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Research Article

Effect of Longevity on Economic Growth, Accounting for Variability in Demographic Transition: Evidence for Pakistan using ARDL Bounds Testing Approach

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Abstract

Rising longevity due to access to better health services affects the growth and composition of the population differently than birth rates. In addition, empirical evidence of the effects of rising longevity on standards of living is ambiguous. From the perspective of developing nations, it is important to understand how rising longevity affects national prosperity, as this allows governments to develop programs for increasing investment in the health sector. This study explicitly tested varying intertemporal impacts of rising longevity on the GDP per capita of Pakistan between 1967 and 2020. An Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration was used to estimate and compare short-run and long-run estimates of longevity. The results indicated that a 1% increase in longevity increased the growth rate of GDP per capita in Pakistan by 0.64% in the long-run. In addition, a 1% increase in life expectancy at birth above 62 years increased economic growth by an additional 0.009%. In general, the estimated effect of increased longevity varied by stages of demographic transition in Pakistan.

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Introduction

Historically, a high birth rate has been the main driver of population growth and a factor in lowering per capita income. Thus, national governments around the world often aim at limiting the birth rate to its replacement level. However, maintaining a low birth rate by keeping the fertility rate at a preferred level has proven difficult in practice because of considerable sociological, cultural, and economic differences among nations, and across regions within a country (Jain & Ross, 2012; Ly, 2013). Some studies suggest that the fertility rate could be adjusted by improving female education (Amarante, 2014) and increasing adult female participation in the labour force (Bloom et al., 2003; Ly, 2013). Others argue that reducing the mortality rate (Angeles, 2010) and initiating policy programs in support of reducing family size (Lin & Shin-Yi, 2009; Xiaofei, 2012) have a desirable influence on the fertility rate. A prudent mix of these approaches has helped several nations with considerable success in controlling population growth, including China (Xiaofei, 2012) and Taiwan (Lin & Shin-Yi, 2009), and allowed them to shift to a higher economic growth trajectory.

More recently, despite low birth rates, many countries have experienced an increase in population because of rising longevity (defined as an increase in life expectancy at birth). This increase in population is in line with the demographic transition model that suggests an initial, albeit, brief period of population expansion due to a high birth rate and a falling death rate (Bloom, 2016). Timonin et al. (2016) noted that although life expectancy has increased in most countries, there are substantial variations in its magnitude among low-income nations. For example, Edwards (2011) reported that between 1970 and 2000, life expectancy at birth in high-income countries increased by 7.1 years (to 77.7 years in 2000), while the standard deviation declined by 3.1 years (to 15.9 years in 2000). In contrast, the author reported that during the same period, life expectancy at birth in South Asian countries increased by 13.1 years (to 60.9 years in 2000) with a decrease of 4.4 years in standard deviation (to 25.7 years in 2000). The corresponding increases in life expectancy were lowest among Sub-Saharan African countries and with the highest levels of standard deviation. In summary, gains in longevity vary considerably across nations, and the levels of life expectancy and uncertainty are generally high in developing countries.

Several studies have investigated whether higher health expenditures lead to higher longevity. For example, Barthold et al. (2014) analyzed data from 27 Organization for Economic Co-operation and Development (OECD) countries and reported that a 1% increase in health expenditures was associated with a 0.06 to 0.13% increase in life expectancy at birth. The authors also reported that health expenditures were generally higher in developed countries than in developing countries. Similarly, in a 26-year longitudinal study of selected individuals in Sweden, Carlsson et al. (2010) reported that improved health was associated with increased life expectancy. Vaupel et al. (2021) argued that a future rise in life expectancy might be slower but its economic consequences would likely be significant. Barlow and Vissandjée (1999) also reported a positive link between per capita health expenditures and life expectancy in a multivariate cross-national analysis. Furthermore, in a panel data analysis of 175 countries, Jaba et al. (2014) found a statistically significant and direct relationship between health expenditures per capita and increased life expectancy at birth.

Heijink et al. (2013) provided further insights on the effect of healthcare expenditures on longevity when they reported that healthcare expenditures as a proportion of GDP in 14 developed countries increased between 1996 and 2016. The authors also noted that increased healthcare spending helped to avoid mortality from particular health conditions. Obrizan and Wehby (2018) also reported that increased healthcare spending was positively related to increased longevity and the effect was more substantial in countries with existing low longevity levels. In addition, Erakhtina (2022) also favours the hypothesis that there exists a positive relationship between an increase in life expectancy and economic growth through improved health. In summary, the insights from the literature suggest that per capita health expenditures are generally higher in high-income countries than in low and middle-income countries. In addition, there is a positive relationship between healthcare expenditures and increased longevity, although the magnitude of this effect differs across nations.

Studies also suggest that, unlike the birth rate, rising longevity has a positive effect on economic growth. These studies vary in terms of research methods and nature of data sets used, as well as country. For example, Sheshinski (2006) reported that a rise in longevity leads to an increase in aggregate savings, and helps to stimulate economic growth. Fisher and Heijdra (2009) also noted that longevity results in increased savings and asset accumulation. Similarly, using an endogenous growth model, Prettner (2013) found that longevity has a positive impact on economic growth in the long-run. Other empirical studies have also reported a positive relationship between longevity and economic growth. In an econometric study using a 45-year time series dataset for Russia, Bloom and Malaney (1998) reported that an increase in both life expectancy and the working-age population stimulated economic growth. Similarly, in an application of a fixed effect model to cross-country data, Li et al. (2007) reported that a 1% increase in life expectancy increased the GDP growth rate by 0.024 %. Using an ARDL model for Kenya, Awago (2023) also reported a positive and statistically significant relationship between longevity and GDP growth between 2000 and 2020. Some other researchers used cross-country panel data and reported a direct relationship between longevity and economic growth (Bloom et al., 2004; Weil, 2007). In addition to the above studies, Lorentzen et al. (2008) conducted econometric analyses using cross-country and India-only data and concluded that rising adult longevity positively influenced economic growth. In general, several econometric studies have found a positive relationship between rising longevity and economic growth. However, there are differences in the magnitude of the effect.

