

POPULATION AGEING AND ECONOMIC GROWTH IN MALAYSIA: EVIDENCE FROM AN ARDL BOUNDS TESTING APPROACH

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Abstract. Malaysia's transition towards an ageing society may influence economic performance through fertility, longevity, dependency and labour force participation. This study investigates these relationships using annual data for 1994–2024 and an autoregressive distributed lag bounds testing framework. The preferred theoretical specification relates the natural logarithm of real GDP to the logarithms of fertility, life expectancy, the old age dependency ratio and labour force participation. Unit-root testing shows, however, that the logged old age dependency ratio and logged labour force participation exhibit second-order persistence. Their first log differences are therefore employed to ensure that every variable included in the ARDL is integrated of order zero or one. BIC selects ARDL(1,1,1,1,1), with controls for the 1998 Asian financial crisis and the 2020 pandemic. The bounds-test F-statistic is 1.449, below the 5% lower bound of 2.86. Hence, the null hypothesis of no level relationship cannot be rejected and long-run coefficients or an error correction model are not estimated. A stationary short-run model finds no statistically significant demographic coefficient at the 5% level. The crisis controls are negative and significant, indicating that exceptional macroeconomic shocks dominate annual changes in real GDP during the sample. Residual and stability tests also identify non-normality, serial correlation in the conditional ARDL and CUSUMSQ instability. The findings do not imply that demographic change is economically unimportant; rather, they show that this 30 years sample does not provide sufficiently robust evidence of a stable long-run ARDL relationship.

Keywords: *population ageing, real GDP, fertility, old age dependency, labour force participation, ARDL*

Introduction

Population ageing changes the balance between economically active individuals and dependants and can affect economic growth through labour supply, productivity, saving, investment and public expenditure (Mohd et al., 2021; Lee and Mason, 2011). Falling fertility gradually reduces the number of future labour market entrants, while longer life expectancy increases the number and share of people surviving into older ages. These developments may place pressure on healthcare, retirement income and household caregiving, particularly when labour force participation does not rise sufficiently to offset slower workforce growth. The economic consequences of ageing are not uniformly negative. Longer lives may encourage greater investment in education and skills because the return to human capital can be realised over a longer horizon (Blackburn and Cipriani, 2002). Labour scarcity may also stimulate automation, organisational innovation and more productive use of available workers. Older households contribute to consumption, saving, caregiving and the expansion of health and service industries. The eventual growth effect therefore depends on healthy longevity, labour market flexibility, productivity and institutional preparedness.

Malaysia is an important case because lower fertility, rising longevity and an increasing old age dependency ratio have developed alongside rapid structural economic

change (Abdul Karim et al., 2023; Mohd et al., 2021). Evidence across Asian economies also indicates that the ageing–growth relationship differs by country and direction of causality. Fertility decline can initially support a demographic dividend by lowering youth dependency, but prolonged sub-replacement fertility can later weaken labour force replacement (Bloom et al., 2009; Goldstein et al., 2009; Mason and Kinugasa, 2008). The transition consequently creates both opportunities and risks that may emerge at different time horizons. Existing Malaysian studies commonly emphasise the fiscal or labour market burden of ageing, while fewer jointly estimate fertility, life expectancy, dependency and participation in a dynamic time series model. Demographic indicators are also strongly trending and may possess different integration orders. Ignoring these properties can produce spurious regressions or invalid long-run conclusions. The ARDL framework is attractive because it accommodates a combination of $I(0)$ and $I(1)$ variables in small samples, provided no included series is $I(2)$ (Pesaran et al., 2001). This study therefore examines whether real GDP and selected demographic indicators exhibit a long-run level relationship in Malaysia and, if cointegration is absent, whether short-run demographic changes explain changes in real GDP. It also evaluates residual adequacy and recursive stability. The contribution lies in applying a transparent transformation strategy: level variables are logged when valid, while $I(2)$ demographic series are represented by their first log differences to preserve the assumptions of the ARDL bounds procedure.

