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Assessing the effects of population aging on health financing structures: Evidence from APEC countries using panel data

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Assessing the effects of population aging on health financing structures: Evidence from APEC countries using panel data

Abstract

Background: An aging population, along with rising chronic diseases and disabilities, is increasing the demand for healthcare services; this places significant pressure on healthcare costs and public finances, particularly in countries with high public health expenditures. Asia-Pacific countries are at the forefront of global population aging, and the rapid demographic transformation in the region has significant economic, social, and political consequences. This study aims to evaluate the impact of selected aging indicators on health financing systems in Asia-Pacific Economic Cooperation (APEC) countries.

Methods: In this study, the proportion of the population aged 60–80 and over, life expectancy at birth, and gender ratio were used as indicators of aging. To examine the effects on health financing in APEC countries during the 2000–2020 period, three separate models were established, including public health expenditures, private health expenditures, and out-of-pocket health expenditures; the analyses were carried out using panel quantile, Driscoll–Kraay, and Ridge methods.

Results: The findings show that life expectancy reduces public health expenditures except in the 90th quartile, while increasing private health expenditures in all quartiles. Although no significant relationship was found for out-of-pocket health expenditures, life expectancy stands out as the most prominent predictor. The Driscoll-Kraay and Ridge results reveal that the population aged 80 and over increases public health expenditures; this is associated with higher life expectancy and lower private health expenditures. Furthermore, the population aged 60 and over reduces out-of-pocket health

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expenditures, while the gender ratio was not found to be significant in all models.

Conclusions: Life expectancy is the strongest predictor of out-of-pocket health expenditures. In contrast, the contribution of the population aged 80 and over to the decline in private health expenditures is limited. Gender ratio does not show a significant impact on health expenditures in APEC countries. These findings highlight the importance of developing age-sensitive and sustainable health financing policies in APEC countries.

Keywords: Health financing systems, Aging indicators, APEC countries, Panel quantile regression method.

1 Introduction

Old age is an inevitable and irreversible period in which the individual passes from physical and mental independence to dependence [1]. In general, individuals over the age of 65 are considered elderly [2]. However, aging is classified into two groups: biological and chronological. Chronological aging refers to the time that has passed since birth. Biological aging describes changes in physical, physiological, and cognitive functions related to molecular and cellular processes [3]. According to chronological age classification, the World Health Organization (WHO) categorizes old age (into three groups: youngest-old (65-74), middle-old (75-84), and oldest-old (85+). Societies in which individuals aged 65 and over make up 4% or less of the population are called a ‘young society’; those with 4-7% are called a ‘mature society’; those with 7-10% are called an ‘old society’; and those with 10% or more are called a ‘very old society’ [2].

Globally, it is projected that the proportion of the population over the age of 60 will nearly double from 12% to 22% between 2015 and 2050. The United

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Nations (UN) estimates that the world's elderly population will grow to 1.6 billion by 2050, with one in six individuals over the age of 65 [4]. Additionally, it is anticipated that the number of people aged 80 and over will increase approximately threefold in the 2020-2050 period, reaching 426 million. The rise in the proportion of the elderly population worldwide is leading to an increase in healthcare expenditures, primarily due to the heightened demand for medical and long-term care services. As a result, this situation places additional pressure on health budgets in various countries, presenting an increasingly significant challenge for the sustainability of public finances [5,6]. This situation is particularly evident in both developed and developing countries, where population aging has accelerated in recent years. The World Social Report (2023) emphasizes that elderly individuals should be central to planning for a sustainable future [4,7]. In addition, The Madrid International Plan of Action on Ageing recommends that governments conduct studies to develop effective, evidence-based policies and programs to address societal aging [8], as various physiological issues commonly arise among elderly individuals [9]. As a result, a loss of bodily function, an increase in chronic diseases, limitations in daily activities, and an increase in home accidents occur [10]. Additionally, 23% of the global disease burden is attributed to disability-related and chronic diseases in individuals aged 60 and over [11]. These health issues that arise in old age increase the healthcare needs of elderly individuals and directly impact the burden on the healthcare system. Consequently, the potential effects of aging on healthcare systems are being

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increasingly discussed. Examining the impact of aging indicators on countries' health financing systems will thus offer valuable data for policymakers.

Behera and Dash (2019), using the generalized method of moments regression approach, examined the impact of macro-fiscal policies on health financing by adopting socioeconomic factors in 85 low- and middle-income countries over the period 2000-2013 [12]. The findings show that ageing and per capita income are positively associated with public health expenditures. The results show that there is a causal relationship between population ageing and health expenditures, reflecting a statistically significant feedback effect [13].

Krabbe-Alkemade et al. (2020) examined the distribution of health expenditures using individual health insurance and social care claims of individuals aged 65 and over in the Netherlands between 2012 and 2016 by performing trend analysis [5]. The results indicate that in the short term, the shift from institutional care to aging in place contributes to a slowdown in the growth of total health expenditures for individuals aged 65 and over. The results of a study analyzing data from 1997 to 2006 in Taiwan, which investigated the extent to which population aging and technological innovation contributed to increased health expenditures, showed that population aging played a more important role in the increase in health expenditures than technological innovation. Lopreite and Zhu (2020) calculated the influence of China's aging population on health expenditures

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and economic growth from 1978 to 2016 using Bayesian vector autoregression models and compared the results with those for the USA [6]. The results showed that in both countries, the aging population significantly impacted three factors: the aging index (which reflects the proportion of older individuals in the population), the ratio of health expenditures to income, and life expectancy, with China's aging population prompting a relatively strong increase in health expenditures.

Cylus et al. (2022) estimated the difference between health incomes and expenditures attributable to ageing from 2020 to 2100 using the population ageing financial sustainability gap for health systems analysis of panel data from countries with different health financing systems in the Western Pacific and Europe. [14]. In this context, they propose the method of the 'aging population financial sustainability gap for health systems' to assess how changes in the age distribution of the population impact health expenditures and income.

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Park and Nam (2022) analyzed the relationship between cognitive function and out-of-pocket medical expenditures due to changes in multiple chronic disease status among individuals aged 60 years and over by analyzing South Korean data between 2014 and 2018 with generalized estimating equations. The results of the study revealed that out-of-pocket expenses are significantly greater in older adults with multiple chronic conditions and cognitive decline, and that medical expenses increase with age [15].

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Yang et al. (2022) investigated the links between population aging, renewable energy budgets, healthcare expenditures, and carbon dioxide emissions using panel data estimation techniques with G7 countries' data between 1985 and 2019 [16]. Recent studies have increasingly focused on the economic impact of aging populations on healthcare systems worldwide. Giordana and Pi Alperin (2023) simulate long-term trends in public health expenditures on healthcare and long-term care in Luxembourg. Their findings indicate that increases in healthcare expenditures are driven primarily by rising production costs, whereas growth in long-term care expenditures is driven mainly by population aging [17]. Similarly, Lopreite et al. (2023) analyzed thematic developments in aging and health expenditures using bibliometric mapping and found that although the aging population increases health costs, these increases can be mitigated by policies and new technologies that improve access to healthcare for older people [7]. The results showed that healthcare expenditures are driven by population aging, which in turn affects renewable energy budgets [16,18–20].