In contrast to the above group of studies which report a positive effect, a second group of studies have found a negative effect of rising longevity on economic growth. For example, using data from 47 countries, Acemoglu and Johnson (2007) found that a 1% increase in life expectancy increased the population by about 2%, but negatively affected economic performance by a small magnitude. Cervellati and Sunde (2011) also analyzed the same data set used by Acemoglu and Johnson (2007) and supported the hypothesis that the effect of life expectancy on economic performance is non-monotonic. Cervellati and Sunde (2011) also reported a negative impact associated with an initial rise in adult longevity on the growth in per capita income. However, after the onset of further demographic transition, longevity increased economic growth. Kuhn and Prettner (2023) used an endogenous growth model to analyze the long-run effect of rising longevity on economic growth in the OECD countries. Their analyses revealed that although rising longevity in combination with increased retirement age leads to increased savings, its impact on long-run economic growth is ambiguous. In a recent article, Chakroun (2024) reported that varying health status may impact economic growth differently across various stages of development. The findings from Cervellati and Sunde (2011) also suggest that the effect of longevity on economic growth may vary with stages of demographic transition. Yet, few studies have explicitly examined these effects over the stages of demographic transition for particular countries.

Another empirical issue relates to the measurement of longevity. Several studies modelled longevity as health (human) capital, which results from the provision of better health services. For example, Bhargava et al. (2001) modelled the effect of health on economic growth using a panel data set and incorporated the adult survival rate (ASR) at age 60 as an indicator of health. The authors reported that a 1% increase in ASR led to a 0.05% increase in GDP growth in poor countries. Using a production function approach and cross-country panel data, Bloom et al. (2004) found a 4% increase in GDP due to a 1% increase in life expectancy.

From the perspective of under-developed nations facing capital scarcity, human capital is important for economic development, where highly skilled but ageing labour is saddled with the responsibility of transferring knowledge and expertise to youth in society. Low longevity levels in these countries can disrupt skills transfer from older to younger generations, and can potentially affect economic growth negatively (Bar & Leukhina, 2010). Previous studies have not explicitly examined whether the effect of longevity on economic growth varies at different phases of the demographic transition of a country. Furthermore, longer-living individuals potentially invest more in formal education (Hansen & Lønstrup, 2012), and in combination with accumulated professional experiences, are better poised to generate higher returns for an extended period. However, there is a gap in the literature regarding what is the threshold level of longevity that individual countries must achieve before a positive impact on economic growth is triggered. This study explicitly isolated the effect of longevity on economic growth according to various stages of demographic transition in Pakistan, thereby helping to determine the threshold longevity level.

The purpose of this study was to assess the impact of rising longevity on economic growth. Longevity (or a rise in life expectancy at birth) is an important measure that not only captures a performance indicator of the health sector but it is also closely associated with economic, social and environmental dimensions of the development process (World Health Organization, 2015). Longevity also allows the accumulation of human capital through education and life experiences, which ultimately contribute to economic growth. Demographic data for Pakistan aptly exhibit various demographic transitional stages, starting from a high birth rate to a relatively low birth rate and changes in life expectancy, although longevity in the country is still considerably lower than in many other countries. Specific research objectives addressed included: i) to determine whether longevity has a stable long-run effect on economic growth; ii) to evaluate the contribution of longevity to economic growth in Pakistan, both in the short-run and the long-run; and iii) to determine how the impact of increasing longevity on economic growth differs according to the various stages of demographic transition in the country.

Literature Review

Economic Growth, Population Trends, and Health Spending Characteristics of Pakistan

In this section, the status of GDP growth and its temporal variation in Pakistan is discussed. Life expectancy at birth statistics are assessed as these relate to demographic transition in the country. Finally, levels and trends in public and private health expenditures are discussed to provide background and context for the rest of the study.

Demographic Transition and Economic Growth in Pakistan

Pakistan is the sixth most populous country in the world and is also one of nine countries where an estimated more than half of the world will reside by 2050 (United Nations, 2015a). In 2015, the working-age population (15-64 years) accounted for about 60% of the total population of Pakistan, while about 5% of the population was above 65 years (United Nations, 2015b). However, the above 65-year segment of the population is projected to rise to 14% by 2030 (Government of Pakistan, 2015). Currently, the population is growing at 2.1% per year (United Nations, 2015b), with a projected doubling of the population within 35 years. In addition, GDP has been rising from 3.9% in 2012-13 to 5.8% in 2020-21 (Government of Pakistan, 2024).

The annual population growth rate in Pakistan showed three distinct phases (Figure 1). First, the annual population growth rate increased from approximately 2.3% during the early 1960s to 3.6% in 1983 (The World Bank, 2024b). A high crude birth rate of above 40 births per thousand of the population coupled with a sharp decline in infant and adult (especially women) mortality rates (Sathar, 1991) explained population growth during these years. The second phase indicates a declining population growth rate starting from 1984 and reaching 2.2% in 2003. A sharp decline in the birth rate associated with a reduction in the fertility rate from 6.2 births per woman in 1975 to 3.8 births per woman in 1997 in urban areas (Sathar, 2001) explained the falling population growth rate during this phase.

