International Journal of Business and Economics
Vol. 7, No. 1, 2022, pp. 186-201

http://ijbe.ielas.org/index.php/ijbe/index
ISSN (online) 2545-4137

https://doi.org/10.5281/zenodo.6596532

EFFECTS OF DEMOGRAPHIC TRANSITION ON JAPAN'S ECONOMIC GROWTH AND INFLATION

Matiur Rahman
Professor of Finance. McNeese State University
Lake Charles, LA 70609
E-mail: mrahman@mcneese.edu

Received: 2022-04-06 Accepted: 2022-04-26 Published online: 2022-05-31

Abstract

This study empirically explores the likely effects of active-age and elderly populations on Japan's real GDP growth and inflation. Annual data from 1986 to 2019 are used to avoid the COVID-19 unusual period. DF-GLS and Ng-Perron unit root tests, ARDL bounds testing procedure for co-integration and associated VECMs are implemented. Unit root tests results display a mixture of I(0) and I(1) behaviors of variables with no I(2) behavior. An ARDL bound testing confirms co-integrating relationship among the variables in both real GDP growth and inflation equations. Their respective associated VECM results reveal relatively fast adjustments toward long-run equilibria. Elderly population shows contractionary effect on real GDP growth, while active-age population reveals, otherwise. In inflation related VECM estimates, both segments of population add to inflationary pressure through respective consumption channels.

Keywords: Demographic Transition, Real GDP, Inflation, Co-integration, Convergence, Causality.
JEL Classification: E 30, E 31, E 32

I. Introduction

Most of the developed countries in the world have been experiencing major demographic transition in several recent decades in term of shrinking working-age population who are in 15 years - 64 years age-group and expanding old-age population in (65 years and above) group. Population in those age groups depicts different consumption, savings and investment behaviors. As a result, they differently influence economic growth and inflation. People in the working-age group relatively spend more on both non-durable and durable goods, save less and borrow more contributing to higher economic growth and acceleration of inflation.

At this stage of the life-cycle, labor productivity is also high with relatively much less health care costs. As people enter retirement age, their consumption needs decline, they pay down accumulated debit, drawdown on past savings and spend more for health care. At this age, labor productivity also falls. As a result, they impede economic growth and create downward inflationary pressure. However, they tend to spend more for consumption out of wealth gains from surging asset prices.

As documented in relatively recent empirical studies, increase in old-age dependency ratio in the absence of further population growth and life expectancy lead to economic stagnation and deflationary tendency. In Japan, old-age population outnumbers working-age population posing fundamental structural economic problems. Consequent depleting workforce, falling labor productivity, declining private consumption, rising precautionary savings, and massive public debt led to economic doldrum and deflation in Japan. To revive economic growth and reignite inflation, the Bank of Japan pursued ultra-low and even negative nominal interest rates policy. But the unusual policy thus far delivered no visible success. For its economic revival, Japan must address the fundamental issue of aging population.

This study empirically explores the effects of working-age population and old-age population on economic growth and inflation in Japan using annual time series data from 1986 to 2019. The remainder of the paper proceeds as follows. Section II dwells on the related literature, in brief. Section III outlines the empirical methodologies. Section IV reports empirical results. Section V concludes with some policy implications.

II. Related Literature, in Brief

The evolving body of important theoretical and empirical literature on the economic effects of aging population lacks a consensus with regard to the various mechanisms through which they impact growth and inflation. Structural aging of the population has profound differing consequences on a country's economic growth across its regions (Albuquerque and Ferreira, 2015). Many economists argue that a country with a higher proportion in the old-age group of population tends to be associated with decreasing productivity levels, lower savings, and higher government spending (Fougere, et al., 2009; Bloom, et al., 2010; Sharpe, 2011; Walder and Doring, 2012). The demographic transition increases the old age dependency ratio, meaning that the smaller working-age group will have to take care of the older age-group (e.g., Lindh, 2004; Navaneetham and Dharmalingam,2012).

Some of the literature argues a negative relationship between population aging and economic growth (e.g., Narciso, 2010; Bloom, et al., 2010; Lisenkova, et al., 2012; Walder and Doring, 2012).

According to the above, individuals' physical capacity, preferences, and needs change due to aging. Thus, the inequality in age structure (a greater proportion in the old-age group) is presumed to adversely affect a country's productivity level. Analyzing the economic consequences of aging in Portugal and focusing on multi-sectoral (or inter-industry) relationships, Albuquerque and Lopes (2010) revealed a negative influence on the value added and employment of Portuguese industries emanating from the changes in the consumption structure due to aging of population.

To add further, private consumption changes have considerable influences on aggregate demand (Walder and Doring, 2012). Population aging also prompts changes in household demand for certain goods (e.g., Bakshi and Chen, 1994; Merette and Georges, 2009; Aguiar, 2011; Walder and Doring, 2012). Changes in the aggregate demand for goods and services as well influence the total productivity level of a country. In fact, the aggregate demand for goods and services is crucial for altering both the production structure and the labor market. They are directly influenced by the changes in age-composition of a country's population.