The increasing proportion of the elderly population is placing significant pressure on public health expenditures and social security budgets in many countries. This is primarily because older individuals have a greater need for long-term care services, chronic disease management, and ongoing health monitoring [21,22]. In contrast, in societies with higher income and education levels, the impact of aging on healthcare expenditures can be partly reflected through private health insurance and private healthcare expenditures.

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Indeed, some empirical studies show that the impact of aging on healthcare expenditures can be particularly pronounced in the private healthcare expenditure channel [23]. On the other hand, the prevalence of multiple chronic diseases, continuous medication use, and increased healthcare utilization in older individuals can also increase out-of-pocket healthcare expenses. It is known that healthcare costs are higher for individuals aged 60 and over compared to other age groups. Institutional factors such as limited insurance coverage in healthcare systems, high out-of-pocket payment rates, or insufficient regulation of the private sector can lead to this financial burden being borne to a greater extent by individuals [24,25].

In summary, the literature examining the impact of aging indicators on health financing systems presents varied results, which are often influenced by model selection and data type. However, few studies have considered the effects of aging indicators on the chronological age classification of the population. There is also limited empirical evidence on how aging-related health system outcomes impact health financing structures. In this context, the current research is expected to fill an important gap in the literature, offering valuable insights for health policymakers and researchers.

2 Methods

2.1 Motivation

In recent years, rising health expenditures—driven by countries' epidemiological transition processes, aging demographic structures, and changes in population dynamics—have heightened the importance of health

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financing systems and underscored the need for effective planning. A research on health financing systems has shown that studies focus on OECD and European countries, especially in sample groups. APEC countries were selected as the sample group for this study because they constitute a significant group comprising 40% of the world population, 55% of the world economy, and 45% of world trade [26]. At the same time, these countries are at the forefront of the global population aging phenomenon. The number of older people in the region is increasing at an unprecedented rate, with the number of older people projected to triple by 2050. The rapid pace of aging in the region therefore has far-reaching and profound economic, social and political implications [27]. One of the most important health system challenges in the APEC region is the rapid ageing of the population, which requires more resources for public pensions and care services [28]. The World Bank and WHO recommend that at least 5 percent of GDP should be allocated to public health expenditures. Although public health expenditures in APEC countries have increased from 2.8 percent to 4 percent in the last 20 years, they are still below the recommended level. This situation leads to an increase in individuals' out-of-pocket payment rates for health expenditures and weakens social protection [29]. Moreover, the gap in the literature regarding the relationship between the chronological age classification of the elderly population and health financing systems highlights the importance of this research. In addition, public health expenditures are mostly considered a parameter of the health financing system in the literature. Another

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innovation of this research is that it allows for comparisons by considering public, private, and out-of-pocket health expenditures as parameters of the health financing system. The study aims to evaluate the influence of selected aging indicators on health financing systems in APEC countries from 2000 to 2020, using panel quantile regression (PQR) and robust estimators methodologies.

The age groups 60+ and 80+ are widely used in international studies to show the level of aging and the size of the elderly population [30,31]. Therefore, data from the 60+ and 80+ age groups in APEC countries were used in this study.

The effects of indicators such as disability-adjusted life years and access to health services on health financing systems have been analyzed in previous studies [32,33]. In this study, based on the Aging Report published by the WHO, the UN Population Fund and Help Age International, indicators such as the proportion of population over 60 and 80 years of age, life expectancy at birth and gender ratio are evaluated for both sexes and the aging phenomenon is discussed from a different perspective.

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2.2 Model, variables, and summary statistics

In this study, aging indicators were selected by considering the WHO website and the ‘Aging Report’ published by the UN Population Fund and HelpAge International. However, the chronological age classification of the population was based on the year ranges used by the WHO and the UN.

The models of the study were established as follows:

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$$lGGHE_{i,t} = \partial_0 + \beta_1 lPP60_{i,t} + \beta_2 lPP80_{i,t} + \beta_3 lLE_{i,t} + \beta_4 lSR_{i,t} + \epsilon_{i,t} \quad (1)$$

$$lPVT_{i,t} = \partial_0 + \beta_1 lPP60_{i,t} + \beta_2 lPP80_{i,t} + \beta_3 lLE_{i,t} + \beta_4 lSR_{i,t} + \epsilon_{i,t} \quad (2)$$

$$lOOPS_{i,t} = \partial_0 + \beta_1 lPP60_{i,t} + \beta_2 lPP80_{i,t} + \beta_3 lLE_{i,t} + \beta_4 lSR_{i,t} + \epsilon_{i,t} \quad (3)$$

In the models, '∂_0' explain to the constant parameter, 'β_1,β_2,β_3, β_4' to the parameter coefficients, 'i' to the country effect, 't' to the time effect, 'ϵ' to the error term, and 'l' to the logarithmic form of the variables. Logarithmic transformation was applied to improve model fit, satisfy the assumptions of linearity and homoscedasticity, and reduce the impact of outliers [34]. 'GGHE' refer to public health expenditures (% of current health expenditure), 'PVT' to private health expenditures (% of current health expenditure), 'OOPS' to out-of-pocket health expenditures (% of current health expenditure), 'PP60' to population aged 60 and over (% of total population, both sexes), 'PP80' to population aged 80 and over (% of total population, both sexes), 'LE' to life expectancy at birth (total), and 'SR' to the sex ratio at birth (male births per female births). GGHE, PVT, OOPS, PP60 and PP80 secondary data, which are reached in the form of annual data, were compiled from the official website of WHO. Similarly, LE and SR secondary data, which represent annual data, were collected from the World Development Indicators on the official website of the World Bank. Because it is not suitable for the data structure, the variables have not been adjusted for inflation and/or purchasing power. Due to the balanced panel time series model structure, Brunei, Hong Kong, Taiwan, Malaysia, and Papua New Guinea countries were not included in the

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model for missing data points. This situation is attributed to the limitation of the research. Subdivision 't' covers the period 2000-2020; 'i' refers to the countries in the sample universe: Australia, Canada, Chile, China, Indonesia, Japan, Korea, Mexico, New Zealand, Peru, Philippines, Russia, Singapore, Thailand, USA and Vietnam.

In the equations, hypotheses regarding prior expectations for the parameter coefficients of the variables β_1,β_2,β_3 and β_4 have been formulated as follows:

The aging population, the rise in chronic diseases, and the increasing need for long-term care are driving up the demand for healthcare services [5,35,36]. This increase puts significant pressure on public budgets, particularly in large-scale public health systems, leading to increased public health spending [21,22]. The increased use of healthcare services by older individuals also reinforces this process. Conversely, the impact of gender ratio on public spending is expected to remain more limited.

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H_1: Increases in the population aged 60 and over, the population aged 80 and over, and life expectancy are expected to increase publicly financed health expenditures, while the effect of the sex ratio is expected to be insignificant.

