KARYA ILHAM PUBLISHING
CONNECTING MINDS, BRIDGING IDEAS, INSPIRING READERS

Journal of Advanced Research in Social and Behavioural Sciences

Journal homepage:
https://karyailham.com.my/index.php/jarsbs/index
ISSN: 2462-1951

Time Series Analysis of Population Aging in Malaysia: The Roles of Economic and Social Determinants

Nurhatiah Ahmad Chukari[1,*], Nur Dini Sharum[2], Ali Albada[3], Asmah Mohd Jaapar[1], Siti Masitah Elias[1]

[1] Risk & Analytics Research Group, Faculty of Science and Technology, Universiti Sains Islam Malaysia. 71800 Nilai, Malaysia
[2] Faculty of Science and Technology, Universiti Sains Islam Malaysia. 71800 Nilai, Malaysia
[3] Faculty of Business, Sohar University, Sohar, Sultanate of Oman

ARTICLE INFO

Article history:
Received 24 April 2026
Received in revised form 26 May 2026
Accepted 2 June 2026
Available online 22 June 2026

Keywords:

Population aging; ARDL bound test; female labor participation; life expectancy; migration

ABSTRACT

Malaysia has been experiencing a gradual increase in the proportion of its elderly population over the years, posing a crucial demographic transition with significant social and economic implications that could be detrimental to its economic growth. This research examines the factors influencing this phenomenon by applying the Autoregressive Distributed Lag (ARDL) model to analyse annual data from 1991 to 2020. The short- and long-run effects of key factors are analysed, including fertility rates, life expectancy, GDP per capita, healthcare quality, migration, and female labour force participation. The findings reveal that fertility rates and GDP per capita have negative, long-run relationships with population aging, while life expectancy and female labour participation are positively associated. Migration has a dual impact: reducing population aging in the long run but temporarily exacerbating it in the short run. The quality of healthcare, however, shows an insignificant relationship with population aging. Addressing these factors will be critical for managing the consequences of population aging. The findings of this study offer valuable insights into the impact of various factors driving population aging, highlighting the need for targeted policy interventions to foster sustainable development in Malaysia.

1. Introduction

The aging of the population is a global demographic phenomenon with profound social, economic, and healthcare implications. The United Nations [1] defined population aging as the population of people aged 60 or 65 years and above. Based on the UN report on "World Population Aging: 1950-2050", the general definition of population aging is the process by which older individuals become a proportionally larger share of the total population [2]. The demographic shift

* *Corresponding author.*
E-mail address: nurhatiah@usim.edu.my

https://doi.org/10.37934/arsbs.43.1.349364

toward an increase in the aging population is mainly caused by the declining fertility rates and increased life expectancy.

Malaysia, like many other developing countries, is experiencing a rapid demographic shift towards an aging population. According to the population projection 2010 - 2040 by the Department of Statistics Malaysia (DOSM) [3] the percentage of old age 65 years and above increases significantly. Based on the recent statistics shown in figure 1, those ages 65 years and above stood at 5.11% in 2010 and continue to increase to 7.5% in 2022 [4] while those ages 14 and below keep on decreasing. Additionally, DOSM projects that Malaysia might nearly have an equal share of young population and older population by 2040 with 18.6% of the young population and 14.5% of the older population making up the total population. On top of that, almost three-fold increase of old age dependency ratio is predicted, i.e. from 7.4 in 2010 to 21.7 in 2040.

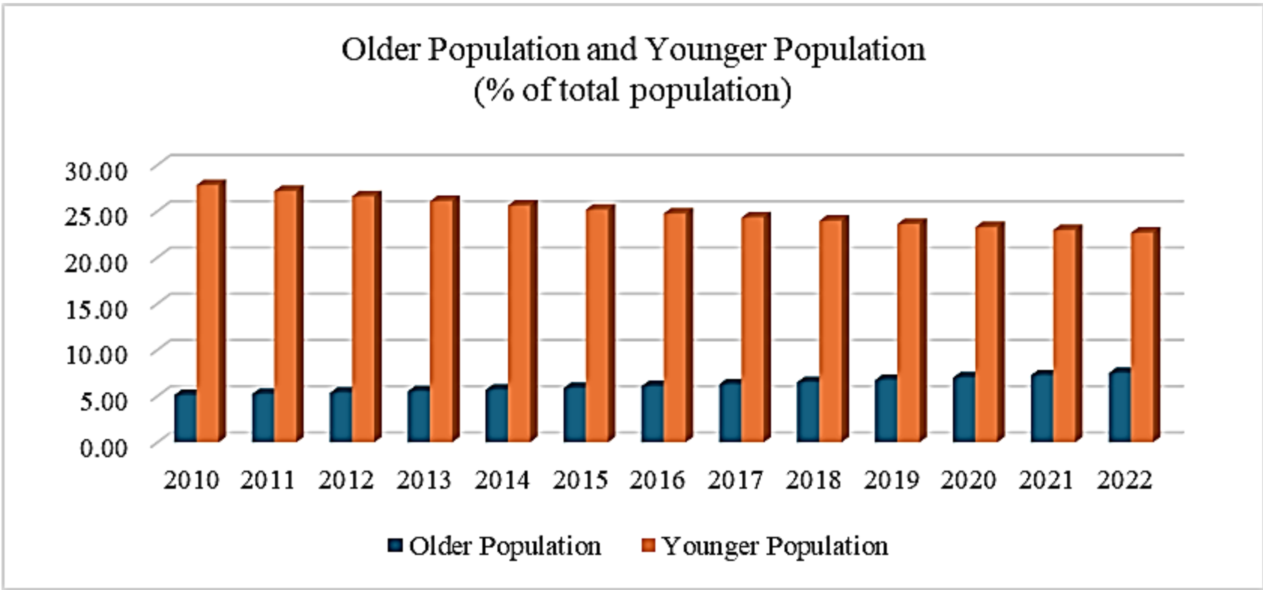


Fig. 1. Percentage of older and younger population
Source: World Bank (2022)

Population aging also impacts both developing and developed countries. Japan has the highest percentage of elderly citizens in the world as of 2020 because their proportion of people aged 65 and above has reached 28.6% [5]. According to Edmond and North [6] Japan consistently continues to have the oldest population in the world and as of 2021, the percentage of people aged 65 and above keep on increasing until 29.8%. In China, the aging population is rapidly expanding where it is expected that over 28% of its population will be aged 60 and above by 2040, up from 18.7% in 2020 [7]. As a result of aging society, Japan and China are facing challenges on their economy such as budget crisis where healthcare expenditure and public spending on pensions are increasing, and reduced in level of education, in Japan, schools started to close while funds for education investment are decreasing because of increases in health spending [8,9]. These statistics emphasize a critical global trend where population aging pose social, economic, and healthcare challenges. Thus, Malaysia needs to be prepared as Malaysia is approaching towards ageing society in the coming decade and this research will provide better foresight for a sustainable development and the well-being of the citizens by examining the significant factors affecting population aging.