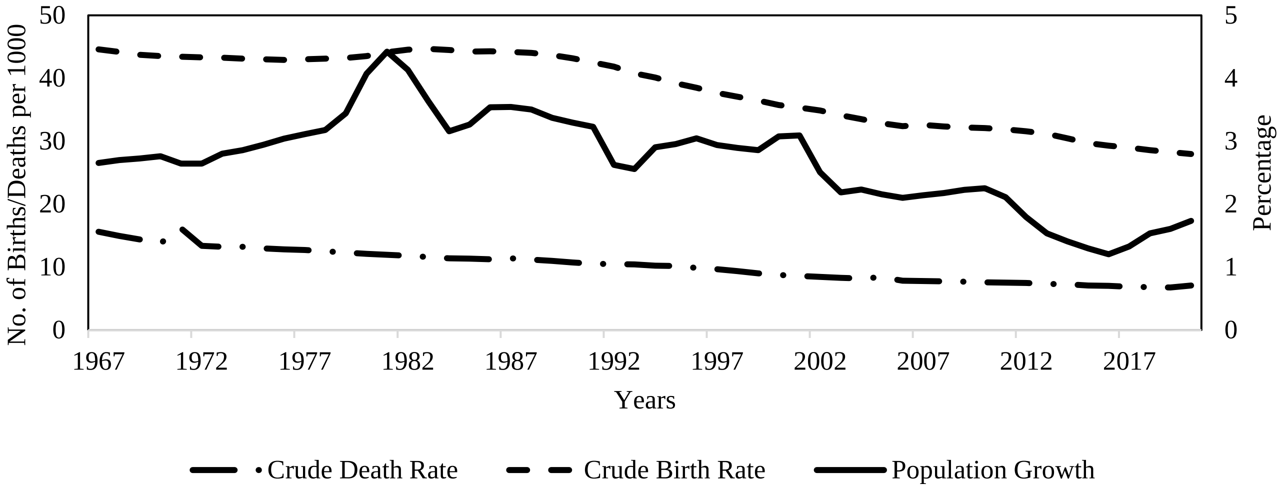

Figure 1: Trends in Crude Death Rate, Crude Birth Rate, and Population Growth in Pakistan, 1967-2020

Data Source: The World Bank (2024b)

The third phase occurred post-1997, during which the birth rate stabilized around 2.0%. Although the birth rate remained stagnant since 2003, slight variation in the national population growth rate is attributed to consistently declining mortality rates, especially in more recent years.

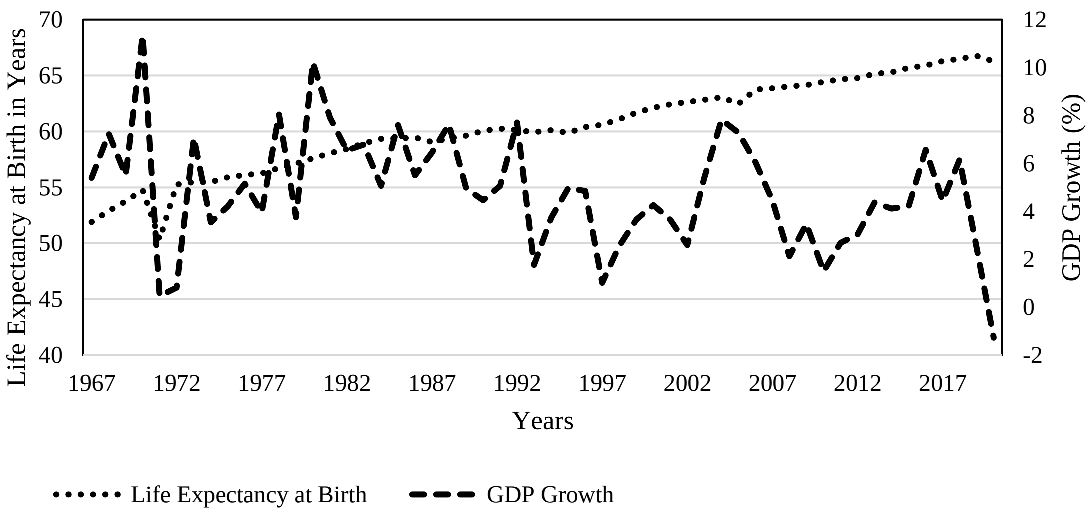

Figure 2: Trends in Life Expectancy at Birth and GDP Growth in Pakistan, 1967-2020

Data Source: The World Bank (2024b)

Life expectancy at birth shows a consistently increasing trend from 1967 to 2020 (Figure 2). By comparison, growth in GDP shows considerable fluctuations during 1970-71 when the country passed through a great political unrest, resulting in the separation of East Pakistan (now Bangladesh) from West Pakistan (now Pakistan). In general, both the fluctuations and GDP growth rate decreased in the post-1971 period; especially after 1991. However, a sharp decline in GDP growth has been experienced in 2020. In summary, while longevity in Pakistan has been increasing, large fluctuations in GDP growth have occurred with relatively lower GDP growth rates in the last two decades than in the period before this.

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Status of Health Expenditures in Pakistan

Total health spending in Pakistan, including public and private spending, increased from 1995 to 2020 (Figure 3) (The World Bank, 2017a, 2024a). Total health expenditures in the country doubled from about US $2 billion in 1995 to US $4.6 billion in 2006 and increased more than three-fold (US $6.69 billion) by 2014 and later. Despite the three-fold increase in total health spending, its share in GDP has remained low. For example, the nation's health spending in 2020 was about 3% of GDP (The World Bank, 2024a). By comparison, the average share of health expenditures among countries in South Asia was 3.1% of GDP, whereas the global average was 10.9%. The data also revealed that between 2003 and 2020, average health expenditures in Pakistan as a proportion of GDP ranged between 2.1% and 2.9% with an annual average of 2.6% of the GDP. In summary, health spending as a percentage of GDP in Pakistan was low relative to the average health expenditures in South Asian countries and globally.

