The impact of population ageing on economic growth in developing countries: Panel ARDL evidence

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SUMMARY

The study aims to analyze the economic effects of population ageing in Japan, Spain, Italy, the United States, South Korea, Germany, France, the United Kingdom, and Canada using the panel ARDL (Autoregressive Distributed Lag) model. GDP per capita was adopted as the dependent variable, while the independent variables included the proportion of the population over 65, health expenditure, the dependency rate, and the level of investment as a proportion of GDP. The results showed varying effects of ageing on economic growth. It had a positive impact in some of the countries under study (the USA, South Korea, and Germany) and a negative impact in others (Spain, Italy, and Japan). Health spending was also found to be an economic burden, while fixed investment was shown to be critical in supporting economic growth. The study recommends improving education and training to increase productivity, embracing innovation and technology, enhancing health systems through preventive care, and implementing flexible policies, such as encouraging women's participation in the labour market and promoting migration.

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1. Introduction

Population ageing is one of the major challenges facing advanced economies worldwide. As populations age and life expectancy increases, the proportion of older persons increases significantly, transforming the demographic structure of societies with profound economic implications. Major countries such as Japan, Spain, Italy, the United States, South Korea, Germany, France, the United Kingdom and Canada face increasing pressure on pension and healthcare systems due to the increasing number of retirees versus the decline in the proportion of young people working. The economic effects of old age are reflected in several aspects, most notably the decline in the workforce, which affects productivity and economic growth, and the increase in government spending on health care and pensions, in addition to the worsening financial burdens on social security funds, which are under pressure to finance pensions. The demographic transition also requires long-term strategies to manage

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resources and mitigate the economic impact, prompting many countries to develop special policies, including raising the retirement age, encouraging migration to bring in young workers, and promoting digital health policies and technological innovations to compensate for workforce shortages and reduce care costs. In light of these challenges, major countries seek to adapt their economic policies to address the effects of ageing, maintain the sustainability of economic growth, and ensure a decent standard of living for all members of society. Thus, the study and analysis of the economic effects of ageing are vital issues for these countries' economic future.

The main problem related to the economic effects of ageing in major countries is how to balance economic growth and ensure the well–being of the elderly in light of the decline of the workforce and the increase in financial pressures on pension and healthcare systems. Policymakers face challenges in financing these systems without compromising living standards, which requires solutions such as migration policies, encouraging employment for the elderly, and supporting technological innovation to reduce costs and increase productivity, considering the different effectiveness of these solutions between countries.

The purpose of this work is to analyze the economic impacts of ageing in Japan, Spain, Italy, USA, South Korea and Germany using a dynamic panel model where per capita GDP is the dependent variable and the following are independent variables: the percentage of population over 65 years of age, health expenditure (public expenditure on healthcare as a percentage of GDP), age dependency ratio (number of dependent persons per person of working age), the level of investment as a percentage of GDP (as a controlling variable). The research gap or added value of focusing on the economic impacts of ageing in Japan, Spain, Italy, the United States, South Korea, Germany, France, the United Kingdom and Canada is to explore how the impact of ageing on growth differs as a function of the health expenditure and the level of investment in each country. Japan, Germany, the United States, Italy, South Korea, Spain, France, the United Kingdom, and Canada were chosen as the study sample based on the high rates of population ageing to examine the economic implications of this phenomenon. Among them, Japan is the oldest country in the world, with 28% of population at the age of 65 years and above, while Germany and Italy have more than 22% and 23% respectively. In Spain, there is also an observed trend of having a similar position in the future. South Korea is one of the countries that experience an unexpectedly fast rate of ageing, which makes it an interesting case to examine the economic impacts of ageing in the context of rapid demographic changes. US has a more heterogeneous population but it also has a slowly rising proportion of elderly population. France is among the European countries with increasing ageing rates with 21% of population over 65 years and has a strong social welfare system; hence it is important to examine the effects of ageing on public finance and social security nexus within this context. Despite having a lower rate of ageing than Germany and Italy the UK have a small but rising elderly population, and a rather different economic environment, with more flexible market policies, enabling comparisons of the impact of ageing in different economic models. Among developed countries, Canada has the highest percentage of elderly population, with more than 19% of people over 65 years of age, it has a well-developed healthcare system and strong social support programs, hence it is crucial to examine Canada as a model for the sustainability of social welfare systems in light of ageing. Choosing these countries enables a comprehensive understanding of the phenomenon across geographical regions, as well as different economic and social systems and hence the impact of ageing on the global economy can be understood in a more detailed manner.