Recent studies show that population aging has substantial economic [10-12]. These studies highlighted that increasing life expectancy directly correlates with a higher population aging, thereby straining pension systems and healthcare. This is due to the increasing expenditure and decreasing national productivity from age-related disease and disability. Besides, declining fertility rates exacerbate aging problems by shrinking the workforce and raising dependency ratios [10,13]. Apart from that, higher GDP per capita is linked with more pronounced population aging, as observed in these studies from China and Romania [12,14]. The reason is probably because GDP improves the quality of people's life and medical conditions which expands their life expectancy. Other than that, Kim *et al.*, [10] and Lewandowska-Gwarda and Antczak [15] found that enhanced quality of healthcare extends lifespans along with the elderly population. Migration also affects population aging because younger individuals tend to migrate to cities, leaving rural areas with older population [12,14]. The younger population often migrates for the purpose of education and job opportunities. Furthermore, female employment rate is said to have a negative association with population aging by Jemna and David [14] but Kim *et al.*, [10] result shows a positive association between them because working women probably have fewer children to maintain work-life balance, hence increasing the aged population proportion.

The rapid aging of the population could impose several challenges on the well-being of social, healthcare and economy in Malaysia. Mohd *et al.*, [16] reveals a negative effect of population aging on Malaysia's economic growth. This indicates that Malaysia's economy will suffer as its population ages. Economic growth will slow down due to the decreases in productivity caused by the reduced in labor force participation [17]. Additionally, public expenditure will also increase because the current pension scheme might not be sustainable and therefore the government's fiscal position will face a larger financial burden. On the other hand, aging population can also lead to higher economic growth that emphasizes technological advancement and human capital investment, focusing on quality over quantity of workers whereby investing in both the young and older workers might produce more quality workers [18]. Hence, these contradictions serve as a purpose to extend the study on population aging.

The demographic shift toward an aging population is a critical global issue with the significant challenges discussed above for achieving sustainable development. This aligns closely with the Sustainable Development Goals (SDGs), particularly SDG 3 that focused on ensuring good health and well-being for all. This emphasizes the need to improve healthcare systems and enhances access to long-term care in response to the growth of older populations. Additionally, SDG 1 of no poverty is also relevant in this issue since older individuals face reduced income after retirement and inadequate pension coverage [1]. As a result, older individuals face a higher risk of falling into poverty. Apart from that, SDG 8 aims to sustain economic growth also affected by population aging as it will decrease the number of working population and cause a reduction in the labor force [19]. Thus, this research contributes toward achieving these goals by examining the factors influencing population aging.

As population aging continues to intensify, it is crucial to understand its underlying factors and effects. Hence, this research aims to examine the key factors of population aging, analyze its impacts and the magnitude of the significant factors. Specifically, this study examines the impact of fertility rates, life expectancy, GDP, quality of healthcare, migration, and female labor participation on Malaysia's population aging in response to the limited research on the factors driving this issue in Malaysia. Furthermore, the Autoregressive Distributive Lag (ARDL) approach is performed to examine the factors by utilizing data spanning 30 years, from 1991 to 2020. By employing the ARDL method, it evaluates the magnitude and significance of these factors on population aging in Malaysia. The findings provide valuable insights for policymakers and contribute to efforts in addressing the consequences posed by the aging population in Malaysia.

2. Literature Review

2.1 Population Aging

Based on previous research, two indicators widely used by most of the research as a measure of population aging are the old-age dependency ratio and percentage of the population aged 65 and above of the total population. Abdul Rashid *et al*., [20], Jemna and David [14] and Nik Norliati and Suriati [21] indicate old age dependency ratio as population aging while Kim *et al*., [10] Yang *et al*., [11] Xu *et al*., [12] and many other studies indicate the latter as population aging. Population aging is a long-run phenomenon as proven by Maity *et al*., [19] using Granger Causality/Block Exogeneity Wald test. The test concludes that economic growth measured by GDP and population aging has no causal relationship between them in the short run.

Increase in population aging will drive several undesirable economic concerns. Bloom *et al*., [22] highlighted five main economic concerns cause by population aging which firstly reduced output in the economy. Secondly, lower saving rates because older adults consume a higher proportion of their income, and this will lead to a scarcity of investment capital. Thirdly, increase in pension demand which will challenge the fiscal integrity of public and private pension systems. Fourthly, loss of national production is caused by the increasing cost of health and disability of aging population. Lastly, the financial burden of health and long-term care expenditures. These economic concerns are also consistent with the conceptual framework highlighted by Maity *et al*., [19] whereas population aging affects economic growth through three mechanisms which are consumption and saving patterns, public social expenditure and human capital. The aging population shifts demand towards health services and away from luxury goods, along with rising government spending on healthcare and pensions, and shrinking labor force, all contribute to slower economic growth.

Kim *et al*., [10] classifies the factors that contribute to an increase in the population aging into three groups which are health and demographic-related factors, female-related factors and GDP per capita since richer countries tend to be older compared to poorer countries. They concluded that countries with more effective healthcare systems and higher female education levels have longer life expectancies, resulting in a larger population aging. Higher female labor force participation and lower fertility rates also contribute to population aging by lowering birth rates that results in fewer children. Furthermore, migration outflow is also one of the strong factors that lead to increase population aging by reducing the number of younger individuals in a region [11]. The research also concluded that population aging process can be hindered by lowering illiteracy rates that improve social provision while improving health conditions. Moreover, net migration also certainly influences population aging whereby negative net migration indicates that emigration of working-age individuals reduces the workforce, necessitating a longer retirement age [23]. Besides, the issues of population aging also can be solved by sustaining economic growth indicated by GDP per capita because it may provide the financial provision to implement any aging policies [24].

2.2 Fertility Rates

The reduced in fertility together with rising life expectancy of Malaysian population lead to a substantial shift in the age structure that resulted to the aging population [20]. The changes in fertility could turn the growth of the population from rapid growth to slow growth. Nik and Suriati [21] specifically emphasized that Malaysia is experiencing an increase in elderly population caused by the lower fertility rates. Many population aging issues would arise due to the declining fertility rate. This includes the issues on housing, healthcare, lack of income, general care, relationship, and family support to take care of the elderly’s life. Lee *et al*., [25] highlighted the importance of fertility as a determinant of age structure whereas very low fertility would result in a lower living standard. Lower fertility causes a decrease in consumption due to lesser elderly consumption. Recent study figured out a negative relationship between fertility rate and elderly population share [10]. This indicates that the elderly population share will increases if woman have fewer children because the number of children proportional to the population will decrease. Also, there will be fewer workers to support the growing number of elderly dependents due to the decrement in fertility [13].