With an aging population, capacity problems or access restrictions in public health services can lead individuals to seek alternatives. This situation increases the tendency to evolve to private healthcare services, especially among higher-income groups [23,37]. The shift of needs that the public sector

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cannot meet to the private sector can lead to increased private healthcare spending as people age. However, the gender ratio is not expected to play a decisive role in this process.

H_2: Increases in the population aged 60 and over, the population aged 80 and over, life expectancy, and sex ratio are expected to increase health expenditures financed by the private sector.

As the population ages, the need for healthcare increases, which may lead individuals to incur direct expenditures in areas where insurance coverage is limited [37,38]. Inadequate coverage of long-term care services, or the exclusion of certain services from reimbursement, can lead to increased out-of-pocket expenses [39,40]. Therefore, aging is expected to have an increasing effect on out-of-pocket healthcare expenditures. The impact of the gender ratio in this area is projected to be limited.

H_3: Increases in the population aged 60 and over, the population aged 80 and over, life expectancy, and sex ratio are expected to increase health expenditures financed within the scope of out-of-pocket payments.

The impact of aging on healthcare spending varies depending on the financing structure. Public healthcare spending is more directly affected by this process due to increased demand for services, while private spending is shaped more by individual preferences and resources [13,23]. Out-of-pocket payments, however, are largely dependent on insurance coverage and cost-sharing. In this context, the impact of aging is expected to be most strongly

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seen in public spending, followed by private spending, and to a more restricted extent in out-of-pocket payments.

H_4: Increases in the population over 60 years of age, population over 80 years of age, life expectancy and the sex ratio are assumed to increase health financing resources from high to low in the public sector, private sector and out-of-pocket payments, respectively.

2.3 Econometric techniques

2.3.1 Preliminary empirical tests

As part of the preliminary empirical tests, cross-sectional dependence (CD), slope homogeneity, and panel unit root tests were performed. In panel data models, the first step in the methodology is to investigate whether all cross-sectional units in the panel are equally affected by a specific shock when it occurs in the series. This situation is assessed using various types and structures of CD tests. The CD is a very important problem in the estimation processes of panel data analyses. Moreover, appropriate unit root, cointegration, and causality tests are required in the selection process and may cause serious problems such as dimensional distortion [38]. In this study, the Breusch-Pagan test recommended for T>N status was used. Breusch and Pagan (1980) proposed the Lagrange Multiplier (LM) test statistic to test zero cross-equation error correlations [41].

The homogeneity or heterogeneity of the constant coefficient and slope parameters across cross-sectional units affects the choice of cointegration and causality estimation methods. This test can be used to test the random

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coefficients model by examining the difference among unit-specific Ordinary Least Squares (OLS) estimators, which do not consider the panel structure of the data, and the weighted average matrices of the within-group estimator. If there is no statistically significant difference among them, the parameters are homogeneous and the hypothesis to be tested is established as H_0:$\beta_i = \beta$ [42,43].

In the third stage of the methodology, it is necessary to identify the stationarity levels of the variables and whether they contain unit roots. In this context, Pesaran (2007) cross-sectional augmented Dickey Fuller (CADF) and cross-sectional Im, Pesaran and Shin (CIPS) unit root tests, which are among the second-generation panel unit root tests recommended for CD between units, were preferred in the study [44]. These tests also address the issue of heterogeneity. The CIPS test statistic value was improved based on the CADF test statistics. The H_0 hypothesis for CIPS and CADF tests is that all variables in question are non-stationary; the H_1 hypothesis meets the assumption that at least one of the variables in question is stationary [45].

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2.3.2 Cointegration tests

Cointegration tests are used to investigate whether a long-term relationship exists between variables. For this purpose, different panel cointegration tests, such as those proposed by Kao (1999), Pedroni (1999), Pedroni (2004), Westerlund (2005) and Westerlund (2007), each offer unique features [46–50]. Among these, the panel cointegration test can yield consistent results even when cross-sectional dependence exists between units [51].

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Furthermore, these tests, based on four different statistics -panel statistics (Pt, Pa) and group statistics (Gt, Ga)- are highly flexible, allowing for heterogeneity in the long-term and short-term parameters of the error correction model [42].

2.3.3 Panel quantile regression

The use of traditional regression methodology in analysis can lead to overestimation or underestimation of relevant coefficients. Since these methods focus on average effects, they may be insufficient to detect a significant relationship [52]. The OLS method is known as the most effective method for estimating the possible relationship between variables. However, the validity and reliability of the method depend on the provision of Gauss-Markov assumptions (linearity, random, non-collinearity, exogeneity, homoscedasticity). These strong assumptions may cause the OLS method not to be preferred in some cases that occur in the data set and model. Some of the limitations of this method are that the OLS method is based on the conditional mean, cannot provide reliable results in the presence of extreme values and in heavy-tailed distributions [53]. However, conditional quantile regression is the adapted version of the quantile regression estimator to the panel data structure, which allows the analysis of the entire conditional distribution of the dependent variable, instead of modeling the dependent variable mean conditionally on the fixed values of the independent variable/s, and thus robust estimates are achieved. The specified models reveal the conditional variability by allowing to determine the range of conditional

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quantiles and control for unobserved individual effects. Quantile regression, which is performed to explain in detail the connection between the quantiles of the distribution of the dependent variable and the independent variables, is based on the minimization of asymmetrically weighted absolute residual squares. Since quantiles provide full information about the distribution of the dependent variable, quantile regression is an important alternative to the conditional mean-based OLS regression [54].

The pooled quantile regression, which was introduced to the literature with the pioneering study by Koenker and Bassett (1978), offers the possibility to examine the midpoints and extremes of the distribution by considering model heterogeneity and the assumption of normality [55]. It provides information about all conditional distributions of the dependent variable with respect to the independent variable in order to estimate the functional relationships between variables for all parts of the probability distribution. Obtaining different results at different quantile values is interpreted as the dependent variable responding differently to changes in the independent variable at different points of its conditional distribution [56]. However, the method is adaptable for cross-sectional models with endogenous variables and facilitates the estimation of complex nonlinear models. It also provides more reliable results by considering time-independent and unit-specific fixed effects [57]. Based on these reasons, the panel quantile regression was preferred in this study.

