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Ageing affecting the Americas?: exploring the growth direction: the relationship between the elderly population and economic growth in the American context

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Abstract

The main aim of this study is to explore the relationship between the elderly population and economic growth in 25 North and South American countries use annual secondary data from 1961 to 2021. Instead of focusing on the conditional mean, this study tests for Granger causality in the entire conditional distribution of the elderly population and economic growth through wavelet coherence analysis. The study findings indicated a unidirectional Granger causality running from per capita gross domestic product (GDP) to the elderly population for Bolivia, Colombia, Guyana, Peru and Puerto Rico and also from elderly population to per capita GDP for Costa Rica, Ecuador and Honduras. However, there is no causal relationship between the elderly population and economic growth for the rest of the countries. Wavelet coherence analysis depicted that economic growth positively led the elderly population in North America during the early 21st century. Furthermore, economic growth had been negatively leading the elderly population in South America throughout the period under consideration. This empirical study shows that policymakers of these economies need to analyse the transformation in the elderly population-economic growth causality robustness throughout the year when devising policies.

Keywords Economy, Elderly population, Granger causality, Coherence analysis

Introduction

With the population ageing, the focus on the elderly generational cohort tends to differ based on many socio, political and economic factors [18]. The Comas-Herrera et al. [6] evidence suggested that high ageing populations tend to place the largest burden on society in terms of population growth. This is attributable to the cognitive impairment of the ageing population along with chronic diseases and infections.Such tendencies can accumulate cost to society. The context of the current study is about understanding the effect of the elderly population and economic growth in the North and South American region. In addition, the report will address reviewing the past literature on the subject and understanding the trends observed within the context of the impact of the ageing population on the per capita gross domestic product (GDP) growth of North and South America using the Panel Granger Causality Test. The report's findings highlight key policy implications and conclusions concerning

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the need for economic growth and future concerns on how the ageing population should be defined and cared for.

As such, this paper aims to provide empirical evidence on the relationship between the ageing population and economic growth in American countries. Applying a granger causality and wavelet coherence analysis, we can reveal the important variations in the distribution of demographic characteristics. In doing so, this paper attempts to fill the research gap by developing a simulation framework using this econometric model to examine the economic implications of population ageing in the American region along with the policies designed to address this topical issue.

As such, this study differs from earlier research, adds to the body of knowledge and is unique in three ways. First, this research study examines a wide range of American nations using up-to-date data gathered over a considerable time. Therefore, this study fills a gap in the existing knowledge on the ageing population and economic growth for several reasons. Even for a brief period, very few research studies have been undertaken thus far for the American region. In light of the scope of the study – i.e. how extensively the countries and years are covered, this study is exceptional. Secondary data of 25 countries during six decades covering 1961-2021 are analysed in this study. Second, a country-by-country study has been done for every country considered, allowing the researchers to examine how the two variables behave in various nations. The study's findings offer critical and new information on how well recent programmes on elderly care in various countries have been effective. The Morsch et al. [26] highlights several evidence-based programs designed to enhance the health and well-being of older adults in the Americas by targeting various domains of intrinsic capacity. The Living Healthy: Chronic Disease Self-Management Program (CDSMP) is widely implemented in countries like Argentina, Brazil, Canada, Chile, Mexico, and the United States, among others, to improve self-management of chronic conditions. Programs such as Vivifrail, Walk with Ease, Capable, and OTAGO focus on enhancing locomotor capacity through tailored interventions in community or clinical settings, though specific countries of implementation are not detailed. Group-based programs like Active Living Every Day, Enhance Fitness, Fit and Strong, Matter of Balance, and Tai Chi for Arthritis/Fall Prevention are commonly utilized in community health and fitness initiatives to promote physical activity, prevent falls, and improve balance and strength. Additionally, one-on-one programs like Program for Encouraging Active Rewarding Lives (PEARLS) focus on mental well-being, while the Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER) combines cognitive and physical interventions to address cognitive decline. While most programs are adaptable to various settings, CDSMP is notably detailed in its country-specific implementation across the region. Typically, cross-country interactions between economic sectors occur. Here, we use an econometric approach that allows for cross-regional contemporaneous correlation. As opposed to a cross-country analysis or time-series analysis on a country-by-country basis, the methodology adopted in this study is more meaningful and effective in achieving the research objectives. Thirdly, the usage of wavelet coherence as supplementary to support the findings from Granger causality is significant as it would provide further insights into the behaviour of the two variables. Wavelet coherence is unique too, since it would provide the direction of both causality and direction of the elderly population and economic growth for different time periods.

The remainder of the paper is organised as follows. In the next section, the literature review discusses empirical evidence regarding the research problem and the underlying variables. The section thereafter explains data and methodology, followed by the results and discussion section, including empirical findings and its interpretations. The last section brings the research to an end.

Literature review

Changes in demographic composition are approaching for many countries globally - specially with the rise of ageing populations, increase in longevity and decrease in fertility rates [16]. The decline in population growth has been noticeable since the mid-1970s, when the adult working-age population in several countries overtook the child population [25]. It is expected that, primarily in South and North America, the ageing population will rise by 14% by the end of 2050. Hence, the prime labour participation will fall behind the aged population in countries worldwide unless much attention is paid to increasing the countries' fertility rate [16].

South America

In a closed population, population ageing is fuelled by two factors: higher life expectancy and slower population growth rates due to declining fertility. Any discussion of this subject is stiffened because both these fundamental factors operate throughout the demographic shift and have effects other than ageing [1, 22, 30]. Lee and Mason [23] pointed out that this change in demographics considering the rise of the ageing population, is inversely connected to the drop in fertility rate as a root cause of the issue of women entering the workforce [7] explores the complex relationship

between female labor supply and fertility rates, highlighting the substantial influence that shifts in female labor force participation can have on fertility choices. It emphasizes that decisions about fertility may change if more women join the workforce. For example, decisions to have fewer children or to postpone having children because of job commitments and other employment-related variables may result from higher labor force participation. Additionally, the document talks about how different circumstances affect fertility decisions. It highlights how family policies, such paid maternity leave and childcare assistance, affect fertility choices. It also examines how social norms, such as cultural perspectives on family size and the distribution of childcare duties between partners, influence fertility decisions. The report also discusses how labor market institutions, like work-life balance and gender equality legislation, affect fertility choices.