2.3 Life Expectancy

Kim *et al*., [10] also examines the effect of life expectancy on the elderly share of the population and showed a positive correlation between them whereas a longer life expectancy will increase the elderly share of the population. Abdul Rashid *et al*., [20] analyzed the aging trend in Malaysia and illustrated that the older age group had gradually increased along with the increment of life expectancy of Malaysian population. This is also consistent with the study on a more developed country such as Lithuania. Garlauskaitė and Zabarauskaitė [23] reveal that the rise in life expectancy also increases the proportion of older people compared to younger people. An increase in life expectancy together with a lower birth rate will probably cause issues and problems in the labor market, particularly, lack of labor resources in many countries because of the older workers having retired and there is no younger worker to substitute them [26]. Moreover, the need for resources to support the elderly will increase as people live longer [13], which might put pressure on financial, health, and the social care systems.

2.4 Gross Domestic Product

A study in China reveals that GDP per capita is the second most influential factor of population aging [12]. The research measured gross domestic product (GDP) per capita as a level of economic development. This study conveys that GDP per capita has a more profound effect on aging. GDP took a regulatory role in aging where it improves the quality of life of the people, medical, as well as hygienic conditions which increases the life expectancy along with the population aging. These studies are also consistent with the study on Romania where they highlight that GDP is a significant factor contributed to the population aging and regions with a higher GDP per capita tend to have a larger aging population [14]. In contrast, economic development might also be the solution to population aging by attracting the inflow of population in underdeveloped areas. Another study on China also emphasized that ensuring a steady and sustained economic growth is essential for addressing the challenges of an aging population because it can provide the financial support to implement any aging policies, improves average annual consumption level and sufficient capital investment [24].

2.5 Quality of Healthcare

Kim *et al*., [10] measures the quality of a country's healthcare system as the number of physicians and the findings show a high positive correlation between the quality of healthcare and the share of population aging. This indicates that better healthcare allows people to live longer, resulting in a higher share of the population aging. Meanwhile, a study in Europe found a weak positive relationship between healthcare and the dependent [15]. Besides, the technological advancement in medicine along with the access to skilled medical professionals like doctors, nurses and physiotherapists are important in improving healthcare, thus contributing to a longer lifespan. However, an ageing population obviously requires health needs, but the number of healthcare workers might not be sufficient according to the World Health Organization. Additionally, Yang *et al*., [11] result is also consistent with that study above that proved health conditions and population aging appear to have a positive correlation at 1% significance level which indicates strong evidence. The population aging process escalates as advancements in healthcare lengthen their life span.

2.6 Migration

Xu *et al*., [12] mentioned that the inflow of the new young laborers from rural areas into cities is caused by the accelerated urbanization development. Also, outflow population has a stronger effect than the inflow population since it raises the aging rate of the outflow areas while inflow population took a role to dilute the aging effect. At a regional level, net migration rates have a lower but significant negative impact on population aging [14]. The population aging will increase since fertility rates are expected to decline especially in the working-age population if the number of emigrants continue to exceed the number of immigrants. Yang *et al*., [11] also concludes that intensive out-migration of the population in Northeast China pose a strong effect on the population aging as people migrate out of the region to the region with supply of jobs. In a more high-income country like Lithuania, net migration is one of the key factors alongside with birth rate contributing up to 90% of the change in the population aging [23].

2.7 Female Labor Participation

On a broader scale, the proportion of women working positively impacts the share of the elderly population and this is probably because of the limited time to have and raise children since they are more occupied with their works [10]. However, an analysis at regional level in Romania reveals that a lower female employment rate is associated with an increase in the population aging [14]. The analysis shows a long-run relationship with population aging among various factors including the previous factors that have been discussed above such as GDP, quality of health, and net migration. These seemingly contrasting findings are probably due to the economic and social conditions that differ from national trends. In addition, female labor participation can offset the declining fertility rates that increase the population aging because the employment status of Malaysian women does not influence their childbearing decisions [27]. Hence, women can have more children and afford childcare by encouraging the female labor participation. Apart from that, raising female labor force participation is a crucial role in sustaining prosperity and counteracting the effects of rapid ageing and even declining populations [28].

3. Data and Methodology

3.1 Data

This research paper utilizes secondary data sourced from the World Bank Database encompassing annual observations over a 30-year period, specifically from the year 1991 through to 2020. This will provide a thorough time frame for the analysis and ensure a robust examination of the trends and patterns. Furthermore, this research employs the ARDL approach to analyse the short-run and long-run relationship and the effect of the factors of interest on population aging. This includes data on the population aging and its associated independent variables which are fertility rates, life expectancy, GDP, quality of healthcare, net migration, and female labour participation. Table 1 exhibits the abbreviation, data sources and description for each of the variables.

Table 1
Summary of variables

Variables	Abbreviation	Data Description
Dependent Variable		
Population aging	DPA	Percentage change in the population ages 65 and above (% of total population)
Independent Variables		
Fertility rates	FR	Fertility rates, total (births per woman)
Life expectancy	DLE	Change in the life expectancy at birth, total (years)
Gross Domestic Product	LNGDP	Log of GDP per capita
Quality of healthcare	PHYG	Growth in the physicians (per 1,000 people)
Migration	NM	Net migration rate (per 1,000 people)
Female labour participation	FLP	Female labour force (% of total labour force)

3.2 Descriptive Statistics

Table 2 presents a summary of descriptive statistics for each variable obtained from yearly data acquired from 1991 until 2020. The change in the proportion of population aged 65 and above has a mean of 0.1104% with a moderate variability of 0.068%. The minimum value of the change in its proportion is 0.0262% while the maximum change is 0.2508%. The mean value of the fertility rates is 2.5337, indicating that women give birth to over two children on average, with the highest value of 3.381 in 1992 and the lowest value of 1.818 in 2020. The change in life expectancy steadily increase with a mean of 0.1544, with maximum value of 0.569, reflecting longer lifespans. This trend aligns with the growing proportion of population aging over the year. Proportional change in GDP per capita are relatively stable, with a mean of 8.7236 and low variability of 0.4577. The growth in physicians appears to have a high skewness of 1.9167, suggesting a fluctuation in its growth, with most years showing lower values and few years showing much higher growth. Net migration rate averages 3.7421, while female labour force participation averages 36.12%, with a low variability suggesting that the participation rate remained relatively steady over time.

