Japan's Ageing Population and Economic Growth: A Crisis or an Opportunity?

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Abstract

Japan faces one of the most rapidly ageing populations in the world, raising pressing concerns about its long-term economic trajectory. This study will examine the impact of demographic ageing on Japan's economic status, with a specific focus on its effect on GDP growth. Using annual data from 1971 to 2022, a Vector Autoregression (VAR(1)) model is employed alongside Impulse Response Functions (IRFs) to capture the dynamic interdependencies between GDP growth and key macroeconomic variables, including labour force participation, inflation, consumption, and ageing indicators. The analysis reveals that ageing exerts a statistically significant and persistent negative effect on GDP growth, primarily through its influence on labour force participation and consumption demand. While the findings highlight the challenges posed by an ageing society, they also underscore the potential for policy adaptation. Structural reforms that enhance labour productivity, support active ageing, and reestablish macroeconomic policy towards demographic realities may help mitigate the adverse effects. Ultimately, whether ageing constitutes a crisis or an opportunity depends on the policy response.

AI Statement

I acknowledge the use of generative AI in drafting and code development in this study. However, the work reported remains entirely my own.

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1. Introduction

1.1 Background and Motivation

Japan is undergoing a profound demographic transformation, characterised by a rapidly ageing population and a decline in birth rates. Having the highest proportion of elderly citizens in the world, Japan serves as a compelling case study for the economic consequences of population ageing. As of 2022, the proportion of individuals aged 65 and over was almost 30% of Japan's total population, a share that continues to rise (World Bank, n.d.-a). The World Economic Forum (2016) has projected Japan's population to fall from 127 million to approximately 83 million by 2100. The article also mentions that "even if the birth rate rose from 1.4 per woman to 1.8 and accepted more immigrants, it would be difficult to prevent a fall below 100 million people. This further deepens the demographic challenge of Japan's ageing population.

To understand how Japan reached this stage, it is important to briefly consider its historical trajectory of economic growth. In the post-war period, particularly between 1958 and 1973, Japan experienced what came to be known as the 'economic miracle'. This miracle for Japan was a period of rapid industrialisation, export-led growth and rising living standards. During this time, the economy grew at an average of 10% annually in real terms (Johnson, 1982, p 274). However, this rapid development also contributed to significant demographic changes. The life expectancy increased, fertility rates started to decline, and an intensive work culture (Ono, 2018) laid the groundwork for the present ageing crisis. Ogawa and Retherford (1993) and many scholars argue that the long-term effect of World War II, coupled with intense economic development, accelerated these demographic shifts. Thus, this very 'miracle' that solidified Japan's status as a global economic powerhouse may have also been the cause of its current demographic challenge. The shift from the post-war economic boom to prolonged stagnation has led to structural challenges impacting labour supply, consumption, productivity and the public finance system. While population ageing is not unique to Japan, the intensity and pace of this transition make Japan an important model for understanding future developments in other advanced economies. Understanding how ageing affects macroeconomic outcomes, especially GDP, is critical for policymakers both in Japan and globally.

1.2 The Impact of Japan's Ageing on Economic Growth

This study seeks to explore how Japan's ageing population affects its economic growth, both directly and indirectly. It will examine key mechanisms such as shifts in labour force participation, changes in household consumption patterns and evolving inflation dynamics. To capture these interrelationships, a Vector Autoregression (VAR) model is employed, which allows for the dynamic analysis of multiple macroeconomic variables over time. The economic implications of ageing are extensive. A shrinking workforce poses significant challenges for productivity and potential output. In addition to this, increased demand for healthcare services and pension provision places a fiscal strain on government budgets. Moreover, changes in consumption patterns among the elderly population may alter the composition of domestic demand, influencing the effectiveness of monetary policy. Many researchers have explored how ageing influences household saving behaviour and consumption, with some scholars suggesting that the selfish life-cycle model can be particularly applicable in Japan (Horioka, 2021). By analysing these macroeconomic effects in the context of Japan, this study contributes empirical evidence to a growing body of demographic economic literature. It also provides insights that are increasingly relevant to other developed economies facing similar demographic transitions. Ultimately, researching a country experiencing the world's highest ageing trend allows an investigation into whether population ageing represents an unavoidable crisis or an opportunity to strategically manage and maintain economic stability and growth.

2. Literature Review

This review explores the academic foundations related to the impact of an ageing population on worldwide economic performance, with a specific focus on Japan. Although this study centres on Japan, the issue of population ageing is a global issue, affecting many developed countries. The review incorporates key empirical studies and theoretical contributions relevant to the relationship between demographic change and macroeconomic variables. Morita (2022) examined the relationship between Japan's ageing population and fiscal multipliers using theoretical and empirical methods. Morita mentions how, in recent years, this topic has caused researchers to actively study how the ageing structure affects the stimulus effect on fiscal policy shocks. Morita (2022, p. 4) employed a three-variable vector autoregression model (VAR), based on Blachard and Perotti (2002), which included government spending, tax revenue and output.

$$y_{it} = B_{i0} + B_{i1} y_{it-1} + \cdots + B_{ip} y_{it-p} + u_{it},$$

$$\text{where } y_{it} = [g_{it}, \tau_{it}, x_{it}]'$$

Morita's model also contains a hierarchical VAR panel model emphasised by Canova and Pappa (2007). He did this by sorting the groups into high-ageing and low-ageing prefectures of Japan using the top and bottom 12 ageing prefectures, respectively. The data in his paper spans a period of 25 years, covering the period from 1990 to 2014. Morita decided to investigate regional variation to see whether the demographic challenges were region-based. His results establish that low-ageing prefectures are in metropolitan areas like Tokyo and Osaka. Reasons could be that younger people will have more economic opportunities in urban areas, and they would migrate from rural areas, causing said rural areas to have a higher ageing population. Moreover, most urban areas will have higher birth rates, which leads to a balanced age population compared to rural areas. A notable strength of this paper is that it only focused on the state-dependency of the government spending multipliers and not tax revenue multipliers. Morita stated that there were data limitations as not all prefectural datasets had all the types of tax revenues. Furthermore, it was necessary to portray that the ageing rate in each prefecture was not related to economic conditions such as recessions and booms. Morita noticed a significant negative correlation between the ageing rate and unemployment in all prefectures, with Okinawa included, which would defeat the purpose of his testing. This is because Okinawa is an outlier, as they have extremely low ageing rates and elevated levels of unemployment, which would suggest that ageing rates are correlated with economic conditions. Therefore, they performed an additional estimate to check the robustness of the main results, excluding Okinawa from the dataset, which strengthened their findings. While Morita's focus was on fiscal policy, this study concentrates on the broader relationship between ageing and GDP growth. Another key difference is that this study will use a VAR model of a time series dataset with a wider period instead of panel data. This will lead to the dataset of this study having a better temporal coverage, which will accentuate the long-term effects on the ageing rate and the economic level more precisely. In addition, the problem with panel data is that they often have regional heterogeneity bias, in which the data assumes that the relationship between variables is homogeneous across the units and over time. Addressing heterogeneity through hierarchical models justifies the reason panel data has

complexity. Morita's paper provides a great insight into how Japan's ageing society affects the government through fiscal policy.

Yoshino and Miyamoto (2017) were among the researchers that Morita (2022) mentioned. They researched the relationship between fiscal and monetary policy with Japan's ageing population and why it is declining. They argued that ageing reduces the potency of policy interventions unless complemented by labour market reforms. Their results suggested that a suitable monetary policy to cope with the ageing population and the elderly citizens working. Yoshino and Miyamoto (2017, p. 32) recommended that policymakers should incentivise the elderly workforce by paying them wages at the level of marginal productivity of labour. The long-term effects of this policy would be that the level of labour increases, causing the level of output to increase as well. This will then lead to a higher consumption level for the elderly. Likewise, this will improve elderly independence and reduce heavily on social welfare, so the tax level and burden of tax for the younger generation will decrease. The younger generation will have a higher disposable income, and their consumption will rise. Therefore, the suggested monetary policy will help combat the issue of Japan's ageing population and improve economic growth. In line with this, they also examined the effect of an expansionary monetary policy shock on the economy by lowering the government bond rate of interest. This led to an increase in inflation, which decreased the real interest rate, causing a boost in consumption and investment. Researchers like Angrick and Nemoto (2017) talk about the negative interest rate policy (NIRP) that Japan and parts of Europe had implemented as an attempt to boost their economy. Honda and Inoue (2019) talk about NIPR being effective, whilst Palley (2016) researched the ineffectiveness and danger of NIPR. This indicates that the NIPR is still a debatable policy to improve an economy, especially an ageing one. In Yoshino and Miyamoto's (2017) paper, their results imply that the effects of monetary policy are weakened in an ageing society. They claim that the only impact ageing has on monetary policy is on consumption, as there are fewer workers in society. Additionally, the increase in consumption from a lower real interest rate will cause a high demand for output, which puts a lot of pressure on workers, resulting in longer working hours and higher wages. Some workers would see this as a benefit, but the overall labour market could see it differently, especially with the current working culture. Therefore, this proves Palley's (2016) research on how NIPR is ineffective for Japan's economy. Yoshino and Miyamoto's paper shows a crucial insight into why government policies are becoming more ineffective when combating the issue of Japan's ageing society.