The Mason and Lee [25] showed that women's participation in the labour force in the past decade grew by 14% in the US itself. This trend is reported in developing countries in South America as well. Moreover, the changes in social dynamics of child rearing, division from the extended families, a rise in divorce and separation rates and the economic challenges of supporting high costs of child rearing are a few of the subvariables which have adversely impacted the growing ageing population [25].

The considerable variety of population dynamics seen across diverse countries is the most significant part of this overall process of change in the age structure and acceleration of the region's population's ageing. ECLAC [8] categorised the nations into four based on the existing age structure of the area. Hence, it is now possible to examine how the interaction of demographic factors with other social and institutional factors impacts how well the social safety systems function. The first category of nations is the oldest in terms of population. This group includes Uruguay, Chile, and Argentina. Over 10% of the population in these nations is over the age of 60. The second group consists of nations with moderate to advanced population ageing proportion, currently a proportion of 8% to 10% older people.

In these nations, the percentage of senior citizens will escalate in the years to come. The only nation in the area that meets these criteria is Brazil. Countries with a moderate population ageing make up the third group. Paraguay is the last nation in the group of nations with a population that is beginning to age. Older people make up a relatively tiny portion of the population in these nations.

North America

There are two different aspects to be discussed in terms of the ageing population in America. Specifically, when it pertaining to North America, the USA territory will be the highly impacted geography with the high level of the ageing population. Gietel-Basten and Sobotka [11] reported that 16.5% of the total population would be above 65 years in the next three decades. The key considerable issue with this ageing population for the US is the chronic health deterioration of the lion's share of this ageing population, along with the lack of productivity of the labour population and the drop in the competitiveness of the US economy. Goldin et al. [12] and Flores-Cerqueda [9] discussed this issue connected with these demographic changes considering the severe blow to the US economy. It is because the bulk of baby boomers who revived the US economy since the 1980s will be in the elderly population by 2030, and the millennial and predeceasing generations have not been able to contribute at the same level. Thus, when the most productivity generation cohort is retiring, the next labour force participation will not be able to match with the same rigor onto the US economy [12].

Further, in terms of health care, the US has much-disputed heath care practices, and more than 30% of the ageing population discussed the issue of having access to quality medical care because of income disparity [9]. Therefore, the majority of this health care burden will be transferred to the working population, which will be an added disadvantage in the long run. However, Coile et al. [5] discussed that the ageing population in the mid-West in states such as Texas had shown higher productivity even after passing 65 years of age and this proves that the ageing population can be deployed for economic activities even after the retirement age. On top of this, new retirees may have greater potential in terms of experience, skills and knowhow and still be a wealth of assets to a country.Yet the utility of this strategy, and the overall ethical compliance with the majority of the population is quite questionable.

However, what is more important in this context is to identify that most existing literature supports the claim that there is a strong negative relationship between the ageing population and economic growth [12]. This is validated by the fact that with the rise of the ageing population – there is a drop in individuals' physical capacity, preferences, and needs will change in line with their advancing age. Therefore, the inequality in the age structure also leads to a rapid drop in the productivity level of individuals [17]. Especially in the US, this trend has been associated with the diminishing value addition to the society linked with the ageing population.

Hence, the overall impact of the ageing population is considered to be a negative trait for the economic growth of a country, which will be assessed in detail in the current study.

Data and methodology

The online edition of the World Bank Database is the primary secondary data source for this study, and the data file used is presented in Table A1 of the Appendix. Due to the lack of long data sets for some countries, the data period for this analysis was limited to 1961 to 2021, during which the data were readily available. The study was mainly confined to 13 South American and 12 North American countries. Argentina, Bahamas, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Guyana, Haiti, Honduras & Caribbean, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Suriname, Trinidad and Tobago, Uruguay and the US are included in this study. Economic growth was measured by each country's per capita GDP growth rate (as an annual percentage) using constant local currency, thereby enabling cross-country comparisons. Moreover, the elderly population was measured using the population aged 65 and older (as a percentage of the total population).

$$Y_{i,t} = \sum_{k=1}^{p} \beta_k Y_{i,t-k} + \sum_{k=0}^{p} \theta_k X_{i,t-k} + u_{i,t} \quad (1)$$

To complement and improve the findings from wavelet coherence analysis, the Granger causality test was used for each nation. Two stationary covariance variables were monitored across T periods and N cross-section units while taking X and Y into account. Granger defines causality for each individual i [1,N] as follows: if we can predict $Y_{i,t}$ more accurately using all available information than if we only had $X_{i,t}$, then the variable $X_{i,t}$ causes $Y_{i,t}$. Assuming a linear Granger causality model, examine a panel data set's time stationary VAR representation. Equation (1) is estimated for each cross-section unit i and time period t [14]. There, $u_{i,t} = \alpha_i + \varepsilon_{i,t}$, where u is normally distributed and p is the number of delays. The regression coefficients θ_k and autoregressive coefficients β_k are thought to be constant for $k \epsilon$ [1, N]. Additionally, as diagnostic tests, the root of the companion matrix and the impulse response of the aged population and per capita GDP for all countries were carried out.

Additionally, the wavelet coherence technique is applied to thoroughly analyse if there is a correlation between the variables under consideration,. Goupillaud and Grossmann discovered the wavelet approach, and the concept's foundation was established based on their expertise. The wavelet approach subdivides the time series into a frequency-time domain [13].

Wavelet coherence analysis is a powerful tool for exploring the causal relationships between two variables in a time series by examining their coherence and phase relationships at different frequencies and time scales. Unlike Fourier analysis, which is better suited for identifying periodic components over the entire time series, wavelet analysis excels in capturing transient, non-stationary features, and sudden shifts in data [2]. Wavelets are localized oscillatory functions with zero mean that decay quickly and are tailored for short-lived patterns, allowing for a more precise characterization of subtle and dynamic oscillations in real-world data. By decomposing the signal into both time and frequency domains, wavelet coherence provides insights into how relationships between variables vary over time, making it an essential tool for uncovering hidden structures and causal links in complex datasets.