2. Previous studies review

Different results are obtained by previous studies on the economic impacts of demographic shifts based on models and analytical approaches used. Most of the studies have indicated that ageing leads to a decline in productivity and economic growth due to a decline in working age population (Aksoy et al., 2019). A study of Peterson (2017) pointed out that low savings rates will lead to low investments which in turn will affect the growth of the economy. Meanwhile Mihajlović and Miladinov (2024) assessed the effect of ageing on emerging economies and reported that an increase in the number of elderly people leads to a negative growth rate of GDP per capita of 0.52%, and that increasing capital formation and savings can help to reduce the impacts of the negative trends. Other studies, for instance, Mitra and Abedin (2021) investigated the link between ageing and FDI flows in the OECD countries and presented rather ambiguous results. Nagarajan et al. (2017) looked at indirect channels, such as consumption and saving, and called for further work in developing countries. Using data from 142 countries. Lee and Shin (2019) found that the adverse impact is only evident when the proportion of elderly is high. Bloom et al. (2010) pointed out that low fertility and higher women's economic activity could partly offset the impacts of ageing in some countries. Acemoglu and Restrepo (2017) suggested that the rapidly ageing nations may gain from higher productivity due to the rapid development of automation, a result which is also supported by Lee et al. (2020) in the case of Japan and Korea. In light of the study conducted by Çiftçi et al. (2023) it can be concluded that the economic growth in OECD countries is negatively influenced by the elderly dependency ratio, while the working-age population has a positive impact on growth. Bawazir et al. (2020) have noted that in the Middle East, middle–aged and elderly workers contribute to economic growth, while the youth dependency ratio negatively affects growth, increasing the role of women in the workforce for a more sustainable economy.

3. Ageing reality in selected developing countries under study

Population ageing is one of the most important economic challenges in developed countries (Bloom et al., 2010), including Japan, Spain, Italy, the United States, South Korea, Germany, France, the United Kingdom and Canada. An upward trend in the population aged 65 and above is clearly demonstrated in Figure 1. The phenomenon of population ageing significantly impacts each country's labour force, productivity, social welfare systems, and healthcare system. In response, countries have adopted various policies and strategies to address these challenges. The following is a detailed country–by–country analysis.

Japan is the world's oldest country, with over 30% of its population aged 65 and above. This demographic shift has led to a shrinking workforce, lower productivity, and slower economic growth (Harada, 2012). It has also placed considerable strain on healthcare and social security systems. The growing number of retirees relative to taxpayers increases the burden on pension funds and public health expenditures. To mitigate these issues, Japan has raised the retirement age, promoted technological solutions to address labour shortages, and encouraged the employment of older individuals. Additionally, it is investing in digital health innovations to reduce long–term care costs.

Spain is also witnessing a rising proportion of elderly citizens, exerting pressure on both its healthcare and pension systems (Navarro–García and Sarria–Santamera, 2023). With the

number of retirees expected to continue increasing until 2050, social spending is becoming unsustainable. Youth unemployment remains high, limiting the workforce's capacity to support the pension system. Low birth rates further exacerbate labour shortages. In response, Spain is implementing pension reforms, including raising the retirement age and restructuring the pension system (OECD, 2022). The government is also promoting family support programs to encourage higher birth rates.

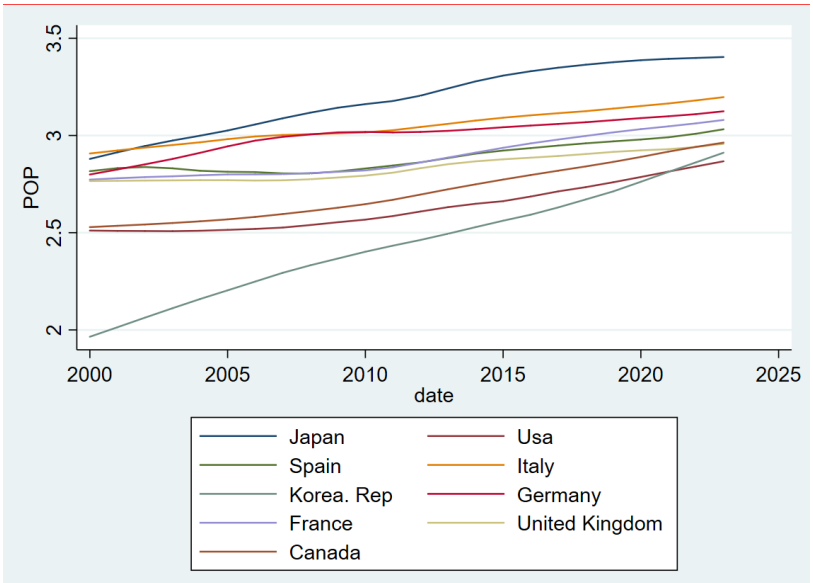

Figure 1. *Population aged 65 and above (% of total population)*

Italy is facing a dramatic increase in the elderly population, contributing to falling productivity and greater pressure on its pension system. With one of the world's lowest birth rates, the demographic imbalance is deepening (Mazzola et al., 2016).The pension system imposes heavy economic and social costs, while increasing reliance on healthcare services strains the public budget. Italy is introducing pension reforms, raising the retirement age, and encouraging higher birth rates through family support initiatives. It is also seeking to attract young foreign workers to address labour market needs.