The mathematical form of the model is as follows [58]:

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$$Q_{y_i}\left(\tau \middle| x_i\right) = x_{it}^{T}\beta_{\tau} \quad (4)$$

In Equation (4), y_{it} is the conditional quantile, x_i is a vector of independent variable/s, and β_τ is the coefficients of the independent variables. Also, τ is the quantile index and takes values between 0 and 1 ($0 < \tau < 1$). The quantile model for panel time series analysis is expressed as follows:

$$Q_{y_i}\left(\tau \middle| \alpha_i, x_{it}\right) = \alpha_i + x_{it}^{T}\beta(\tau) \quad (5)$$

Here, parameter α_i represents the individual-specific effects. The suggested process for estimating the model simultaneously in different quantiles is as follows:

$$\min_{(\alpha,\ \beta)} \sum_{k=1}^{K} \sum_{t=1}^{T} \sum_{i=1}^{N} w_{it} p_{\tau k}(y_{it} - \alpha_i - x_{it}^{T}\beta(\tau_k)) \quad (6)$$

In Equation (6), the notations K, T and N describe the number of quantiles, period interval and number of cross-sectional units, respectively. Supposedly $y_{it} - \alpha_i - x_{it}^{T}\beta(\tau_k) = \varphi$, the weights are shown as follows:

If $\varphi < 0$, $w_{it} = \tau$

If $\varphi > 0$, $w_{it} = 1 - \tau$

It is also calculated whether the parameter estimates for different quantile values are equal via the H_0 hypothesis:

$$H_0 = \beta(\tau_1) = \beta(\tau_2) = \ldots = \beta(\tau_k) \quad (7)$$

The H_0 hypothesis is interpreted through the Wald test. Rejection of the hypothesis explains that the parameters exhibit significant differences between quantiles and provides support for the use of the PQR.

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2.3.4 Robustness checks

2.3.4.1 Driscoll-Kraay estimator

Driscoll and Kraay (1998) developed standard non-parametric time series covariance matrix estimators to be robust to all forms of spatial and seasonal correlation when $T > N$ in panel data models [59]. The methodology applies a Newey-West correction to the series of cross-sectional averages. This correction ensures consistent covariance matrix estimators, regardless of cross-sectional size, by providing corrected standard error estimates. The Driscoll-Kraay estimator further produces robust errors that are consistent with spatial and periodic correlation in the presence of heteroscedasticity, even when both T and N are large [60]. Considering the $T > N$ condition of the balanced panel structure of this study, the specified estimator was preferred due to the existence of heterogeneity, autocorrelation and cross-sectional dependence problems in the established models.

In the panel data model in the equation below [60]:

$$Y_{it} = \beta X_{it} + \mu_{it} \quad (8)$$

Under the assumptions that the error term is heteroskedastic, autocorrelated and inter-unit correlated, the parameters give consistent estimates with the pooled least squares method.

$$\hat{\beta} = (X'X)^{-1}X'Y \quad (9)$$

The Driscoll-Kraay standard errors of the parameter estimates are calculated by the square roots of the diagonal elements of the asymptotic covariance matrix.

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$$V(\hat{\beta}) = (X'X)^{-1}\hat{S}_T(X'X)^{-1} \quad (10)$$

$\hat{S}_T$ in equation (10) is shown in the follows:

$$\hat{S}_T = \hat{\vartheta}_0 + \sum_{j=1}^{m(T)} w(j,m)[\hat{\vartheta}_j + \hat{\vartheta}_j'] \quad (11)$$

$m(T)$ is the lag length for autocorrelation. The Bartlett weights shown as $w(j,m(T)) = 1 - j/(m(T)+1)$ ensure that $\hat{S}_T$ is positive. It also allows the autocovariance function to take lower weights from higher orders.

2.3.4.2 Ridge estimator

In case of multiple linear connections in the established model, biased regression methods are used to make parameter estimation. While the main purpose in Shrunken regression, Principal Components regression and Eigenvalues regression is to select the appropriate variable, the main purpose in Ridge regression is to make parameter estimation with the smallest variance [61]. In this context, Ridge regression analysis was preferred for the problem of multiple linear connections between independent variables (population over 60 and 80 years of age) in this study. The solution method of Ridge regression is a technique like the OLS estimator. The technique is preferred because it can provide lower values than the variance values obtained from the OLS estimator and reduces the size of the regression coordinates. The solution is achieved by adding a small and positive constant (k) to the diagonal elements of the $(X'Y)$ matrix formed by the variables in the standard form before calculating the coefficient estimates. It is aimed to significantly reduce the number of matrix conditions

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by adding positive constants to the diagonal elements of the correlation matrix of independent variables. Accordingly, the Ridge regression solution is shown as follows [61,62]:

$$\hat{\beta}_{RR} = [(X\hat{}'X) + kM]\hat{}(-1)X'Y \quad (12)$$

When $k = 0$ the Ridge regression solution is equivalent to the OLS solution. Therefore, the estimation process is also explained as a linear transformation of the OLS estimation. The k in the equation is a fixed variable and takes a value between 0 and 1 $(0 < k < 1)$. M is the unit matrix, and X and Y are the representations of the variables in the data set.

3 Results

The results in Table 1 confirm evidence of panel cross-sectional dependence at the 1% significance level in all series of variables according to the Breusch-Pagan LM test. Furthermore, the evidence indicates that the H_0 hypothesis of slope homogeneity for all the variables is rejected at the 1% significance level, confirming the presence of heterogeneity. Thus, it is concluded that the parameters are not homogeneous and vary from unit to unit.

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Table 1 Cross-sectional dependence and slope homogeneity results.

Test	lGGHE	lPVT	lOOPS	lPP60	lPP80	lLE	lSR
Cross-sectional dependence							
Breusch-Pagan LM	618.03*	600.08*	1127.82*	2338.25*	2193.75*	1890.80*	619.47*
Slope homogeneity							
chi2(15)	6056.93*	7257.44*	8148.86*	3619.59*	8068.06*	5064.51*	32810.74*

Note: The * symbol indicates a 1% significance level.

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The type of unit root test was chosen in line with the 2nd generation panel unit root tests recommended for CD. The results of the preferred CIPS and CADF unit root tests are presented in Table 2. These results indicate that all variables included in the model are stationary and do not contain unit roots at first difference I(1) levels.

Table 2 Panel unit root results.

Variables	CIPS		CADF	
	Level	**Δ**	**Level**	**Δ**
lGGHE	-2.07***	-3.72*	-1.72	-2.54*
lPVT	-1.79	-3.59*	-1.46	-2.50*
lOOPS	-2.11***	-3.75*	-1.70	-2.66*
lPP60	-1.44	-3.11*	-1.76	-2.77*
lPP80	-2.08***	-4.93*	-1.47	-3.19*
lLE	-1.93	-3.68*	-1.25	-2.14**
lSR	-2.04	-3.95*	-2.04	-2.54*

Note: Δ notation is the first difference operator. The symbols *, **, and *** represent significance levels of 1%, 5%, and 10%, respectively.

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In the next stage of the analysis, tests were applied to determine whether the normal distribution assumption was met in the established model and whether there was a multicollinearity problem. The results of the Shapiro-Wilk W and Skewness/Kurtosis normality and variance inflation factor (VIF) tests performed in this context are summarized in Table 3. The normal distribution test results for the error terms show that the H_0 hypothesis was rejected at a 1% significance level and that the normal distribution assumption was not met in the established model. The failure to meet the

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normal distribution assumption indicated the suitability of the PQR model for analysis procedures. However, the multicollinearity problem between the independent variables could not be rejected for the lPP60 and lPP80 variables. In this direction, Ridge regression was performed for the multicollinearity problem.

Table 3 Normal distribution and multicollinearity results.