Table 2
Descriptive statistics

	DPA	FR	DLE	LNGDP	PHYG	NM	FLP
Mean	0.1104	2.5337	0.1544	8.7236	0.0618	3.7421	36.121
Median	0.1010	2.298	0.1515	8.6706	0.0447	3.9495	35.4492
Maximum	0.2508	3.381	0.569	9.3176	0.3266	5.654	38.7454
Minimum	0.0262	1.818	-0.116	8.0689	-0.0437	1.557	34.7814
Std. Dev.	0.0680	0.5530	0.1518	0.4577	0.0725	1.5402	1.3934
Observations	30	30	30	30	30	30	30

3.3 Method and Model

The factors influencing population aging in Malaysia are being examined through time series analysis in this research paper. The Augmented Dickey-Fuller (ADF) unit root test is utilized to first assess the stationarity of the data and determine the order of the integration of each variable. The ARDL approach is applicable not only for trend-stationary regressors which is I(0), but also valid when the regressors are first-difference stationary (I(1)) according to Pesaran and Shin [29]. This implies that whether the series are I(0) or I(1), the ARDL model can still be used. In addition, ARDL approach provides robust estimation for a small sample size, given that this research paper will examine a small sample size of 30 years [30].

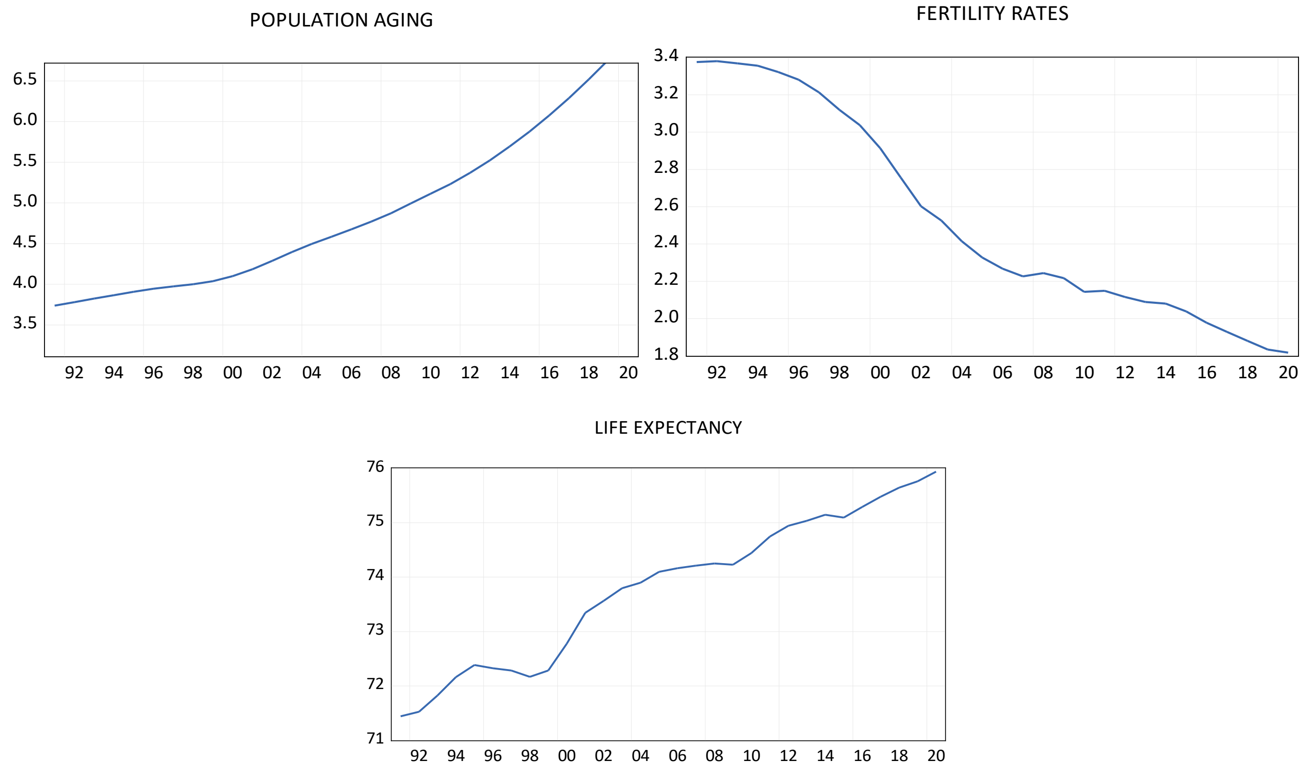
The model to estimate the relationship between the independent variables and the dependent variable can be specified as follows:

$$DPA_t = \alpha_0 + \beta_1 FR_t + \beta_2 DLE_t + \beta_3 LNGDP_t + \beta_4 PHYG_t + \beta_5 NM_t + \beta_6 FLP_t + e_t \quad (1)$$

where DPA represents population aging, FR represents fertility rates, DLE represents life expectancy, LNGDP represents GDP per capita, PHYG represents physician growth rate, NM represents net migration rate, and FLP represents female labour participation.

3.4 Unit Root Test

The Augmented Dickey-Fuller (ADF) test is employed to determine whether each variable contains a unit root. If the null hypothesis of a unit root test is rejected, the series is stationary. The time series plots in Figure 2 illustrates the possible need for order integration of the variables. On the other hand, Table 3 presents the results of the Augmented Dickey-Fuller (ADF) test at both the level and first-difference forms, providing the insights into the integration order of the variables. The results of the ADF test indicate that the variables show a mix of stationarity at level and first-difference. Specifically, the variables FR, DLE and PHYG are stationary at level form I(0). On the other hand, the variables DPA, LNGDP, NM, and FLP are non-stationary at level but become stationary after first differencing I(1). Given that all variables are either I(0) or I(1), the ARDL bound testing approach is suitable for modelling the relationships between the variables and analyzing the effect of the independent variables on population aging [30].