Continuous and discrete are the two main wavelet transforms. These transformations occur based on the way wavelets are shifted and scaled. A wavelet, which is constructed by the function $\psi^{(a,b)}(x)$ with contraction, a and translation b, can be mathematically denoted as shown in Equation (2),

$$\psi^{a,b}(x) = |a|^{-\frac{1}{2}} \psi\left(\frac{x-b}{a}\right) \quad (2)$$

Pioneering research explained how to analyse and the explanation of the results in wavelet coherence [3, 21, 28, 32]. In this study, the wavelet approach is employed to further graphically demonstrate that there is a causal link between the aged population and economic development.

The wavelet coherence approach can be used to explain how one variable leads the other in bivariate analysis. Wavelet coherence is superior to traditional methods like Granger causality since it can explain the direction and strength of the causal relationship between two variables across the studied period. It is possible to ascertain the direction and the variable that leads the other variable in wavelet coherence by analyzing two time series [29].

Wavelet coherence analysis offers a significant advantage in capturing time-frequency dynamics between variables. Unlike traditional correlation-based methods, it allows for the exploration of time-varying and frequency-dependent relationships without requiring data to be strictly stationary or stable. This makes wavelet coherence particularly suitable for understanding complex, evolving relationships over time, such as those influenced by demographic and economic variables [15]. However, since wavelet coherence does not facilitate country-specific analysis, we complemented it with Granger causality analysis.

Granger causality analysis is a robust statistical tool for identifying predictive relationships between variables. It tests whether changes in one variable systematically precede changes in another, thereby enabling the inference of temporal causality [19]. This method is especially useful for country-wise analysis, as it provides a means to evaluate directional relationships at a granular level. Together, these methods allow us to uncover both dynamic, frequency-based interactions and country-specific causal patterns, offering a comprehensive view of the relationship between demographic shifts and economic growth [20].

Results and discussion

The study's primary purpose is to examine the causal relationship between the elderly population and economic growth utilising secondary data from a panel data set covering the period from 1961-2020. The research analysed 1,525 observations across 25 American countries.

Table A2 Appendix presents the summary of descriptive statistics. Results show that among the countries covered in this study, Guyana on the South American had the highest per capita GDP per capita growth rate, while Nicaragua on the North American continent had the lowest per capita GDP per capita growth rate. Specifically, Puerto Rico on the North American continent, shows the largest adult population growth, while Nicaragua on the North American continent, shows the lowest adult population growth.

Figure 1 illustrates the flow of per capita GDP growth rates from 1961 to 2021 in South American countries and Fig. 2 represents North American countries. In Fig. 1 (A), Suriname showed an increase in per capita GDP in 1966 compared to other countries. According to Fig. 1A and B, Argentina and other South American countries, in particular, experienced an economic recession in 2001. In Fig. 1 (B), due to reasons such as stagnation, inflation and crisis, Brazil's economy declined compared to other countries during 1981-1992 and in 2016, all countries considered in this study underwent an economic recession. Figure 2(A) shows that the economy has generally fluctuated, but in the Bahamas in 1981, the economy has undergone a major setback. According to Fig. 2(A), several countries experienced an economic recession in 1981-1996.

Figures 3 and 4 depict the growth rates of the elderly population over 65 in South and North American countries. According to Fig. 3(A), the elderly population of Uruguay shows a remarkable increase, while Argentina too shows a higher growth compared to the others. In accord with Fig. 3(B), a similar variation is reported in all countries. Moreover, in Fig. 4(A), the elderly population in the US and Puerto Rico has grown compared to that in other countries. As in every country, the elderly population is expanding, but as Fig. 4(B) shows, the elderly population in Belize has slightly dropped between 1996-2006.

Unit root test

The per capita GDP growth rate variable underwent a Dfuller unit root test first. For all 25 American countries, the per capita GDP variable was unit root at the first level. The elderly population variable was then put through the same test, and the researchers found that Argentina was unit root at the elderly population's first level (EPOP) and Uruguay was unit root at the first difference (DEPOP). All 23 remaining nations became stationary at the second difference (DDEPOP).

The researchers then conducted the Pperron unit root test for the per capita GDP growth rate variable. The per capita GDP variable was stationary at the first level for all 25 countries, identical to the Dffuler test. The elderly population variable was then subjected to the Pperron test, and it was shown that Uruguay has unit roots at the elderly population's first difference (DEPOP). The remaining 24 countries became stationary from the second difference in the elderly population (DDEPOP).

Lag length criteria

The optimal lag length in the VAR specification is determined based on Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC). This VAR Lag Selection Criteria Table (Table A5 Appendix) presents results using the first tenth lags of the endogenous variables as instruments. According to Liew [24], the optimal lag length should be the one that minimises the SBIC, AIC, and HQIC information criteria. When mixed results are obtained, the decision is based on the minimum value in the AIC criterion.

According to S5 Appendix, selecting zero lags for Argentina, Belize, Haiti, Mexico and the US, lowers the AIC, HQIC, and SBIC criteria. Besides, in Guatemala, Nicaragua, Paraguay, Trinidad and Tobago, and Uruguay, the AIC, HQIC, and SBIC criteria are lower when selecting one lags. Further, the AIC criterion is lower when selecting one lag for Bahamas, Puerto Rico, Suriname, and Chile. In our case, selecting nine lags for Brazil and six lags for Ecuador lowers the AIC criterion. Further, the HQIC and SBIC criteria are lower when selecting zero lags for Caribbean and Colombia. But selecting eight lags for the Caribbean and ten lags for Colombia lowers the AIC criterion. Here, the AIC criterion is lower when selecting two lags for Bolivia and Costa Rica, four lags for Guyana, five lags for Panama and Peru, and six lags for Dominican Republic and Honduras.

