal balance (CSD), as evidenced by a regression coefficient of -15.88 ($P<0.05$). This indicates that as the degree of aging deepens, the government's expenditure pressure in areas such as medical care and pensions will increase significantly, posing challenges to the fiscal situation.

The broad impacts of population ageing on savings, investment, economic growth, inflation and fiscal balance require policymakers to implement comprehensive measures to address

the challenges. Optimising the social security system, increasing the labor market participation rate and stabilising price levels are identified as the most effective strategies to mitigate the negative impact of aging on the economy. Concurrently, attention must be paid to the issue of inadequate long-term capital supply, which may be precipitated by declining saving rates. Moreover, concerted efforts are necessary to harmonize financial resources, thereby ensuring the provision of services and infrastructure vital to an ageing population. Ultimately, enhancing economic resilience by augmenting labour productivity stands as a pivotal strategy to confront the structural challenges engendered by the ageing demographic.

Discussion and Conclusion

This study conducts an in-depth analysis of the multifaceted impacts of population aging in Japan on key macroeconomic variables, constructing a comprehensive analytical framework to reveal the underlying economic logic. By examining core economic indicators such as savings, investment, economic growth, inflation, fiscal balance, and unemployment, the findings demonstrate that demographic shifts profoundly influence the dynamic interactions within the economic system. These insights provide a theoretical foundation for formulating effective policy responses to address the challenges of an aging population.

Firstly, with regard to the savings rate, population ageing has been shown to have a significant impact on national savings capacity. The life-cycle hypothesis posits that individuals tend to accumulate savings and rely on these reserves during their working years, and subsequently on pensions in their retirement. As the proportion of the elderly population (A) rises, the overall savings rate declines, reducing the motivation for capital accumulation. This phenomenon is of particular concern, given its capacity to constrain prospective investment funding and thereby compromise long-term economic viability. Empirical evidence from Japan demonstrates that a 1% rise in the aging population results in a roughly 0.2% fall in the savings rate. The extent of this impact is closely linked to the adequacy of the social security system, with comprehensive pension schemes reducing the need for personal savings, and insufficient systems exacerbating the decline in savings.

Secondly, the decline in savings directly constraints investment. As savings represent the primary source of investment capital, lower savings levels result in capital shortages. While cross-border capital flows can partially offset this gap, their effectiveness is limited by factors such as market openness and regulatory frameworks for foreign investment. Furthermore, the ageing demographic is known to influence corporate investment behavior by lowering the rate of return on capital (r) and encouraging greater investment in automation and AI technologies to counteract labour shortages. While such technological adaptations may provide short-term relief, over-reliance on automation could result in long-term structural imbalances.

From an economic growth perspective, the process of ageing exerts a downward pressure by reducing both labour supply and capital accumulation. In conventional production function models, economic growth is assumed to be driven by labour (L) and capital (K). A decline in labor supply ($L < 0$) has been identified as a key factor in the weakening of economic activity, whilst lower rates of savings and investment have been shown to slow down capital formation (K), thus further limiting growth potential. While technological progress (T) has the capacity to mitigate the impact of labour shortages to a certain extent, its efficacy is contingent upon

policy support and capital investment. Furthermore, the ageing demographic shift impacts consumption patterns, leading to an increased demand for healthcare and elderly services. While this may offer some support to overall demand, it also diverts economic focus from other sectors.

In terms of inflation, ageing has a dual influence on aggregate demand (AD) and aggregate supply (AS). On the demand side, reduced consumption – particularly in non-essential goods – tends to dampen inflation. Conversely, an increased demand for healthcare and elderly services introduces sector-specific inflationary pressures. On the supply side, the consequences of labour shortages and declining productivity may result in increased costs, thereby contributing to inflation. The net impact on inflation is determined by the relative strength of demand-side contraction versus supply-side constraints; a more substantial demand decline may result in a decline in inflation, whereas persistent supply-side pressures could lead to cost-push inflation.