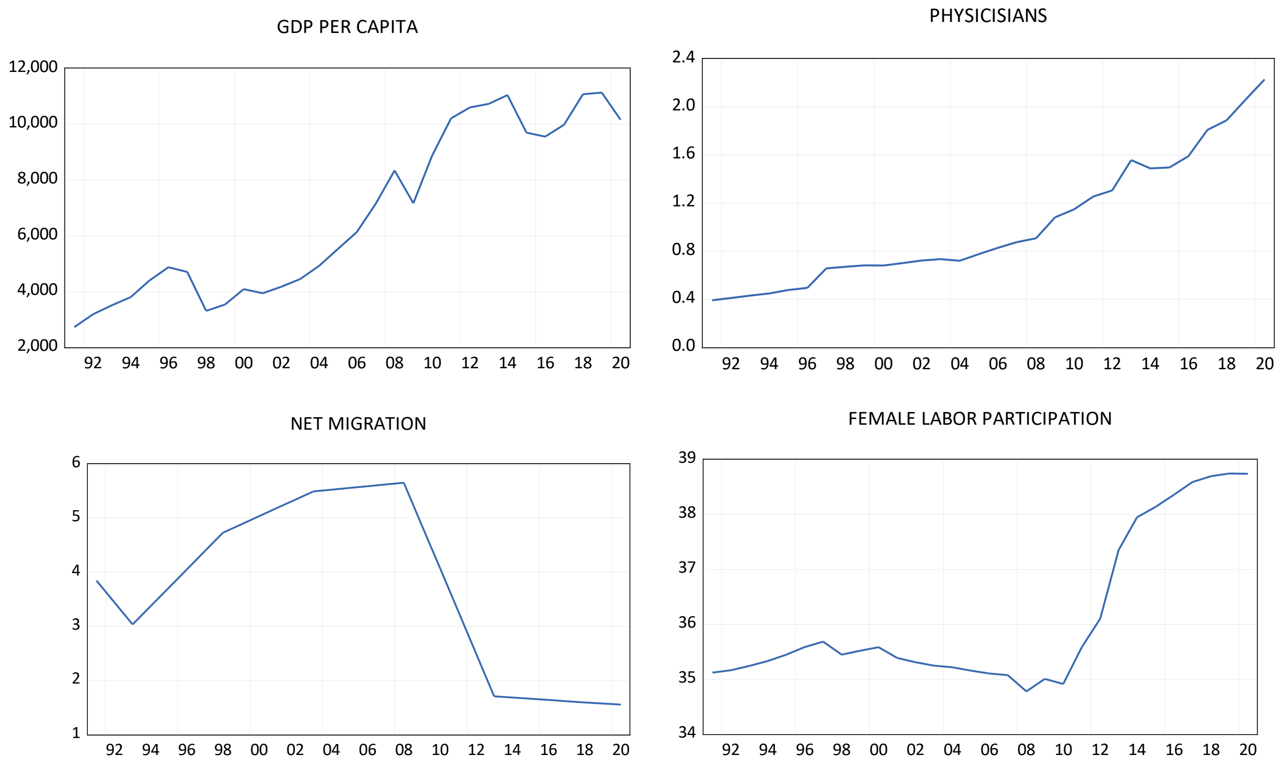


Fig. 2. Percentage of older and younger population

Table 3
Unit Root (ADF) Test

Variables	Level		First-Difference		Order of Integration
	ADF Statistics (p-value)	Decision	ADF Statistics (p-value)	Decision	
DPA	2.612188 (0.9967)	Accept H_0	-2.478715 (0.0153)	Reject H_0	I(1)
FR	-2.399122 (0.0184)	Reject H_0			I(0)
DLE	-1.997028 (0.0455)	Reject H_0			I(0)
LNGDP	1.807571 (0.9804)	Accept H_0	-4.252566 (0.0001)	Reject H_0	I(1)
PHYG	-3.595565 (0.0008)	Reject H_0			I(0)
NM	-0.676028 (0.4151)	Accept H_0	-2.037125 (0.0418)	Reject H_0	I(1)
FLP	1.038621 (0.9172)	Accept H_0	-2.596711 (0.0114)	Reject H_0	I(1)

3.5 Autoregressive Distributed Lag (ARDL) Bound Test

This research employs the Autoregressive Distributed Lag (ARDL) model bounds testing method to examine the long-run relationship between the explanatory variables of fertility rates, life expectancy, GDP, quality of healthcare, net migration and female labour participation, and its dependent variable, population aging. Furthermore, the Error Correction Model (ECM) is being used to capture the short-run relationships. The estimation of the model can be outlined as follows:

$$\Delta DPA_t = \alpha_0 + \sum_{p=1}^{q} \beta_{1p}\Delta FR_{t-p} + \sum_{p=1}^{q} \beta_{2p}\Delta DLE_{t-p} + \sum_{p=1}^{q} \beta_{3p}\Delta LNGDP_{t-p} + \sum_{p=1}^{q} \beta_{4p}\Delta PHYG_{t-p} + \sum_{p=1}^{q} \beta_{5p}\Delta NM_{t-p} + \sum_{p=1}^{q} \beta_{6p}\Delta FLP_{t-p} + \delta_1 FR_{t-1} + \delta_2 DLE_{t-1} + \delta_3 LNGDP_{t-1} + \delta_4 PHYG_{t-1} + \delta_5 NM_{t-1} + \delta_6 FLP_{t-1} + \varepsilon_t \quad (2)$$

From Eq. (2), the Δ denotes the first difference operator, q represents the maximum number of lag length, selected based on the Akaike Information Criterion (AIC) of the ARDL model, and ε is the error term. β_1to β_6 represent the coefficient for the lagged difference for independent variables that captures the short-run effects of changes on DPA, while δ_1to δ_6 represent the long-run relationships between the variables under this research. The existence of a long-run cointegration relationship is proven only if the computed Wald F-statistic exceeds the upper critical bound. Furthermore, the short-run dynamics of the model, along with the lagged error correction term (ECT), are estimated through Error Correction Model (ECM) as follows:

$$\Delta DPA_t = \alpha_0 + \sum_{p=1}^{q} \theta_{1p} \Delta FR_{t-p} + \sum_{p=1}^{q} \theta_{2p} \Delta DLE_{t-p} + \sum_{p=1}^{q} \theta_{3p} \Delta LNGDP_{t-p} + \sum_{p=1}^{q} \theta_{4p} \Delta PHYG_{t-p} + \sum_{p=1}^{q} \theta_{5p} \Delta NM_{t-p} + \sum_{p=1}^{q} \theta_{6p} \Delta FLP_{t-p} + \gamma ECT_{t-1} + \vartheta_t \quad (3)$$

The coefficient of the ECT, γ measures the speed of adjustment to the long-run equilibrium, and ϑ is the residual term. For the series to be able to adjust to its equilibrium, the coefficient of γ must be less than zero and statistically significant. Then, various diagnostic tests are conducted to assess the robustness and the reliability of the model. The tests help verify the validity of the estimated parameters, and it include the test for autocorrelation, heteroscedasticity, normality, model specification, and stability of the coefficients. Table 4 outlined the null hypotheses for each test.

Table 4
Null hypothesis of diagnostic tests

Test	Null Hypothesis
Autocorrelation	No serial correlation exists at any order
Heteroskedasticity	Homokedasticity is present in the model
Normality	The residual follows a normal distribution
Ramsey RESET	The model is correctly specified
CUSUM	The coefficients in the model are stable

4. Results and Discussions

The optimal ARDL model was selected based on the Akaike Information Criterion (AIC), whereas the model ARDL (2, 1, 1, 0, 1, 2, 1) determined to be the best model due to its lowest AIC value. Following model selection, the bound test for cointegration was conducted to examine the presence of a long-run relationship among the variables. Based on table 5, the F-statistics value of 9.217543 exceeds the upper bound critical value of 4.05 at 1% significance level. Hence, the null hypothesis of no cointegration is rejected, confirming the existence of a long-run equilibrium relationship between the independent and dependent variables under this research.