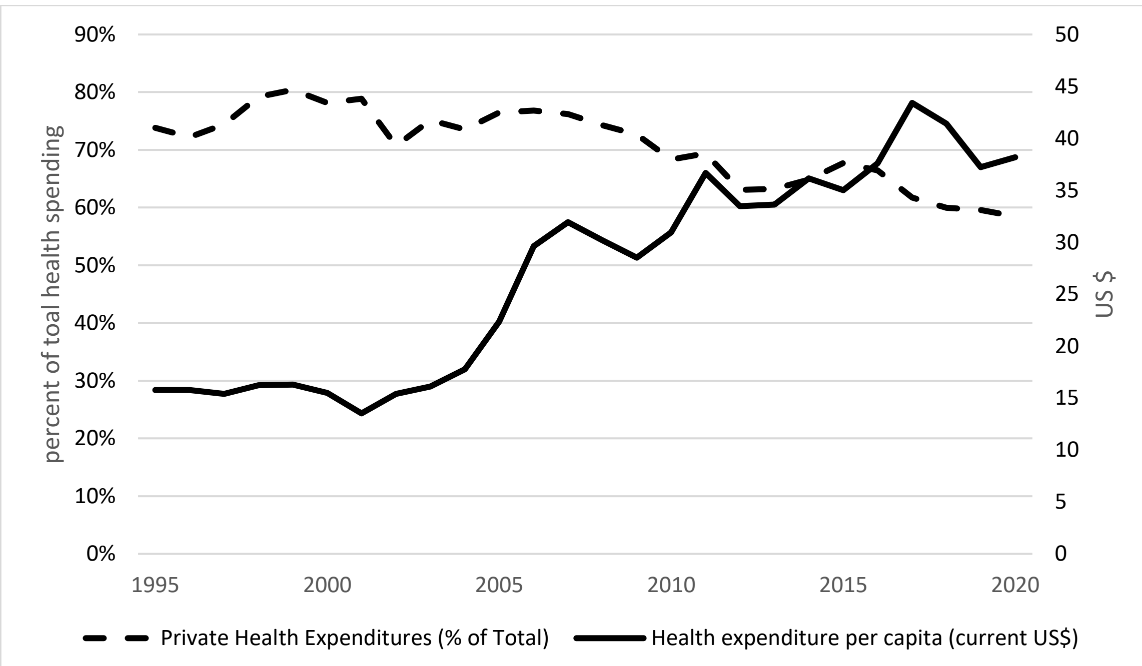

Figure 3: Public and private health expenditures in Pakistan, 1995-2020

Data Sources: (The World Bank, 2017a, 2024a)

Further disaggregation of total health expenditures between public and private health spending reveals that a major proportion of health expenditures was incurred by the private sector (Figure 3) although a relatively bigger decrease has been experienced in recent years. These health expenditures covered direct household (i.e., out-of-pocket) spending, private insurance, charitable donations, and direct service payments by private corporations but excluded spending on water and sanitation. Between 1995 and 2020, the share of private sector spending decreased from a high of 74% in 1999 to 58% in 2020. Abbas and Hiemenz (2013) noted that the low share of public health expenditures in total health spending occurred due to various reasons. For example, a considerable proportion of the population (especially the poor) used health services mainly in times of critical need due to inadequate availability of universal health services resulting in high out-of-pocket private health expenditures. Additionally, the provision of relatively cheap private health services in rural areas without access to public hospitals undermined the perceived need to increase the public health budget. Consequently, public expenditures remained low even though the country's GDP grew by about 4% between 2011 and 2020.

In general, health spending remained below US$20 per capita in Pakistan between 1995 and 2004. However, between 2005 and 2020, it exhibited a continuous and considerable increase. This increase in per capita expenditures was partly due to an increase in public health spending, the share of which increased from 26% of total health expenditures in 2004 to 42% in 2020. In summary, the recent increase in public health spending led to an increase in per capita health expenditures in the country, although it was low compared with most other nations around the world.

Theoretical Model

In this study, a theoretical framework by French (2012) is applied to determine the impact of changes in longevity on economic growth in Pakistan. The theoretical framework is presented by considering a closed economy producing product (Y_t) using a production function specified as:

$$Y_t = \mathrm{A_t}\, K_t^{\alpha}\, S_t^{\beta}\, H_t^{\gamma} L_t^{1-\alpha-\beta-\gamma} \tag{1}$$

where A_t denotes the level of productivity during year t, K_t represents the physical capital, S_t denotes the human capital from formal education, H_t is the human capital associated with health and accumulated experience, and L_t is labour. The output Y produced per capita may be represented as:

$$y_t = \mathrm{A_t}\, k_t^{\alpha}\, s_t^{\beta}\, h_t^{\gamma} \tag{2}$$

where $y_t = \frac{Y_t}{L_t}$, $k_t = \frac{K_t}{L_t}$, $s_t = \frac{S_t}{L_t}$, and $h_t = \frac{H_t}{L_t}$. The output produced is either consumed or reinvested by the household in any of the three forms of capital (i.e., physical capital, education, and health). The growth in each type of capital follows the following mathematical form:

$$\frac{\partial k}{\partial t} = i_k - (\delta + n)k \tag{3}$$

$$\frac{\partial s}{\partial t} = i_s - (\delta + n)s \tag{4}$$

$$\frac{\partial h}{\partial t} = i_h - (\delta + n)h \tag{5}$$

where i_k is the investment in physical capital, i_s is the investment in formal education, and i_h is the investment in health. Additionally, n denotes the population growth rate, and δ represents the capital depreciation, which is assumed to be the same for all forms of capital.