Temsumrit (2023) analysed whether the ageing population affects economic growth through the channel of government spending on a worldwide scale. Her paper relates to this study significantly, as the models are very similar despite using different datasets. She states that an increase in the ageing population influences the slowdown in economic growth, as effective labour participation is shortened, leading to changes in the patterns of consumption and investment. Temsumrit mentions that an ageing population dramatically increase the pressure on public expenditures as the elderly will demand more programs and support for them. This led to the US healthcare spending to GDP increasing by 30% as their ageing population rises. This causes a long-term setback in economic growth as the government requires more income to meet the demand. She also agrees with Yoshino and Miyamoto's (2017) research, as fiscal policies are ineffective in an ageing society. Temsumrit used unbalanced panel data from 87 industrialised and developed countries from 1996 to 2017. The justification was to exclude countries that could bias her estimation, which would not demonstrate reliability in her findings. Temsumrit (2017, p. 4) has a table that illustrates the collected countries categorised by continents, as well as the model she used to test the relationship between government spending and age population. As shown in the table below, Jamaica is selected twice on two different continents, Africa and North America. This will cause the data to be inconsistent, which leads to a data bias and an unreliable model.

Table 1
Selected countries classified by continent.

Continent	Country
Asia	Afghanistan, Armenia, Azerbaijan, Bangladesh, Bhutan, China, India, Indonesia, Iran, Israel, Japan, Jordan, Kazakhstan, South Korea, Kuwait, Kyrgyz Republic, Macao, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Russian Federation, Singapore, Sri Lanka, Thailand, Turkey, Viet Nam
Africa	Algeria, Egypt, Ethiopia, Jamaica, Kenya, Liberia, Madagascar, Mauritius, Namibia, Nigeria, South Africa, Tunisia, Uganda
Europe	Albania, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom
North America	Costa Rica, Dominican Republic, El Salvador, Guatemala, Jamaica, Mexico, USA
Oceania	Australia, New Zealand
South America	Argentina, Bolivia, Chile, Colombia, Uruguay

Source: The author, data from and classified by the World Bank.

$$G_{i,m,t} = \alpha + \beta_1 G_{i,m,t-1} + \beta_2 \mathrm{Old}_{i,t} + \beta_3 Y_{i,t} + \beta_4 X'_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t}$$

Temsumrit's empirical strategy analyses the relationship between old-age dependency ratio ($Old_{i,t}$), government spending ($G_{i,m,t}$), and economic growth ($Y_{i,t}$). Her results indicate that a 1% increase in the old-age dependency ratio leads to a 0.06% increase in government spending at 95% and 99% confidence intervals. Therefore, it reveals the impact a slight increase in the ageing society has on government spending. The model that she uses will be remarkably comparable to the model that this study will use, but the difference in this study will be a VAR model with time series data. This signifies that the model of this paper will be perfect for analysing policy impacts and forecasting economic indicators. Similarly to Morita (2022), Temsumrit would have similar downsides to using panel data. A downside stated previously was data inconsistency, as she had duplicate data in two distinct groups. Her measurement of economic growth is GDP per capita. This study will instead use real annual GDP growth as it measurement of economic growth. Although per capita GDP is one of the best measurements showing the average income of an individual, it does not measure the inequality or the real wealth of every individual in the country. In Japan's example, citizens in metropolitan areas on average will have a higher income than those in rural areas. The data would be much simpler to use annual GDP growth of Japan, as it is much easier to explain.

Briefly mentioned in Chapter 1.2, the selfish life-cycle model assumes individuals primarily save for their retirement rather than for altruistic reasons, such as leaving bequests. Horioka (2021) finds that this model is more applicable in Japan than in any other country, using a comprehensive literature survey and empirical analysis for further support. He cites in his paper that there were lower bequest motives among households and stronger individual saving behaviour. The life-cycle model explains that individuals want to smooth their consumption over their lifetimes (Horioka, 2021, p. 174). These trends are linked to factors such as longer life expectancy, a rapid growth in the ageing population, and structural features of Japan's pension and social security systems. Cultural shifts away from intergenerational financial support may also reinforce the model's relevance. This implies that saving decisions are more likely to reflect self-interest and precaution than intergenerational altruism. Horioka's paper also supports Yoshino and Miyamoto's (2017) research. One of the reasons is that the elderly consume less and save more, especially with the lower bequest motives. Implying that as the population ages, there will be fewer demands for goods and services, lowering the gross domestic product of Japan. With the lower bequest motives, the younger generation will have less income, which also lowers their consumption and demand for goods. Another reason why Horioka's paper supports Yoshino and Miyamoto

(2017) is the long-run effects on labour participation, as the tax imposed on workers is what finances the pension benefits for retirees. Horioka's paper provides an insight into why consumption levels in the elderly, especially in Japan, are as low as they are.

The review highlights the complex relationship between population ageing and economic growth. Empirical findings consistently suggest that ageing societies face reduced labour force participation, increased fiscal burdens and weakened policy effectiveness. While existing studies, such as those in this review, provide valuable insights, most rely on panel data or focus on fiscal multipliers. This study, however, builds on these foundations by employing a time series VAR model to analyse Japan's macroeconomic dynamics over a longer period. In doing so, this study aims to contribute fresh empirical evidence to a growing body of research.

3. Data and Methodology

3.1 Data Collection

This part of the study outlines the strategies used to reveal and test the relationship between ageing and economic growth. The data used in this study were obtained from the World Bank database and cover the period from 1971 to 2022. These datasets are collected at the national level and provide an annual time series for a range of macroeconomic and demographic indicators relevant to Japan. All variables are expressed either as annual percentage changes or population ratios, depending on the nature of the indicator, and are seasonally unadjusted. The selection of this time frame was based on both the availability of historical data and the need to capture long-term structural changes in Japan's economy. As this study focuses on the long-run macroeconomic effects of population ageing, it is essential to stretch the analysis to include both periods of rapid economic growth, 'the miracle', and more recent decades of demographic transition and economic stagnation.

3.2 Variable Descriptions

This study incorporated five key macroeconomic and demographic variables. Each variable was selected for its theoretical relevance and empirical significance in understanding the relationship between ageing populations and economic performance, especially in the context of Japan. Gross Domestic Product (GDP) growth, measured as the annual percentage change

in GDP, is the primary dependent variable for this study. This variable is used to measure the annual rate of economic expansion or contraction. It helps to capture the overall health of Japan's economy over time. Final consumption expenditure growth captures changes in both private and public consumption, which are expected to differ in ageing societies due to shifting household preferences and increased demand for services such as healthcare.
The labour force participation rate, defined as the proportion of individuals aged 15 and above actively engaged in the labour market. This variable serves as a proxy for labour supply, which is useful for this study. Furthermore, the variable offers insights into the broader employment dynamics, potentially by age. Inflation, measured by the annual change in the consumer price index (CPI), is included to account for price-level movements. This may reflect the changes in demand patterns and cost structures associated with demographic shifts. Finally, the key demographic variable is the proportion of Japan's population aged 65 and above, expressed as a percentage of the total population. The variable serves as the primary indicator of population ageing and captures the long-term structural transition in Japan. All variables are collected annually from 1971 to 2022. Their inclusion in the empirical model is supported by theoretical frameworks and previous empirical research, examining the macroeconomic implications of ageing populations, as mentioned in Chapter 2.

In selecting variables for a VAR model, there is utmost importance in balancing theoretical insight with statistical feasibility. VAR models require the variables to be endogenous and preferably stationary, and the number of included variables must be limited to preserve the degrees of freedom, especially when the dataset has a fixed period. This explains why the VAR model in this study only consists of five variables and no more, as it will cause overfitting, which then reduces the model's reliability. Therefore, only variables with clear theoretical justification and consistently available historical data were considered for inclusion in the model. In summary, the five variables listed in this study are best fitted to use and demonstrate the impact ageing has on Japan's economy in a VAR(1) model.

3.3 Limitations of Data

While the dataset provides strong coverage over time, several limitations should be noted. Due to the unavailability of reliable elderly-specific labour force data across the full period, this study uses total labour force participation as a proxy. This may misrepresent trends specific to the elderly group. Additionally, including the elderly participation rates could

significantly reduce the sample size and weaken the ability to detect long-term relationships. This is because the data could only be available after the 2000s, which is very recent and not useful. Although appropriate for long-term trends, annual data may smooth over short-term fluctuations such as policy shocks or temporary economic events. Annual data also limits the number of observations being tested and constructed in a model. Most datasets, especially demographic data, are only collected annually and not at a quarterly frequency, which justifies the use of annual data in this study. In addition to this, the dataset ends in 2022, during a period still affected by the COVID-19 pandemic. This is important to note as the pandemic may have temporarily influenced the economic indicators this study is investigating. Important institutional and policy variables, such as pension system reforms, retirement age changes, were not included due to the absence of consistently reported and quantifiable data for Japan spanning the entire period. These variables, including the elderly participation rates, would be very insightful to investigate in future research. Moreover, it would either introduce large gaps or limit estimation to more recent decades. National-level data obscure regional disparities in ageing, such as rural versus urban demographic trends. Studies like Morita (2022) highlight how regional variation can be important. However, in some cases, regional data can be collected using different methods or definitions, making it difficult to compare regions more accurately. Similar to Temsumrit (2023), categorising the data incorrectly can cause misinterpretations. Variables such as healthcare expenditure are not used in this study due to data limitations, even though they may interact strongly with the variables being tested in this study. As mentioned in Chapter 3.2, a key limitation of this study is the restricted number of variables included in the model. Since the data has only 52 annual observations, the degrees of freedom are taken when multiple endogenous variables and lags are included in the model. This suggests that adding another variable to the dataset will heavily impact the estimation reliability of the model. Therefore, the data have variable inclusion restrictions for the model's validity. A way to combat this issue and examine the robustness of the model is to replace variables with other variables that fit within the fixed dataset and will demonstrate similar dynamic relationships compared to the original model. This could display that other variables, not included in the dataset, would have a similar significance to the model as the replaced variables.