Literature review and conceptual framework

Endogenous growth theory relates long-run output to human capital, innovation and productive labour (Romer, 1990). The generational-economy perspective adds that age groups differ in production, consumption, saving and transfer dependence (Lee and Mason, 2011). A changing population structure can therefore influence both current resource allocation and future capital accumulation. Fertility can affect growth differently across stages of demographic transition. Declining fertility reduces youth dependency and can release resources for education, health and investment, creating conditions for a demographic dividend. The dividend depends on employment, skills and institutions and is not automatic (Bloom et al., 2009). Persistently low fertility eventually slows labour force replacement, and behavioural shifts such as delayed marriage may sustain low birth rates (Goldstein et al., 2009). Its expected long-run sign is consequently ambiguous. Life expectancy reflects longevity and aspects of population health. Longer expected lives may raise human-capital investment and extend productive participation (Blackburn and Cipriani, 2002). However, additional years of life do not necessarily increase output when they coincide with poor health or early retirement. The growth effect depends on whether longevity is healthy and supported by opportunities for continued economic activity.

The old age dependency ratio captures older persons relative to the working-age population. Conventional theory predicts a negative relationship because a rising ratio may reduce effective labour supply and increase pension, healthcare and care expenditure (Mohd et al., 2021). Adaptive investment, automation and growth of the silver economy can partly offset this burden (Park and Shin, 2023). Labour force participation is the direct utilisation channel: higher participation increases effective labour input, although aggregate participation also responds to economic cycles and household conditions (Abdul Karim et al., 2023). The conceptual framework links fertility and longevity to age structure, age structure to dependency, and dependency

plus participation to productive labour and real GDP. Because these pathways interact and evolve slowly, the study first tests for a long-run level relationship. In the absence of cointegration, interpretation is restricted to stationary short-run changes rather than imposing an unsupported equilibrium relationship.

Materials and Methods

The analysis uses annual Malaysian data from 1994 to 2024. Real GDP is measured in constant US dollars; fertility is births per woman; life expectancy is years at birth; the old age dependency ratio is the population aged 65 and above relative to the working-age population; and labour force participation is the economically active population aged 15 and above as a percentage of the corresponding population. Real GDP and life expectancy and the remaining series are consistent with World Development Indicators definitions. The preferred theoretical level model is:

$$LGDP_t = \beta_0 + \beta_1 LFR_t + \beta_2 LLE_t + \beta_3 LOADR_t + \beta_4 LLFPR_t + \varepsilon_t \quad \text{Eq. (1)}$$

Because ARDL bounds testing does not permit I(2) variables, the estimable conditional model replaces LOADR and LLFPR with their first log differences:

$$LGDP_t = \beta_0 + \beta_1 LFR_t + \beta_2 LLE_t + \beta_3 \Delta LOADR_t + \beta_4 \Delta LLFPR_t + \varepsilon_t \quad \text{Eq. (2)}$$

The Augmented Dickey Fuller (ADF) and Phillips Perron (PP) tests are applied with an intercept to determine the integration order of each logged series. ADF lag lengths are selected using BIC, while the PP test employs a Bartlett-kernel Newey West correction for serial dependence and heteroskedasticity. With only 30 usable observations after constructing the model transformations, the maximum ARDL lag is two and BIC selects ARDL(1,1,1,1,1). Impulse dummies for 1998 and 2020 control for the Asian financial crisis and pandemic. The unrestricted conditional error-correction representation tests the joint null that all lagged level coefficients are zero. If the F-statistic exceeds the upper bound, a level relationship is supported; if it falls below the lower bound, no long-run relationship is inferred (Pesaran et al., 2001). When cointegration is not supported, long-run coefficients and the error correction term are not interpreted. A separate stationary model is estimated using $\Delta LGDP$, ΔLFR , ΔLLE , $\Delta^2 LOADR$ and $\Delta^2 LLFPR$, together with the crisis dummies. This model captures only short-run associations. Diagnostic tests assess normality, serial correlation, heteroskedasticity, functional form and recursive stability (*Table 1*).

Table 1. Variable measurement and transformation.

Symbol	Variable	Measurement in preferred model	ARDL transformation
LGDP	Real GDP	Natural log of constant US\$	Level log
LFR	Fertility	Natural log of births per woman	Level log
LLE	Life expectancy	Natural log of years	Level log
LOADR	Old age dependency	Natural log of ratio (%)	$\Delta LOADR$
LLFPR	Labour force participation	Natural log of rate (%)	$\Delta LLFPR$

Note: Δ denotes first difference. LOADR and LLFPR are differenced because their level logs display I(2) behaviour over the sample.