South Korea is experiencing one of the fastest ageing populations due to a steep decline in birth rates. This trend has led to labour shortages and mounting pressure on the pension system (Han et al., 2023). The country heavily depends on public funds to finance healthcare, creating financial challenges as demand rises. To counteract this, South Korea has introduced family support programs, such as subsidies for education and childcare, to boost fertility rates. It also promotes employment among older individuals and invests in healthcare technologies.

While the United States faces a less severe ageing trend compared to countries like Japan or Germany, it is still encountering significant challenges in sustaining its pension and healthcare systems as life expectancy rises. Migration has partially offset the impact by contributing to population growth and labour supply. However, the ageing population continues to increase pressure on health and social services. In response, the U.S. government is implementing healthcare reforms, supporting immigration to sustain workforce levels, and working on social security reforms to ensure the system's long–term viability.

Germany is among the most rapidly ageing countries in Europe, resulting in serious labour shortages and escalating pension and healthcare costs. The growing number of retirees is putting intense pressure on public finances. In response, Germany is promoting migration policies to attract young workers and encouraging the employment of older adults through flexible retirement schemes. The country is also expanding long–term care programs to better support its ageing population.

In France, the share of the population over 65 reached 21% in 2023 and continues to grow. The pension and social security systems are under financial strain, prompting the government to raise the retirement age to 64. Nevertheless, the ageing population drives the healthcare system adoption to meet increased demand for elderly care.

In the United Kingdom, the elderly population accounted for 19% in 2022 and is projected to reach 25% by 2050. The National Health Service (NHS) is under considerable pressure, and the government is responding by gradually increasing the retirement age to 68 by 2046 and promoting phased retirement to reduce the financial burden.

Canada had an elderly population of 19% in 2021, projected to reach 23% by 2030. Labour shortages are being addressed through increased immigration. However, the country is also facing the funding healthcare issues. To ensure long–term sustainability, Canada is reforming its public pension system and promoting senior employment and lifelong learning initiatives.

Table 1. *Comparative summary of countries' policies towards ageing*

Country	Core challenges	Policies
Japan	Lack of manpower and high care costs	Raising the retirement age, encouraging the employment of the elderly, using technology
Spain	Pressure on pension systems and youth unemployment	Raising the retirement age, supporting young families, pension reform programs
Italy	Low productivity and pension system costs	Incentivizing childbearing rates, raising the retirement age, limiting immigration policy
South Korea	Low birth rates and shortage of labor force	Family support, elderly employment, healthcare technology development
United States	Pressures on pension and welfare systems	Social security reforms, immigration programs to compensate for manpower shortages
Germany	Shortage of manpower and healthcare costs	Immigration policy to attract workers, support the employment of seniors, reform pension and long–term care systems
France	Ageing population, pension system burden and declining birth rates	Pension system reforms, encouraging childbirth through incentives, supporting employment for the elderly
United Kingdom	Labour shortage in certain sectors and increased social welfare costs	Pension system reforms, immigration programs to attract workers, supporting flexible work for the elderly
Canada	Ageing population and labour shortage in certain sectors	Active immigration policy to attract workers, improve long–term care programs, support families to enhance birth rates

Source: author's framework based on Terai et al. (2021)

The ageing population significantly affects the economies of developed countries, increasing the financial burdens on pension and healthcare systems and reducing the growth of the workforce (May, 2012). Policies vary from country to country, but they intersect in some actions, such as raising the retirement age, encouraging immigration, supporting young families, and using technology to improve health care, as summarized in Table 1.

4. Data, methodology and tools

The economic effects of old age are in several key aspects, most notably the decline in the workforce, which leads to lower productivity and economic growth, along with higher government spending on health care and pensions and increased financial burdens on social security funds that are facing increasing pressure to secure sustainable funding for pensions. This demographic shift also requires the adoption of long–term strategies to manage resources and minimize negative economic impacts, prompting many countries to develop innovative policies that include raising the retirement age, encouraging migration to attract young workers, promoting the use of digital technology in health and innovation to compensate for workforce shortages and reduce care costs. Accordingly, the annual data were employed to measure the impact of ageing on the population over 65 years, expressed as the percentage of population over 65 (POP), while GDP per capita (GDP) is used as a measure of economic growth. Health expenditure (HEALTH) is presented in the form of a proportion of the GDP to establish the link between health care and economic growth. Age dependency ratio (AGEDEP) is given in % of workforce, and investment level, i.e. the gross fixed capital formation as a percentage of GDP, has served as a control variable (GFCF). All data where retrieved from two sources: World Development Indicators (WBD, 2024) and Public Knoema DataHub (Knoema, 2024), and the sample includes Japan, Spain, Italy, the United States, South Korea, Germany, France, the United Kingdom and Canada ($N = 9$). The study methodology will be divided into several parts, starting with the descriptive statistics of the variables to determine the extent of these variables' development during the observed period 2000–2023 ($T = 24$). Then, we move to testing the stationarity of the variables, and finally we estimate a dynamic panel model to determine the short–term and long-term equilibrium relationship between variables with respect to panel ARDL (Autoregressive Distributed Lag) specification.