Table 5
Bound test

Test Statistic	Value	K
F-statistic	9.217543	6
	Critical Value Bounds	
Significance	I(0)	I(1)
10%	1.75	2.87
5%	2.04	3.24
2.5%	2.32	3.59
1%	2.66	4.05
Conclusion	Cointegrated	

Given that the long-run relationship exists between the variables, this research proceeds to examine the influence of the factors on population aging in Malaysia. The focus is on analysing how the factors impact population aging and estimating the magnitude of these effects. Both the long-run and short-run models are estimated using the ARDL approach, with the Ordinary Least Squares (OLS) method applied to evaluate the speed of adjustment. The short-run dynamics of the model are further examined through the Error Correction Model (ECM). The results are presented in Table 6.

Table 6 illustrates the result of the long-run and short-run estimates of ARDL model. Fertility rates (FR) show a significant negative relationship with population aging (DPA) in the long-run. A one unit decreases in FR is associated with a 0.096059 unit increases in DPA. Among the variables examined, fertility rates have the most substantial effect on population aging as it has greater magnitude than the effects observed for the other variables. The result depicts that population aging is expected to accelerate when women have fewer children, leading to a higher proportion of elderly peoples within the population. This result aligns with the previous studies of Abdul Rashid *et al*., [20] Nik and Suriati [21], and Kim *et al*., [10] which highlighted that lower fertility rates contribute to an increase in aging population. These researchers conclude that the increment in the proportion of the elderly population is due to the reduction in number of children proportional to the population. Subsequently, the imbalance between the growing elderly population and reduced working-age widens the disparity in the demographic structure. However, the short-run estimates indicate a significant positive relationship between FR and DPA which is inconsistent with the previous studies. For every one-unit decrease in the fertility rate, indicates a 0.075248-unit decrease in population aging. This result suggests that decrease in fertility rates also leads to a decrease in population aging. Despite lower fertility rates, the current older population is living longer and healthier, which can mask or delay the expected increase in the proportion of elderly people in the population.

Table 6
Long-run and short-run estimates

Variables	Long-run		Short-run	
	Coefficient	P-value	Coefficient	P-value
FR	-0.096059	0.0000	0.075248	0.0002
DLE	0.073994	0.0004	0.019996	0.0003
LNGDP	-0.027021	0.0380		
PHYG	0.024534	0.5002	-0.000368	0.9586
NM	-0.008616	0.0012	0.016972	0.0002
FLP	0.017241	0.0000	-0.001896	0.5704
CointEq(-1)			-0.532657	0.0000

Meanwhile, life expectancy (DLE) and DPA exhibit a significant positive relationship both in the long-run and short-run. In the long-run, a unit increases in the DLE will contribute to an increase in the DPA by 0.073994. Over time, aging population becomes a larger share of the total population. This long-term trend arises as more people from younger population live to older ages when life expectancy rises. This stimulates the growth of the older population. Similarly, Garlauskaitė and Zabarauskaitė [23] Abdul Rashid *et al*., [20] and Kim *et al*., [10] concluded that higher life expectancy leads to a greater share of elderly population in the population. Conversely, the impact is smaller over the short-run, with a unit increases in DLE resulting in an increase in DPA by only 0.019996. This suggests that while changes in life expectancy have an immediate impact on population aging, the magnitude of this effect is more pronounced over a longer period because the working-age population may not be growing at the same rate as the number of elderly peoples.

Besides, this research also observed a significant and negative impact of GDP per capita (LNGDP) on the DPA at a 5% significance level in the long-run. This negative long-run relationship diverges from expectations, as previous studies, such as Xu *et al*., [12], and Jemna and David [14] suggested a positive impact of economic development on population aging due to improved healthcare, quality of life, and living standards. However, the result might imply that economic growth in Malaysia may provide the financial resources needed to address challenges posed by an aging population through support systems or policy interventions, consistent with the arguments of Rao and Gao [24]. The finding implied that population aging would reduce when the economic growth is improved. Hence, 1% increase in LNGDP corresponds to a 0.027021-unit decline in DPA. In the short run, no dynamic relationship between LNGDP and DPA is observed, suggesting that immediate economic changes are unlikely to have a substantial impact on aging trends.

Apart from that, net migration (NM) significantly affect population aging in the long-run, showing a negative relationship between the variables. This indicates that NM adversely affect DPA with an increase in one unit of NM leads to a 0.008616-unit decrease in DPA. Net migration refers to the difference between the number of people migrate into a country and the number who migrate out of it. The finding indicates more people migrates into Malaysia can help to reduce the population aging by increasing the younger population in the country. The result is consistent with prior research by Yang *et al*., [11] Jemna and David [14] and Xu *et al*., [12] which highlighted that higher number of immigrants could offset the population aging growing trends. Nonetheless, the short-run results show an unexpected positive relationship, where a rise in net migration by 1,000 individuals leads to a 0.016972-unit increase in population aging. While immigration may help mitigate population aging in the long-run, the immediate impact may not be as apparent due to the possibility that new immigrants coming from older populations, which temporarily could increase the population aging.

Furthermore, female labour participation (FLP) has a significant positive long-run relationship with population aging, where 1% increase in female labour participation corresponding to a 0.017241-unit increase in population aging. This finding contradicts the previous studies by Siah and Lee [27] and Yuko and Kalpana [28] who found a negative association and even argued that increased female labour force participation could offset aging population by promoting higher fertility rates. The observed positive relationship may reflect reduced birth rates among working women, as concluded by Kim *et al*., [10]. Women in the workforce often have fewer children due to the time and energy spent on the careers, which may contribute to population aging. In the short run, the effect of female labour participation is insignificant, implying no immediate influence on aging dynamics.

As illustrated in Table 6, the coefficient of the error correction term (CointEq(-1)) is -0.532657 and is statistically significant, indicating a strong adjustment towards the long-run equilibrium from the short-run. This result aligns with Banerjee *et al*., [31] that emphasizes the importance of a strong significant error correction term in confirming the existence of a stable long-run relationship. The negative sign suggests that any short-run deviations from the long-run equilibrium are corrected at a rate of approximately 53.27% per period. The speed of adjustment is relatively fast, implying that the system rapidly returns to equilibrium after any shocks or disturbances.

Table 7
Diagnostic test results

Test	Results (p-value)
Autocorrelation (Breush-Godfrey Serial Correlation LM Test)	0.859574 (0.4478)
Heteroskedasticity (Breush-Godfrey Serial Correlation LM Test)	1.448579 (0.2554)

Normality Test	1.223973 (0.542273)
Ramsey RESET Test	3.223080 (0.0758)

Table 7 summarizes the diagnostic results, including the autocorrelation, heteroscedasticity, normality, and Ramsey RESET test. The p-values for the Breusch-Godfrey Serial Correlation LM Test and the heteroskedasticity test are both greater than 0.05, indicating that the null hypotheses are failed to be rejected. This suggests that the model has no issues with autocorrelation or heteroskedasticity. Similarly, the p-value for both the normality and Ramsey RESET test exceed 0.05, suggests that the residuals are normally distributed, while the Ramsey RESET test confirms the correct specification of the model. These results ensure that the model is robust and properly specified, supporting the validity of the long-run and short-run relationships examined in this research.