3.4 Methodological Approach: VAR(1) Model

To investigate the dynamic relationship between Japan's ageing population and economic growth, this study employs a VAR model of order one. The order of one represents the number of lags added to the explanatory variables in this model. VAR models are particularly useful in macroeconomic analysis as they treat all variables as endogenous, allowing for the identification of feedback loops and interdependence amongst multiple periods. The structure of the VAR(1) model is given by the following system of equations:

$$GDP_t = \alpha_1 + \beta_1 GDP_{t-1} + \beta_2 AGE_{t-1} + \beta_3 CON_{t-1} + \beta_4 LFPR_{t-1} + \beta_5 INF_{t-1} + \varepsilon_{1t} \quad (1)$$

$$CON_t = \alpha_2 + \beta_6 GDP_{t-1} + \beta_7 AGE_{t-1} + \beta_8 CON_{t-1} + \beta_9 LFPR_{t-1} + \beta_{10} INF_{t-1} + \varepsilon_{2t} \quad (2)$$

$$LFPR_t = \alpha_3 + \beta_{11} GDP_{t-1} + \beta_{12} AGE_{t-1} + \beta_{13} CON_{t-1} + \beta_{14} LFPR_{t-1} + \beta_{15} INF_{t-1} + \varepsilon_{3t} \quad (3)$$

$$INF_t = \alpha_4 + \beta_{16} GDP_{t-1} + \beta_{17} AGE_{t-1} + \beta_{18} CON_{t-1} + \beta_{19} LFPR_{t-1} + \beta_{20} INF_{t-1} + \varepsilon_{4t} \quad (4)$$

$$AGE_t = \alpha_5 + \beta_{21} GDP_{t-1} + \beta_{22} AGE_{t-1} + \beta_{23} CON_{t-1} + \beta_{24} LFPR_{t-1} + \beta_{25} INF_{t-1} + \varepsilon_{5t} \quad (5)$$

Where:

α = constant term

ε= error term

GDP = GDP growth (annual%)

CON = final consumption expenditure growth (annual%)

LFPR = labour force participation rate

INF = inflation rate, consumer prices (%)

AGE = % of total population aged 65 and over

This study specifically uses VAR(1), which captures the relationship between each variable and its lagged values, while also modelling how past values of all variables jointly influence current values.

3.5 Justification for Model Selection

The VAR(1) model was chosen for many reasons. Dynamic interdependence is a key reason as ageing affects multiple macroeconomic variables simultaneously, such as consumption, labour force participation and inflation. Making a system-wide approach essential for this study, the framework of this model accommodates this complexity. Prior empirical research on ageing and fiscal or economic dynamics in Japan, including Morita (2022), has

successfully used VAR-based methods, demonstrating the models' relevance to the Japanese context. The VAR model is extremely useful for forecasting and policy analysis. The framework of the model allows for the construction of Impulse Response Functions (IRFs), which illustrate how shocks to the ageing population variable affect GDP growth and other variables over time. This provides practical insights for policymakers seeking to mitigate the demographic risks.

4. Empirical Results

4.1 Introduction

This section presents the empirical results from the VAR(1) analysis conducted to examine the impact of Japan's ageing population on key macroeconomic indicators. This chapter will include the summary statistics of the variables, the coefficient estimates of the VAR model and the dynamic response patterns obtained through impulse response functions (IRFs).

4.2 Descriptive Statistics

The summary statistics for the variables included in the VAR model are provided in Table 4.1. These offer insights into the long-term behaviour over the past five decades.

Table 4.1
Descriptive Statistics

Variables	Mean	Standard Deviation	Minimum	Maximum	Number of Observations
Real GDP Growth (% annual)	2.24	2.68	-5.69	8.41	52
Consumption Growth (% annual)	2.35	2.23	-2.62	8.17	52
Labour Force Participation Rate (%)	62.21	1.65	59.01	65	52
Inflation Rate, Consumer Prices (% annual)	2.4	4.26	-1.35	23.22	52
Population Aged 65+ (% of population)	17.03	7.43	7.32	29.92	52

As expected, the average share of the elderly population has steadily increased over time, from around 7% to close to 30% in the space of five decades. As mentioned earlier in chapter 1.1, Japan's rapid economic growth, especially during the 'miracle' era, and the life expectancy rising from 73 to 84 from 1971 to 2022 (World Bank, n.d.-b) could be the

potential reason for the population to age. Meanwhile, GDP growth has shown signs of decline in the most recent decades. Japan's GDP growth has reached its lowest, within this dataset, in 2009 (World Bank, n.d.-c). However, the growth rate starts to grow, but not as close to the maximum value achieved. The labour force participation rate has been the most consistent variable in this dataset, with the smallest range. However, due to the current trends of Japan's ageing, the labour force participation rate could potentially experience a massive drop in the distant future, particularly if the population declines to less than 100 million (World Economic Forum, 2016). Inflation has remained relatively low, with a few periods of deflation and a period of high rates. Consumption has fluctuated in response to broader economic cycles, but the overall trend is that the rate of consumption is slowly declining throughout the decades.

4.3 VAR(1) Estimation Results

The results of the VAR(1) estimation are presented in Table 4.2 below. Each column corresponds to an equation in the system, as shown in Chapter 3.4, where the listed variable is the dependent variable.

Table 4.2

Estimated VAR(1) Coefficients for Japan, 1971–2022

	Real GDP Growth (%)	Population Aged 65+ (%)	Labour Force Participation Rate (%)	Final Consumption Expenditure Growth (%)	Inflation, Consumer Prices (annual,%)
Real GDP Growth(%)$_{t-1}$	-0.118	-0.007	0.080*	-0.072	-0.024
	(0.233)	(0.0158)	(0.0376)	(0.1731)	(0.1980)
Population Aged 65+ (%)$_{t-1}$	-0.239*	0.990***	0.032*	-0.194**	0.317***
	(0.093)	(0.0063)	(0.0150)	(0.0691)	(0.0790)
Labour Force Participation Rate (%)$_{t-1}$	-0.368	-0.075***	1.011***	-0.077	0.332
	(0.308)	(0.0209)	(0.0498)	(0.2292)	(0.2622)
Final Consumption Expenditure Growth (%)$_{t-1}$	0.405	-0.013	-0.019	0.178	1.347***
	(0.330)	(0.0224)	(0.0533)	(0.2452)	(0.2805)
Inflation, Consumer Prices (annual,%)$_{t-1}$	-0.055	-0.016*	0.002	0.027	0.793***
	(0.089)	(0.0060)	(0.0143)	(0.0660)	(0.0755)
Constant	28.523	5.369***	-1.427	9.974	-28.671'
	(20.201)	(1.3709)	(3.2603)	(15.0123)	(17.1696)
Observations,n	51	51	51	51	51
R^2	0.4083	0.9996	0.9574	0.5096	0.8305
F-statistic	6.21	24980	202.3	9.353	44.11

Notes: Each column corresponds to a separate equation in the VAR(1) model, where the variable listed in the column header is the dependent variable. Model estimated for Japan using annual data from 1971 to 2022 (n = 51). All variables are treated as endogenous. Standard errors are shown in parentheses. *** significant at the 0.1% level, ** at the 1% level , * at the 5% level , and ' at the 10% level respectively. All variables are expressed in growth rates or percentages.

4.3.1 Real GDP growth

The main finding in this study is that the proportion of the population aged 65 and above has a statistically significant negative effect on GDP growth. From Table 4.2, it indicates that a one percentage point increase in the elderly population reduces real GDP growth by approximately 0.239%. This result is consistent with the economic theory that ageing lowers aggregate output by shrinking the labour force and reducing overall productivity. Although Table 4.2 shows that ageing has weak significance (at 90% confidence) to GDP growth, Table 4.3 shows how significant ageing is on GDP growth.

Table 4.3

Estimated VAR(1) Coefficients (GDP and AGE) for Japan, 1971 to 2022

	Real GDP Growth (%)	Population Aged 65+ (%)
Real GDP Growth(%)$_{t-1}$	0.134	-0.007
	(0.144)	(0.011)
Population Aged 65+ (%)$_{t-1}$	-0.189***	1.012***
	(0.054)	(0.004)
Constant	5.055***	0.260**
	(1.168)	(0.092)
Observations, n	51	51
R^2	0.3653	0.9995
F-statistic	13.81	4.58E+04

Notes: This table shows only the relationship between the real GDP growth and proportion of the ageing population. Standard errors are shown in parentheses. *** significant at the 0.1% level and ** at the 1% level respectively. All variables are expressed in growth rates or percentages.

Table 4.3 shows that the coefficient is significant at the 0.1% level. This implies that at a 99% confidence level, the proportion of the population over 65 has a strong negative statistical effect on GDP growth. Therefore, suggesting that a one percentage point increase in the ageing population leads to the GDP growth declining by 0.189%. Interestingly, none of the other lagged variables shown in Table 4.2 is statistically significant in the GDP growth equation. This proposes the idea that the ageing demographic is the dominant driver in this context. The multiple R^2 is 0.408, signifying that approximately 41% of the variation in GDP growth is explained by the lagged variables, which is reasonable for time series data.