To examine the impact of population ageing on growth in the countries under study, and based on previous studies presented in the theoretical aspect, a dynamic panel model is used, i.e. the natural logarithm of the panel ARDL specification in terms of pooled mean group style, which takes into account a white noise (u_{it}) and the fixed effect (v_i) of each country:

$$\begin{aligned}\Delta logGDP_{it} = &\sum_{j=0}^{p} \alpha_{1ij} \Delta logPOP_{i,t-j} + \sum_{j=0}^{p} \alpha_{2ij} \Delta logHEALTH_{i,t-j} + \sum_{j=0}^{p} \alpha_{3ij} \Delta logGFCF_{i,t-j} \\ &+ \sum_{j=0}^{p} \alpha_{4ij} \Delta logAGEDEP_{i,t-j} + \sum_{k=1}^{q} \gamma_{ik} \Delta logGDP_{i,t-k} + \beta_1 logPOP_{i,t-1} \\ &+ \beta_2 logHEALTH_{i,t-1} + \beta_3 logGFCF_{i,t-1} + \beta_4 logAGEDEP_{i,t-1} + v_i + u_{it}\end{aligned} \tag{1}$$

where countries are represented by the subscript $i = 1, 2, \ldots, 9$, the time is indicated by the subscript $t = 1, 2, \ldots, 23$, coefficients α's indicate short–run effects while coefficients β's indicate long–run effects. The ECM (Error Correctoin Model) specification of Equation 1 is

given in Equation 2.

$$\begin{aligned}\Delta logGDP_{it} = &\sum_{j=0}^{p} \alpha_{1ij} \Delta logPOP_{i,t-j} + \sum_{j=0}^{p} \alpha_{2ij} \Delta logHEALTH_{i,t-j} + \sum_{j=0}^{p} \alpha_{3ij} \Delta logGFCF_{i,t-j} \\ &+ \sum_{j=0}^{p} \alpha_{4ij} \Delta logAGEDEP_{i,t-j} + \sum_{k=1}^{q} \gamma_{ik} \Delta logGDP_{i,t-k} + \delta_i ECT_{t-1} + v_i + u_{it}\end{aligned} \tag{2}$$

where δ is the speed of adjustment and ECT is the error correction term. The *a priori* expectations are stated as follows: β's > 0, α's > 0, $\delta < 0$ and significant.

5. Empirical results

The study's descriptive analysis aims to give an overview of the variables' trends from a statistical point of view (Table 2). Economic and demographic indicators in the United States, Spain, Italy, Germany, Japan, and South Korea show marked variation reflecting diverse challenges and opportunities. In the United States, where GDP per capita is around $80,000 the proportion of the population over 65 (16%) and the impact of high health spending (17% of GDP) reflect the economy's strength. Europe, Italy, and Germany have high proportions of the population over 65 (23% and 22%, respectively), with health spending between 9% and 11% and GDP per capita of $40,000 and $60,000 respectively. Spain, which faces similar demographic challenges with a population above 65% of 20%, has a GDP per capita of $35,000. In Asia, Japan is among the countries with the highest ageing populations (28%) with a clear impact on the dependency ratio (68 dependents per 100 people of working age). Still, it maintains a per capita GDP of $50,000 thanks to a high investment (24% of GDP). On the other hand, South Korea reflects a privileged position as it combines a relatively low ageing rate (16%) and high investment (29% of GDP) with a per capita of $45,000. These indicators reflect those demographic changes, such as ageing and dependency ratios. These present significant challenges that may affect productivity and economic growth, but they also highlight the importance of investment and economic policies to promote sustainability.

The data indicate a clear disparity in economic and demographic indicators among the six countries. Japan has the highest population ageing (24.58%) and a high dependency ratio (60.58%), posing a major challenge to its economic growth despite maintaining a good investment level (25.32%). On the other hand, the United States shows remarkable economic strength with the highest GDP per capita (55,415.03) and a moderate ageing rate (13.96%), which enhances its stability. Germany and Italy face challenges associated with rising ageing (20.18% and 21.16%, respectively) and increasing healthcare costs, with good productivity levels. In contrast, Korea is projecting a positive model thanks to its high investment (30.59%) and low ageing rate (11.91%), boosting growth potential. Overall, these countries show varying impacts of population ageing on the economy, making investments in technology and targeted policies necessary to mitigate these challenges.

The correlation matrix (Table 3) shows the relationship between economic and demographic variables and illustrates the impact of population ageing on the economy. The results suggest that countries with high health spending typically record higher GDP per capita, reflecting the importance of investing in health to support economic growth. The high proportion of people over 65 is also associated with an increase in age dependency and health spending, highlighting the challenges faced by these countries in allocating resources. Con-

versely, fixed investment appears to be negatively affected by higher health spending and dependency ratio, indicating fiscal pressures that limit long-term investments. Overall, the matrix reflects the need to balance economic policies between health spending and investment to promote economic growth and reduce the impact of ageing.