A country with rising elderly population will face falling or stabilizing demand for property (housing) and higher demand in the stock markets. These are the likely outcomes if older people tend to be higher risk-takers (Bakshi and Chen, 1994). Bakshi and Chen (1994) stressed that the people in retirement age will have fewer responsibilities at the later stages of life. Therefore, they will likely use their income to invest in riskier assets in larger proportion.

In addition to consumption of durable goods, households' consumption of non-durable goods is also expected to drop significantly during the retirement and unemployment period (Aguiar, 2011). Among perishable goods, food expenditure is one of the major forms of expenditure that declines after retirement (Aguiar, 2011; Aguila, et al., 2011). Furthermore, the authors stress that the expenditures on restaurant foods will also fall once individuals are out of their employment. In fact, retirees will replace their outside food consumption with home-cooked food, as they have more leisure time after retirement.

To note, even though an increase in the retirement age will help offset a shrinking labor market, workers of different ages are not perfect substitutes. So, this will likely result in a decline in labor productivity (Lisenkova, et al., 2012). At the same time, the authors reveal that population aging will decrease a country's stock of human capital. In return, they together will exert a negative influence on a country's economic growth (Narciso, 2010; Lisenkova, et al., 2012). An aging population is expected to reduce the supply of labor force leading to shrinking economic growth consequent upon lower productivity levels. Again, higher participation of women in the labor force increases labor productivity, at a cost of lower the fertility rates and declining birth rates (Alders and Broer, 2004).

In recent years, the low levels of inflation in economically advanced countries may be linked to changing demographic structures (e.g., Shirakawa, 2011a, b, 2012, 2013; Bullard, et al. 2012). As a result, a larger proportion of the elderly in advanced economies may make it more difficult to escape the low-inflation trap. The link between demography and inflation may also have significant implications for the conduct of monetary policy. This component of inflation is forecastable. So, it could be taken into account in conducting the monetary policy.

Some studies suggest the existence of a link between inflation and the age-structure of a population, as repeatedly mentioned in Shirakawa (2011a, b, 2012, 2013). The former Governor of the Bank of Japan stated that an aging population could lead to an increase in deflationary pressures, primarily owing to expectations of a slowdown in economic growth. In addition, it may cause a reduction in consumer demand and investment.

A popular and traditional view emerges from the life-cycle hypothesis. As the median age of a population increases, more households finance their consumption from accumulated savings and do not directly contribute to value-addition. Therefore, the discrepancy between aggregate demand and output in the economy rises and demand-driven inflationary pressure develops. At the same time, as the labor supply shrinks, wages are pushed up. This increases cost-push inflation.

Changing consumption preferences with aging lead to declining aggregate demand and consequent lower inflation. Analyzing changing consumption and saving patterns (e.g., Ando and Modigliani, 1963) suggests that net consumer cohort (dependents) drive up real equilibrium interest rate. Net savers, on the contrary, reduce it. This trend was also analyzed by Anderson, et al. (2014). Using the IMF- GIMF Model, they find deflationary pressures stemming from aging, declining GDP growth and falling land prices. Furthermore, empirical research conducted for Germany by Faik (2012) and for sample of OECD countries by Gajewski (2015) show that demographic aging exerts downward pressure on prices.

Bullard, et al., (2012) indicate that a redistributive effect of greater proportion of older people can cause the society to favor lower inflation. They opine that central banks' monetary decisions are influenced by inflationary preferences of dominant voter groups. When the elderly is the dominant group in a society, their tendency to prefer lower inflation rates may lead to the appearance of deflationary pressures. This may likely contribute to low rates of inflation or even deflation.

Another view is that it is not aging per se that causes deflationary or inflationary pressures. According to Katagiri, et al. (2014), the effects of aging may depend on its causes. In their view, aging is deflationary when caused by an increase in longevity. The contrast occurs by a decline in birth rate. They show that over the past 40 years, aging caused yearly deflation of about 0.6 percentage points in Japan.

International Journal of Business and Economics
Vol. 7, No. 1, 2022, pp. 186-201
http://ijbe.ielas.org/index.php/ijbe/index
ISSN (online) 2545-4137

III. Empirical Methodologies

The simple estimating models, in general functional forms, are presented below:

$LRGDP = f(LPASF, LPBSF)$-- (1)

$INF = f(LPASF, LPBSF)$-- (2)

In log-linear forms, equations (1) and (2) are respectively as follows:

$LRGDP_t = \alpha + \beta_1 LPASF_t + \beta_2 LPBSF_t + e_t$ −−−−−−−−−−−−−−−−−−−−−−−−−−−(3)

α>0, β_1<0, β_2>0

$INF = \beta_0 + \beta_3\, LPASF + \beta_4\, LPBSF + u_t$ −−−−−−−−−−−−−−−−−−−−−−−−−−−(4)

β_0>0, β_3<0, β_4>0

Here, LRGDP = log of real GDP, LPASF= log of population above 64 years, LPBSF= log of population in (15 years – 64 years), INF = Inflation rate, e= error-term in equation (3), u= error-term in equation (4) and t= time subscript. Both e and u are independently and identically distributed (iid).