4.3.2 Population Aged 65 and Above

As expected, the ageing population variable is highly autoregressive, with the coefficient of 0.990 (at a 0.1% significance), which suggests near-complete persistent growth year to year. This result is intuitive as demographic changes occur gradually over decades and not suddenly. The equation shows that the ageing population has a significant negative effect on labour force participation, supporting the view that a rising elderly population reduces the share of individuals in the labour market. Although the negative coefficient (-0.075) is relatively small, the coefficient is significant at a 0.1% level. Meaning that the impact that ageing will have on labour force participation could be more detrimental in the future, if the population continues to age, and no policies are made to improve the labour market with the demographic shift. The proportion of the ageing population is slightly significant (at the 5% level) to inflation. This could suggest that ageing can reduce inflation rates for many reasons. Older individuals save more and consume less, which can cause deflationary pressure on prices. Moreover, there are inflationary pressures, such as high demand for healthcare services, which could minimise the negative coefficient. However, there is no significant feedback from GDP growth and consumption, implying that ageing is exogenous in the model. This means that ageing shapes macroeconomic outcomes but is not easily influenced by them in the short run.

4.3.3 Labour Force Participation Rate

The labour force participation equation shows a strongly positive autoregressive behaviour. The strong significance of the coefficient 1.011 (at a 0.1% significance) reflects the structural stability of labour market engagement. However, the equation displays several important interactions. The equation shows that the labour force is also significantly affected by the lagged ageing demographic. With the coefficient of 0.032 at a 5% significance level, this indicates a mild positive relationship between the two variables, possibly reflecting delayed retirement or an increase in elderly employment. This result supports Yoshino and Miyamoto's (2017) recommended policy of incentivising the elderly into the workforce. As expected, the equations show that the lagged GDP growth has a positive impact on labour force participation. Although the impact is slightly positive on GDP growth, this suggests that stronger economic conditions may encourage greater participation. This portrays that the older individuals are perhaps being drawn back into work or delaying their retirement. Together, these results highlight the key channel through which ageing affects the economy, stating that reducing the effective labour supply constrains Japan’s productive potential.

4.3.4 Final Consumption Expenditure Growth

The consumption equation reveals a statistically significant negative effect of ageing, specifying that an increase in the elderly population leads to a decline in final consumption growth by 0.194%. This result is consistent with the life-cycle consumption theory, in which older individuals save more and consume less, particularly on durable goods (Horioka, 2021). Other variables, including GDP growth, labour force participation and inflation, do not have statistically significant effects on consumption. However, the ageing variable alone provides strong explanatory power, and the R^2 is 0.51, establishing that more than half of the variation in consumption growth is explained by the model. This result reinforces the view that population ageing alters the structure of aggregate demand, potentially leading to slower economic growth unless offset by strategic policies or productivity improvements.

4.3.5 Inflation (Consumer Prices)

The results show that inflation has a strong autoregressive behaviour, meaning that the current values of inflation are often determined by its previous values. The coefficient being 0.793 at 0.1% significance points out that there is strong inflation persistence, which is typical of consumer price behaviour in macroeconomic models. The ageing demographic has a positive and strongly significant effect on inflation, implying that ageing may contribute to price pressures in the economy. The possible price pressures caused by ageing could be healthcare, long-term care services or sectoral demand shifts. Ma (2024) explains that ageing causes a strain on healthcare systems, potentially causing an inflationary pressure in the sector. Final consumption also has a strong positive effect on inflation, implying that an increase in consumption leads to a 1.347% increase in inflation. This makes sense as when consumer demand for goods rises significantly, the excess demand puts upward pressure on prices as the economy is unable to supply them, leading to demand-pull inflation. Notably, GDP growth and labour force participation do not appear to significantly affect inflation in this model, implying that inflationary pressures may be driven more by factors such as consumption dynamics or external supply shocks rather than domestic economic activity or the conditions of the labour market. The R^2 for the inflation equation is 0.8305, suggesting a very good fit and supporting the notion that inflation in Japan is tightly linked to both demographic factors and past inflationary trends.

4.4 Impulse Response Function Analysis

Impulse Response Functions (IRFs) are used to examine how a time shock to a given variable affects the dynamic behaviours of the system over time. In this context, IRFs help assess how a shock to the share of Japan's elderly population influences real GDP growth and other macroeconomic outcomes across a 10-year horizon. Using the VAR(1) model in Chapter 4.3, the IRFs were generated using orthogonalised shocks with a 95% confidence interval based on 100 bootstrap replications. The bootstrapping methods are used to assess the statistical reliability of the impulse function. This approach generates the confidence intervals by repeatedly resampling the data, allowing for inference without relying on strong parametric assumptions.

4.4.1 Response of Real GDP Growth to a Shock in Ageing

The impulse response of real GDP growth to a one standard deviation positive shock in the proportion of the population aged 65 and above is shown in Figure 4.1.

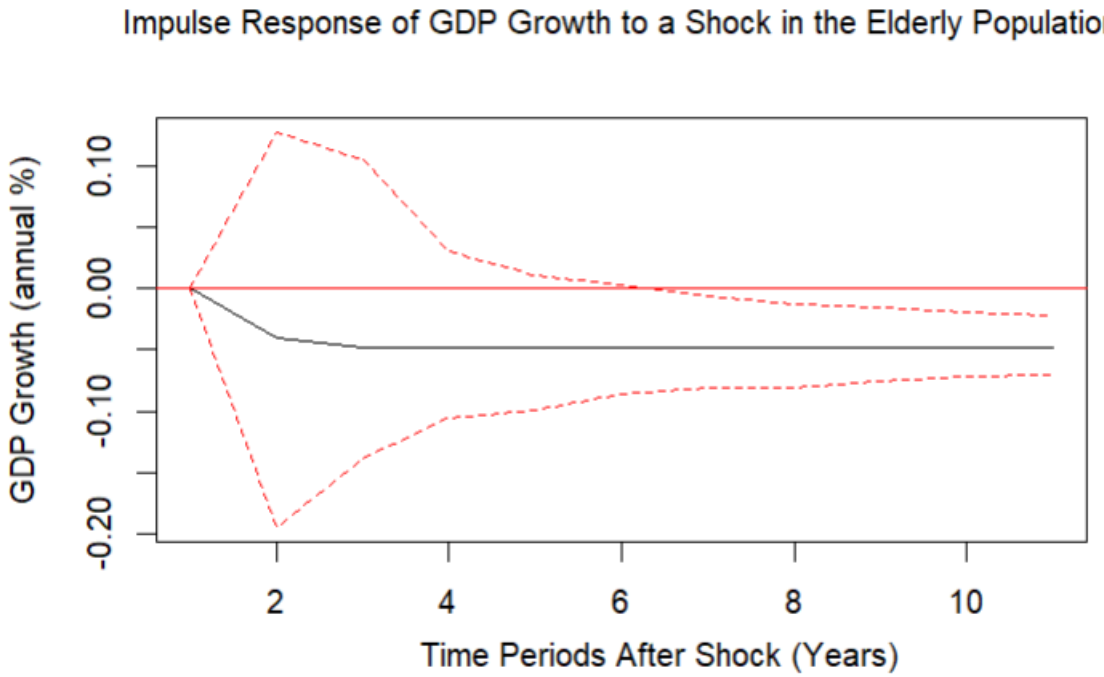

Figure 4.1: IRF of GDP growth to a shock in the Elderly Population Proportion

Figure 4.1 shows that the impact of an ageing shock on real GDP growth is negative and persistent. The black line represents the response of GDP growth to the ageing shock, while the red dashed lines represent the 95% confidence interval. Following the shock, GDP growth immediately declines and reaches its lowest point in the second year. The magnitude of the

drop is approximately -0.05 percentage points, and then the response of GDP growth flattens from year 3 onwards. The response remaining negative throughout the entire ten-year period indicates that the economic consequences of demographic ageing are not merely short-term disruptions but represent a long-lasting structural drag on GDP growth. The confidence intervals originally widen at the start of the response, but after 5 years, they fall and remain under zero, confirming the significance of the result. Appendix A1 and A2 show the same IRF for GDP growth and ageing shock but with different time horizons, 5 and 15 years, respectively. Appendix A1 illustrates the same results shown in Figure 4.1, as the response declines in the same way, and its confidence intervals follow the same pattern. An IRF with a shorter time period indicates that the VAR models are usually more accurate in the near term, which is effective for studying the initial impact and short-term transmission of shock. However, a shorter time period would mean that an IRF may miss out on long-term effects or persistent shocks. Also, it may not capture the delayed responses of certain variables. Appendix A2 shows the IRF of Figure 4.1, but with five more years added to it. The overall response of GDP to a shock in age is similar to the original graph, portraying that ageing stunts economic growth. The advantages of a longer time horizon are that it helps to identify long-run equilibrium or persistent impacts, and it is useful when exploring structural relationships that slowly unfold. However, the downside of the longer time period is that the IRF might be dominated by noise or model assumptions in the long term. Also, the forecasting power becomes a lot weaker over time, which means that the uncertainty of results in the far future rises. Therefore, using an IRF that has a time horizon of 10 years, in this study, works best. Overall, the IRF shown in Figure 4.1 shows that a shock to ageing lowers GDP growth in the short term and then stunts the growth in the long term.