Marginal returns to each type of capital can be expressed as:

$$\frac{\partial y_t}{\partial k_t} = A_t \alpha k_t^{\alpha-1} s_t^{\beta} h_t^{\gamma} \tag{6}$$

$$\frac{\partial y_t}{\partial s_t} = A_t \beta\, k_t^{\alpha} s_t^{\beta-1} h_t^{\gamma} \tag{7}$$

$$\frac{\partial y_t}{\partial h_t} = A_t \gamma k_t^{\alpha} s_t^{\beta} h_t^{\gamma-1} \tag{8}$$

The household can invest in all three forms of capital in such a way that marginal returns equate to each other as shown by the following expressions.

$$\frac{\partial y_t}{\partial k_t} = \frac{\partial y_t}{\partial s_t} = \frac{\partial y_t}{\partial h_t} \tag{9}$$

$$A_t \alpha k_t^{\alpha-1} s_t^{\beta} h_t^{\gamma} = A_t \beta\, k_t^{\alpha} s_t^{\beta-1} h_t^{\gamma} = A_t \gamma k_t^{\alpha} s_t^{\beta} h_t^{\gamma-1} \quad (10)$$

The following relationships involving k, s, and h can be derived from expression (10).

$$k = \left(\frac{\alpha}{\gamma}\right) h; s = \left(\frac{\beta}{\gamma}\right) h \quad (11)$$

Substituting equation (11) into equation (2) yields an expression for output per capita in terms of health capital:

$$y_t = \mathrm{A_t} \left(\frac{\alpha h_t}{\gamma}\right)^{\alpha} \left(\frac{\beta h}{\gamma}\right)^{\beta} h_t^{\gamma} \quad (12)$$

Taking the log of equation (12) and simplifying leads to:

$$\ln y_t = a + b\, h \quad (13)$$

where $a = \ln A_t + \alpha \ln \alpha + \beta \ln \beta - \alpha \ln \gamma - \beta \ln \gamma$, and $b = \alpha + \beta + \gamma$. In this study, life expectancy at birth is considered a basic indicator of health and social development (World Health Organization, 2015), and used in the mathematical modelling for subsequent estimations.

Testing for Stationarity

In this study, both short-run and long-run effects of longevity on the economic performance of Pakistan were estimated using time series modelling. The standard ordinary least square (OLS) method leads to spurious results in the presence of unit roots, which is the case for most macroeconomic variables (Nelson & Plosser, 1982). Furthermore, the choice of appropriate multivariate time series analysis depends on the stationarity of the particular series. It was also important to differentiate between trend stationary (TS) and difference stationary (DS) series in choosing the correct method for achieving stationarity (Patterson, 2011; Rudebusch, 1992). Among various tests of stationarity, the widely used Augmented Dickey-Fuller test (ADF) was used in this study.

Selection of Multivariate Time Series Model

To estimate the long-run impact of rising longevity on economic growth, the Autoregressive Distributive Lag (ARDL) bounds testing approach to cointegration (Pesaran et al., 2001) was adopted. The approach allows for testing cointegration regardless of the order of integration of variables; variables may either be in levels, I(0) or differenced I(1), or a mix of both. However, this method is unsuitable if any variable is of an order higher than I(1). Other popular approaches inherently require variables to be integrated into the order 1, i.e., I(1) (Pesaran et al., 2001). Long-run estimates using an ARDL model are generally unbiased even when some variables are endogenous (Odhiambo, 2009), and the approach is not sensitive to sample size (Amusa et al., 2009).

In the first stage of the ARDL bounds testing, the following unrestricted error correction model is estimated to determine cointegration among variables using the two bounds as delineated by Pesaran et al. (2001).

$$\boldsymbol{\Delta y_t = \alpha_0 + \beta_1 t + \beta_Y y_{t-1} + \beta_L h_{t-1} + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + \sum_{j=0}^{p} \phi_j \Delta h_{t-j} + e_t} \quad (14)$$

where y denotes GDP per capita, t is the time index (years), and h represents the life expectancy at birth (years). Lagged values of the first difference for each of these variables (except the time trend) entered in the model as Δy_{t-i} and Δh_{t-j}. Additionally, α_0 is a drift parameter, while $\beta 1, \beta_Y, \beta_L$ represent coefficients for time trend, and long-run multipliers for GDP growth per capita and life expectancy, respectively. The coefficients related to short-run dynamics are ϕ_i for GDP growth per capita and ϕ_j for life expectancy.

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The restricted form of the model may be represented as:

$$\Delta y_t = \alpha_0 + \beta_1 t + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + \sum_{j=0}^{q} \phi_j \Delta h_{t-j} + e_t \quad (15)$$

The Wald test was used to determine the existence of a long-run relationship between y_t, and h_t. The null hypothesis ($H_0: \beta_Y = \beta_L = 0$) implies that there is no level relationship between the two variables. In contrast, the alternative hypothesis ($H_1: \beta_Y \neq \beta_L \neq 0$) implies that there exists a long-run relationship.

The estimated *F*-statistic (Wald test statistic) is compared with critical upper and lower bounds values for the asymptotic case (Pesaran et al., 2001) and for the small sample case (Narayan, 2005). If the estimated *F*-statistic is greater (smaller) than the upper (lower) bound critical value, the null hypothesis is not accepted (not rejected), and it is concluded that a long-run relationship exists (does not exist) between the variables. Finally, if the value of the *F*-statistic lies between the upper and lower critical bound values, then the test is inconclusive.

If the null hypothesis is rejected, long-run values are estimated using the following equation:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i y_{t-i} + \sum_{j=0}^{q} \beta_j h_{t-j} + e_t \quad (16)$$

The short-run coefficients were estimated using the error correction method (Equation 17) in which the error correction term (ECM) is the estimated residuals from the estimated equation (16).