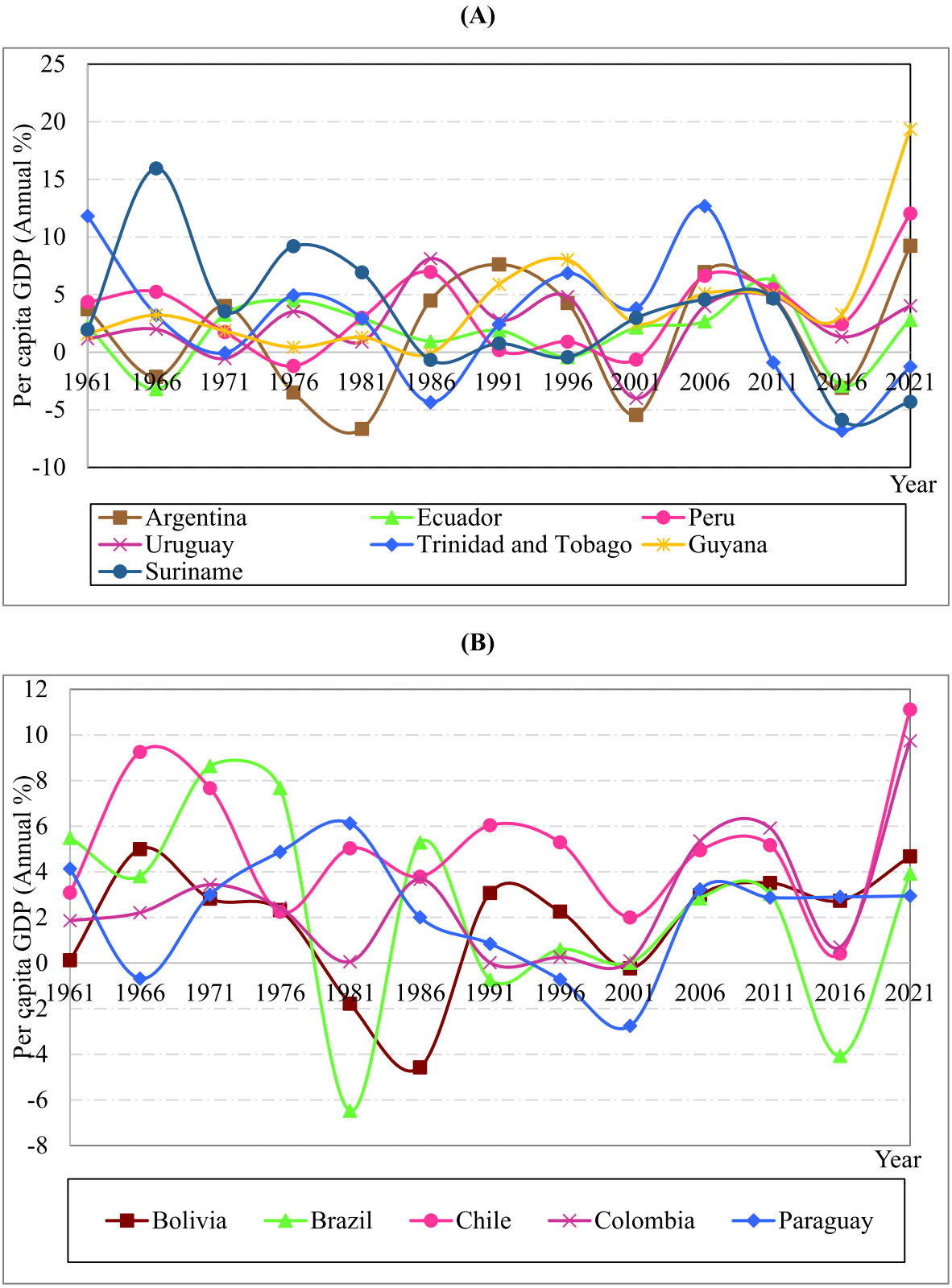

Fig. 1 South American Per capita GDP growth (annual percentage): a comparison. Source: Based on WDI [31]