This study employs the linear and unrestricted autoregressive distributed lag (ARDL) bounds testing approach for co-integration invoking (Pesaran and Pesaran 1997; Pesaran, Shin and Smith 2001; Pesaran and Shin 1999). This methodology is preferable to classical co-integration procedures, as developed in (Johansen 1988, 1991; Johansen and Juselius 1990) that require sample period to be very long and all variables to depict I(1) behavior. To state several advantages, the ARDL co-integration approach can be applied regardless of the time series properties of the variables in the sample regardless of its size and to avoid the problem of spurious correlation (Granger and Newbold, 1974). It allows for inferences on long-run estimates from relatively shorter sample period(s) that are not possible under classical co-integration procedures. Furthermore, ARDL model can accommodate greater number of variables in comparison to Vector Autoregressive (VAR) models. This approach is also more flexible with respect to lag-structures since it can accommodate different optimal lags for different variables in the model. Finally, the VECM framework is used to capture the short-run and the long-run dynamics in the system along with the speed of adjustment toward long-run equilibrium originating from any short-run external shocks.

Pre-testing for unit roots in time series variables and determination of first-order integration or I(1) behavior are not required for this procedure because of the assumption that the variables could be I(0) or I(1). However, (Nkoro and Uko 2016) opine that the presence of any I(2) variable(s) may crash the system.

http://ijbe.ielas.org/index.php/ijbe/index
ISSN (online) 2545-4137

So, it is desirable to implement some efficient unit root tests to ensure that no I(2) variable(s) is/are included in the estimating model. Following Elliot et al. (1996), and Ng and Perron (2001), the efficient DF- GLS and Ng–Perron tests are applied in this paper, respectively. The Standard ADF, PP and KPSS tests are not implemented due to their high sensitivity to lag-selection. Moreover, the ARDL approach to co-integration is applied to a single equation. The existence of a long-run relationship between or among the variables is established by testing for the significance of lagged variables in levels in an error-correction mechanism regression. Thus, the first lags of the variables under study in levels are added to the equation to create the error-correction mechanism equation for performing additional test by computing the joint F-test on the significance of all the lagged levels of the variables. The ARDL form of equation is estimated by simple OLS where the optimal lag-lengths are selected by Akaike (1969) Information Criterion (AIC). AIC is a measure of relative quality of a statistical model dealing with the trade-off between goodness of fit and complexity of the model. Smaller AIC- value indicates a better fit and minimum loss of information (Burnham and Anderson, 2002).

There are several ways for ascertaining the ARDL co-integration. In this paper, linear ARDL representations for co-integrating relationship are implemented as follows:

$$\Delta LRGDP_t = \alpha_1 + \sum_{i=1}^{n} \beta_i \Delta LRGDP_{t-i} + \sum_{i=0}^{n} \pi_i \Delta LPASF_{t-i} + \sum_{i=0}^{n} \Omega_i \Delta LPBSF_{t-i} + \psi LRGDP_{t-1} + \gamma LPASF_{t-1} + \theta LPBSF_{t-1} + \omega_t \text{ ---------------- } (5)$$

$$\Delta INF_t = \alpha_2 + \sum_{i=1}^{n} \alpha_i \Delta INF_{t-1} + \sum_{i=0}^{n} \gamma_i \, LPASF_{t-i} + \sum_{i=0}^{n} \varepsilon_i \, \Delta LPBSF_{t-i} + \pi INF_{t-1} + \phi LPASF_{t-1} + \delta LPBSF_{t-1} + \gamma_t \text{ ------------- } (6)$$

Where, Δ stands for the first difference operator, 't' is the time subscript, 'i' is the lag indicator and ω and γ are the error terms with assumed standard i.i.d. properties.

Null hypothesis for no co-integration in equation (5)

$$H_0: \psi = \gamma = \theta = 0$$

Alternative hypothesis for co-integration:

$$H_A: \psi \neq \gamma \neq \theta \neq 0$$

For equation (6), $H_0: \pi = \phi = \delta = 0$, $H_A: \pi \neq \phi \neq \delta \neq 0$

Since each of the above is a single equation, endogeneity is less of a problem because it is free of residual correlation. Furthermore, ARDL technique provides unbiased estimates of the long-run model (Harris and Sollis 2003). This study applies the modified F-test, provided by Pesaran, Shin and Smith (2001). They also provided tables with two critical values related to the lower I(0) and upper I(1) bounds for co-integration tests. For I(2) behavior of any variable, the system crashes (Harris and Sollis, 2003). If computed F-value exceeds the upper bound I(1) critical value at a given level of significance, the null hypothesis of no co-integration is rejected.