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + \sum_{j=1}^{q} \phi_j \Delta h_{t-j} + \gamma_1 ECM_{t-1} + e_t \quad (17)$$

Data

Time series data to investigate the impact of rising longevity (i.e., life expectancy at birth) on economic growth in Pakistan were obtained from World Bank online databases (The World Bank, 2017a, 2024b). Life expectancy at birth implies the number of years a newborn infant would live if prevailing patterns of mortality at the time of birth were to stay the same throughout the infant's life (The World Bank, 2024b). The data consisted of six variables with 54 observations covering 1967 to 2020. Population-related variables included crude birth rate per 1000 of population, crude death rate per 1000 of population, annual growth in population (%), and life expectancy at birth. Besides the data on various population-related variables, annual GDP per capita in constant 2015 US dollars for Pakistan was also used. In addition, health expenditures data were collected from the Health, Nutrition and Population online database on the World Bank website for 1995 and 2020 (longitudinal data before 1995 was not available). The variables of interest included annual health expenditures in the current US$, yearly public and private health expenditures as a percentage of GDP, and annual health expenditures per capita in the current US$.

Empirical Results and Discussion

The bounds testing approach for cointegration requires that variables are not integrated of the order 2, i.e., I(2). To determine the order of integration, a unit root test based on the Augmented Dickey-Fuller (ADF) test was applied to the selected variables with initial lags of 10 based on the criterion suggested by Schwert (1989). Results of the ADF test suggest that the log of GDP per capita was non-stationary and the log of life expectancy at birth was stationary at a 1% significance level (Table 1). Furthermore, both tested variables were stationary at a 1% significance level after differencing once. It is also important to note that the trend coefficient was statistically significant in levels for both variables but it was insignificant once the variables were differenced

(Table 1). Overall, the unit root test confirmed that the log of GDP per capita was I(1) while the log of life expectancy at birth was I(0).

Table 1: Augmented Dickey-Fuller Test for Unit Roots (1967-2020)

	Log of GDP per capita	**Log of GDP per capita differenced**	**Log of life expectancy at birth**	**Log of life expectancy at birth-differenced**
Drift	1.17**	0.0195***	2.7733***	0.0106**
Rho	-0.181**	-0.8743***	-0.6946***	-1.5245***
Trend	0.003**	-0.0001	0.0028***	-0.00013
Lags	1	0	0	0
ADF Statistic	-2.377	-5.9182	-5.4276	-12.287
ADF-critical values				
1%	-4.144	-4.144	-4.1408	-4.137
5%	-3.498	-3.498	-3.4969	-3.495
10%	-3.178	-3.178	-3.177	-3.176
Decision:	Do not reject	Do not accept	Do not accept	Do not accept
H0: Series has a unit root				

Note: ***, **, * denotes statistical significance at 1%, 5% and 10%, respectively.

Table 2: Lag Order Selection Using the Three Selected Information Criteria

Lags	**AIC**	**SBIC**	**HQIC**
0	-5.132695	-4.915003	-5.055948
1	-5.190620*	-4.929390*	-5.098524*
2	-5.163725	-4.858956	-5.056280
3	-5.109674	-4.761367	-4.986879
4	-5.055928	-4.664083	-4.917784
5	-5.053463	-4.618080	-4.899970
6	-5.183415	-4.704494	-5.014573
7	-5.186580	-4.664120	-5.002388
8	-5.133296	-4.567298	-4.933755
9	-5.089516	-4.479980	-4.874626
10	-5.147818	-4.494743	-4.917578

Note: * indicates the optimal number of lags.

The absence of serial correlation in the unrestricted model is a key requirement of the bounds testing approach (Pesaran et al., 2001) that requires optimal lag selection. Thus, the unrestricted model in equation (18) is estimated for various lag orders (p) from 1 to 10 to determine optimal lags using: i) Akaike's information criterion (AIC); ii) Schwarz's Bayesian information criterion (SBIC); and iii) Hannan-Quinn information criterion (HQIC). Compared with equation (14), expression (18) includes two slope dummies to capture the variation (breaks) in the effect of longevity at various stages of demographic transition. The slope dummy for 1978-2002 is denoted by D_{7802}, while D_{0320} covers the period between 2003 and 2020. The lower and upper ends of these two break periods were determined by regressing the log of life expectancy at birth on the log of

GDP per capita using OLS, and then applying the Bai-Perron test (Bai & Perron, 2003) for a maximum of two breaks. A trend variable was included as the associated coefficient for the log of GDP per capita was statistically significant at a 1% level (Table 1).

$$\Delta Y_t = \alpha_0 + \alpha_1 Trend + \beta_2 D_{7802} + \beta_3 D_{0320} + \beta_Y Y_{t-1} + \beta_L h_{t-1} + \sum_{i=1}^{p} \phi_i \Delta Y_{t-i} + \sum_{j=0}^{p} \phi_j \Delta h_{t-j} + e_t \quad (18)$$

Koehler & Murphree (1988) suggested the use of SBIC and HQIC criteria over AIC for more parsimonious results. Results show that all the lag selection criteria such as AIC, SBIC, and HQIC pointed towards the same optimal lag level of 1 (Table 2) for this data. This is also supported by Wooldridge (2020) who suggested 1-2 lags for the annual data.

Table 3: Bounds Test for the Existence of Level Relationship Between the Selected Variables

	Significance Level				
	0.05		**0.01**		**Source**
K	**I(0)**	**I(1)**	**I(0)**	**I(1)**	
1	6.56	7.30	8.74	9.63	(Pesaran et al., 2001)
1	6.930	7.785	9.80	10.675	(Narayan, 2005)
Wald-test statistic = 29.514					
Probabilities of LM test for lags 1-3: 0.4877, 0.7569, 0.8699					

Note: Lower bound values are associated with I(0), upper bound values are associated with I(1).