Table 2. *Descriptive statistics of the variables*

Country	Statistic	logGDP	logPOP	logHEALTH	logGFCF	logAGEDEP
Japan	Mean	29.0916	3.1882	2.0450	3.2303	4.0943
	Std.dev.	0.0460	0.1724	0.2038	0.0495	0.1420
	Min	29.0140	2.8795	1.7334	3.1188	3.8595
	Max	29.1584	3.4034	2.3418	3.3495	4.2644
USA	Mean	30.4749	2.6294	2.0872	3.0485	3.9267
	Std.dev.	0.1398	0.1193	0.2505	0.0646	0.0346
	Min	30.2497	2.5078	1.7125	2.9077	3.8867
	Max	30.7249	2.8672	2.8094	3.1418	3.9977
Spain	Mean	27.8044	2.8858	1.8277	3.1003	3.8796
	Std.dev.	0.0870	0.0748	0.1366	0.1884	0.0575
	Min	27.6087	2.8048	1.5836	2.8545	3.8106
	Max	27.9540	3.0319	2.0618	3.4021	3.9508
Italy	Mean	28.2756	3.0487	1.8853	2.9731	3.9795
	Std.dev.	0.0329	0.0851	0.1027	0.0923	0.0552
	Min	28.1916	2.9072	1.7047	2.8167	3.8781
	Max	28.3296	3.1971	2.2513	3.0755	4.0583
South Korea	Mean	27.8710	2.4414	1.2505	3.4202	3.6500
	Std.dev.	0.2428	0.2738	0.3521	0.0304	0.0390
	Min	27.4065	1.9649	0.6685	3.3658	3.5968
	Max	28.1989	2.9112	2.1748	3.4710	3.7394
Germany	Mean	28.8164	3.0011	2.1504	3.0198	3.9486
	Std.dev.	0.0875	0.0899	0.1264	0.0500	0.0548
	Min	28.6904	2.7992	2.0222	2.9485	3.8532
	Max	28.9400	3.1244	2.5416	3.1405	4.0616
France	Mean	28.4863	2.8904	2.0707	3.0757	4.0422
	Std.dev	0.0796	0.1052	0.0847	0.0434	0.0603
	Min	28.3370	2.7731	1.9417	3.0124	3.9817
	Max	28.6136	3.0796	2.2315	3.1634	4.1382
UK	Mean	28.6478	2.8370	2.0465	2.8517	3.9908
	Std.dev.	0.0994	0.0683	0.1831	0.0479	0.0452
	Min	28.4605	2.7657	1.7038	2.7544	3.9349
	Max	28.8049	2.9569	2.4069	2.9041	4.0578
Canada	Mean	28.0075	2.7079	1.9995	3.1161	3.8498
	Std.dev.	0.1267	0.1430	0.1517	0.0668	0.0625
	Min	27.7822	2.5286	1.7932	2.9755	3.7836
	Max	28.2094	2.9631	2.4932	3.1984	3.9713

Source: authors' computation using Stata 15

Table 3. *Correlation matrix of the variables*

	logGDP	logPOP	logHEALTH	logGFCF	logAGEDEP
logGDP	1.0000				
logPOP	0.1085	1.0000			
logHEALTH	0.4871	0.6801	1.0000		
logGFCF	−0.2108	−0.3037	−0.5386	1.0000	
logAGEDEP	0.3792	0.7930	0.7464	−0.4827	1.0000

Source: authors' computation using Stata 15

Next part aims to assess the temporal properties of the variable employed in this study and for this purpose, panel unit–root tests like LLC, IPS and ADF will be employed. The rule of thumb is that if the $p-$value for an LLC test (Levin et al., 2002), IPS test (Im et al., 2003) and ADF test (Dickey and Fuller, 1981) is less than 0.05 (5% significance level), the tested variable will be classed as stationary or not contain a unit–root. On the other hand, if the probability value of test statistics LLC, IPS and ADF is greater than 0.05, then the tested variable is assessed to be unstable or have unit–root and from Table 4 it can be observed that individual GDP is stationary at levels while the rest of the variables all stabilize after the 1st differences, and hence we use GDP as I(0) and the rest of the variables as I(1). All variables are transformed into logs and included in model estimation.

Table 4. *Stationarity tests in the levels and in first differences*

Levels	LLC test	IPS test	ADF test
logGDP	−3.5424***	0.2896	0.3366
logPOP	2.2649	4.2450	5.7134
logHEALTH	4.4563	5.8728	−2.1292
logGFCF	−1.2400	−40.5610	0.3102
logAGEDEP	−1.8613**	4.0749	−0.2630
Differences	**LLC test**	**IPS test**	**ADF test**
ΔlogGDP	−6.0659***	−5.7763***	21.6409***
ΔlogPOP	−2.2798**	−1.1735	−1.4420
ΔlogHEALTH	2.6567	−0.9528	12.3975***
ΔlogGFCF	−4.9197***	−4.4721***	7.3061***
ΔlogAGEDEP	−1.3600*	−0.8718	−1.4950