Results and Discussion

This section presents the empirical findings in a systematic sequence. It begins with descriptive statistics to summarise the distributional characteristics of the variables used in the estimable specification. The time series properties are then examined using the Augmented Dickey Fuller and Phillips Perron unit root tests before the selected ARDL(1,1,1,1,1) specification is evaluated through the bounds test. Conditional ARDL and stationary short-run estimates are subsequently reported, followed by residual diagnostic and parameter-stability tests. This sequence ensures that the estimated relationships are interpreted in accordance with the integration properties of the variables and the statistical adequacy of the model. *Table 2* summarises the distributional characteristics of the transformed variables employed in the model. LGDP, LFR and LLE are expressed in natural logarithms, whereas LOADR and LLFPR enter as first log differences. The descriptive results provide an initial view of central tendency, dispersion and distributional shape, formal time series inference nevertheless depends on the unit-root, bounds and diagnostic tests reported below (*Table 3 to Table 9*).

Table 2. Descriptive analysis.

Variable	Mean	Med	Max	Min	SD	Skewness	Kurtosis	JB	Prob	Obs
LGDP	26.151	26.145	26.770	25.488	0.395	-0.077	1.680	2.152	0.3410	30
LFR	0.807	0.795	1.188	0.489	0.207	0.306	2.067	1.620	0.4449	30
LLE	4.311	4.320	4.341	4.276	0.019	-0.535	2.089	2.442	0.2949	30
Δ LOADR	0.019	0.018	0.033	0.004	0.009	-0.193	1.759	2.082	0.3530	30
Δ LLFPR	0.005	0.005	0.016	-0.006	0.005	0.784	4.735	4.773	0.0920	30

Note: Statistics refer to the variables used in the estimable ARDL specification. The common sample is 1995–2024 after constructing first log differences. SD=Standard Deviation; JB=Jarque-Bera.

Table 3. Correlation matrix.

Variable	LFR	LLE	Δ LOADR	Δ LLFPR
LFR	1.000	-0.898	-0.883	0.189
LLE	-0.898	1.000	0.794	-0.111
Δ LOADR	-0.883	0.794	1.000	-0.086
Δ LLFPR	0.189	-0.111	-0.086	1.000

Note: Pairwise Pearson correlations are calculated for the regressors in the estimable specification over 1995–2024.

Table 4. Variance inflation factor results.

Regressor	VIF	Tolerance	Assessment
LFR	9.326	0.107	Moderate
LLE	5.249	0.191	Moderate
Δ LOADR	4.697	0.213	Acceptable
Δ LLFPR	1.090	0.918	Acceptable

Note: VIF values assess linear dependence among the contemporaneous regressors. They do not establish exogeneity or rule out endogeneity arising from simultaneity, omitted variables or measurement error.

Table 5. Unit-root test results.

Variable	ADF level	ADF 1st diff.	ADF 2nd diff.	PP level	PP 1st diff.	PP 2nd diff.	Order
LGDP	-1.021	-5.708**	-7.056**	-1.774	-7.630**	-13.544**	I(1)
LFR	-1.698	-6.109**	-7.673**	-2.364	-6.139**	-15.301**	I(1)
LLE	-1.214	-6.086**	-8.367**	-0.917	-6.614**	-16.093**	I(1)
LOADR	-1.465	-1.594	-3.426**	3.921	-1.520	-4.292**	I(2)
LLFPR	-1.092	-2.823	-5.299**	-0.999	-2.509	-6.419**	I(2)

*Note: ** indicates stationarity at the 5% level using an approximate intercept-only critical value of -2.97. ADF lag lengths are selected by BIC. PP statistics use a Bartlett-kernel Newey West correction. LOADR and LLFPR are shown in their original logged levels to establish their integration orders.*

Table 6. ARDL bounds test.

Test statistic	Value	I(0) bound, 5%	I(1) bound, 5%	Decision
F-statistic	1.449	2.86	4.01	No level relationship

Note: Case III asymptotic critical values for k=4.

Source: Pesaran et al. (2001).

Table 7. ARDL estimation results: ARDL(1,1,1,1,1).

Variable	Coefficient	Std. Error	t-Statistic	Probability
const	7.209	3.142	2.294	0.036
lgdp(-1)	0.905	0.071	12.683	0.000
lfr	0.128	0.174	0.740	0.470
lfr(-1)	-0.194	0.158	-1.224	0.239
lle	0.571	0.664	0.859	0.403
lle(-1)	-1.661	0.686	-2.422	0.028
dloadr	-1.096	0.964	-1.137	0.272
dloadr(-1)	4.905	2.456	1.997	0.063
dllfpr	0.861	1.099	0.784	0.444
dllfpr(-1)	0.491	1.181	0.416	0.683
D1998	-0.133	0.024	-5.501	0.000
D2020	-0.087	0.025	-3.443	0.003

Note: The table follows the reporting format of the reference ARDL paper. These are conditional ARDL coefficients and are not long-run elasticities because the bounds test does not support cointegration.