Normal distribution

Test	W	V	z	Prob> z	Pr(Skewness)	Pr(Kurtosis)	chi2(2)	Prob>chi2
Shapiro-Wilk W	0.8619	31.1501	6.7881	0.0023	–	–	–	–
Skewness/Kurtosis	–	–	–	–	0.0798	0.0010	27.98	0.0031

Multicollinearity

Variable	VIF	1/VIF
lPP60	10.60	0.094384
lPP80	12.64	0.0779135
lLE	2.14	0.466455
lSR	1.15	0.872877
Mean VIF	6.63	0.872877

Table 4 shows the G_t, G_a, P_t and P_a test statistics for the Westerlund (2007) panel cointegration test [50]. Since the probability values are resistant to

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inter-unit correlation and the panel is heterogeneous, it is correct to make comments on this basis on G_t ve G_a statistics. In this context, according to the statistics, the H_0 hypothesis is rejected in all the models and there is a cointegration connection between the variables.

Table 4 Panel cointegration results.

Statistics	Model 1: ΔlGGHE	Model 2: ΔlPVT	Model 3: ΔlOOPS
Gt	0.0000*	0.0000*	0.0000*
Ga	0.0000*	0.0000*	0.0000*
Pt	0.0000*	0.0000*	0.0000*
Pa	0.0000*	0.0000*	0.0000*

Note: The * symbol indicates a 1% significance level.

Table 5 presents the results of the PQR calculated for the 10th-90th bandwidths. Considering the publicly financed health expenditure model, the life expectancy variable was negatively and statistically significant at all quantile values except the 90th. Although there were no quantile values where all variables included in the model were statistically significant, the 20th to 80th percentile range had the highest number of significant variables. All variables were insignificant at the 90th quantile. In addition, the results at the median (50th) indicated that the population aged 80 and over increased public health expenditures but decreased life expectancy. The fact that the population aged 80 and over increases public health expenditures suggests that hypothesis H1 is partially supported. The parameter that most significantly affects public health expenditures is life expectancy at the 10th

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quantile value (-1.91), while the least impactful parameter is the population aged 80 and over at the 60th quantile value (0.13).

The results of the private sector-financed health expenditure model showed that the life expectancy parameter was positive and statistically significant at all quantile values. The finding that life expectancy increases private healthcare expenditure indicates that hypothesis H2 is partially confirmed. However, the population parameter for those aged 60 and over was insignificant at all quantile values. There was no single quantile value at which all the variables in this model were statistically significant. According to the results for the median (50th), life expectancy increases private health expenditures, while the population aged 80 and over decreases them. In addition, the parameter that most significantly affects private health expenditures is life expectancy at the 10th quantile value (3.28), whereas the least impactful parameter is the population aged 80 and over at the 70th quantile value (-0.15).

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When examining the out-of-pocket payment health expenditure model, no statistically significant parameters are found across all quantile values. The parameter most positively associated with out-of-pocket payments of health expenditures is life expectancy. The finding that life expectancy increases health expenditures in the out-of-pocket model partially supports hypothesis H3. Although there is no quantile value at which all the parameters in this model are statistically significant, the 10th quantile value is where all parameters become meaningless. Additionally, the results at the median

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(50th) indicate that life expectancy increases out-of-pocket health expenditures. This finding suggests that the population aged 80 and over has contributed to a reduction in out-of-pocket health expenditure. The parameter that most influences out-of-pocket health expenditures is life expectancy (2.82) at the 20th quantile value, while the parameter that has the least effect is the population aged 80 and over (-0.14) at the 60th quantile value.

Table 5 Panel quantile regression results.

Quantiles	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
Model ΔlGGHE = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR)									
ΔlPP60	0.5366	0.0509	-0.0463	0.0031	0.0768	0.0904	0.2123	0.2129	-1.0471
ΔlPP80	0.1292	0.1820**	0.1708*	0.1502*	0.1564*	0.1395**	0.1968**	0.2042	0.2651
ΔlLE	-1.9192***	-1.5746*	-1.4076*	-1.3074*	-1.2322*	-1.1302*	-0.9761**	-1.7610**	-1.9275
ΔlSR	-2.4113	-1.6869	-0.7415	0.1100	0.0726	-0.5284	-1.6009	-1.5496	-3.3537
Model ΔlPVT = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR)									
ΔlPP60	-0.0866	0.1253	-0.1505	-0.1036	-0.0527	0.0338	0.0017	-0.3019	-0.7374
ΔlPP80	-0.1801	-0.1735	-0.1415	-0.2612*	-0.2084*	-0.1965**	-0.1559**	-0.1948**	-0.1697
ΔlLE	3.2810***	3.0591*	1.6044**	1.1656*	1.2662*	1.3794*	1.4969*	1.7238*	1.8072***

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ΔlSR	4.1549	2.9206**	2.0720	1.4805	0.1809	0.9104	1.5552	1.0592	0.6820

Model ΔlOOPS = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR)

ΔlPP60	-0.8815	-0.7627**	-0.3970	-0.3270	-0.2329	-0.2191	-0.2308	-0.3968**	-0.7836
ΔlPP80	-0.1941	-0.2636	-0.2454	-0.1213	-0.1789*	-0.1411*	-0.2247**	-0.2226**	-0.1495
ΔlLE	2.5516	2.8271*	1.7164**	1.2283*	1.3823*	1.4721*	1.6779*	1.8867*	2.2809
ΔlSR	0.3169	1.3428	2.5557	1.3698	0.3083	0.6153	0.9159	0.1298	1.5897

Note: The symbols *, **, and *** represent significance levels of 1%, 5%, and 10%, respectively.

Figure 1 shows the distribution graphs of the PQR model used in the research.