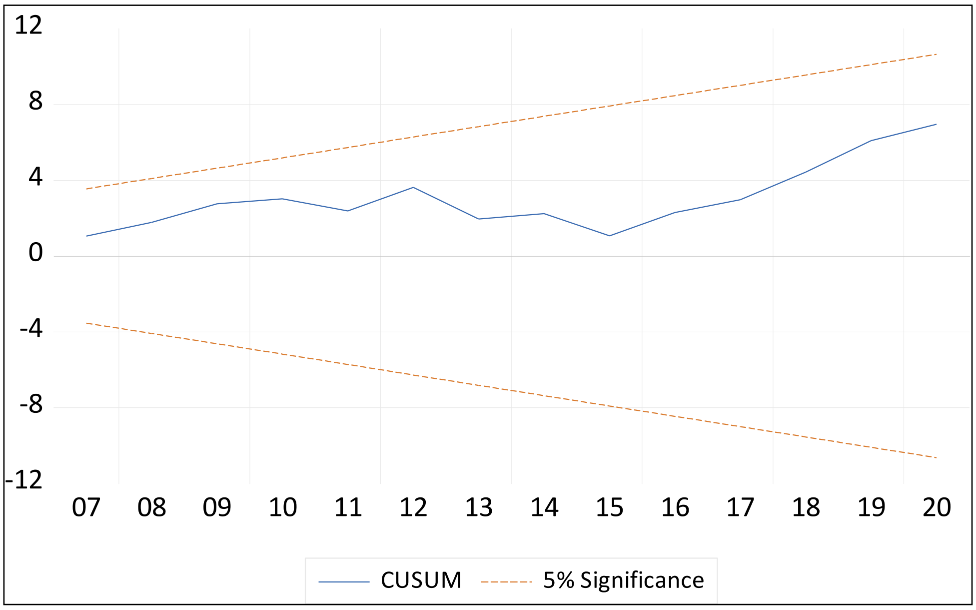


Fig. 3. CUSUM test graph

Figure 3 illustrates the graph of the cumulative sum (CUSUM) test, where the blue line representing the CUSUM statistic remains within the 5% significance critical bounds of the two red lines. This finding indicates that the ARDL model is stable and reliable. Consequently, the analysis confirms the absence of misspecification and structural instability in the model, both in the short and long run.

5. Conclusions

The aim of this research is to examines the factors influencing population aging in Malaysia and its effects. The aging population has become a critical concern, with nations experiencing shifts in demographic structures that pose significant economic and social challenges [1]. Recognizing the profound implications of this shift, the Twelfth Malaysia Plan (2021-2025) emphasizes the need for targeted policies to address aging, as well as ensuring sustainable development [32]. In response to these issues, this research intends to present a comprehensive understanding of the long-run and long-run impacts on population aging by incorporating key variables such as fertility rates, life expectancy, GDP per capita, quality of healthcare, migration, and female labour participation.

The findings reveal that fertility rates and GDP per capita shows a significant negative relationship with population aging in the long run. A decline in fertility rates reduces the proportion of young individuals in the population, thus accelerating the aging process. Conversely, a higher GDP per capita appears to minimize the aging trends, possibly by providing financial resources to implement supportive policies and infrastructure. Life expectancy and female labour participation are positively associated with population aging in the long run. Higher life expectancy contributes to an increasing elderly population as more individuals live longer, while higher female labour participation may indirectly lead to reduced birth rates, as working women often have fewer children due to time constraints and career demands. The impact of net migration varies across time horizons. While net migration mitigates aging trends in the long run by increasing the inflow of younger individuals, it surprisingly exacerbates aging in the short run, which could be attributed to temporary demographic shifts. Further, it is noteworthy that the quality of healthcare has insignificant relationship with population aging in Malaysia, which contradict with the global studies that emphasizes the role of healthcare in extending life expectancy and accelerate aging.

Limitations include data collection from 1991 to 2020, a period marked by substantial demographic and economic transformations. While the analysis provides robust insights, it does not account for more recent developments, such as the possibility Malaysia's shift toward a high-income nation and its implications for aging. Future research should incorporate more recent data and consider additional factors like technological advancements or urbanization, which could further refine the understanding of aging dynamics.

In conclusion, this research highlights the significance of demographic, economic, and social factors in shaping population aging. The research supports the SDGs by providing insights into the factors that influence population aging. This research highlights the importance of improving healthcare systems to ensure the well-being of an aging population, contributing to SDG 3 of good health and wellbeing. In addition, considering the need in regulating adequate pension systems and extension of retirement age is crucial in addressing economic vulnerabilities, supporting SDG 1 (No Poverty) and SD8 (Decent Work and Economic Growth). The findings offer critical insights for policymakers to design specific policies, such as enhancing economic growth, supporting family planning, and achieving work-life balance for women. Hence, Malaysia can develop effective strategies to mitigate the challenges of population aging, ensuring sustainable economic growth, promoting overall societal well-being, in line with the SDGs.

Acknowledgement

We would like to express our gratitude to the Risk & Analytics (RA) Research Group of the Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM), for supporting this research by providing research seminars as well as its members' role in assisting where needed. This research was funded by the Research Publication Scheme from the Research and Innovation Management Centre, Universiti Sains Islam Malaysia.

References

[1] United Nations. (2017) World Population Ageing Report 2017. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/files/documents/2020/May/un_2017_worldpopulationageing_report.pdf
[2] United Nations. (2001). World population aging: 1950-2050.