Table 8. Short-run estimation results.

Variable	Coefficient	Std. Error	t-Statistic	Probability
const	0.051	0.006	9.210	0.000
D(lfr)	0.033	0.152	0.219	0.828
D(lle)	0.847	0.608	1.392	0.178
D2(loadr)	-0.540	0.944	-0.572	0.573
D2(llfpr)	0.951	1.037	0.918	0.369
D1998	-0.127	0.024	-5.345	0.000
D2020	-0.097	0.026	-3.712	0.001

Table 9. Diagnostic and stability test results.

Diagnostic test	Statistic	Probability	Decision at 5%
Jarque-Bera normality	11.279	0.0036	Reject normality
Breusch-Godfrey LM	8.976	0.0112	Serial correlation detected
Breusch-Pagan	8.908	0.6304	Homoskedasticity not rejected
Ramsey RESET	1.310	0.3010	Specification not rejected
CUSUM	Within boundaries	-	Stable
CUSUMSQ	Boundary crossed	-	Unstable

Note: Residual non-normality, serial correlation and CUSUMSQ instability limit strong inference from the conditional ARDL model.

The correlation matrix shows strong negative correlations between LFR and LLE and between LFR and Δ LOADR. Consistent with these correlations, the VIF for LFR is 9.326 and that for LLE is 5.249, indicating notable but not perfect multicollinearity; Δ LOADR records a VIF of 4.697, while Δ LLFPR has a low VIF of 1.090. The values help explain the imprecision of individual demographic coefficients and require cautious coefficient level interpretation. However, VIF is only a collinearity diagnostic. It neither demonstrates that the regressors are exogenous nor resolves potential simultaneity, omitted variable bias or measurement error. The ADF and PP tests provide consistent evidence that LGDP, LFR and LLE are non-stationary at level but stationary

after first differencing; these variables are therefore classified as I(1). In contrast, LOADR and LLFPR remain non-stationary after the first difference and become stationary only after the second difference, indicating I(2) behaviour in their original logged levels. Since the ARDL bounds procedure cannot include I(2) regressors, the estimable specification uses Δ LOADR and Δ LLFPR. These transformations are one order lower than the original series and prevent the I(2) level variables from entering the bounds model directly. The computed F-statistic of 1.449 is below the 5% lower bound of 2.86 and also below the 10% lower bound. The null hypothesis of no level relationship cannot be rejected. Consequently, the data do not support cointegration between real GDP, fertility, life expectancy, changes in old age dependency and changes in labour force participation during 1995–2024. Long-run elasticities and an ECM speed of adjustment coefficient are therefore not reported.

The lagged dependent variable is strongly significant, reflecting persistence in logged real GDP. The lag of life expectancy is negative and significant, while the lag of Δ LOADR is marginally significant at 10%. These individual conditional coefficients do not establish long-run demographic effects because the joint bounds test fails. Both crisis dummies are negative and statistically significant, confirming substantial output disruptions in 1998 and 2020. None of the demographic-change coefficients is statistically significant at the 5% level. Changes in fertility are close to zero, while changes in life expectancy are positive but imprecisely estimated. Accelerations in old age dependency and labour force participation are also insignificant. By contrast, D1998 and D2020 are negative and significant, indicating that the Asian financial crisis and pandemic explain exceptional short-run contractions in real GDP. The evidence therefore does not support a measurable short-run demographic effect within this annual sample. The model does not suffer from detectable heteroskedasticity or RESET functional-form misspecification. However, the residuals are non-normal and serially correlated, and CUSUMSQ indicates instability. These weaknesses reinforce the bounds-test conclusion that a stable long-run demographic relationship should not be claimed from this specification.

Stability figures

CUSUM remains within the 5% boundaries, providing evidence of stability in the recursive coefficient mean. CUSUMSQ crosses a 5% boundary, indicating instability in squared recursive residuals. The model is therefore not fully stable (*Figure 1* and *Figure 2*).