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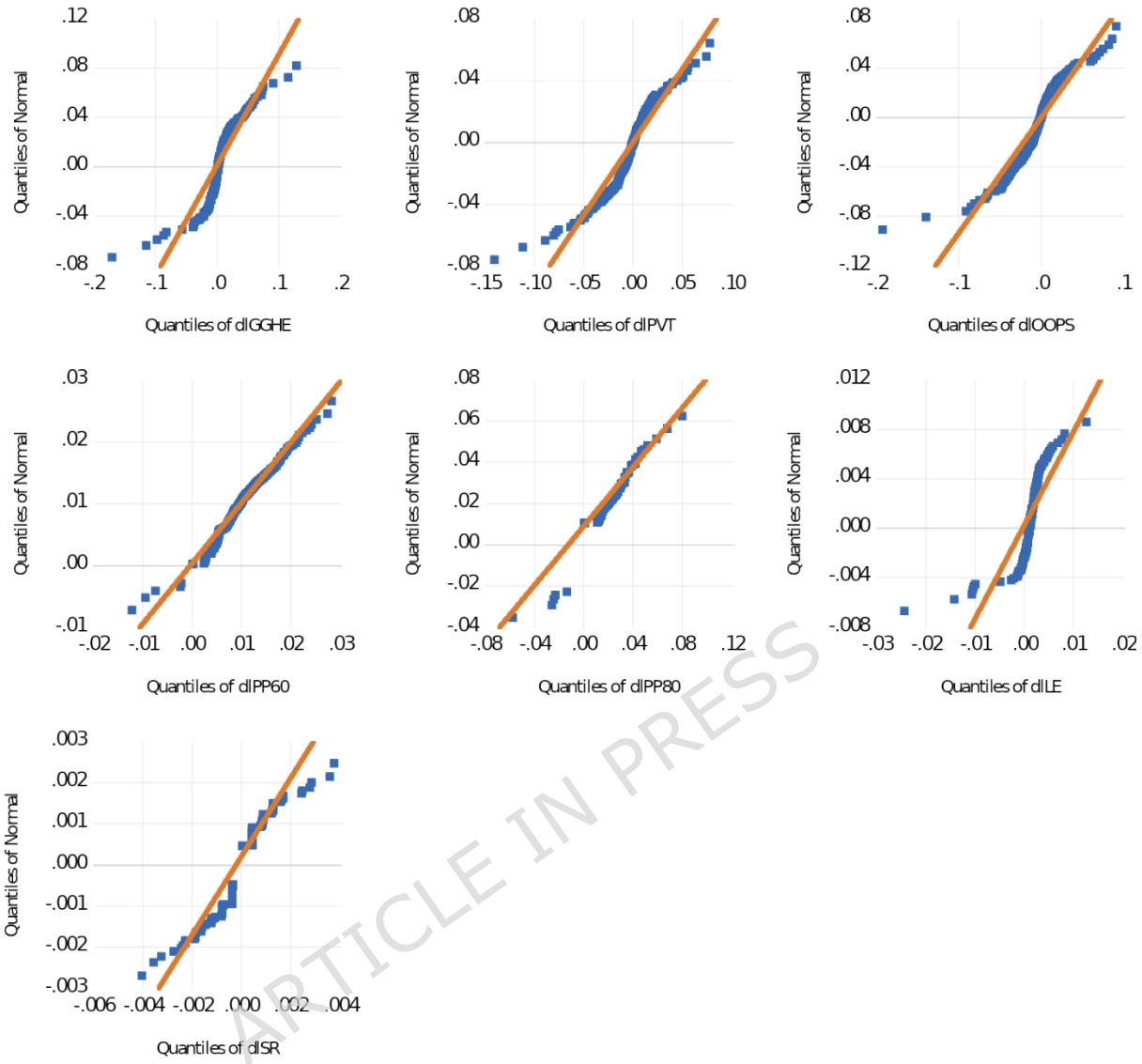

Fig. 1 Quantile distribution graphs of variables.

Table 6 presents the results of the assumptions for the models. In this context, Wooldridge, Breusch-Pagan Cook-Weisberg, and Breusch-Pagan LM test were performed to assess autocorrelation, heterogeneity, and cross-sectional dependence, respectively, among the different PQR analyzed for the 10th-90th quantile range. As a result of Wooldridge's test, the H_0 hypothesis, which states that there is no first-order autocorrelation, was rejected at the 1% significance level, except for the publicly financed health expenditure model.

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It was determined that first-order autocorrelation exists in the other two models. The Breusch-Pagan Cook-Weisberg test rejected the H_0 hypothesis at the 1% significance level, except for the private sector health expenditure model, indicating that the heterogeneity assumption between different quantiles was not met in the other two models and the heterogeneity assumption between different quantiles was not met in the other two models. According to the results of CD, the H_0 hypothesis was rejected in all the models, confirming correlation between the units.

Table 6 Results related to model assumptions.

Assumptions	Heterogeneity		Autocorrelation		CD	
Models	chi2(1)	Prob>chi2	F(1, 15)	Prob > F	LM stat.	p-val.
ΔlGGHE = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR)	41.77	0.0000*	3.058	0.1008	174.1877	0.0009*
ΔlPVT = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR)	0.51	0.4732	3.531	0.0798***	222.6166	0.0000*
ΔlOOPS = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR)	5.56	0.0184**	7.877	0.0133**	178.4086	0.0004*

Note: The symbols *, **, and *** represent significance levels of 1%, 5%, and 10%, respectively.

Autocorrelation, heterogeneity, and CD assumptions were estimated and interpreted using Driscoll-Kraay robust standard errors. Additionally, Ridge regression analysis was performed to address the multicollinearity problem in the 60+ and 80+ age population datasets as independent variables. The results of both robust estimators are shown in Table 7. The results revealed that the population aged 80 years and over and life expectancy affected publicly funded health expenditures. Specifically, a 1% increase in the

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population aged 80 and over resulted in a 0.25% increase in public health expenditures, while a 1% increase in life expectancy led to a decrease of 1.74% in public health expenditures. Additionally, both the population aged 80 and over and life expectancy also influenced health expenditures financed by the private sector. Although the population aged 80 and over has contributed to a reduction in private sector health expenditures, life expectancy for this group has increased. In addition, the explanatory power of this model was greater than that of the public health expenditure model. When the health expenditure model financed by out-of-pocket payments is examined, it is seen that the variables of population aged 60 and over, population aged 80 and over and life expectancy are statistically significant. According to the results, a 1% increase in the variables of population aged 60 and over and population aged 80 and over reduces out-of-pocket health expenditures by -0.63% and -0.19%, respectively. At the same time, a 1% increase in the life expectancy variable increases it by 2.40%. When all three models were evaluated together, the sex ratio variable was found to be statistically insignificant. Based on the findings, the H4 hypothesis has not been confirmed in terms of its effect level. In addition, it is seen that the root mean square error (RMSE) values are quite low in all models. Therefore, it is understood that the model fits the data well and its predictive power is high. These results provide different empirical evidence for the research hypotheses.

Table 7 Driscoll-Kraay and Ridge regression results.

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Variable	Coef.	Std. err.	P>|t|	Coef.	Std. err.	P>t
	Driscoll-Kraay test			Ridge regression test		
Model ΔlGGHE = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR) R^2 = 0.557 RMSE = 0.0256						
ΔlPP60	0.3203	0.2645	0.245	0.3203	0.2645	0.227
ΔlPP80	0.2516**	0.0924	0.016	0.2516**	0.0916	0.006
ΔlLE	-1.7407*	0.5052	0.004	-1.7407*	0.5628	0.002
ΔlSR	-0.5837	0.9516	0.549	-0.5837	1.6776	0.728
C	0.0004	0.0035	0.911	0.0004	0.0029	0.894
Model ΔlPVT = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR) R^2 = 0.770 RMSE = 0.0229						
ΔlPP60	-0.2373	0.2186	0.295	-0.2373	0.2373	0.318
ΔlPP80	-0.1874**	0.0594	0.007	-0.1874**	0.0822	0.023
ΔlLE	2.3258**	0.9301	0.024	2.3258*	0.5049	0.000
ΔlSR	1.0114	0.9635	0.310	1.0114	1.5050	0.502
C	-0.0028	0.0023	0.249	-0.0028	0.0026	0.286
Model ΔlOOPS = f (ΔlPP60, ΔlPP80, ΔlLE, ΔlSR) R^2 = 0.747 RMSE = 0.0268						
ΔlPP60	-0.6346*	0.1829	0.003	-0.6346**	0.2777	0.023
ΔlPP80	-0.1905**	0.0813	0.033	-0.1905***	0.0962	0.048
ΔlLE	2.4028**	0.9698	0.026	2.4028*	0.5908	0.000
ΔlSR	0.1321	0.7796	0.868	0.1321	1.7611	0.940
C	-0.0014	0.0029	0.634	-0.0014	0.0031	0.652

Note: The symbols *, **, and *** represent significance levels of 1%, 5%, and 10%, respectively.