When it is below the lower bound I(0) critical value, there is no evidence of co-integration. In case, it falls within the band of the above critical values, the evidence is inconclusive on the presence of co-integration.

On the evidence of co-integrating relationship among the variables, the associated vector error-correction models (VECMs) are estimated to examine the short-run dynamics, long-run convergence and the speed of adjustment towards the long-run equilibrium. The associated general vector error-correction models following Engle and Granger (1987) are specified below:

$$\Delta LRGDP_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta LRGDP_{t-i} + \sum_{i=0}^{n} \pi_i \Delta LPASF_{t-i} + \sum_{i=0}^{n} \Omega_i \Delta LPBSF_{t-i} + \mu EC_{t-1} + \omega_t \dots\dots\dots\dots\dots\dots\dots\dots (7)$$

$$\Delta INF_t = \alpha_0 + \sum_{i=1}^{n} \gamma_i \Delta INF_{t-i} + \sum_{i=0}^{n} \varepsilon_i \Delta LPASF_{t-i} + \sum_{i=0}^{n} \delta_i \Delta LPBSF_{t-i} + \mu' EC_{t-1} + \nu_t \dots\dots\dots\dots\dots\dots\dots (8)$$

Where, EC_{t-1} = error-correction term, and ω_t and ν_t= residual terms in equations (7) and (8), respectively.

The estimated coefficient $(\hat{\mu})$ or $(\hat{\mu}')$ of the error-correction term (EC_{t-1}) is expected to be negative for long-run convergence and long-run causal flows, amid short-run fluctuations arising from positive or negative external shocks. The significance of this coefficient is ascertained by the associated pseudo t-value. If the short-run coefficients are non-zeros, the lagged changes in LRGDP, INF, LPASF and LPBSF lead the current change in LRGDP and INF in the short run. Their relative numerical magnitudes would indicate relative strength of short-run influences of the relevant explanatory variables on the dependent variable. The sum of the coefficients of each lagged independent variable would show the net interactive feedback effect with other variables.

For parameter stability, the CUSUM and the CUSUM-Squares tests are performed with 5% confidence interval following Pesaran and Pesaran (1997). Often, they provide contradictory findings depending on whether the structural break occurs in the intercept or in the slope. The CUSUM test has relatively higher power for the structural break in the intercept. In case it occurs in the slope, the CUSUM-Squares test has relatively higher power.

Annual data from 1986 to 2019 prior to the COVID-19 pandemic are used for this empirical investigation since the economy of Japan has been in contractionary mode during this period. Data sources include World Development Indicators and

International Financial Statistics, published by the World Bank and the International Monetary Fund (IMF), respectively.

IV. Empirical Results

To ascertain the non-stationarity of each variable and to ensure that no variable is I(2), efficient DF-GLS (Elliot, et al., 1996) and Ng-Perron (Ng and Perron, 2001) unit root tests are implemented in lieu of standard PP (Phillips and Perron, 1988) and KPSS (Kwiatkowski, et al., 1992) tests for their super-sensitivity to lag-selections. The test results are reported as follows:

Table 1: **Unit Root Test**

Dickey-Fuller Generalized Least Square (DF-GLS)

Variable	Levels		First Difference	
	Without Trend	With Trend	Without Trend	With Trend ***
LRGDP	-61346**	-6.2882***	-10.2491**	-10.351***
INF	-6.1053***	-6.3320***	-0.0738	-10.211***
LPASF	-2.4626**	-2.7353*	-1.2450	-1.0131.
LPBSF	-0.6506	--1.1507	- 5.0204***	-5.68012***

NG-Perron

Variable	Levels		First Difference	
	Without Trend	With Trend	Without Trend	With Trend
LRGDP	1.3838	-3.4834**	-1.38385	4.8712***
INF	1.3322	4.9415***	17.932***	6.7291***
LPASF	6.6450***	10.2215***	11.7799***	17.2585***
LPBSF	0.5108	3.2226**	7.66604***	8.3380.***

Note: *, ** and *** denote non-stationarity at 10%, 5% and 1% significance levels, respectively. Where, LRGDP = log real GDP; INF = Inflation Rate; LPASF = log of population over sixty-four years; LPBSF = log of population in (15 years – 64 years).

The above unit root tests results display non-stationarity of three variables except LPBSF (active age population in the (15-64) age-group both with and without trend at 1% or 5% or 10% level of significance, as shown above in the note. On first-differencing, however, there is a mixed picture of I(0) and I(1) behaviors of the variables at varying levels of significance with no variable depicting I(2) behavior. In view of the above evidence, ARDL bounds testing for co-integration is implemented, next.