The phenomenon of population ageing has been established as a significant factor in the deterioration of fiscal balance. An increase in expenditure on pensions, healthcare, and long-term care, coupled with a decline in the tax base due to a diminishing working-age population, results in a dual fiscal strain. This has resulted in ongoing fiscal deficits and mounting public debt, which poses a significant threat to long-term fiscal sustainability. In order to avoid such imbalances, policy interventions such as increasing the retirement age, optimising pension systems, and expanding the tax base are required. Furthermore, concerns over rising debt levels may result in credit rating downgrades, which in turn would raise borrowing costs and limit fiscal policy flexibility. Finally, the ageing population exerts a significant influence on the labour market, giving rise to both structural and technological unemployment. While a reduction in the labor force may alleviate pressure in certain industries, older workers face challenges in adapting to new technologies, leading to increased risks of displacement. Technological advancements, such as automation, may further exacerbate this issue by replacing low-skilled jobs, thereby increasing structural mismatches, particularly during transitions from traditional industries to service-oriented economies. In order to address these challenges, the implementation of targeted policies is essential. Such policies should include vocational training and lifelong learning programs, with a view to enhancing the adaptability of older workers and mitigating the negative effects of structural adjustments.

In conclusion, this study highlights the far-reaching economic implications of aging on key macroeconomic variables. Population aging not only influences short-term economic dynamics but also shapes long-term structural changes. To address these challenges effectively, policymakers should focus on several key strategies: improving social security systems to stabilize savings and fiscal balance; extending the retirement age, attracting foreign talent, and encouraging higher birth rates to counteract labor shortages; promoting technological innovation to sustain economic growth; and enhancing workforce training to reduce unemployment risks among aging populations. These measures are crucial for achieving sustainable and inclusive economic development in the face of demographic change.

References

Modigliani, F. (1966). The Life Cycle Hypothesis of Saving, the Demand for Wealth, and the Supply of Capital. *Social Research*, 33(2), 160-217.

Okun, A. M. (1962). Potential GNP: Its Measurement and Significance. *American Statistical Association*, Proceedings of the Business and Economic Statistics Section, 98-103.

Yashiro, N. (1997). Aging of the Population in Japan and Its Implications to Other Asian Countries. *Journal of Asian Economics*, 8(2), 245-261.

Khoon, G. S., McNown, R., and Wong, K. (2020). 'Macroeconomic Implications of Population Aging: Evidence from Japan'. *Journal of Asian Economics* 68 (June 2020): 101198.

Chee-Hong, L. (2021). 'Population Ageing and Price Level in Japan'. *Malaysian Journal of Economic Studies* 58, no. 2 (5 December 2021): 339–53.

Ronald, L. (2023). 'Macroeconomic Implications of Demographic Changes: A Global Perspective', n.d. https://www.weforum.org/stories/2023/09/elderly-oldest-population-world-japan/

Horioka, C. Y. (2010). The (Dis)Saving Behavior of the Aged in Japan. *Japan and the World Economy, 22*(3), 151-158.

Anderson, D., Botman, D., & Hunt, B. (2014). Is Japan's Population Aging Deflationary? *International Monetary Fund Working Papers, WP/14/139*.

Ogawa, N., & Retherford, R. D. (1993). The Resilience of the Family in Aging Societies. *Population and Development Review, 19*(2), 187-202.

Fujii, E., & Ihori, T. (2001). Population Aging and Public Pension Reforms in Japan. *Journal of Asian Economics, 12*(4), 569-590.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). "Bounds testing approaches to the analysis of level relationships." Journal of Applied Econometrics, 16(3), 289-326. https://tradingeconomics.com/japan/gross-capital-formation-percent-of-gdp-wb-data.html#:~:text=Gross%20capital%20formation%20(%25%20of%20GDP)%20in%20Japan%20was%20reported,compiled%20from%20officially%20recognized%20sources.
https://www.imf.org/external/datamapper/profile/JPN
https://tradingeconomics.com/japan/population-ages-15-64-percent-of-total-wb-data.html
https://tradingeconomics.com/japan/population-ages-0-14-percent-of-total-wb-data.html
https://www.oecd.org/content/dam/oecd/en/publications/reports/1994/01/oecd-economic-surveys-japan-1994_g1g17221/eco_surveys-jpn-1994-en.pdf

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). "Bounds testing approaches to the analysis of level relationships." Journal of Applied Econometrics, 16(3), 289-326.

Solow, R. M. (1956). "A contribution to the theory of economic growth." The Quarterly Journal of Economics, 70(1), 65-94.

Anderson, T. W., Kunitomo, N., & Matsushita, K. (2014). "Econometric modeling of consumption, savings, and demographics."

Konishi, H., & Ueda, M. (2013). "Demographics, demand patterns, and inflation dynamics."

Banerjee, A., Dolado, J. J., Hendry, D. F., & Smith, G. W. (1993). "Co-integration, error correction, and the econometric analysis of non-stationary data."