4 Discussion

Elderly individuals currently represent a significant portion of the global patient burden [11]. Furthermore, it is projected that by 2050, one in six people globally will be aged 65 or older [4]. On this basis, it can be anticipated

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that public health expenditures to support elderly healthcare will continue to increase in the future. In this respect, the effects of aging indicators on health financing systems in APEC countries were examined in the present study. The primary findings derived from the robust estimator indicate that the population aged 80 and above contributes to an increase in publicly financed health expenditures, while simultaneously leading to a decrease in privately financed health expenditures. Individuals aged 80 and above typically experience greater burdens of chronic diseases, disabilities, and age-related conditions, requiring more intensive and long-term care. These needs are often met through public healthcare systems or social insurance programs, leading to increased public expenditure [63]. There are several possible explanations for this finding. First, many elderly individuals may have limited private health insurance or financial resources, resulting in a reliance on publicly financed healthcare programs, such as national health services or public insurance schemes. As they age, private insurance may become more costly or unavailable, prompting a shift toward public funding. Second, they often require long-term care services, such as home healthcare, nursing facilities, and palliative care. In many countries, these services are more likely to be covered by public funds, especially for low-income or elderly populations, further increasing public expenditure. Furthermore, many APEC countries, such as China, Canada, and Japan, have publicly financed social insurance or retirement systems for the elderly [64–66]. In fact, this observation supports the increase in public expenditures for the elderly

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population. Finally, because their disposable income is limited, they cut back on private health expenditures and increasingly depend on public funding for essential services such as healthcare and social support [67]. Further, in many welfare states, a legal and moral obligation to protect the elderly-particularly the oldest-old-from poverty, illness, and social exclusion leads to expanding budget allocations for their care [68].

Another significant finding of this study is that the population aged 80 and over contributes to a reduction in privately financed health expenditures while increasing life expectancy. Several potential reasons could explain this finding. In many countries, older adults, particularly those aged 80 and above, may qualify for public healthcare programs, social insurance, or government subsidies, which provide extensive healthcare services. This reduces the need for private financing, as a large portion of medical expenses are covered through public means [69]. Furthermore, private health insurance premiums typically increase with age, making it difficult for individuals over 80 years of age to afford comprehensive coverage. As a result, they may forgo private insurance, reducing privately financed health expenditures. Notably, older populations are more likely to be in long-term care facilities, where healthcare costs are often publicly funded or covered through public assistance programs. This public support reduces their reliance on expensive private healthcare services while still improving longevity.

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According to the findings of our study, an increase in public health expenditures is positively associated with life expectancy, a result that aligns with similar studies in the literature which consistently demonstrate the beneficial impact of higher healthcare expenditures on population health outcomes. A study conducted in China found that public health expenditures have a positive and statistically significant partial moderating effect on the relationship between green taxation and life expectancy [70]. Similarly, research from European countries identified public health expenditures on social protection and healthcare as the most influential factors in explaining life expectancy at birth, followed by per capita gross national income, educational attainment, and environmental protection expenditures [71]. However, a separate cross-sectional analysis of 31 European countries challenged this view, suggesting that healthcare expenditure is not the primary driver of life expectancy. Instead, it highlighted the greater importance of social protection expenditures, the quality of healthcare services, and healthy lifestyle choices [72]. One possible explanation is that in China, where healthcare access and infrastructure have been expanding rapidly, increased public health expenditures may have a more substantial impact on population health outcomes. APEC countries —ranging from highly developed economies such as Japan, South Korea, and Australia to emerging economies such as Vietnam and the Philippines—are experiencing increases in life expectancy. However, this also means that a growing share of elderly citizens, particularly those aged 80+, often require more complex and costly

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healthcare services. The finding that life expectancy correlates with higher private health expenditures suggests that, as people live longer, many may turn to private healthcare services to supplement gaps in public health systems.

The findings of the present study suggest that the population aged 60 and over and the population aged 80 and over play a significant role in reducing the burden of out-of-pocket health expenditures. Many countries offer greater public health support or specific health insurance plans for older adults, which can reduce their need to pay out of pocket. Seniors often qualify for subsidies or public health benefits, easing the financial burden of healthcare [39]. This is expected, as health insurance provides financial protection against the cost of illness. A population-based cross-sectional study by Aregbeshola and Khan (2024) in Nigeria revealed that a high proportion of older adults incur out-of-pocket health expenditures [73]. This implies that older adults are not protected from the financial hardship of OOPS by the Nigerian healthcare system. In contrast, a study in Kenya reported that older adults with health insurance coverage had an increased risk of OOPS compared with those without health insurance coverage [74]. This difference may be explained by the fact that older adults with insurance in Kenya might be more likely to seek medical care because they expect insurance to cover it. This can lead to increased utilization of healthcare services, some of which might require OOPS if they are only partially covered or if deductibles and co-pays apply. Another possible explanation for this is

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that insured older adults in Kenya might prefer private healthcare providers for better quality care, but these services may not be fully covered by insurance. This can result in substantial OOPS costs as insurance only partially covers private care, whereas uninsured individuals may rely more on public facilities with lower OOPS. A growing body of literature analyzes the correlation between health financing systems and health outcomes. In studies on the impact of these systems, Gabani, Mazumdar, and Suhrcke (2023) report that transitioning from out-of-pocket payment models to government-financed systems improves most outcomes more effectively than transitioning to social health insurance models [12]. The study also explains that state financing increases life expectancy, and that increases in non-contributory state financing, rather than social health insurance financing, are more likely to enhance health system outcomes.

In this study, it was determined that increases in the gender ratio did not affect health expenditures, despite well-documented evidence of gender inequality in healthcare expenses, particularly in developing countries. However, findings from National Health Survey rounds (1999-2008) in India indicate that among elderly individuals, the gender gap in health expenses is so stark that approximately 91% of total health expenses incurred by the elderly are spent on males [75]. This disparity likely reflects cultural and socioeconomic norms that prioritize men’s health needs over women’s, leading to substantial differences in expenditures. Similarly, even in developed countries, elderly women report better health and prioritize

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healthcare less, resulting in fewer hospital stays and physician visits than men do [76]. However, recent data from 2020 show that healthcare expenditures in the USA for females aged 65 and over accounted for 55% of all healthcare expenditures for older adults ($683 billion), whereas expenditures for males over age 65 accounted for the remaining 45% ($560 billion), suggesting shifts in expenditure patterns among elderly populations [77]. This could reflect changes in healthcare utilization as populations age, where women, who often live longer and experience age-related health conditions, incur higher cumulative costs.