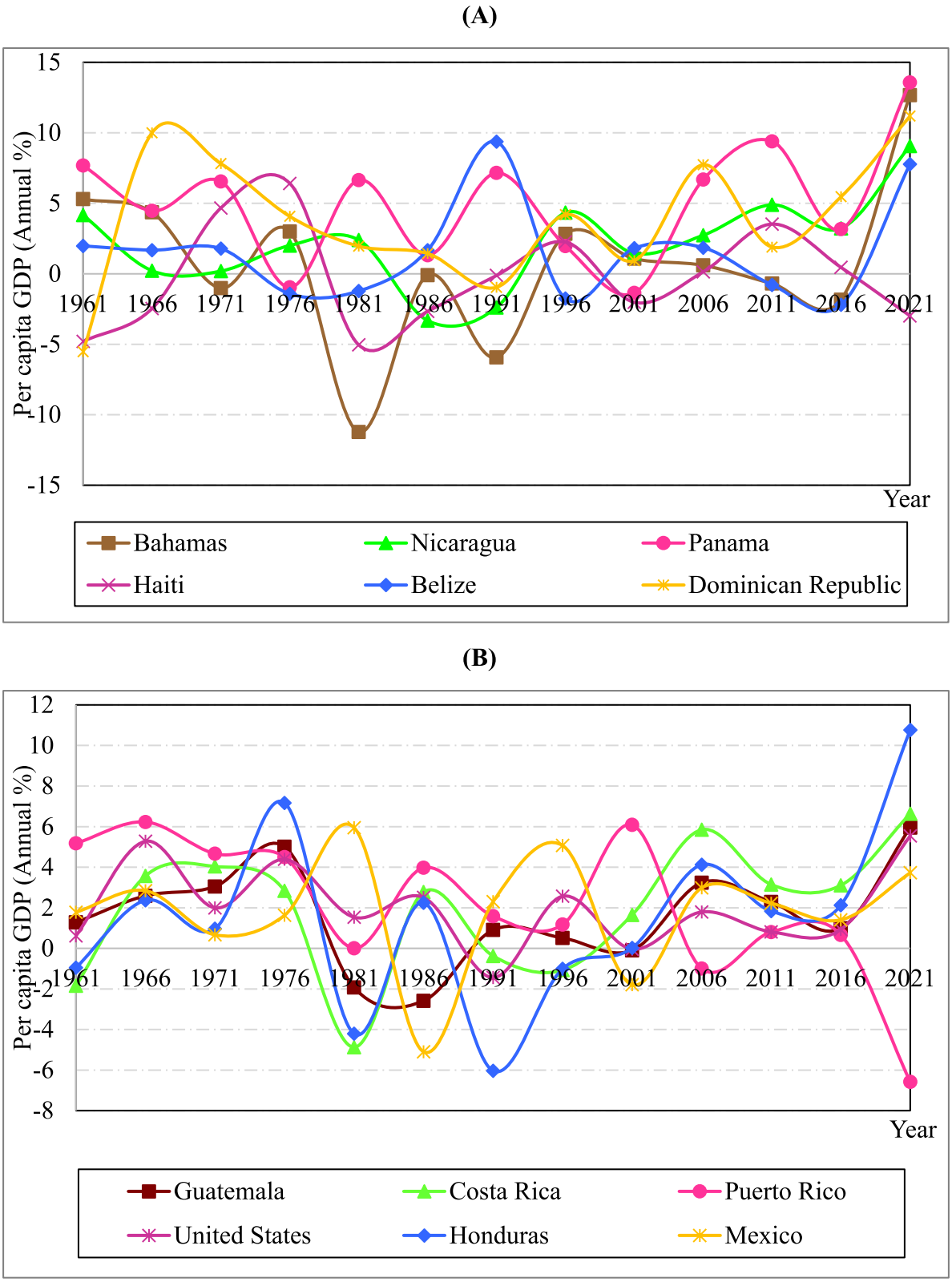

Fig. 2 North American Per capita GDP growth (annual percentage): a comparison. Source: Based on WDI [31]

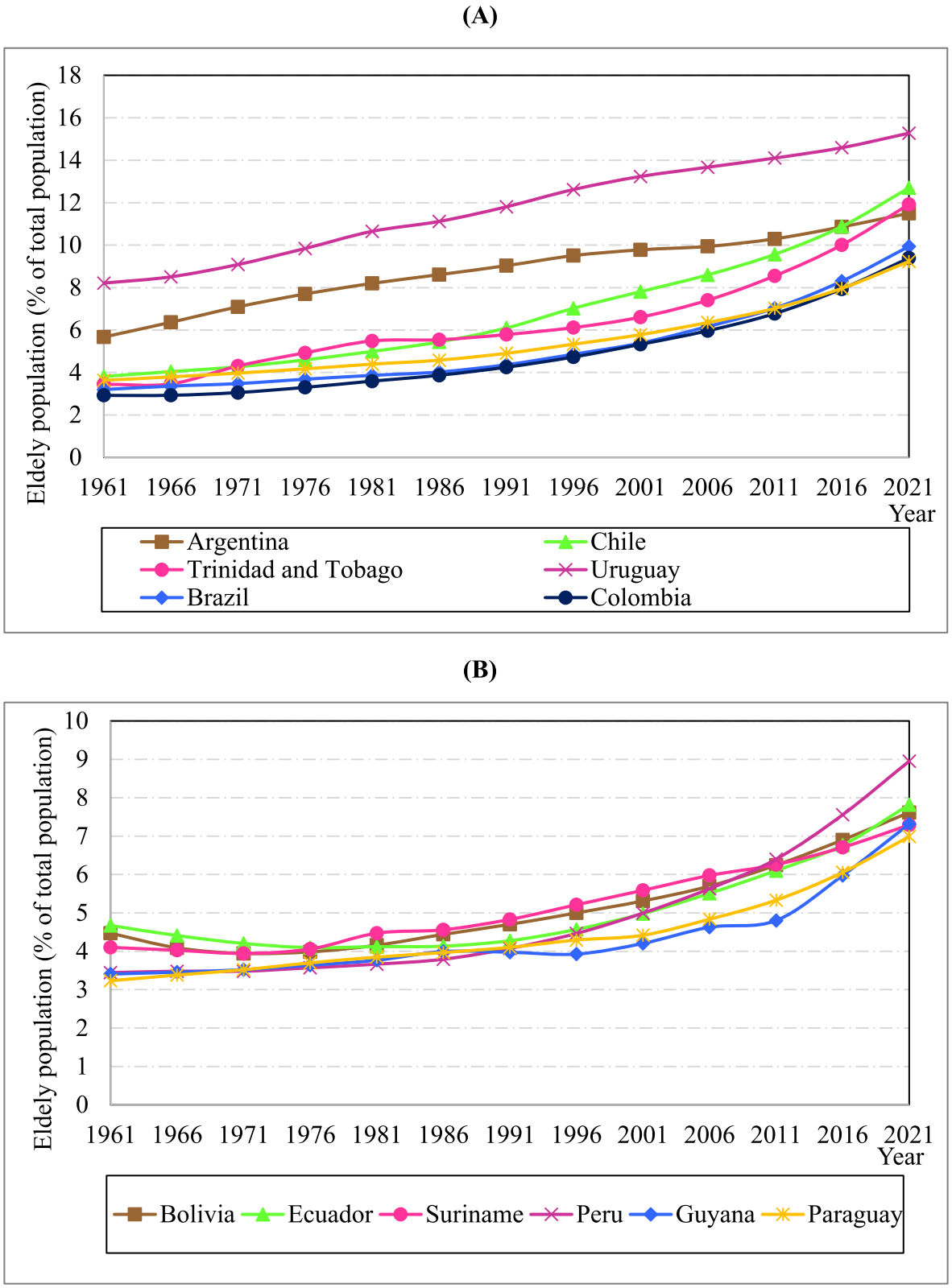

Fig. 3 South American Population aged 65 and older: a comparison. Source: Based on WDI [31]