Bounds testing results for co-integration of real GDP equation (5) are reported as follows:

Table 2 (a)ARDL Long-Run Form and Bounds Test
Dependent Variable: Δ(LRGDP)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.66E+79	3.70E+79	0.000000	0.0000
LRGDP(-1)	-2.131061	0.406918	-5.237077	0.0000
LPASF(-1)	-3.20E+71	4.27E+71	0.000000	0.0000
LPBSF(-1)	-9.95E+71	4.41E+71	0.000000	0.0000
Δ(LRGDP(-1))	1.282461	0.319069	4.019386	0.0007
Δ(LRGDP(-2))	0.748886	0.232358	3.222982	0.0043
Δ(LRGDP(-3))	0.334668	0.161802	2.068371	0.0518
Δ(LPASF)	1.70E+72	1.47E+73	0.000000	0.0000
Δ(LPASF(-1))	-1.50E+73	2.11E+73	0.000000	0.0000
Δ(LPASF(-2))	9.61E+73	2.02E+73	0.000000	0.0000
Δ(LPASF(-3))	-7.54E+73	1.63E+73	0.000000	0.0000
Δ(LPBSF)	-4.73E+71	2.79E+72	0.000000	0.0000
Δ(LPBSF(-1))	2.59E+72	3.48E+72	0.000000	0.0000
Δ(LPBSF(-2))	-1.45E+73	3.60E+72	0.000000	0.0000
Δ(LPBSF(-3))	8.56E+72	2.44E+72	0.000000	0.0000

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	13.03704	10%	2.63	3.35
k	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

As observed in Table 2(a), the coefficients of LRGDP (-1), LPASF (-1) and LPBSF (-1) in levels are non-zeros. Hence, the null hypothesis of no-cointegration ($H_0: \psi = \gamma = \theta = 0$) is rejected. In addition, the computed F-statistic at 13.03704 is exorbitantly higher than the upper-bound critical values at the aforementioned levels of significance. This is a clear rejection of the null hypothesis of no co-integration. Subsequently, the associated VECM (7) is estimated.

The associated vector error-correction model (7) estimates are reported as follows:

Table 2 (b) VECM Estimates
Dependent Variable: Δ(LRGDP)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Δ(LRGDP(-1))	1.282461	0.244838	5.237998	0.0000
Δ(LRGDP(-2))	0.748886	0.181811	4.119031	0.0005
Δ(LRGDP(-3))	0.334668	0.135384	2.471985	0.0225
Δ(LPASF)	1.70E+72	1.13E+73	0.000000	0.0000
Δ(LPASF(-1))	-1.50E+73	1.94E+73	0.000000	0.0000
Δ(LPASF(-2))	9.61E+73	1.82E+73	0.000000	0.0000
Δ(LPASF(-3))	-7.54E+73	1.09E+73	0.000000	0.0000
Δ(LPBSF)	-4.73E+71	2.15E+72	0.000000	0.0000
Δ(LPBSF(-1))	2.59E+72	2.87E+72	0.000000	0.0000
Δ(LPBSF(-2))	-1.45E+73	2.76E+72	0.000000	0.0000
Δ(LPBSF(-3))	8.56E+72	1.84E+72	0.000000	0.0000
EC_{t-1}	-2.131061	0.275187	-7.744055	0.0000

R-Squared	0.823415	F= 41.04
Adjusted R-squared	0.766986	AIC=4.61251

As observed in Table 2(b), the coefficient of the error-correction term (EC_{t-1}) has again the expected negative sign showing convergence toward long-run equilibrium. Its absolute numerical value at 2.131061 is overly significant in term of the associated pseudo t-value at 7.7441. This indicates complete adjustment toward long-run equilibrium in less than half a year (12 months / 2.1311). For short-run dynamics, an increase in the population in the age-group of 65 years and above unleashes net negative influences on real GDP growth. In contrast, an increase in the active-age population exerts net positive impact on real GDP growth reflecting demographic dividend.R^2 at 0.77 shows that 77% of the change in real GDP growth is due to the above factors. F-statistic at 41.04 confirms overall significance of the estimated model. AIC value at 4.61 reveals that optimum lag-lengths entail minimum information loss. In Appendix-A, figures (1) and (2) show some instability in the parameters both in terms of CUSUM and CUSUM-squares tests that use 5% critical band.

ARDL bounds test results for co-integration of inflation equation (6) are reported below:

Table 3 (a) ARDL Long-Run Form and Bounds Test				
Dependent Variable: Δ(INF)				
Conditional Error Correction Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.76E+54	2.07E+53	0.000000	0.0000
INF(-1)*	-3.195298	0.250817	-12.73954	0.0000
LPASF(-1)	3.34E+46	3.30E+45	0.000000	0.0000
LPBSF(-1)	9.38E+45	1.63E+45	0.000000	0.0000
Δ(INF(-1))	1.365467	0.185978	7.342099	0.0000
Δ(INF(-2))	0.709916	0.132060	5.375701	0.0000
Δ(INF(-3))	0.274421	0.084656	3.241590	0.0041
Δ(LPASF)	1.96E+47	6.21E+46	0.000000	0.0000
Δ(LPASF(-1))	8.38E+46	1.06E+47	0.000000	0.0000
Δ(LPASF(-2))	1.61E+47	7.56E+46	0.000000	0.0000
Δ(LPBSF)	8.37E+46	1.58E+46	0.000000	0.0000
Δ(LPBSF(-1))	1.52E+47	2.13E+46	0.000000	0.0000
Δ(LPBSF(-2))	1.47E+47	1.68E+46	0.000000	0.0000
Δ(LPBSF(-3))	1.12E+47	1.33E+46	0.000000	0.0000
F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	59.23577	10%	3.17	4.14
k	2	5%	3.79	4.85
		2.5%	4.41	5.52
		1%	5.15	6.36

Table 3(a) pertaining to estimates of equation (6) show that none of the coefficients of INF (-1), LPASF (-1) and LPBSF (-1) is zero. So, the null hypothesis of no co-integration ($H_0: \pi = \phi = \delta = 0$) is rejected. At the same time, the computed F-statistic at 59.23577 is far above the upper bound critical values at all the above levels of significance. This isa clear affirmation of co-integrating relationship among variables. As a result, the associated vector error-correction model (8) is estimated.

The estimates of the associated vector error-correction model (8) are as follows:

Table 3(b) ARDL Error Correction Regression
Dependent Variable: Δ(INF)

ECM Regression
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.76E+54	1.29E+53	0.000000	0.0000
Δ(INF(-1))	1.365467	0.164743	8.288443	0.0000
Δ(INF(-2))	0.709916	0.114745	6.186890	0.0000
Δ(INF(-3))	0.274421	0.075134	3.652406	0.0016
Δ(LPASF)	1.96E+47	5.48E+46	0.000000	0.0000
Δ(LPASF(-1))	8.38E+46	9.81E+46	0.000000	0.0000
Δ(LPASF(-2))	1.61E+47	6.91E+46	0.000000	0.0000
Δ(LPBSF)	8.37E+46	1.28E+46	0.000000	0.0000
Δ(LPBSF(-1))	1.52E+47	1.89E+46	0.000000	0.0000
Δ(LPBSF(-2))	1.47E+47	1.45E+46	0.000000	0.0000
Δ(LPBSF(-3))	1.12E+47	1.22E+46	0.000000	0.0000
EC_{t-1}	-3.195298	0.228540	-13.98135	0.0000
R-squared 0.638589		Adjusted R-.607883		F= 16.60
				AIC=3.84516

As observed in Table 3(b), the coefficient of the error-correction term (EC_{t-1}) has the expected negative sign indicating convergence toward long-run equilibrium. The absolute numerical magnitude of the coefficient at 3.195298 is statistically highly significant in term of the associated pseudo t-value at 13.98 in absolute term. This also shows that the complete adjustments take less than four months (12 months/3.20). For the short-run, increases in aging and the active-age populations feed into higher inflation with interactive positive feedback effect. So, the inference that elderly population dampens inflation is not necessarily true. R^2at 0.61 shows that 61% of the change in inflation rate is due to changes in explanatory variables. F-static at 16.60 indicates overall significance of the estimated model. Low value of AIC at 3.85 shows minimum loss of information for optimum lag-lengths. In Appendix-B, figure (1) shows some parameter instability during the Great Recession. At the same time, figure (2) suggests parameter stability within the 5% critical band.

V. Conclusions with Some Policy Implications

To sum up, efficient DF-GLS and Ng-Perron unit root tests reveal a mixed picture of I(0) and I(1) variables with no I(2) variable. ARDL bounds testing for real GDP growth and inflation equations confirm co-integrating relationship among the variables.

The estimates of the associated vector error-correction model for real GDP growth indicate relatively rapid adjustments for convergence toward long-run equilibrium. There are evidences of contractionary effects of aging on real GDP growth, while active-age population has expansionary effect on the above. The estimates of the VECM for inflation indicate even faster adjustments toward long-run equilibrium. However, surges in both groups of population add to inflationary pressure.

To mitigate current economic problems of low growth and low inflation, Japan should strive to solve the problem of shrinking workforce by allowing more in-migration of upscaled foreign labor at least in the short run. At the same time, Japan should come up with long-term high population growth strategies offering a wide variety of fiscal and financial incentives on the domestic front. In closing, shrinking labor force due to declining fertility rate and aging population poses a serious economic challenge to Japan's policymakers.

