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Infrastructure Development and Life Expectancy in Pakistan: A Time Series Analysis

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Abstract
This research investigated the correlation between life expectancy and various determinants, including health infrastructure, personnel, environmental quality, transportation, and income, utilizing data from 1991 to 2023. Analytical methods such as ARDL and ARDL-ECM demonstrated both immediate and sustained associations. Past enhancements in life expectancy exert limited influence on present levels. In the short term, increases in healthcare personnel positively impact life expectancy, whereas health infrastructure exhibits negative effects in the short run and positive effects in the long run. CO2 emissions adversely affect life expectancy across both temporal frameworks. Economic growth may temporarily reduce life expectancy but has the potential to augment it in the long term. Transportation services display detrimental short-term effects and beneficial long-term effects. Investment in healthcare personnel and infrastructure is vital, whereas environmental degradation undermines life expectancy. Enhancing road networks and transportation systems is advantageous for health outcomes.

Keywords: Life expectancy, ARDL, Pakistan.

Introduction

The role of infrastructure is crucial in attaining socioeconomic prosperity. Access to fundamental necessities and adequate or accessible infrastructure facilities not only facilitates economic growth but also enhances the average life expectancy and living conditions of individuals. In Pakistan, the distribution of infrastructure resources is uneven across different regions. Certain areas possess more facilities such as schools, colleges, hospitals, etc., while others suffer from deficits or a lesser quantity of these amenities. Pakistan's geographical diversity includes mountainous regions, desert plains, and river courses, and the infrastructure in these diverse areas varies significantly. Consequently, residents in different parts of the country may experience differences in life expectancy attributable to disparities in infrastructure. The region exhibits noticeable uneven economic growth. During the early 1970s, geographic dissimilarity was among the primary causes of civil unrest and continues to be a source of criticism in economic and political domains. Following the civil war, Pakistan experienced limited domestic discourse on regional issues, which remains somewhat underappreciated (Zaidi, 1989: 300). Despite this partial national debate, the Seventh Five-Year Plan explicitly recognizes profound geographical disparities and endeavors to diminish them. This plan aims to fulfill basic needs, elevate living standards, and foster economic development in impoverished areas (Government of Pakistan, 1988: 129). Variations in infrastructure distribution across regions significantly influence regional and economic development, as well as the life expectancy of the inhabitants in those areas.

Health indicators in Pakistan have improved over the past 25 years but still lag. Average life expectancy rose from 59 years to 67 years between 1990 and 2015. It has since improved due to better facilities and skilled birth attendants, and infant and under-5 mortality rates have also declined. Life expectancy increased in all provinces between 1990 and 2019 due to reductions in maternal deaths, newborn deaths, and deaths from nutritional diseases. Baluchistan saw the smallest reduction, Islamabad maintained a high life expectancy, and Azad Jammu and Kashmir had the second-highest life expectancy in the country at 68.6 years (Hafeez et al., 2023)

Life expectancy is a key indicator of a population's overall health and well-being, representing the average lifespan from birth. It mirrors the efficiency of healthcare systems, accessibility to medical services, sanitation standards, nutrition, socioeconomic factors, and public health efforts within a nation. Grasping life expectancy trends in Pakistan is essential for policymakers, healthcare practitioners, and researchers to pinpoint areas for enhancement, allocate resources effectively, and introduce specific measures to improve citizens' quality and duration of life. Life expectancy is intricately linked with the quality of infrastructure, prompting us to investigate variations across different provinces. Disparities in infrastructure development contribute to differing life expectancies among the provinces of Pakistan. Surprisingly, there appears to be a dearth of research on this pertinent issue.

Research Question

Is there any relationship between infrastructure and life expectancy in Pakistan?

Is there any relationship between life expectancy, environmental quality, health expenditures, and transport services?

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Literature Review

This section presents various studies related to the topic under study. The details are as follows.

Infrastructure development

The issue of regional disparity holds particular significance and has persistently been a crucial aspect of the country's overall economic development. Geographic inequities played a central role in the civil war of the 1970s and continue to incite economic and political unrest. Despite the post-war regional income gap in Pakistan, comprehensive national discourse on this matter has been notably limited (Zaidi, 1989: 300). The Seventh Plan, issued in 1988, recognized these disparities and adopted a comprehensive approach aimed at addressing these gaps (Government of Pakistan, 1988: 129). This situation is reflected in federal expenditure and grant aid allocations; however, such broad generalizations tend to overlook significant intra-provincial differences at the district level (Pasha & Hasan, 1982: 157). The majority of economic inequality in Pakistan stems from differences within provinces rather than between them. The provinces ranked by income disparity are NWFP, Sindh, Punjab, and Balochistan (De Kruijk, 1986: 685).