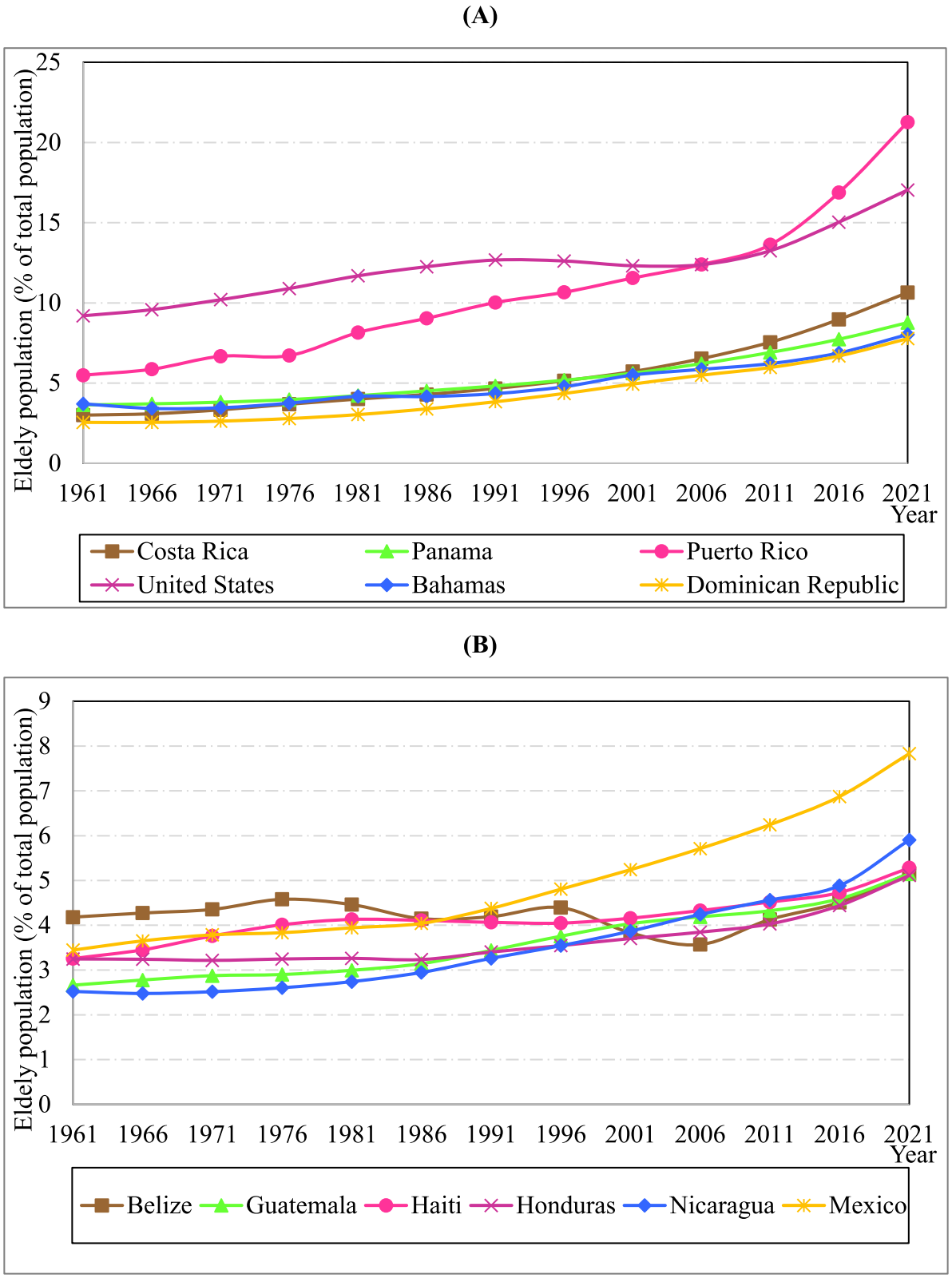

Fig. 4 North American Population aged 65 and older: a comparison. Source: Based on WDI [31]

Granger causality test

The empirical results of the Granger causality between per capita GDP and the elderly population growth rate are shown in Table 1. Only for Bolivia, Colombia, Guyana, Peru and Puerto Rico, a unidirectional linear Granger causality are running from per capita GDP to the elderly population. A unidirectional causality running from the elderly population to per capita GDP is evident for Costa Rica, Ecuador and Honduras. For Argentina, Bahamas, Belize, Brazil, Chile, Dominican Republic, Guatemala, Haiti, & Caribbean, Mexico, Nicaragua, Panama, Paraguay, Suriname, Trinidad and Tobago, the US and Uruguay, there is no causal relationship between the elderly population and economic growth. However, there is no bidirectional relationship between the elderly population and economic growth. It is worth noting that the causal test results are inconsistent with previous findings, and this may be because of diverse methods, data sample periods or model settings. Therefore, this study will focus on the nonlinear causal relationship between health care expenditure and economic growth.

The causal relationship observed in the current analysis indicates a unidirectional linear Granger causality running from per capita GDP to the elderly population only for Bolivia, Colombia, Guyana, Peru and Puerto Rico. A unidirectional causality running from the elderly population to per capita GDP is evident for Costa Rica, Ecuador and Honduras. For Argentina, Bahamas, Belize, Brazil, Chile, Dominican Republic, Guatemala, Haiti & Caribbean, Mexico, Nicaragua, Panama, Paraguay, Suriname, Trinidad and Tobago, the US and Uruguay, there is no causal relationship between the elderly population and economic growth. Hence this contradicts the confirmation of the previous literature review.

Therefore, it requires an extended analysis of the subject, including considering alternative methods and sample data sets for concrete evidence regarding the elderly population and the GDP growth in the Americas. Primarily in Bolivia, Colombia, Guyana,

Table 1 Granger causality test results for the period of 1961-2021

South American Countries	**PGDP → DEPOP**	**DEPOP → PGDP**	**PGDP → DEPOP**
Uruguay	2.812	1.159	no-way (↮)
	PGDP → DDEPOP	**DDEPOP → PGDP**	**PGDP → DDEPOP**
Argentina	0.668	1.461	no-way (↮)
Bolivia	17.809[c]	2.145	one-way (→)
Brazil	2.082	0.780	no-way (↮)
Chile	5.867	2.768	no-way (↮)
Colombia	6.248[a]	0.132	one-way (→)
Ecuador	0.674	8.353[b]	one-way (←)
Guyana	8.922[b]	0.609	one-way (→)
Paraguay	3.476	0.452	no-way (↮)
Peru	8.695[b]	2.247	one-way (→)
Suriname	1.845	2.566	no-way (↮)
Trinidad and Tobago	0.932	1.823	no-way (↮)
North American Countries	**PGDP → DDEPOP**	**DDEPOP → GDP**	**GDP → DDEPOP**
Bahamas	3.600	0.743	no-way (↮)
Belize	0.663	0.413	no-way (↮)
Costa Rica	1.815	8.271[b]	one-way (←)
Dominican Republic	1.544	0.720	no-way (↮)
Guatemala	2.026	0.099	no-way (↮)
Haiti	0.632	0.922	no-way (↮)
Honduras	2.494	9.010[b]	one-way (←)
Mexico	3.722	4.587	no-way (↮)
Nicaragua	1.177	1.934	no-way (↮)
Panama	2.169	0.458	no-way (↮)
Puerto Rico	0.461[a]	0.461	one-way (→)
US	1.297	6.099	no-way (↮)