Using equation (18) with 6 initial lags for both dependent and independent variables, the search for an appropriate specification favoured an ARDL (1,0) model (Table 3). With one exogenous regressor (k=1), the estimated Wald test statistic of 29.514 was greater than the upper bound value of 9.63 at 1% significance level and 7.30 at 5% significance level. This suggests the presence of a long-run relationship between the selected variables. It is important to note that the upper and lower bounds reported here from tables published by Pesaran et al. (2001) are related to large samples. Narayan (2005) argued that bounds values are sensitive to the total number of observations (T), and the author estimated and reported bounds values for samples with fewer observations such as 55 observations. The estimated Wald test statistic, when compared with the reported upper bound critical values of 10.67 at 1% significance level and 7.78 at 5% significance level for 55 observations, confirmed the presence of a long-term relationship between the selected variables. For lags 1-3, estimated probabilities for the Lagrange Multiplier (LM) test, as reported in Table 3, suggest no serial correlation at 1% significance level.

Table 4: Estimated Long-Run Coefficients of ARDL (1,0) model, 1967-2020

Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
Log of life expectancy at birth	0.6435**	0.3181	2.0226	0.0489

Note: ***, **, * denotes statistical significance at 1%, 5% and 10%, respectively.

The long-run estimates based on the selected ARDL (1,0) suggest that a 1% increase in life expectancy at birth resulted in about 0.63% increase in the growth rate of GDP per capita (Table 4). This result is in line with Bloom et al. (2004) who found a positive relationship between an increase in GDP and life expectancy. However, their result is based on increases in GDP which is not directly comparable with the current study that uses growth in GDP per capita as the dependent variable. The result is also supported by the findings of Mierau and Turnovsky (2014) who reported that a 1% increase in life expectancy would lead to a 0.20% increase in economic growth.

Table 5: Short-Run Coefficients and Error Correction Estimates of ARDL (1,0) model, 1967-2020

Variables	Coefficient	Std. Error	t-Statistic	Prob.*
Short-run Elasticities				
Dependant variable: Difference of log of GDP per capita				
C	-2.1752**	0.8951	-2.4301	0.0191
TREND	-0.0033***	0.0009	-3.7852	0.0004
First Difference of log of GDP per capita	0.1347	0.1480	0.9102	0.3675
Log of life expectancy	0.5569**	0.2255	2.4694	0.0173
SD7802	0.0025	0.0032	0.7759	0.4418
SD0320	0.0097*	0.0054	1.8079	0.0772
Error Correction Estimates				
C	-2.1752***	0.2806	-7.7534	0.0000
TREND	-0.0033***	0.0006	-5.7297	0.0000
D7802	0.0025	0.0027	0.9351	0.3546
D0320	0.0097**	0.0047	2.0770	0.0434
ECM_{t-1}	-0.8653***	0.1114	-7.7661	0.0000
R-squared = 0.569				
Adj. R-squared = 0.532				

Note: ***, **, * denotes statistical significance at 1%, 5% and 10%, respectively.

Results of the short-run and error correction models are reported in Table 5. Short-run estimates suggest that the log of life expectancy at birth is positively associated with the growth rate in GDP per capita in Pakistan. A similar result is also obtained for the South Asian data by Munir and Shaid (2021) who reported that a 1% increase in life expectancy would increase GDP per capita by 0.2%. Coefficients related to both slope dummies were positive indicating that increased longevity tended to increase GDP per capita in the short-run. However, only one of the two slope dummies, the one associated with 2003 and 2020 (i.e., D0320) was statistically significant at a 5% level, and it indicates a positive short-run effect of 0.009% on the growth rate of GDP per capita. This result is supported by Cervellati and Sunde (2011) who argued that the effect of life expectancy on economic growth varies by stages of demographic transition. The value of life expectancy at birth between 2003 and 2020 was about 62 years or higher. These results empirically show that the impact of an increase in life expectancy differs by various stages of demographic transition. Furthermore, a negative and statistically significant coefficient associated with the first lag of the error correction term (ECM_{t-1}) suggests an adjustment speed of about 87% per year in response to a longevity shock in the long-run. In conclusion, a positive impact of rising longevity on economic growth is found in the short-run, especially during the later years of demographic transition.

Table 6: Diagnostic Tests

Test Statistic	*F*-Statistic	Prob.*
LM test of residual serial correlation	$F(2,44)=0.280$	0.756
Ramsey's RESET test	$F(1,45)=1.336$	0.253
Normality (Jarque-Bera) test	0.800	0.670
Heteroskedasticity (Breusch-Pagan-Godfrey) test	$F(5,46)=0.780$	0.569

*Note: ***, **, * denotes statistical significance at 1%, 5% and 10%, respectively.*