REFERENCES

Aguiar, M. (2019). Consumption versus Expenditure. *Journal of political economy*, 113, 919-948. Retrieved from https://www.journals.uchicago.edu/doi/10.1086/491590

Aguila, E., Attanasio, O. and Meghir, C. (2011). Changes in Consumption at Retirement: Evidence from Panel Data.*The Review of Economics and statistics*, 93, 1094-1099.
Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5293287/

Akaike, H. (1969). Fitting autoregressive for prediction. Annals on the Institutes of Statistical Mathematics, 21.243-247.
Retrieved from https://www.ism.ac.jp/editsec/aism/pdf/021_2_0243.pdf

Albuquerque, P.C. and Ferreira, J. (2015). Envelhecimento, emprego e remuneracoesnasregioesportuguesas: umaanalise shift-share – Ageing, Employment and Remunerations in Portuguese Regions: A Shift-Share Analysis. EURE, 41 (122), 239-260.
Retrieved from https://www.scielo.cl/scielo.php?script=sci_abstract&pid=S0250-71612015000100011&lng=n&nrm=iso

Albuquerque, P.C. and Lopes, J.C. (2010). Economic Impacts of Ageing: An Inter-Industry Approach." *International Journal of Social Economics*, 37(12), 970-986. Retrieved from https://ideas.repec.org/p/ise/isegwp/wp12010.html

Alders, P. and Broer, D.P. (2004). Aging, Fertility, and Growth. *Journal of Public Economics*, 89, 1075-1095.
Retrieved from
https://econpapers.repec.org/article/eeepubeco/v_3a89_3ay_3a2005_3ai_3a5-6_3ap_3a1075-1095.htm

Anderson D., Botman, D., & Hunt, B. (2014). Is Japan's Population Ageing Deflationary? IMF Working Paper 14/139, August.
Retrieved from https://www.imf.org/external/pubs/ft/wp/2014/wp14139.pdf

Ando, A., & Modigliani, F. (1963). The 'Life-Cycle' Hypothesis of Saving: Aggregate Implications and Tests. *American Economic Review*, 53(1), 55-84. Retrieved from https://www.jstor.org/stable/pdf/1817129.pdf

Bakshi, G.S. and Chen, 2. (1994). Baby Boom, Population Aging and Capital Markets. *Journal of Business*, 67 (2), 165-202. Retrieved from https://www.jstor.org/stable/2353102?seq=1

Bloom, D.E., Canning, D, and FINK, G. (2010). Implications of Population Aging for Economic Growth. *Oxford review of Economic Policy*, 26, 583-612. Retrieved from https://econpapers.repec.org/article/oupoxford/v_3a26_3ay_3a2010_3ai_3a4_3ap_3a583-612.htm

Bullard, J. Garriga, C., & Walker, C.J. (2012). Demographics, Redistribution, and Optimal Inflation. *Federal Reserve Bank of St. Louis Review*, 94(6), 419-439. Retrieved from https://files.stlouisfed.org/files/htdocs/publications/review/12/11/Bullard.pdf

Elliot, G., Rothenberg, T.J., and Stock, J. H. (1996). Efficient test for an autoregressive unit root.Econometrica, 64: 813-836. Retrieved from https://www.jstor.org/stable/2171846?seq=1

Engle, RF-and Granger, C.W. J. (1987). Co-integration and error-correction representation, estimation and testing.Econometrica, 55: 251-276. Retrieved from https://www.jstor.org/stable/1913236?seq=1

Faik, J. (2012). Impacts of an Aging Society on Macroeconomics and Income Inequality-the Case of Germany since the 1980s. Society for the Study of Economic Inequality Working Paper Series No. 2012-272, Society for the Study of Economic Inequality, Verona. Retrieved from http://www.ecineq.org/milano/WP/ECINEQ2012-272.pdf

Fougere, M., et al. (2009). Population Ageing, Time Allocation and Human Capital: A General Equilibrium Analysis for Canada. *Journal of Economic Modelling*, 26, 30-39. Retrieved from https://econpapers.repec.org/article/eeeecmode/v_3a26_3ay_3a2009_3ai_3a1_3ap_3a30-39.htm

Gajewski, P. (2015). Is Ageing Deflationary? Some Evidence from OECD Countries. Applied Economics Letters, 221(11), 916-919. Retrieved from https://www.tandfonline.com/doi/full/10.1080/13504851.2014.987911

Granger, C.E.J. and Newbold, P. (1974). Spurious regressions in econometrics. Journal of Econometrics, 2: 111-120. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.353.2946&rep=rep1&type=pdf

Harris, R. and Sollis, R. (2003). Applied time series, modeling and forecasting. John Wiley and Sons, Chichester, U.K.