Source: Authors' calculation based on STATA software

[a] Denotes significance at the 10% level, [b]Denotes significance at the 5% level, [c]Denotes significance at the 1% level. *DEPOP* First difference of elderly population, *DDEPOP* Second difference of elderly population

Peru and Puerto Rico, there is only a unidirectional linear Granger causality running from per capita GDP to the elderly population. However, as Gietel-Basten and Sobotka [11] identified that there is a strong link between the ageing population and economic growth. Thus, Murillo [27] proved that in such cases, a more focused policy implication, developing strong encouragement for child rearing, and creating child friendly policies should be initiated. The challenges observed in the US as a dominant economy and not having a causal relationship is contrary to the literature findings. However, Amarante et al. [4] disclosed Latin American countries as the world's economic powerhouse with the strongest economic gains and the majority of political power, the study also needs to dig deeper into the issues unearthed in these regions. In addition, the data from Canada, another top-tier economy in the world has not been assessed in the current study, which needs to be assessed in the long term. Because Canada is known as a country that welcomes immigrants with a lenient approach and this has to be examined in terms of economic growth in the long term [17]. In other words, Canada's approach for immigrants seems much relaxed against those of other countries which significantly affect demographics, the elderly population and the GDP.

Flores-Cerqueda [9] affirmed that in developing countries in South America, as per social and cultural norms, it is perceived that the ageing population is more economically active than the working population. This argument suggests that a positive interaction exists between ageing and economic growth. As the scholar noted, the ageing population with a very collective culture in South America focuses extensively on saving more – which provides more resources for investment as well as R&D – and hence creating a solid boost to the economy. Notably, the South American culture of family centered living is more celebrated and is considered to be an engine for economic growth.

However, there is a strong need for analysing the South and North America in dissimilar terms considering the economic development phases of the country, differences in political views, cultural diversity and health conditions and chronic diseases concerning the elderly population.

Wavelet coherence analysis

The wavelet coherence approach was originally used in engineering but has expanded over time into the social sciences and other fields. This is a powerful technique that allows the direction of the arrow to represent the direction and predecessor between the two variables over different time periods. The top-right position indicates that the second variable causes the first variable (positive), the bottom-right position signifies that the first variable causes the second variable (positive), and the top-left position means the second variable causes the first variable (negative) [10]. In this study, the first variable was economic growth, and the second variable was the elderly population. Illustrations were developed in R Studio (Fig. 5).

Leftward arrows indicate a negative link between economic development and the senior population between 1980 and 1990, both in the short and medium horizons (medium and high frequencies). The upward and leftward arrows depict how ageing populations are being led by economic growth. The elderly population and economic growth are negatively correlated in 2006 and 2010, whereas upward and leftward arrows show that the elderly population is being led by economic growth.

In South America, the increase in the first birth rate is booming as the economy develops. Therefore, the

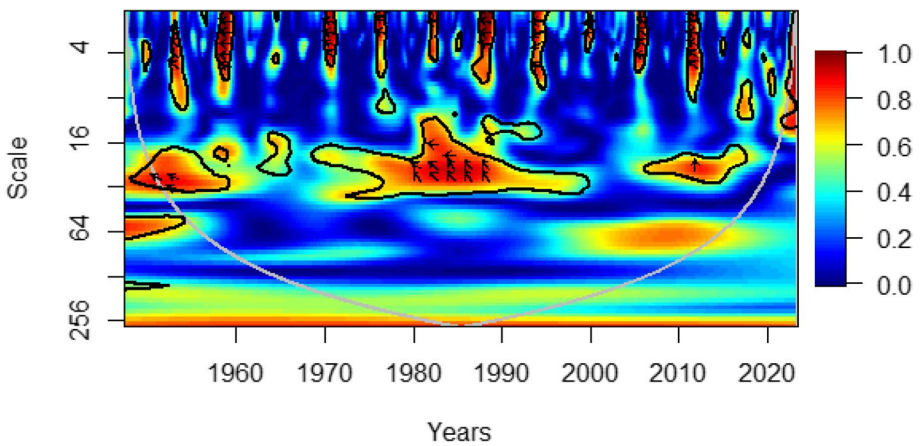

Fig. 5 South American region; GDP vs EPOP. Source: Authors' Illustration

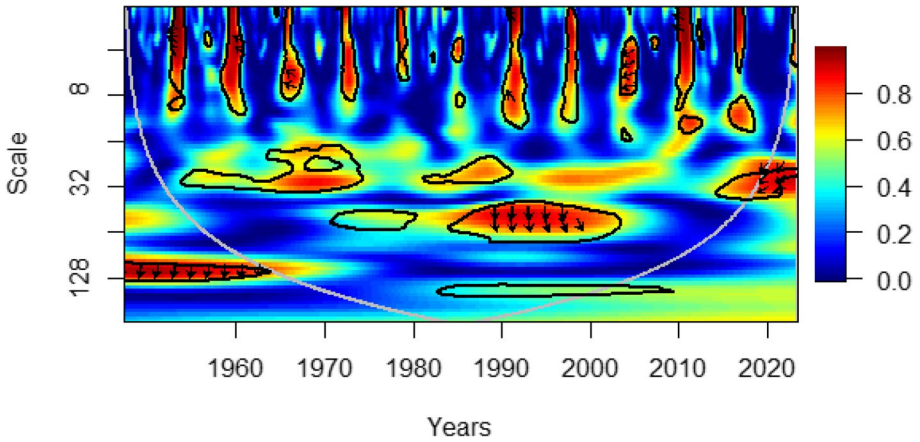

Fig. 6 North American region; GDP vs EPOP. Source: Authors' illustration

proportion of the elderly population can be explained by the rising fertility rate associated with economic growth (Fig. 6).