These findings suggest that life expectancy has the strongest impact on out-of-pocket health expenditures, whereas the population aged 80 and above contributes the least to reductions in private health expenditure. In Europe, several studies [78] show that life expectancy increases total and public healthcare expenditure, especially due to higher long-term care and end-of-life costs. In North America, life expectancy often correlates with higher Medicare and Medicaid expenditures in the USA [40]. Similarly, studies in Europe consistently show that those aged 80+ contribute disproportionately to public and total healthcare expenditures due to multimorbidity and long-term care needs [79]. The findings of these studies are consistent with the observed effects of aging on health expenditures. People living longer tend to use more healthcare services over their extended lifespan, which raises out-of-pocket health expenditures overall. This sustained demand likely drives the strong impact of life expectancy on these expenditures.

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The sex ratio was statistically insignificant in this study likely because it is not directly linked to health financing dynamics. Further, the sex ratio at birth is largely stable over time and may not meaningfully reflect the ageing-related population changes that drive health expenditures. Hence, across APEC countries, sex ratios may not vary significantly in a way that would systematically influence macro-level health financing systems. Findings from population-based study confirm this result [80]. Among the three models, the private sector-financed health expenditure model provides the most comprehensive explanation of health expenditures, whereas the publicly financed health expenditure model accounts for them to the least extent. Public funds should prioritize preventive care, chronic disease management, and long-term support services that reduce the financial burden on individuals as they age. Further, governments could offer tax incentives, public-private partnerships, or co-investment schemes to attract private sector investment in aged care infrastructure and services, especially for populations younger than 80 where their engagement appears more effective. Future research could explore which components of public health expenditure (e.g., institutional care vs. community care) are most effective in promoting healthy aging and financial protection.

Several important limitations need to be considered. Firstly, the period 2000-2020 was selected due to the data constraints of the countries in the sample set. This temporal path also caused a limitation in terms of the countries included in the model. In this context, Brunei, Hong Kong, Taiwan, Malaysia

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and Papua New Guinea countries were not included in our analysis on the APEC countries scale. Secondly, the number of variables explaining the aging parameters in the selected period. For example, since the population aged 100 and over contains the number ‘0’ in most of the countries in the sample set, calculations cannot be made within the model algorithms. Also, the dependency ratio could not be included in the analysis due to insufficient data. Secondly, while we selected key aging indicators based on internationally recognized sources (WHO, UN Population Fund), we acknowledge that the model does not incorporate several other important factors that could influence health financing, such as GDP per capita, healthcare system structure, technological innovation, insurance coverage, and disease burden. Future research could integrate these additional covariates to yield a more comprehensive analysis. Furthermore, the generalizability of our findings is limited to APEC countries, which, while diverse, may not represent regions with different economic development levels, healthcare systems, or demographic structures. Caution should therefore be exercised when extrapolating these results to other global regions, particularly those with lower health system capacity or distinct cultural and policy contexts. Finally, although we used different regression techniques (PQR, Driscoll-Kraay and Ridge estimators) to account for cross-sectional dependence, heteroskedasticity, multicollinearity and heterogeneity, the potential for residual bias remains, particularly from variables that are not available or cannot be measured in all countries. In this

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context, we recommend that future research be supported by both causality analysis and different regression methods.

While this study offers valuable insights into the relationship between aging and health financing across APEC countries, it treats these nations as a largely homogenous analytical unit. This approach may oversimplify the substantial cross-country differences that could significantly influence the observed associations. APEC countries include both high-income economies and middle-income nations. These differences in economic capacity affect how countries finance healthcare and respond to population aging. For example, high-GDP countries are more likely to have robust social security systems and universal health coverage, whereas low- and middle-income countries may rely more heavily on out-of-pocket payments, which affects both access and expenditure patterns. High-income APEC countries such as Japan, Australia, and Canada generally operate mature health financing systems characterized by universal health coverage and well-established public long-term care programs.

A more policy-oriented interpretation of these findings requires distinguishing between high- and middle-income APEC countries, particularly in terms of long-term care, acute care, and preventive services. In high-income economies such as Japan, the United States, and Australia, aging—especially among those aged 80 and above—is likely to increase demand for publicly financed long-term care, including home-based and institutional services. In these settings, strengthening preventive services

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and chronic disease management may help delay functional decline and contain future costs. In these settings, population aging is more likely to increase public expenditures related to long-term care, including institutional care, home-based services, and chronic disease management. By contrast, middle-income APEC economies such as Vietnam, Thailand, and the Philippines often rely on mixed financing systems with a larger share of out-of-pocket and private expenditures, particularly for acute medical services. In these countries, rapid population aging may place additional pressure on households if long-term care infrastructure and social protection systems remain underdeveloped. Moreover, the type of health expenditures associated with aging may differ across income groups. While long-term care and chronic disease management dominate expenditures growth in high-income countries, middle-income countries may experience a stronger rise in acute care expenditures due to delayed diagnosis and weaker primary care systems. Finally, the pace of aging, fertility rates, and burden of chronic disease vary widely. For example, Japan has one of the world's most rapidly aging populations, while other APEC countries are still in earlier stages of demographic transition. These differences may change how strongly aging indicators, such as the percentage of the population aged 80+, influence health financing variables.

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5 Conclusions

The most significant contribution of this study is its detailed and multifaceted analysis of the impacts of aging populations and life expectancy on public,

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private, and out-of-pocket health expenditures. This study offers critical insights for policymakers and healthcare planners in APEC countries on how to better structure health financing systems in response to demographic shifts, thereby contributing to the field of health economics and aging studies. To the best of the author's knowledge, no previous study has examined the impact of aging indicators on health financing systems in APEC countries and made inferences about the health financing methods of aging indicators. Aging populations across APEC countries have major implications for healthcare systems, economic growth, and social security frameworks [27]. Therefore, the findings of the present study are expected to provide a comprehensive framework of how the elderly population affects health financing systems in APEC countries, using panel data models, and to make a significant contribution to guiding future research efforts in this area.

Overall, these findings underscore the need for proactive health financing strategies in APEC countries, particularly in adapting systems to meet the growing demands of an aging population, balancing public-private resource allocations, and reducing individual financial burdens. APEC countries should use these findings to guide strategic reforms in healthcare financing, balancing public resources to support an aging population while encouraging sustainable private sector engagement. Additionally, the findings could serve as a benchmark for countries with similar demographics or financing challenges, helping policymakers set realistic targets for healthcare funding in the context of an aging society.

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Declarations

Clinical trial number

Not applicable.

Ethics approval and consent to participate

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects. All data publicly available for researcher without any restrictions.

Consent for publication

Not applicable

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare no competing interests.

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Authors' contributions

Conception and design of the research: MN, GS, VD. Acquisition of data: GS, MN. Analysis and interpretation of the data: GS. Obtaining financing: None. Writing of the manuscript: MN, GS, VD, GB. Critical revision of the manuscript for intellectual content: MN, GS, VD, GB. All authors reviewed the manuscript.

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