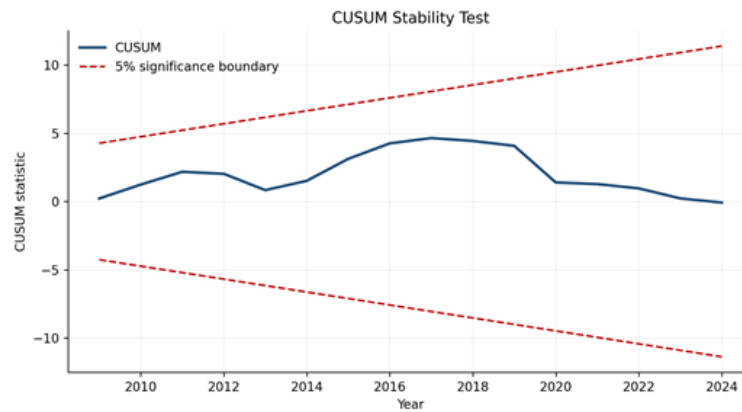


Figure 1. CUSUM test with 5% significance boundaries.

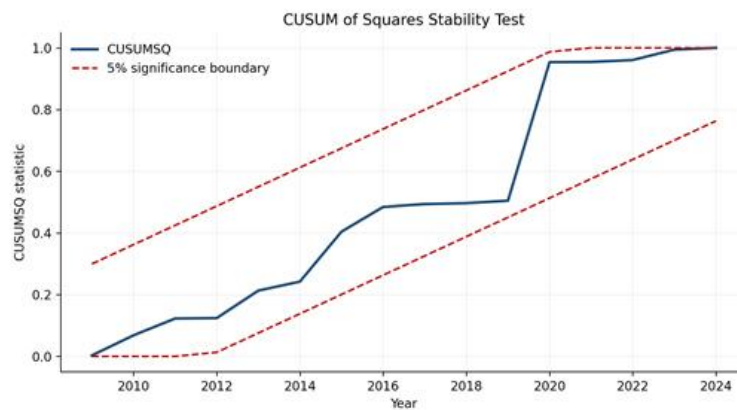


Figure 2. CUSUM of Squares test with 5% significance boundaries.

The absence of cointegration means that real GDP and the selected demographic indicators did not follow a sufficiently stable common long-run path over the 1995–2024 estimation period. This result does not establish that population ageing has no economic consequences. Rather, it indicates that those consequences cannot be identified as a stable equilibrium relationship using the present variables, transformations and small annual sample. Demographic influences may emerge over horizons longer than 30 years and may operate indirectly through capital formation, productivity, healthcare expenditure, migration and education. Lee and Mason (2011) emphasise that age structure affects multiple intergenerational flows, while Bloom et al. (2009) show that demographic dividends depend on complementary economic conditions. Omitting these transmission variables can weaken the direct statistical relationship between aggregate demographic indicators and GDP. The significant crisis dummies demonstrate that large macroeconomic shocks dominate annual movements in real GDP. Residual non-normality and CUSUMSQ instability further suggest that linear parameters may not be constant across crisis and non-crisis periods. Structural break ARDL, rolling estimation or a longer sample may therefore be more informative. The findings should be framed as evidence of non-cointegration rather than converted into unsupported long-run elasticities.

Conclusion

This study examines population ageing and real GDP in Malaysia using logged level data and an ARDL bounds testing approach. To satisfy the integration assumptions, the I(2) logs of old age dependency and labour force participation are entered as first log differences. The bounds F-statistic falls below the lower critical value, providing no evidence of a long-run level relationship. A stationary short-run model also finds no significant demographic coefficient at the 5% level, while the 1998 and 2020 crisis effects are large and significant. The results do not justify the conclusion that fertility, longevity, dependency or participation directly caused changes in Malaysian real GDP during the sample. They instead underline the importance of model specification, integration order and structural instability. Policymakers should continue preparing for population ageing through healthy-ageing initiatives, labour force attachment, reskilling and fiscal planning, but these recommendations arise from the broader demographic literature rather than statistically significant coefficients in this model. Future research should extend the sample, incorporate capital formation, productivity, health expenditure, education and migration, and test explicit structural breaks. Alternative approaches such as ARDL models with break-adjusted critical values or models designed for higher-order integration may clarify whether demographic relationships become visible once structural change and additional transmission channels are considered.

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Conflict of interest

The authors confirm that there is no conflict of interest involved with any parties in this research study.

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