4.4.2 Impulse Response Function Analysis on Levelled GDP

To visualise the relationship between ageing and the levels of GDP using the explanations in Chapter 4.4.1 and Figure 4.1, another VAR(1) model was created using the Local Currency Unit (LCU) of Japanese Yen (JPY) of GDP and final consumption expenditure. To justify why consumption needs to be levelled, as well as GDP, is to ensure that the VAR model is consistent and valid with its results. This also assesses the robustness of the impulse response function using an alternative specification to explain the relationship. Figure 4.2 illustrates the IRF of GDP levels to a positive shock to the ageing population.

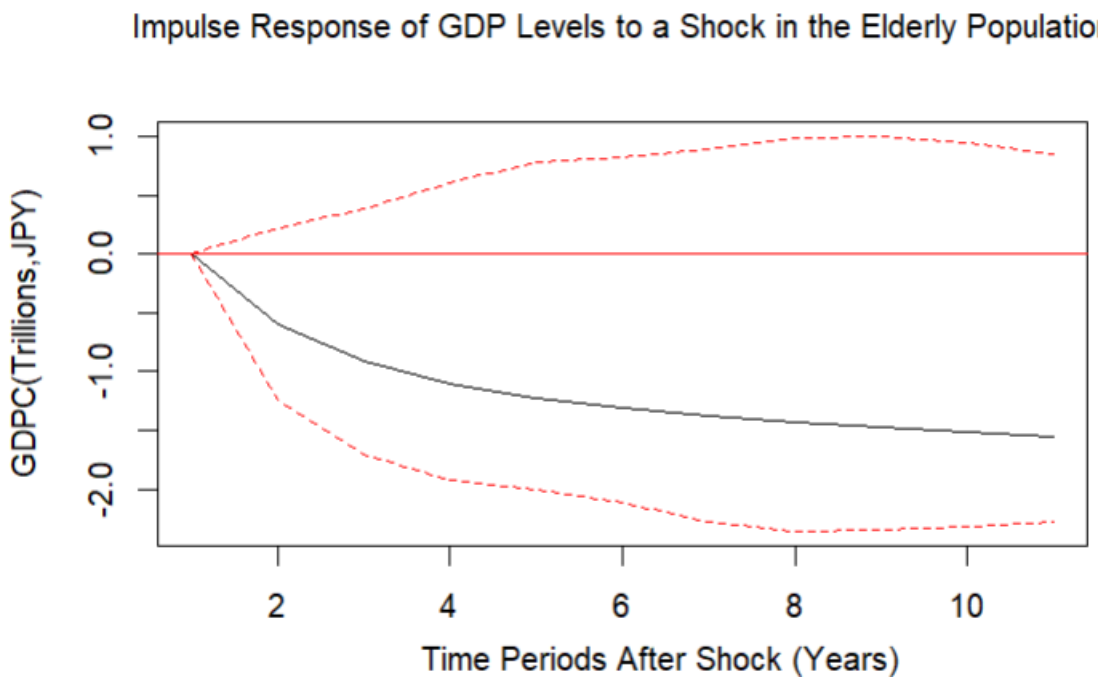

Figure 4.2: IRF of GDP (LCU) to a shock to the Elderly Proportion

Following the shock in Figure 4.2, there is a sharp and significant negative impact on GDP levels, which continues to deepen over time. This indicates that the increase in the elderly population exerts a persistent contractionary effect on GDP. While the impulse response function indicates a persistent and negative impact of an ageing population on GDP levels, the relatively wide confidence bands suggest some uncertainty in the magnitude of this effect. The fact that the upper bound of the confidence interval remains above and close to zero implies that the long-run impact of ageing on GDP may be less severe than expected. Therefore, while demographic ageing appears to exert downward pressure on economic output statistically, the effect may not be as strong or as certain as initially assured. This explains the finding in Figure 4.1, as although GDP growth is shown to decline due to ageing, the value of the decline may be too low to impact the GDP levels. These findings underscore the central argument of this study. Japan's ageing population persistently constrains economic growth, one that cannot be mitigated without policies such as structural reforms in labour markets, pensions and productivity-enhancing investment.

4.5 Robustness Checks

To ensure the reliability of the baseline VAR(1) model results, this section presents a series of robustness checks. These include the use of alternative demographic indicators, substitution

of key macroeconomic variables and changes to the variable transformations. Each modification tests the sensitivity of the core result, that Japan's ageing population has a negative and persistent impact on the country's economy.

4.5.1 Using the Old-Age Dependency Ratio

As an alternative to the proportion of the population aged 65 and above, the old-age dependency ratio (OADR) was used. The OADR is a measurement used to indicate the ratio of older dependents (normally aged 65 and over) to the working-age population (typically aged 15-64). The measure reflects the economic pressure on the working population to support retirees. The percentage of the population aged 65 and over was selected as the primary measure of ageing in this study for its clarity and wide use in macroeconomic literature. The OADR assumes that people aged 65 and over are completely dependent on the working-age population. Many people over 65 remain active in the labour market, and not all aged between 15 to 64 are employed. The OADR is more often used to focus on the economic burden on the workforce and is used for dependency cost analysis.

The VAR(1) model was re-estimated with OADR replacing the ageing variable (Appendix B). The results remained broadly consistent. The old-age dependency ratio displayed a negative and statistically significant effect on GDP growth, reinforcing the conclusion that a growing elderly population constrains economic performance through increased fiscal pressure and reduced labour supply. The impulse response analysis also showed a negative response of GDP growth following a demographic shock under this specification, as shown in Figure 4.3.

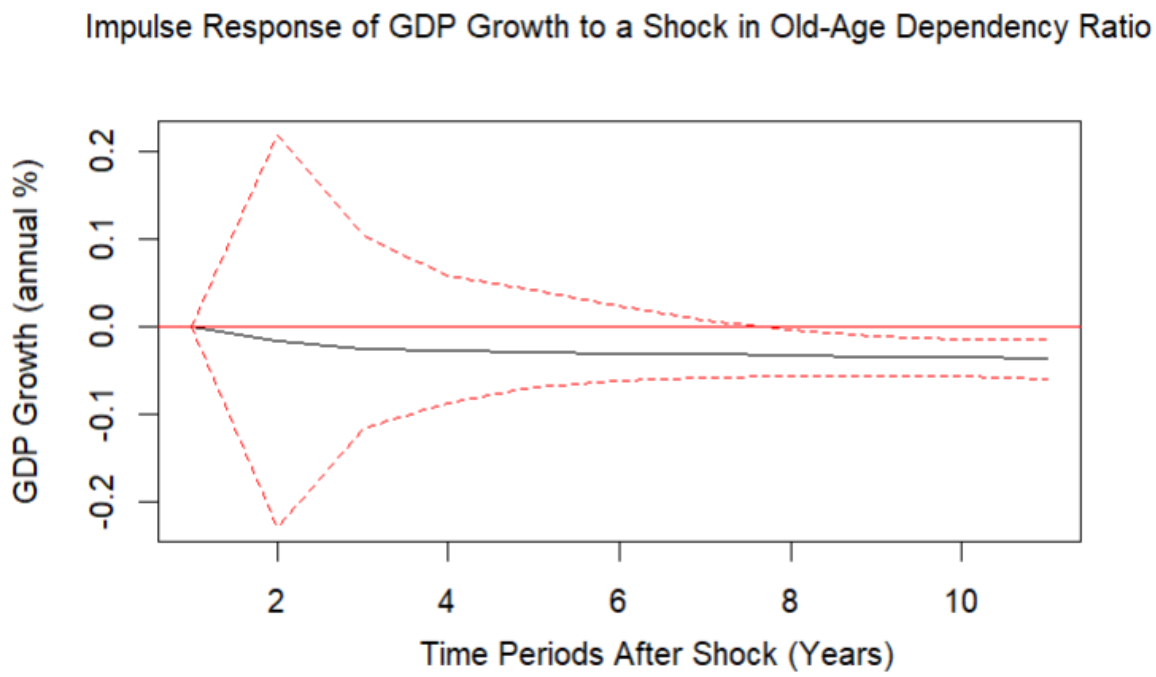

Figure 4.3: IRF of GDP growth to a shock in Old-Age Dependency Ratio

Figure 4.3 shows an IRF graph that is similar to Figure 4.1. The graphs, seeming identical, indicate that the old-age dependency ratio has almost the same impact on Japan's economy as does the percentage of the elderly population. Therefore, replacing the demographic variable with another ageing variable ensures the reliability of the baseline VAR(1) model.

4.5.2 Substituting Inflation with Fertility Rate

As mentioned in Chapter 3.3, to examine whether the macroeconomic effects of ageing are robust to different modelling assumptions, the inflation variable was replaced with the fertility rate (births per woman). Fertility is a long-run demographic indicator that affects the future ageing dynamics and economic sustainability. Fertility rates are an important measure for the economy, as it is often used to forecast the population in the future, as aforementioned by The World Economic Forum (2016). When included in the model, the fertility rate was positively associated with GDP growth and negatively correlated with the ageing variable, which was expected. The impulse response analysis under this specification had also shown a similar response of GDP growth to a shock in the ageing variable, shown in Figure 4.4.