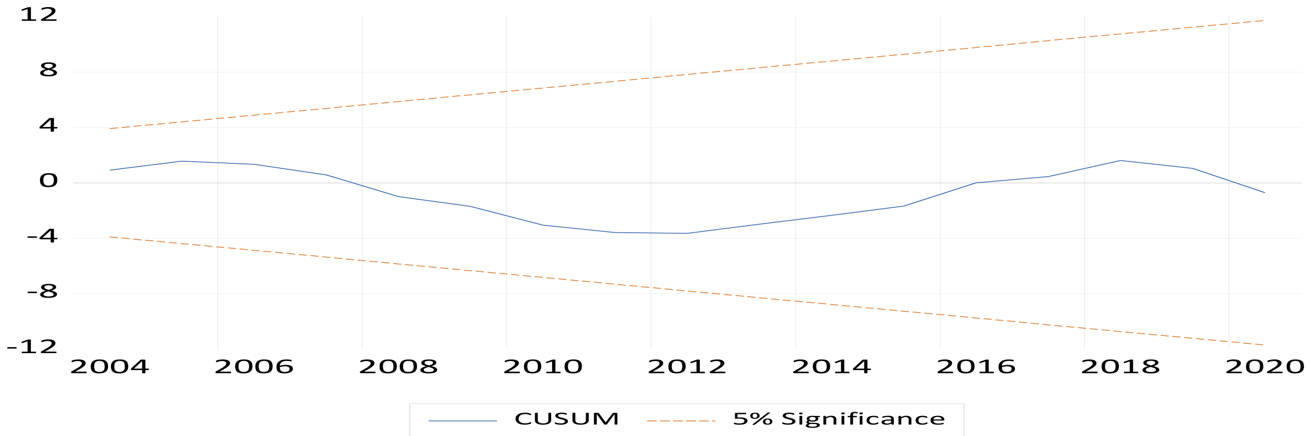

Figure 4: Plot of Parameter Stability in ARDL (1,0) model at 95% Confidence Interval Based on Cumulative Sum of Recursive Residuals (CUSUM)

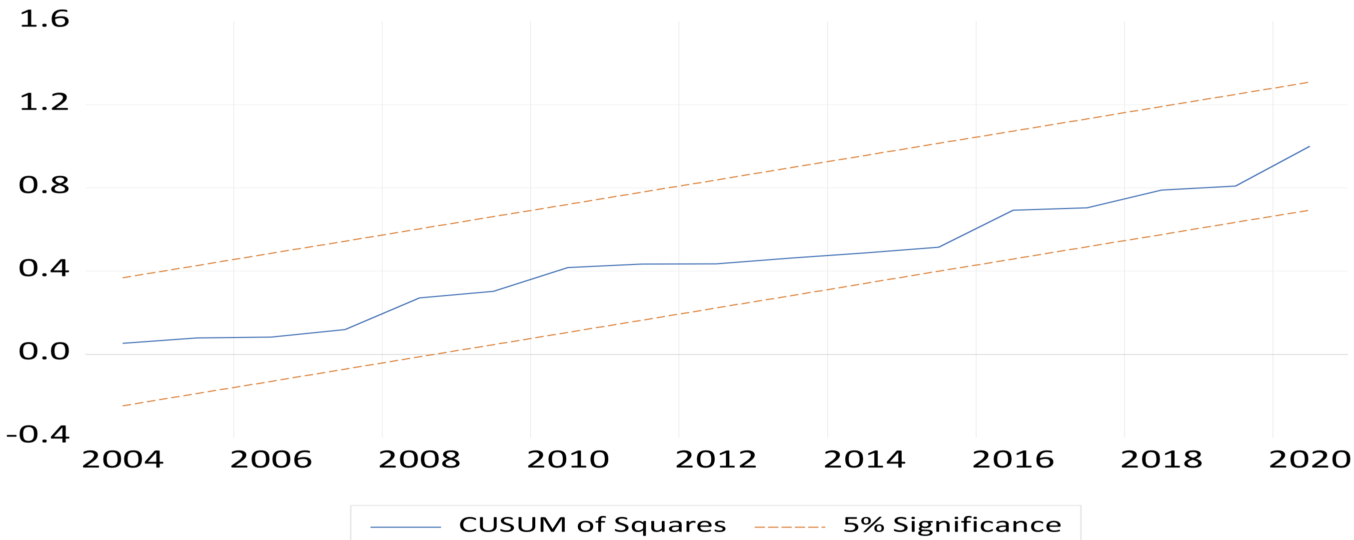

Figure 5: Plot of Parameter Stability in ARDL (1,0) model at 95% Confidence Interval Based on Cumulative Sum of Squared Residuals (CUSUMS)

Several diagnostic tests were performed to determine the stability of the estimated ARDL (1,0) model. A statistically insignificant value of the LM test suggests no serial correlation (Table 6). Ramsey's RESET test statistic indicated that ARDL (1,0) was not mis-specified. The Jarque-Bera test statistic was not significant at the 5% level and suggests that the estimated residuals were normally distributed. Breusch-Pagan-Godfrey test of Heteroskedasticity revealed an absence of Heteroskedasticity. Finally, plots of parameter stability (Figure 4-5) such as the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squared residuals (CUSUMS) suggest that the estimates of the ARDL (1,0) model were generally stable for the sample studied. In summary, the estimated ARDL (1,0) passed all the diagnostic tests.

Summary and Conclusion

Various countries have been experiencing demographic transitions because of rising longevity and falling birth rates. Several studies suggest that longevity is positively associated with economic performance, while other studies found contrasting effects. In this paper, the impact of rising longevity on GDP per capita in Pakistan was evaluated using data for 1967-2020 using the bounds test approach to cointegration by Pesaran et al. (2001).

Results suggest that a rise in longevity had a stable and positive long-run effect on economic growth in Pakistan; a 1% increase in life expectancy at birth increased growth in GDP per capita by 0.64% in the long-run. The estimates for slope dummies suggest that from 2003 onwards (with life expectancy at birth about 62 years or higher), a 1% increase in life expectancy increased the growth rate of GDP per capita by an additional 0.006%. In general, the impact of rising longevity on Pakistan's economic performance varied with stages of demographic transition. The short-run estimates were also consistent with the long-run estimates. Overall, the results of this study suggest that rising longevity has a positive impact on economic performance. Given that rising longevity is linked to better healthcare access among other determinants of health, the results of this study provide empirical evidence to support increasing health sector investment in Pakistan beyond current levels.

Finally, the study incorporates life expectancy at birth as a measure of longevity ignoring gender differences. However, further research can be conducted on segregating the effect of male and female life expectancy at birth. This future research would help explore untapped avenues for economic growth.

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