Between 1990 and 2000, arrows pointing to the right indicate a positive correlation between economic growth and the elderly population. The right and down arrows indicate economic growth leading the elderly population. Moreover, in 2004, left-pointing arrows show a short-term negative correlation between economic growth and an ageing population. The left and down arrows indicate that the ageing population leads to economic growth.

Rising standards of living and improved care for the elderly because of economic growth in the 1990s should have led to increased life expectancy for a person. Therefore, the proportion of the elderly in the total population rose in the medium term. As illustrated by the wavelet coherence diagram for the year 2004 and as supported by the existing literature, the North American region had a high proportion of the elderly, so high spending on care for them had a negative impact on economic growth.

Conclusions and policy implications

While inherent differences exist between the countries in terms of a cumulative context, the study focused that the per capita GDP is, in fact, often being impacted by the growth of the ageing population. Henceforth, these considerations must be considered when developing further research strategies to identify the ageing population's impact on the countries' economic growth. Particularly with different political, cultural, and social issues on the ageing population in both North and South America – it won't be easy to fathom a sustainable solution to minimise the economic impact of the ageing population. Therefore, these mediator variables should also be considered for further studies when analysing the ageing population and their connected issues,. Through such a comprehensive assessment of the economic impact of the ageing population, there can be more specific problem identification, which will be easier to diagnose and implement through systemic decision making. These factors can be brought into future studies; therefore, intensifying the current study's generalisability.

Granger causality test results for South American countries show that Bolivia, Colombia, Ecuador, Guyana, and Peru have unidirectional causality, while the rest of the countries show no directionality. Granger causality test results for North American countries show that Costa Rica, Honduras, and Puerto Rico have unidirectional causality, while the rest of the countries show no directionality. Wavelet coherence analysis conclude that economic growth positively led the elderly population in North America during the late 21st century. Furthermore, economic growth had negatively led the elderly population in South America during this period.

The major policy implication in dealing with the ageing population in both North and South America is to consider the long-term impact of the ageing population and understand the need for talent outsourcing. When a country's dependency ratio rises, it may not be viable for the existing native population to fulfil the given production requirement. Therefore, this relates to the fact that the countries which are largely affected by this ratio outsource their talent from countries with a strong fertility rate [18]. Thus, specifically, countries such as the US need to reconsider this strategy. The countries such as the Bahamas, Puerto Rico and Bahamas, with strong informal economies connected to the tourism industry, will face a much different future in managing their ageing population. Hence the policies is should be developed based on the context of that particular country [4].

Considering the impact of the ageing population in Latin America, the countries in this region need to

identify the substantial impact it may incur not only in the short term but also in the medium and long term. Therefore, the policy reforms in Cuba and Mexico are a requisite in terms of preventing growth in the pension deficit by 2030, increasing the retirement age by five years, reducing benefits for the ageing population by about 28% [4, 17]. Therefore, increasingly leading to a better universal ageing care plan for the elderly population is pivotal for Latin American nations.

The policy reforms, in general, have to be developed to enable countries to withstand the demographic transition., in particular, considering the high short term to medium term migration trends observed in these countries – compared to other regions. Therefore, apart from the US, which has a strong formal registration process of migrants, many countries in North America have a 'moving population trend' which needs to be addressed in making policy decisions.

As this research is based on data on the GDP and the elderly population, limitations of the variables are encountered in this study. First, not all countries in the American region were included in the index because of various reasons, such as lack of data. Second, in this study, only two variables were used to obtain these conclusions. However, since it offers a foundation for future research in this area, more demographic and economic variables relevant to this sphere of research can be added for a broader scope paving the way to conduct extensive research studies. This approach could offer economic insights by integrating elements like the dependence ratio, savings rates, and household income, migration indicators, price inflations, unemployment rates and etc. This exclusion represents a limitation of our study, as these variables could provide a more nuanced understanding of the dynamics between demographic changes and economic outcomes. Future research could address this limitation by incorporating these additional indicators, using advanced techniques such as Granger causality tests, to explore their combined impact on economic growth. It is recommended that a long-term follow-up study be conducted to examine how the countries' index values have increased after a few years. This way, it is possible to identify the nations whose index values have significantly improved. The greatly enhanced index components and the countries' contributions throughout these years can be connected through further investigations. Whilst the current study explains the nature of behaviour between two variables, the elderly population and economic growth, further studies with moderator variables and additional data can assist nations in finding practical solutions for optimising elderly care expenses.

The Granger causality test, while effective for identifying directionality in time-series data, is inherently limited in capturing complex, dynamic, or nonlinear relationships. The test's results are sensitive to the choice of lag length and the time horizon considered, potentially overlooking long-term or delayed bidirectional effects. Additionally, the scope of the analysis is constrained by the availability and quality of data, which may not fully account for structural factors such as healthcare systems, labor market dynamics, or cultural differences that influence the elderly population's economic impact. Lastly, our results focus on a specific temporal and geographic context, which may limit their generalizability to other settings. These limitations underscore the need for further research using advanced methodologies, such as nonlinear modeling or extended time-series datasets, to deepen the understanding of this complex relationship.

Furthermore, Future research could expand on this work by applying cointegration analysis to identify long-term equilibrium relationships between the elderly population and economic growth. This would be particularly valuable in understanding how shared trends and structural breaks influence these dynamics. Integrating cointegration methods with techniques like Granger causality and wavelet coherence could also offer a more comprehensive perspective on short-, medium-, and long-term interactions, paving the way for more robust policy recommendations.

Supplementary Information

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Supplementary Material 1. Table A1 Data file.

Supplementary Material 2. Table A2 Appendix. Descriptive statistics.

Supplementary Material 3. Table A3 Appendix. Dfuller test result.

Supplementary Material 4. Table A4 Appendix. Pperron test results.

Supplementary Material 5. Table A5 Appendix. Lag length criteria results.

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All authors contributed to the conception and design of the project. T.J. and R.J. composed the writing of the manuscript. T.J., R.K., T.N. and S.A. carried out a significant share of tasks on statistical work in the manuscript. R.J provided critical knowledge in drafting the paper and supervised the entire study. The authors have read and approved the final manuscript.

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Declarations

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