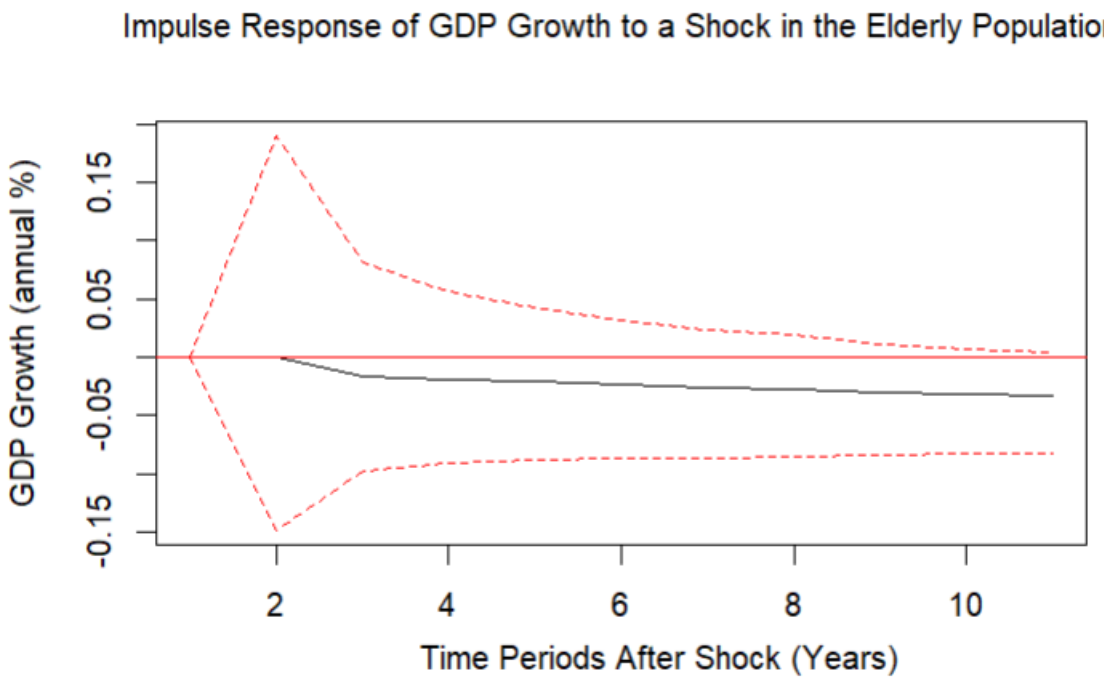

Figure 4.4: IRF of GDP growth to a shock in the Elderly Proportion (excluding inflation, including fertility rates)

Figure 4.4 shows that GDP growth declines as there is a positive shock to ageing. The response in this IRF, however, establishes that the decline continues throughout the years, as the black line has a steeper slope in contrast to the black line in Figure 4.1. Furthermore, the upper band remains positive and narrows down to zero in the later periods, suggesting that there might be a limit to the statistical significance of GDP growth. Despite the absence of full statistical significance, the negative and persistent trend closely mirrors that of Figure 4.1. This consistency supports the robustness of the relationship between population ageing and GDP growth. The inclusion of fertility did not essentially alter the effect of ageing on GDP. This suggests that the original results were not dependent on the presence of the inflation variable. This specification also supports the broader demographic view that population renewal is essential to long-term economic stability.

4.5.3 Using GDP and Consumption in Levels

To explore the impact that ageing has on GDP in absolute terms, as mentioned in Chapter 4.4.2 and Figure 4.2, the model was re-estimated using real GDP and finance consumption expenditure in levels. These two variables were expressed in trillions of JPY instead of growth rates in the baseline VAR model. This change allows for a more policy-relevant interpretation, for example, how much GDP in yen terms declines after a demographic shock.

The impulse responses from this specification (Figure 4.2) showed a similar pattern to the baseline model, with GDP levels falling following an ageing shock. However, the response was slightly more gradual, reflecting the smoother path of level variables over time. The persistence and direction of the results confirm that the negative economic effect of ageing is not an artefact of data scaling. Therefore, it explains the robustness of the baseline model.

4.5.4 Model Diagnostics

Ensuring that the estimated VAR(1) model is valid and robust, a set of standard diagnostic tests was conducted. These tests assess whether the model satisfies the key assumptions required for reliable inference. These include heteroskedasticity, normality, absence of autocorrelation and dynamic stability. The results are summarised below.

ARCH-LM Test: Heteroskedasticity

The ARCH-LM (Autoregressive Conditional Heteroskedasticity- Lagrange Multiplier) test examines whether the variance of the residuals (the observed estimate of the error term) remains constant over time. If heteroskedasticity is present in the model, it shows that the variance of the residuals is not constant throughout the model. This can distort the standard error estimates, making them unreliable.

Null Hypothesis (H_0): Residuals exhibit homoskedasticity (p-value > 0.05)

The test was applied to each equation in the VAR model, and the p-values were above the 5% significance level. This indicates the failure to reject the null hypothesis, and there is no evidence of heteroskedasticity in the residuals. This then supports the reliability of the model's standard error estimates.

Jarque-Bera Test: Normality

The Jarque-Bera (JB) test assesses whether the distribution of the residuals deviates from the normal distribution, based on skewness and kurtosis. Normality is important as it ensures that the confidence intervals are valid.

Null Hypothesis: Residuals are normally distributed (p-value> 0.05)

The value of the p-value of the JB test is 0.043, leading to a rejection of the null hypothesis at a 5% significance level. This suggests that there is some evidence of non-normality in the residuals. However, this is not uncommon in macroeconomic time series data. The use of bootstrapped confidence intervals for IRFs addresses the normality issue and ensures robustness of the model. Since the p-value is close to the threshold, this could also suggest that there is weak evidence in rejecting the null hypothesis.

Portmanteau Test**:** Serial Correlation

The Portmanteau test assesses whether residuals are serially correlated, which means that the errors from the regression are not independent over time. This means that the value of one residual is correlated with the value of the previous residual. In time series models, this normally indicates that the model is missing important dynamics, such as lagged effects, leading to biased standard errors. This would make the VAR model unreliable and misleading.

Null Hypothesis: There is no autocorrelation in the residuals (p-value> 0.05)

The results show that the p-value of this test was 0.9039, meaning that we fail to reject the null hypothesis. This expresses that there is no evidence of serial correlation, which suggests that the VAR model appropriately captures the underly time dynamics of the data. Signifying that the relationship being ageing and GDP growth is dynamic.

Eigenvalue Roots: Stability

The purpose of this test is to check whether all characteristic roots (eigenvalues) of the companion matrix lie inside the unit circle. This is a requirement for dynamic stability in VAR models because it ensures that the model's behaviour does not lead to unrealistic forecasts. It also means that the system will return to equilibrium after a shock and not diverge over time.

Null Hypothesis: The VAR system is stable (all eigenvalues <1 in modulus)

The eigenvalues are 0.986, 0.986, 0.854, 0.138 and 0.138, meaning that all roots were found within the unit circle. This indicates the failure to reject the null hypothesis, which suggests that the VAR(1) model is dynamically stable. Although three eigenvalues are close to one, which could suggest some persistence in the system. This means that the model does not exhibit drastic behaviour and remains valid for impulse response analysis. The eigenvalues explain why the figures in this study behave as they do.

Each diagnostic test supports the statistical validity of the VAR(1) model in this study. The model passes the checks for homoskedasticity, lack of autocorrelation and dynamic stability. Although the residuals show mild deviation from normality, this is accounted for using bootstrapped impulse response functions. The diagnostics confirm that the VAR model satisfies its key assumptions, providing a robust foundation for the results and interpretation presented in this study.

4.5.5 Summary of Robustness Findings

The robustness of the baseline VAR(1) model has been tested using multiple alternative specifications and diagnostic checks. Across all exercises, the core finding of the negative relationship between ageing and GDP growth remains consistent and stable. Substituting the percentage of the population over 65 with the old-age dependency ratio yields similar results, confirming that the negative macroeconomic effect is not specific to the original demographic measure used. This means that either measurement can be used to explain the relationship being ageing and Japan's economy. Likewise, replacing inflation with the fertility rate produced comparable estimates and supported the broader theoretical link between demographic structure and economic performance. Transforming GDP and final consumption expenditure from growth rates into levels (in trillions of yen) produced impulse response patterns in line with the baseline model. This suggests that the model's conclusions are not sensitive to the form of data transformation and remain interpretable in both relative and absolute economic terms.

The model also passed a series of standard diagnostic checks. Tests for heteroskedasticity (ARCH-LM), serial correlation (Portmanteau) and stability (eigenvalue modulus) all confirm that the model satisfies key statistical assumptions. Although the Jarque-Bera test indicated

that the model has mild deviation from normality, the use of bootstrapped confidence intervals (via IRFs) ensures that the reasoning of the model remains robust. Overall, the robustness checks reinforce the credibility of the empirical findings. The consistency of results across all exercises confirms that the negative relationship being population ageing and GDP growth is both structurally persistent and statistically sound.

5. Discussion

This section will discuss the empirical results presented in Chapter 4 and evaluate them concerning the wider economic literature on demographic change and economic growth. It will explore the main transmission channels through which Japan's ageing population affects macroeconomic outcomes and reflect on the theoretical and policy implications of the findings.