Note: ***, ** and * indicate significance levels at $p < 0.01$, $p < 0.05$ and $p < 0.1$

Results of stability tests of variables (Table 4) indicate that most variables (logPOP, logHEALTH, logGFCF and logAGEDEP) are not stationary at their baseline level but become stationary at the first differences. After conducting the unit root–tests, we ensured no stationary time–series of the second degree. Therefore, at this stage, the panel ARDL (dynamic panel data model) will be estimated using the following estimators: MG (Mean Group) estimator, PMG (Pooled Mean Group) estimator, and DFE (Dynamic Fixed Effects) estimator. These methods give the long–run and short–term parameters and the speed of adjustment to the long–run equilibrium.However, before that, the optimal lag length for the panel ARDL model is determined as the minimal lag for each variable across observed countries, i.e. the 1 time lag was determine as minimal for logGDP, logPOP and logHEALTH, 2 time lags with

respect to logAGEDEP and zero time lag for logGFCF is found as optimal.

The Pedroni, Kao and Westerlund cointegration tests given by the panel model indicates that there is a long–term relationship between the variables (Table 5). In the Pedroni test the statistics such as Phillips–Perron and Augmented Dickey–Fuller gave very high values which means that the null hypothesis is rejected and cointegration is denied whenever $p < 0.05$. However, the modified Phillips–Perron test statistic was non-applicable, hence the results should be interpreted with a lot of caution. Different from this, the Kao test results were more effective, and all of the statistics were significant at 5% significance level, which supports the existence of common integration among the variables. The Westerlund cointegration test result presented is a cointegration. Thus, these results support the conclusion that there is a long–term relationship between economic variables, which enhances the stability of the model and its long–term economic interpretability.

Table 5. *Panel cointegration tests*

	Pedroni test	Kao test	Westerlund test
H_0 : no cointegration			
H_1 : all panels are cointegrated			
Number of panels	9	9	9
Number of periods	23	22	22
Cointegrating vector: panel specific			
Panel means: included			
Time trend: not included			
AR parameter: panel specific			
Variance ratio		−2.2344	0.0127
Modified Phillips–Perron	1.6939**		
Phillips–Perron	−1.2403		
Augmented Dickey-Fuller	−1.4395*	−2.2093**	
Modified Dickey–Fuller		−2.9546***	
Dickey-Fuller t		−2.7415***	
Unadjusted modified Dickey–Fuller		−3.2310***	
Unadjusted Dickey-Fuller t		−2.8386***	

Note: ***, ** and * indicate significance levels at $p < 0.01$, $p < 0.05$ and $p < 0.1$

The study investigated if there is a long–term equilibrium between GDP growth and the other independent variables using the pooled mean group (PMG) estimator designed for dynamic heterogeneous panels. The PMG is a technique that sits in between the DFE and the MG estimator. Because it incorporates pooling (which shows the DFE) and averaging (the MG estimator). Although the long–run coefficients must be identical, the PMG estimator allows for discrepancies between the short–run and error variance coefficients. The cointegrating link between non–stationary variables serves as the basis for estimating the long–term interaction between variables. Pesaran et al. (1999) offer the maximum likelihood PMG estimator for heterogeneous dynamic panels that fit within the ARDL model.

The unit–root test results in Table 4 show that all variables are stationary in the first differences to estimate the panel ARDL model. We will apply panel linear ARDL(1,1,1,0,2) to estimate the PMG, MG, and DFE for the panel data of the studied group of countries to obtain the coefficients of the relationship between the model variables. Then, we will apply a Hausman test (Hausman, 1978) for comparison between the estimates of MG, PMG and DFE

in order to determine which method is most preferred so that we can provide a consistent and effective result by testing the null hypothesis for homogeneity constraints. The Hausmann test results are presented in Table 6, and indicate the rejection of the null hypothesis, meaning that the PMG method is appropriate in this case.

Table 6. *Panel ARDL results obtained by different estimators*

Long–term estimates	MG	PMG	DFE
logPOP	1.3748***	1.2261***	0.4514***
	(0.6156)	(0.1914)	(0.1723)
logHEALTH	0.08982	0.2402***	0.4111***
	(0.0796)	(0.0489)	(0.1282)
logGFCF	0.47139***	0.6776***	0.4306***
	(0.1440)	(0.1078)	(0.1261)
logAGEDEP	−0.8742	−0.8882***	−0.5216***
	(0.7956)	(0.3016)	(0.1926)
Short–term estimates	**MG**	**PMG**	**DFE**
Error correction term	−0.7294***	−0.2201***	−0.1823***
	(0.1266)	(0.0739)	(0.0371)
ΔlogPOP	1.0106	−0.4985	0.6241*
	(1.7382)	(0.7145)	(0.0222)
ΔlogHEALTH	−0.2198***	−0.2321***	−0.1301***
	(0.0554)	0.05516	(0.3270)
ΔlogGFCF	0.0739	0.1168	0.2311***
	(0.0888)	(0.0811)	(0.0476)
ΔlogAGEDEP	−0.8534	0.1595	−0.5723728
	(2.3229)	(0.5353)	0.3537
Constant term	19.5651***	5.7598***	4.9807***
	(3.9591)	(1.9282)	(1.0417)
R^2	0.4170		
Observations	207		
F(5, 210)	30.04***		
Heteroskedasticity	0.12		
Hausman test results			
MG vs PMG	$p = 0.2335$	PMG is efficient	
DFE vs PMG	$p = 1.0000$	PMG is efficient	
MG vs DFE	$p = 0.0882$	MG is efficient	