https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/files/documents/2021/Nov/undesa_pd_2002_wpa_1950-2050_web.pdf
[3] Department of Statistics Malaysia. (2016, November 9). Population Projections: 2010-2040. https://open.dosm.gov.my/publications/population_projection
[4] World Bank, World Development Indicators. (2022). https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS
[5] Statistics Bureau of Japan. (2021). Population census 2020: Summary of results. https://www.stat.go.jp/english/data/kokusei/2020/summary/pdf/01.pdf
[6] Edmond, Charlotte, and Madeleine North. "More than 1 in 10 people in Japan are aged 80 or over. Here's how its ageing population is reshaping the country." In *World Economic Forum*. 2023. https://www.weforum.org/agenda/2023/09/elderly-oldest-population-world-japan/
[7] United Nations. (2019). World Population Prospects 2019: Highlights. United Nations.
[8] D'Ambrogio, E. (2020). Japan's ageing society (Briefing PE 659.419). https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2020)659419
[9] Wang, Meng-Yun, Hsing-Chou Sung, and Jie-Yi Liu. "Population aging and its impact on human wellbeing in China." *Frontiers in Public Health* 10 (2022): 883566. doi: https://doi.org/10.3389/fpubh.2022.883566
[10] Kim, Jungsuk, Cynthia Castillejos Petalcorin, Donghyun Park, and Shu Tian. "Determinants of the elderly share of population: a cross-country empirical analysis." *Social Indicators Research* 165, no. 3 (2023): 941-957. https://doi.org/10.1007/s11205-022-03052-y
[11] Yang, Ling, Kai Zhao, and Zhen Fan. "Exploring determinants of population ageing in Northeast China: From a socio-economic perspective." *International Journal of Environmental Research and Public Health* 16, no. 21 (2019): 4265. https://doi.org/10.3390/ijerph16214265
[12] Xu, Xin, Yuan Zhao, Xinlin Zhang, and Siyou Xia. "Identifying the impacts of social, economic, and environmental factors on population aging in the Yangtze River Delta using the geographical detector technique." *Sustainability* 10, no. 5 (2018): 1528. https://doi.org/10.3390/su10051528
[13] Harper, Sarah. "Living longer within ageing societies." *Journal of Population Ageing* 12, no. 2 (2019): 133-136. https://doi.org/10.1007/s12062-019-09248-4
[14] Jemna, Danuț-Vasile, and Mihaela David. "Determinants of ageing in Romania. Evidence from regional-level panel analysis." *CES Working Papers* 13, no. 1 (2021): 17-32.
[15] Lewandowska-Gwarda, Karolina, and Elżbieta Antczak. "Urban ageing in Europe—spatiotemporal analysis of determinants." *ISPRS International Journal of Geo-Information* 9, no. 7 (2020): 413. https://doi.org/10.3390/ijgi9070413
[16] Mohd, Siti Nur Ain, Ayunee Anis Ishak, and Doris Padmini Selvaratnam. "Ageing population's impact on economic growth in Malaysia from 1981 to 2019: evidence from an autoregressive distributed lag approach." *Frontiers in Public Health* 9 (2021): 731554. https://doi.org/10.3389/fpubh.2021.731554
[17] Mawar, M. Yunus, and M. Adib Ismail. "Impact of population ageing on the Malaysian economy." In *Proceedings of the 6th International Conference on Management and Muamalah 2019 (CoMM 2019)*, pp. 30-36. 2019.
[18] Ismail, Normaz Wana, S. W. Abd Rahman, T. A. T. A. Hamid, and Rusmawati Said. "Aging and economic growth: empirical analysis using autoregressive distributed lag approach." *Sains Malaysiana* 45, no. 9 (2016): 1345-1350.
[19] Maity, Shrabanti, and Anup Sinha. "Linkages between economic growth and population ageing with a knowledge spillover effect." *Journal of the Knowledge Economy* 12, no. 4 (2021): 1905-1924.https://doi.org/10.1007/s13132-020-00696-4
[20] Abdul Rashid, Saharani, Puzziawati Ab. Ghani, Noorizam Daud, Zulkifli Ab Ghani Hilmi, Siti Noorul Ain Nor Azemi, Sharifah Norhuda Syed Wahid, and Mohd Rizal Razak. "Malaysia's ageing population trends." In *Regional Conference on Science, Technology and Social Sciences (RCSTSS 2014) Business and Social Sciences*, pp. 981-990. Singapore: Springer Singapore, 2016. https://doi.org/10.1007/978-981-10-1458-1_88
[21] Nor, Nik Norliati Fitri Md, and Suriati Ghazali. "Malaysia towards an ageing country." *Geografia* 17, no. 3 (2021): 234-245. https://doi.org/10.17576/geo-2021-1703-17
[22] Bloom, David E., Somnath Chatterji, Paul Kowal, Peter Lloyd-Sherlock, Martin McKee, Bernd Rechel, Larry Rosenberg, and James P. Smith. "Macroeconomic implications of population ageing and selected policy responses." *The Lancet* 385, no. 9968 (2015): 649-657. https://doi.org/10.1016/S0140-6736(14)61464-1
[23] Garlauskaitė, Agnė, and Rasa Zabarauskaitė. "Lithuanian population aging factors analysis." *Mokslas–Lietuvos ateitis/Science–Future of Lithuania* 7, no. 2 (2015): 199-209. https://doi.org/10.3846/mla.2015.747
[24] Rao, Congjun, and Yun Gao. "Influencing factors analysis and development trend prediction of population aging in Wuhan based on TTCCA and MLRA-ARIMA: C. Rao, Y. Gao." *Soft computing* 25, no. 7 (2021): 5533-5557. https://doi.org/10.1007/s00500-020-05553-9

[25] Lee, Ronald, Andrew Mason, Nta Network, Ronald Lee, Andrew Mason, Eugenia Amporfu, Chong-Bum An et al. "Is low fertility really a problem? Population aging, dependency, and consumption." *Science* 346, no. 6206 (2014): 229-234. https://doi.org/10.1126/science.1250542

[26] Khavinson, Vladimir, Irina Popovich, and Olga Mikhailova. "Towards realization of longer life." *Acta Bio Medica: Atenei Parmensis* 91, no. 3 (2020): e2020054. https://doi.org/10.23750/abm.v91i3.10079

[27] Siah, Audrey KL, and Grace HY Lee. "Female labour force participation, infant mortality and fertility in Malaysia." *Journal of the Asia Pacific Economy* 20, no. 4 (2015): 613-629.https://doi.org/10.1080/13547860.2015.1045326

[28] Yuko, K., & Kalpana, K. (2016). “SHE is the answer”. International Monetary Fund. Finance & Development, Vol. 53, No. 1. https://www.imf.org/external/pubs/ft/fandd/2016/03/kinoshita.htm

[29] Shin, Yongcheol, and M. Hashem Pesaran. "An autoregressive distributed lag modelling approach to cointegration analysis." In *Econometrics and economic theory in the 20th century: The Ragnar Frish centennial symposium*, pp. 371-413. Cambridge University Press, 1999.

[30] Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. "Bounds testing approaches to the analysis of level relationships." *Journal of applied econometrics* 16, no. 3 (2001): 289-326.https://doi.org/10.1002/jae.616

[31] Banerjee, Anindya, Juan Dolado, and Ricardo Mestre. "Error-correction mechanism tests for cointegration in a single-equation framework." *Journal of time series analysis* 19, no. 3 (1998): 267-283.

[32] Economic Planning Unit. (2021). Twelfth Malaysia Plan 2021-2025. Prime Minister's Department, Malaysia. https://rmke12.ekonomi.gov.my/en