5.1 Interpreting the Main Results

Results from the VAR(1) model provide robust evidence that Japan's ageing population has a statistically significant negative impact on its GDP growth. This then causes the GDP in absolute terms to slow down in its growth, showing few signs that the economy is improving. This relationship remained consistent across multiple model specifications and robustness checks, including alternative demographic indicators and variable transformations. The impulse response analysis adds further confirmation that the effect of a demographic shock is persistent over time. Following an increase in the proportion of the elderly, there has been a decline in Japan's economic growth. From Table 4.2, the decline in GDP growth is predominantly explained by two key channels: a reduction in labour force participation and weaker consumption dynamics. The estimated coefficient linking population ageing to labour force participation (-0.075) was significantly negative, showing that fewer people participate in the workforce as the population ages. This is consistent with expectations from life-cycle labour models and supports the findings of Yoshino and Miyamoto (2017), who highlighted the decline in labour input as a primary driver of Japan's growth slowdown. Similarly, the negative correlation between ageing and final consumption growth reflects the changing household consumption patterns. Older individuals tend to consume less overall and are more likely to shift spending towards services such as healthcare, rather than spending on

investment goods or durable consumption. This aligns with Temsumrit (2023), in which they noted that an ageing population places long-term pressure on public expenditure and private demand.

5.2 Inflation and Ageing: A Mixed Relationship

An interesting result from the model is that the ageing population is positively correlated with inflation. This finding contrasts with the traditional expectations that ageing leads to deflation through weaker aggregate demand, which is heavily explained by the consumption patterns of the elderly. In Japan's context, however, this may reflect sector-specific inflationary pressures, especially in healthcare, caregiving and housing services, where demand increases as the population ages. It is also possible that ageing may reduce supply-side capacity, such as labour shortages, leading to an upward pressure on wages and prices in certain industries. The impulse response function (Appendix C) for inflation reveals a two-phase dynamic response to a positive shock in the share of the elderly population. In the short term (within the first four years), the response of inflation is slightly negative, suggesting a modest deflationary effect. This likely reflects declining aggregate demand as the older populations tend to reduce their consumption. However, beginning around year 6, the response crosses above zero and becomes mildly inflationary. This upward movement could be due to supply-side constraints such as labour shortages and rising healthcare costs, or an increased fiscal spending in support of the elderly (Yoshino and Miyamoto, 2017). These will lead to an upward pressure on wages and prices in certain industries. Nevertheless, the IRF for inflation showed only a moderate and short-lived response, suggesting that the link between ageing and inflation is likely to be context-dependent and may also vary by sector and over time. These findings echo the mixed evidence in the literature. Liu and Westelius (2017) are an example of a paper that debates whether ageing has deflationary or inflationary effects on the economy. At the end of their paper, they believe that ageing has deflationary effects.

5.3 Endogeneity and Demographic Exogeneity

The results also indicate that ageing behaves as an exogenous process within the VAR system. The ageing dependent variable was highly autoregressive and showed little to no response to changes in GDP growth, inflation or labour force participation (even though the coefficient for labour force participation was strongly significant). This confirms the widely held assumption in demographic economics that population ageing is driven by long-term structural factors, such as an increase in life expectancy and fertility rate, and not short-term

economic fluctuations. As Morita (2022) and Lindh and Malmberg (1999) argue, this exogeneity strengthens the case for treating demographics as a critical constraint on macroeconomic policy planning.

5.4 Implications for Fiscal and Labour Market Policy

The persistence and magnitude of the impact of ageing on GDP growth have important implications for fiscal and labour market policies in Japan. If the shrinking workforce continues to lessen the economic output, efforts to maintain growth must focus on raising the labour force participation, especially among older workers. At the same time, the government must address rising public expenditure on pensions and healthcare without excessively burdening younger generations. A potential approach is to promote intergenerational equity in tax and transfer systems. This way, the fiscal pressure on the working-age population will reduce, meaning that they can consume and save more income, which will benefit the economy as a whole in the future.

5.5 Theoretical Contributions and Relevance to Other Economies

This analysis forms part of a broader academic effort to examine the macroeconomic effects of population ageing, especially on GDP. While much of the existing work has used cross-country panel data or structural models, this study applies a time series VAR approach to a single-country case, capturing the unique dynamics of Japan's demographic challenges and economic transition. The findings are also relevant for other ageing societies, particularly in Europe and East Asia, where similar demographic trends are expected to intensify in the future. The Japanese case highlights the importance of forward-looking policy design in managing demographic pressures on growth, productivity and public finance.

6. Conclusion

6.1 Overview

This study set out to explore how Japan's ageing population is a problem for its economic growth. Using a time series VAR(1) model with annual data from 1971 to 2022, the analysis examined the relationship between GDP growth, labour force participation, consumption, inflation and ageing demographics altogether. The findings offer empirical support for the

idea that ageing is not just a social but also a macroeconomic one, as it is gradually reshaping the structure and progression of Japan's economy.

6.2 Key Insights and Implications

The important conclusion is that population ageing in Japan exerts a persistent negative effect on economic growth, which is especially shown through channels of a declining labour force participation and consumption. These channels reflect long-term behavioural and structural shifts rather than short-run volatility. While the link between ageing and inflation was less definitive, the results show a transition from mild deflationary pressures to potential cost-push inflation in the longer term. Notably, the use of impulse response functions revealed that demographic shocks do not dissolve quickly. The economy adjusts slowly, which confirms that ageing is a structural challenge rather than a transitory disruption.

The findings strengthen the urgency of labour market reform, particularly measures that extend working life and support broader participation. Structural policies aimed at boosting productivity, such as investment in automation, workforce skills and health-related support, are likely to be more effective in addressing the growth slowdown than fiscal policies. Ageing complicates the use of both monetary and fiscal policy. The diminished inflation response suggests that traditional policy tools become less effective in an ageing economy. To maintain stability, policymakers must adapt their strategies to reflect the shifts in demographic realities.

6.3 Limitations and Directions for Future Research

While the findings of this study were robust across many specifications, some limitations must be acknowledged. Due to data constraints, this study used total labour force participation as a proxy for elderly workforce engagement. While the data was informative, this variable may understate the unique impact of ageing on workforce dynamics. Having access to age-disaggregated labour participation would allow more precise modelling of this relationship.

The analysis focusing purely on national-level trends will likely obscure important regional variation. Urban areas like Tokyo may respond differently to demographic change than rural areas, which are more likely to have a higher elderly population and where public resources are limited. A panel VAR approach using prefectural data could help unpack this

heterogeneity. Additionally, cross-country analysis will provide a better insight into which parts of the world would be affected by ageing.

While population ageing is often associated with slower growth due to many factors listed in this model, certain variables could capture ageing as a support to the economy. Future research could explore variables that capture the potential benefits of an ageing society. The model did not account for policy shifts such as changes in pension, retirement age and healthcare spending due to limitations in time-consistent data. The future research for these limitations could be to integrate structural policy variables or explore the use of Structural VAR (SVAR) frameworks to capture long-run relationships and policy feedback effects. The model also does not account for technological variables, such as technological adoption and how they interact with ageing. Future research could be to check whether ageing societies have become more technology-dependent.

Furthermore, while the variables selected in this study were based on economic theory and empirical modelling, future research could employ more regulated methods for variable selection (using Chapters 3.2 and 4.5 as examples). A method best for this model is the Bayesian Averaging of Classical Estimates (BACE) framework (Sala-I-Martin, Doppelhofer, & Miller, 2004). This framework systemically accounts for uncertainty in the model by averaging across many possible model specifications to identify robust predictors of economic growth. This will help and explain where "significant variables become weak" and when "insignificant variables become significant" using several model specifications as seen in Sala-I-Martin, Doppelhofer, & Miller's (2004, p. 831) paper. Techniques like the BACE framework could enhance model robustness and offer more comprehensive insights into the long-term macroeconomic consequences of demographic change.

6.4 Final Thoughts

Japan's demographic transition represents an extreme and ongoing economic challenge, but also an opportunity for policy innovation and long-term strategic planning. As the world's most rapidly ageing society, Japan offers a preview of demographic futures many advanced economies may face. This study has shown that ageing has a measurably negative impact on GDP growth, especially through its impact on labour force participation and consumption. However, these effects are not irreversible. This situation could be a crisis or an opportunity, depending on Japan's policy response. If structural issues such as labour shortages, fiscal

pressure and stagnant productivity are left unaddressed, then the demographic trend may lead to prolonged economic stagnation. In this case, the ageing population is a crisis, but not because of the ageing itself. It will be because of the lack of preparation to change and combat the issue. On the other hand, the demographic shift also creates a unique opportunity to improve its economy by embracing automation, investing in elderly care technologies, and reforming tax and pension systems to ensure intergenerational fairness. If approached strategically, Japan has the potential to transform what appears to be a demographic burden into sustainable economic growth that is inclusive of all people. To conclude, the purpose of this study was to suggest that population ageing is not inherently a crisis; it is a crucial and structural turning point. This is also insightful for ageing societies that could follow in Japan's proverbial footsteps. The management of this turning point will determine whether it leads to a long-term decline or a way to adapt economically.