Note: ***, ** and * indicate significance levels at $p < 0.01$, $p < 0.05$ and $p < 0.1$; standard errors in parenthesis

The panel model results present both short–term and long–term effects of demographic and economic factors on economic growth. The proportion of the population over 65 years (logPOP) has a positive and significant effect on economic growth (logGDP) in the lon–run by all three methods (MG, PMG, and DFE), which means that this group may contribute to growth through consumption or savings according to Bloom et al. (2010), but opposite to Aksoy et al. (2019) who argued that an increase in the elderly population results in lower productivity and growth due to reduced workforce. Health expenditure (logHEALTH) had a significant negative short–term effect, which indicates that high healthcare costs are a fi-

nancial burden on the economy in the long run, which is in agreement with Peterson (2017) who pointed out that inefficient healthcare expenditure is an economic (Yang, 2020). The author also established that high healthcare spending limits growth in countries with public sector–financed healthcare systems, which is in line with the negative results obtained in this study.

However, fixed investment as a share of GDP (logGFCF) had a positive effect in the short and long–run, with significant results in the long–run, indicating that investment is a key determinant of long–run economic growth. This finding is in agreement with Solow (1956) who explained economic growth through capital accumulation, when economic growth is tied to capital accumulation, with the help of the positive role of investment. The same can be said for the study of Barro (1991) which also supported the idea that more investment in infrastructure is beneficial for growth over the long run, contrary to the results of Huang and Xie (2013) who found that ineffective investments may even have a negative effect.

Table 7. *PMG estimates by country*

Country	Japan	US	Spain	Italy	South Korea
Error correction term	0.0288	−0.1426**	−0.0963	−0.2169**	−0.0049
	(0.1035)	(0.0560)	(0.0609)	(0.0952)	(0.0516)
ΔlogPOP	1.1050	0.9836	0.4438	−0.9921	1.5298
	(2.5801)	(1.2961)	(0.8942)	(1.9119)	(0.9344)
ΔlogHEALTH	−0.2241*	−0.0931***	−0.5329***	−0.1218*	−0.0790*
	(0.1231)*	(0.0259)	(0.0912)	(0.0661)	(0.0452)
ΔlogGFCF	0.3275	0.1509**	0.0519	0.3319*	−0.2570*
	(0.1754)	(0.0731)	(0.0998)	(0.1799)	(0.1347)
ΔlogAGEDEP	−1.2976	−1.8097	−1.4371	2.5606	−0.6802
	(2.1521)	(1.8405)	(0.9148)	(2.2294)	(0.8077)
Constant term	-0.7415	4.0344**	2.4541	5.5526**	0.1048
	(2.6839)	(1.5820)	(1.5247)	(2.4419)	(1.2891)
Country	Germany	France	UK	Canada	
Error correction term	−0.5575***	−0.0623	−0.5150***	−0.4141***	
	(0.1034)	(0.1065)	(0.1068)	(0.1173)	
ΔlogPOP	−0.0937	−1.5892	−0.3395	−5.5346*	
	(0.4643)	(1.5252)	(1.1201)	(2.8509)	
ΔlogHEALTH	−0.4294***	−0.2139**	−0.3237***	−0.0712**	
	(0.0608)	(0.0828)	(0.0606)	(0.0325)	
ΔlogGFCF	−0.1429	0.5124***	0.0669	0.0096	
	(0.1160)	(0.1821)	(0.1364)	(0.1139)	
ΔlogAGEDEP	1.2505**	2.1616	−0.0946	0.8269	
	(0.5420)	(2.1564)	(0.9268)	(1.4321)	
Constant term	14.5495***	1.6323	13.5664***	10.6857***	
	(2.8050)	(2.7673)	(2.8614)	(3.0272)	

Note: ***, ** and * indicate significance levels at $p < 0.01$, $p < 0.05$ and $p < 0.1$, standard errors in parenthesis

As for the elderly dependency ratio (logAGEDEP), had a mixed effect in the short–run and long–run, with a positive but not significant effect in the long–run and a negative and significant effect in the short–run, indicating variation as a function of context and policy. Bloom and Finlay (2009) argued that an increase in the elderly dependency ratio means that

fewer resources can be devoted to growth, which is in line with the negative results reported. According to Maestas et al. (2023) the elderly dependency ratio is a costly economic burden that is only mitigated by effective policies, which also accounts for the negative results. However, Lee and Mason (2010) pointed out that the dependency ratio can be managed positively by enhancing the productivity of the working-age population, which could account for the long–term results seen in the PMG model. In the short–term, all models had a negative and statistically significant coefficient on the error correction term (ECT), meaning that the models readjust to the equilibrium aftershocks, with the fastest rate of adjustment seen in the MG model.