Johansen, S. (1988). Statistical analysis of co-integration vectors. Journal of Economic Dynamics and Control, 12: 231-254. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/0165188988900413

Johansen, S. (1991). Estimation and Hypothesis testing of co-integration vectors in gaussian vector autoregressive models.Econometrica, 59(6): 1551-1580. Retrieved from https://www.jstor.org/stable/pdf/2938278.pdf

Johansen, S. and Juselius, K. (1990). Maximum likelihood estimation and interference on co-integration with application to the demand for money. Oxford Bulletin of economics and Statistics, 52: 169-210.
Retrieved from https://econpapers.repec.org/article/blaobuest/v_3a52_3ay_3a1990_3ai_3a2_3ap_3a169-210.htm

Katagiri, M., Konishi, H., & Ueda, K. (2014). Aging and Deflation from a Fiscal Perspective. Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute, Working Paper No. 218.
Retrieved from https://www.dallasfed.org/~/media/documents/institute/wpapers/2014/0218.pdf

Kwiatkowski, D., Phillips, P.C.B. Schmidt, P., and Shin, (1992). Testing the null hypothesis of stationarity against the alternative of a unit root.Journal of Econometrics, 54: 159-178.
Retrieved from https://cowles.yale.edu/sites/default/files/files/pub/d09/d0979.pdf

Lindth, T. (2004, February). Is Human Capital the Solution to the Ageing and Growth Dilemma?*OeNB workshop*.
Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8390542/

Lindth, T. and Malmberg, B (2009). European Union Economic Growth and the Age Structure of the Population. *Economic Change and Restructuring*, 42, 159-137. Retrieved from https://www.jstor.org/stable/43755167?seq=1

Lisenkova, K., Merette, M. and Wright, R. (2012). Population Aging and the Labor Market: Modelling Size and Age-specific Effects". *Economic Modelling*, 35, 981-989. Retrieved from https://strathprints.strath.ac.uk/45315/

Mackinnon, J. G. 1991. Critical Values for Co-integration Tests. In *Long-Run Economic Relationships*: *Readings in Integration*, edited by R. F. Engle and C.W. J. Granger, 267-276. Oxford, UK: Oxford University Press.

Merette, M. and Georges, P. (2009). Demographic Changes and the Gains from Globalization: A Multi-Country Overlapping Generation CGE Model, *Department of Economics Working Papers No. 0903*, University of Ottawa. Retrieved from https://sciencessociales.uottawa.ca/economics/sites/socialsciences.uottawa.ca.economics/files/0903E.pdf

Narciso, A. (2010). The Impact of Population Aging on International Capital Flows. *MPRA Paper*, 26457. Retrieved from https://www.jstor.org/stable/43755167?seq=1

Navaneetham, K. and Dharmalingam, A. (2012). A Review of Age Structural Transition and Demographic Dividend in South Asia: Opportunities and Challenges. *Journal of Population Ageing*, 5, 281-298.
Retrieved from https://research.monash.edu/en/publications/a-review-of-age-structural-transition-and-demographic-dividend-in

Ng, S. and Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power.Econometrica, 64: 813- 836.
Retrieved from http://www.columbia.edu/~sn2294/pub/ecta01.pdf

Pesaran, H. M. and Shin, Y.(1999). An autoregressive distributed lag – Modeling approach to co-integration analysis, in econometrics and economic theory in the 20th century. The Ragnar Frish Centennial Symposium, S. Strom Ed. Cambridge University Press, U.K., 371-413.

Pesaran, H. M., Shin, Y. and Smith, R.J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3): 289-326. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1002/jae.616

Pesaran, H.M. and Pesaran, B. (1997). Working with microfit 4.0interactive econometric analysis. Oxford University Press, U. K.

Sharpe, A. (2011). Is Aging a Drag on Productivity Growth? A Review Article on Aging, Health and Productivity: The Economics of Increased Life Expectancy. *International productivity Monitor*, 21, 82-94.
Retrieved from https://ideas.repec.org/a/sls/ipmsls/v21y20115.html

Shirakawa, M. (2011a, June 1). Bubbles, Demographic Change and Natural Disasters. Opening Speech at 2011 Annual International Conference hosted by the Institute for Monetary and Economic Studies, the Bank of Japan.
Retrieved from https://www.bis.org/review/r110606c.pdf

Shirakawa, M. (2011b, December 22). Globalization and Population Aging: Challenges Facing Japan. Speech to the Board of Councilors of Nippon Keidanren.
Retrieved from
https://www.boj.or.jp/en/announcements/press/koen_2011/data/ko111222a1.pdf

Shirakawa, M.(2012, May 30). Demographic Changes and Macroeconomic Performance: Japanese Experiences. Opening Remark at 2012 BOJ- IMES Conference hosted by the Institute for Monetary and Economic Studies, the Bank of Japan. Retrieved from https://www.imes.boj.or.jp/research/papers/english/me30-2.pdf

Shirakawa, M. (2013, February 28). Toward Strengthening the Competitiveness and Growth Potential of Japan's Economy. Speech at the Executive Member Meeting of the Policy Board of Nippon Keidanren Tokyo.
Retrieved from https://www.bis.org/review/r130315a.pdf

Walder, A.B. and Doring, T. (2012). The Effect of Population Ageing on Private Consumption – a Simulation for Austria Based on Household Data up to 2050. *Eurasian Economic Review*, 2, 63-80.Retrieved from
https://econpapers.repec.org/article/spreurase/v_3a2_3ay_3a2012_3ai_3a1_3ap_3a63-80.htm