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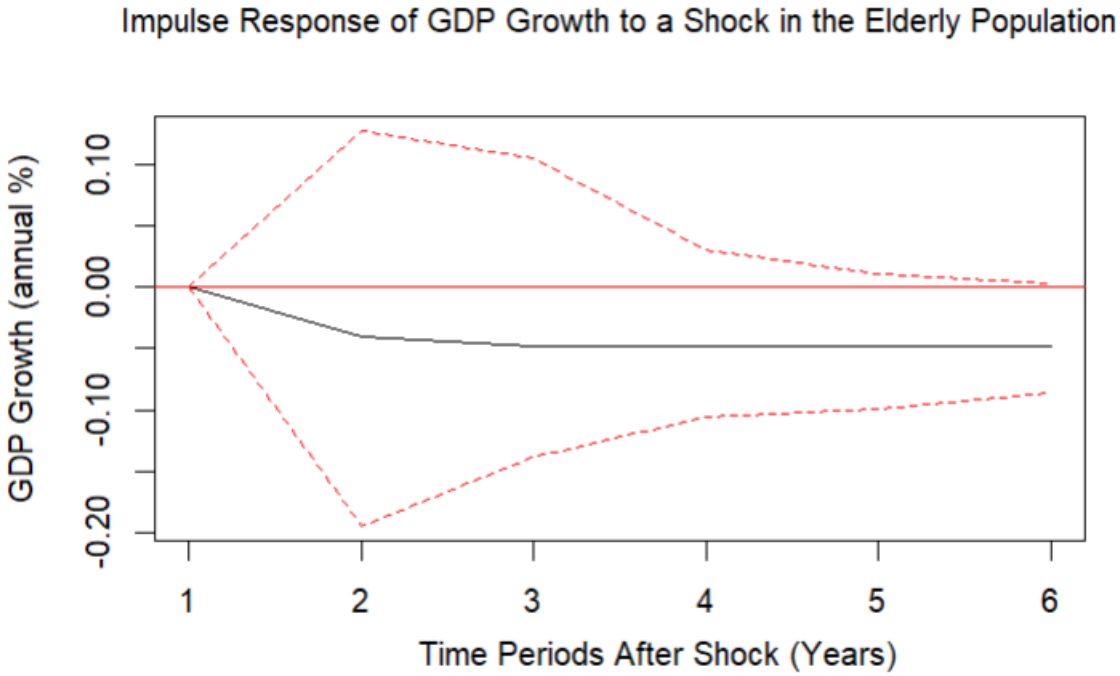
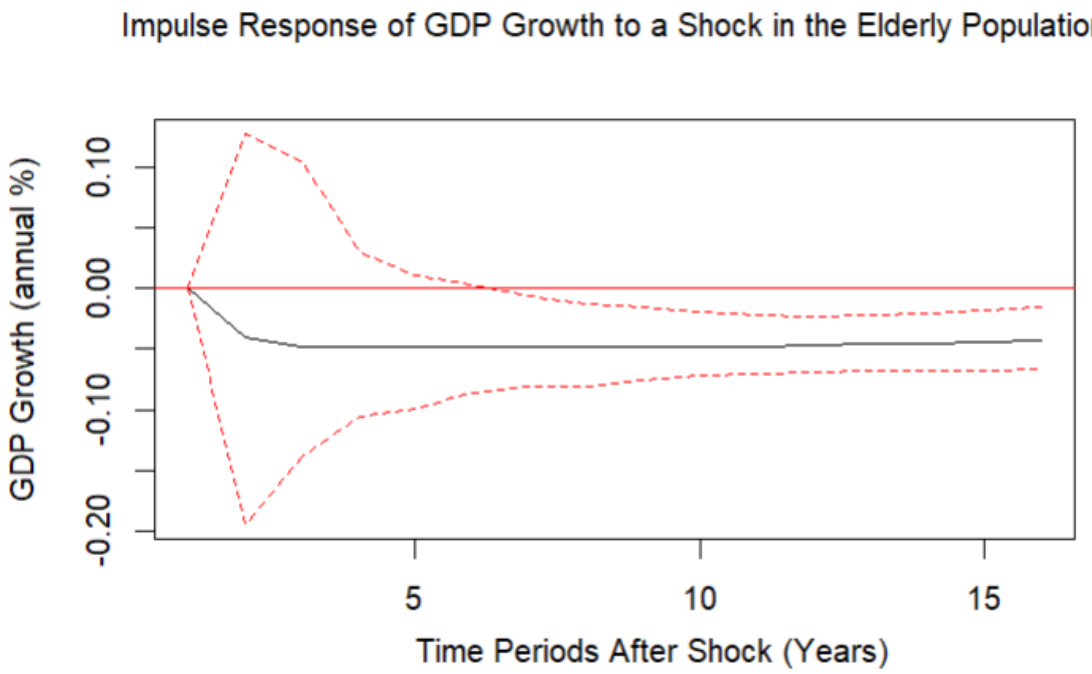
Appendices

Appendix A1*:* IRF graph of GDP to Ageing Proportion Shock (n.ahead = 5)



Appendix A2: IRF graph of GDP to Ageing Proportion Shock (n.ahead = 15)



Appendix B: VAR(1) Model- Replacing Age over 65+ with Old-Age Dependency Ratio

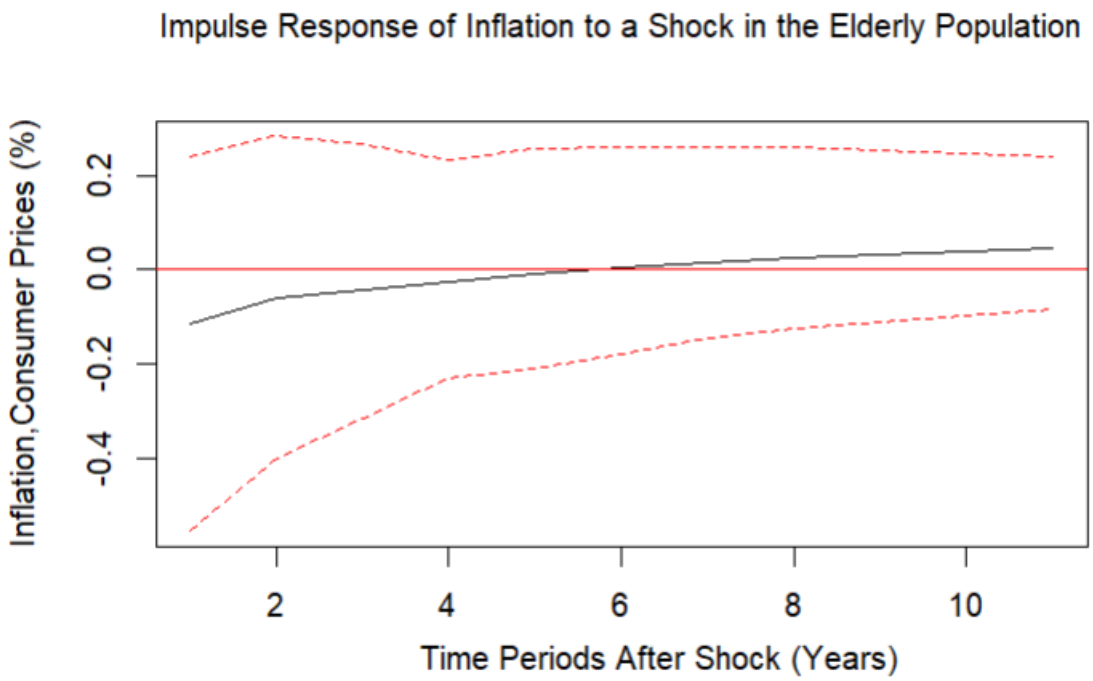
Table

VAR(1) Model - Old Age Dependency Ratio

	Real GDP Growth (%)	Old-Age Dependency Ratio (%)	Labour Force Participation Rate (%)	Final Consumption Expenditure Growth (%)	Inflation, Consumer Prices (annual,%)
Real GDP Growth(%)$_{t-1}$	-0.105	0.003	0.078*	-0.062	-0.043
	(0.2384)	(0.0293)	(0.0369)	(0.1769)	(0.2013)
Old-Age Dependency Ratio (%)$_{t-1}$	-0.103*	0.992***	0.020*	-0.088*	0.158***
	(0.0498)	(0.0061)	(0.0077)	(0.037)	(0.042)
Labour Force Participation Rate (%)$_{t-1}$	-0.261	-0.209***	1.018***	-0.005	0.268
	(0.3093)	(0.0381)	(0.0479)	(0.2295)	(0.2611)
Final Consumption Expenditure Growth (%)$_{t-1}$	0.482	-0.031	-0.017	0.23	1.293***
	(0.334)	(0.0411)	(0.0517)	(0.2478)	(0.2819)
Inflation, Consumer Prices (annual,%)$_{t-1}$	-0.017	-0.019.	-0.0004	0.055	0.754***
	(0.0871)	(0.0107)	(0.0135)	(0.0646)	(0.0736)
Constant	20.187	14.081***	-1.781	4.306	-23.127
	(19.9813)	(2.458)	(3.0935)	(14.8257)	(16.8672)
Observations	51	51	51	51	51
R^2	0.3802	0.9996	0.9589	0.488	0.8249
F-statistic	5.522	22000	210.2	8.579	42.41

Note: This table presents the VAR(1) model results using the old-age dependency ratio as the demographic variable in place of the percentage of the population aged 65 and over. Standard errors and p-values are reported.*** significant at the 0.1% level, ** at the 1% level , * at the 5% level , and ' at the 10% level respectively.

Appendix C: IRF graph of Inflation to the Elderly Population


Impulse Response of Inflation to a Shock in the Elderly Population
Inflation, Consumer Prices (%)
0.2
0.0
-0.2
-0.4
2
4
6
8
10
Time Periods After Shock (Years)