The Hausman test for efficiency revealed that PMG model is the most efficient and the best specifying model for the data which increases the confidence in the results. Furthermore, there was no problem of heteroscedasticity or autocorrelation in the panel data which supports the validity of the models. On this basis, it can be advised to encourage fixed investments because of their positive impact on the growth of the economy, to control the amount of healthcare spending in order to lessen its effects on the economy, and to design policies that will help control population and reduce the economic pressure of the elderly dependency ratio. These findings provide a more complete view of the impact of demographic and economic factors on growth and the role that context and policies play in determining the impact of these factors.

6. Conclusion

Population ageing is one of the biggest challenges facing many developed countries, as it negatively affects economic growth by increasing the financial burdens associated with health care, reducing the size of the workforce, and increasing age dependency ratios. Analyses have shown that the impact of these challenges varies between countries based on their economic and demographic contexts. For example, Japan and Spain are experiencing a strong negative impact due to high health spending costs and an ageing population, which requires improving spending efficiency and encourageing innovation to compensate for labor shortages. In contrast, the United States and Germany show relative resilience, with ageing contributing to growth thanks to thoughtful employment and investment policies, but still face challenges associated with healthcare costs.

The recommendations note the need to develop comprehensive strategies to address these challenges. In the short term, countries need to improve the efficiency of health expenditures and restructure health systems to ease the financial burden. In the long term, it is recommended to stimulate innovation and investment in productive technologies to compensate for the manpower shortage, along with applying flexible demographic policies, such as encouraging migration and increasing the participation of women and the elderly in the labor market. Investment in education and training should be strengthened to improve the quality of human capital. Despite the challenges posed by population ageing, it also presents opportunities for countries that adopt innovative and effective policies. Improving spending efficiency, spurring innovation, and developing flexible demographic policies can turn this challenge into an opportunity for sustainable economic growth. The future depends on the ability of countries to adapt to demographic shifts, ensuring the exploitation of human and technological capital to balance demographic burdens and economic growth.

The study points to important lessons for developing countries regarding managing demographic changes and their economic effects. Although most developing countries currently have a young population, the future may hold similar challenges for developed countries if they do not invest in managing demographic shifts. This requires enhancing investment in human capital through improved education and training, which contributes to increasing the workforce's productivity and compensating for its potential shortfall due to ageing. The study also emphasises the importance of innovation and technology, as developing countries can reduce the impact of population ageing by adopting modern technologies to improve productivity. Concerning health systems, the results show the need to enhance efficiency and focus on preventive care, especially with limited resources. On the other hand, developing countries should adopt flexible demographic policies, such as encouraging women's participation in the labour market and stimulating migration to bridge workforce gaps. In addition, productive investments in industry, energy, and sustainable agriculture must be improved to boost economic growth. With many young people, developing countries have a unique opportunity to exploit demographic dividends through education and effective job creation. Finally, strengthening international cooperation and leveraging the experiences of developed countries in managing population ageing are effective means of ensuring the sustainability of future economic growth.

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Utjecaj starenja stanovništva na gospodarski rast zemalja u razvoju: panel ARDL nalazi

SAŽETAK

Ovo istraživanje analizira ekonomske učinke starenja stanovništva u Japanu, Španjolskoj, Italiji, Sjedinjenim Američkim Državama, Južnoj Koreji, Njemačkoj, Francuskoj, Ujedinjenom Kraljevstvu i Kanadi, koristeći panel ARDL model (autoregresijski model s distribuiranim pomacima). BDP po stanovniku je zavisna varijabla, dok su nezavisne varijable uključivale udio stanovništva starijeg od 65 godina, izdvajanja za zdravstvo, stopu ovisnosti te razinu investicija izraženu kao udio u BDP-u. Rezultati su pokazali raznolike učinke starenja na gospodarski rast. U nekim analiziranim zemljama (SAD, Južna Koreja i Njemačka) starenje je imalo pozitivan učinak, dok je u drugim (Španjolska, Italija i Japan) djelovalo negativno. Izdaci za zdravstvo identificirani su kao ekonomski teret, dok su fiksne investicije pokazale ključnu ulogu u poticanju rasta. Istraživanje sugerira unapređenje obrazovanja i osposobljavanja radi povećanja produktivnosti, prihvaćanje inovacija i tehnologije, jačanje zdravstvenih sustava kroz preventivnu skrb te uvođenje fleksibilnih politika poput poticanja sudjelovanja žena na tržištu rada i promicanja migracija.

KLJUČNE RIJEČI

rast, izdaci za zdravstvo, panel ARDL, starenje stanovništva

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