Jamal and Malik analyzed Sindh and found that the lack of road paving was a major factor in the high rates of growth in various districts in the 1980s. Their findings underscore the necessity of analyzing and comprehending regional differences in development (Jamal & Malik, 1988: 168). Additionally, in KP, income in both rural and urban settled areas is more evenly spread than in other provinces. In Sindh, people living in cities earn more than people in cities of Punjab and Baluchistan, although the average income in urban Sindh is often underreported (Kardar, 1987: 25-26).

Cigu et al. (2018) analyze transport infrastructure's impact on EU-28 countries' economic activity from 2000-2014, finding it influences economic performance even when considering other factors. Scholars like Arvin, Pradhan, and Norman discuss transport infrastructure's role in sustainable development but often overlook public policy decisions. Sousa Roseta-Palma and Martins (2019) focus on the relationship between economic growth, transport infrastructure, and public policy, examining government performance. Transport infrastructure has long been a key tool for policymakers aimed at reducing disparities, inequalities, and fostering economic growth (Bröcker & Rietveld, 2009).

Canning and Pedroni (2008) suggest that excessive infrastructure investment can effect growth. Crafts (2009) highlights that governments must fund transport infrastructure through public revenue like taxes. Farhadi (2015) observed economic improvements from infrastructure spending. Zhou et al. (2018) found that strategic planning involving public input and cost-effectiveness enhances sustainability and social balance, comparing China and Germany. Numerous scholars emphasize the vital role of transport infrastructure as both consumption and investment goods (Arvin et al., 2015; Phang, 2003; World Development Report, 1994; Bhatta & Drennan, 2003; Lakshmanan, 2007), supporting related industries. Aschauer (1990) noted road

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construction spurred U.S. growth from 1960-1985, Moomaw and Williams (1991) credited roads for manufacturing growth, and Pereira (2000) showed highway investment boosted private sector output between 1956-1997.

Transport infrastructure has shown positive effects on the economy (Cantos et al., 2005; Berechman et al., 2006)., Jiwattanakulpaisarn et al. (2012) found that higher highway density correlates with better economic performance. Economic activity is dependent on developed transport infrastructure; This is true except for railways (Banister, 2012). Research also shows that air transport infrastructure improves economic growth, demonstrated through fixed-effects regressions, Granger-causality, and co-integration analyses. However, some studies using pooled OLS, random effects, or fixed-effects models suggest a less pronounced effect.

Life Expectancy

ŞENTÜRK and Ali (2021) studied the socioeconomic determinants of total and gender-specific life expectancy in Turkey. They showed that educational attainment, purchasing power, and economic development stage are key determinants. Another study indicates that, in the long term, economic growth and death rate are inversely related, but in the short term, they are directly related (Dimitrios Varvarigos, 2008). Variations are due to healthcare access, literacy, sanitation, clean water, and technology level (Kakwani, 1993; Gerring et al., 2005; Grosse & Aufiey, 1989; Preston, 1980; Lake & Baum, 2001; Navarro et al., 2006; Franco et al., 2004; Mahfuz, 2008; Shen & Williamson, 1997; WHO, 2005). Life expectancy is linked to social security, maternal care, income, education, fertility, and government spending (Poikolainen & Eskola, 1988; Navarro et al., 2006; Halicioglu, 2010; Wolfe, 1986; Preston, 1976; Hertz et al., 1994; Cumper, 1984; Lake & Baum, 2001).

Williamson and Boehmer (1997) found that education, reproductive autonomy, and economic participation significantly and positively influence life expectancy. Lin et al. (2003) revealed that democracy, nutrition, and socioeconomic conditions boost life expectancy short-term. Yavari and Mehrnoosh (2006) investigated causes of decreased expectancy in 89 developing countries across regions, linking physician density, caloric intake, literacy, healthcare spending, and income per capita to longer life. Bergh and Nilsson (2010) studied globalization's effects on 92 developing countries from 1970-2005, finding life expectancy closely tied to income, nutrition, literacy, and doctor ratio

Bayati et al. (2013) evaluated the applicability of the Grossman model within the context of the East Mediterranean region, utilizing health data spanning from 1995 to 2007. Their analysis demonstrated that employment levels influence life expectancy in a manner that differs between males and females, thereby underscoring the importance of simultaneously promoting economic development and enhancing medical infrastructure to attain increased life expectancy. Mahmud et al. (2013) investigated the relationship between health expenditure and life expectancy in Bangladesh from 1995 to 2011, noting that female life expectancy has consistently exceeded that of males. Ali and Ahmad (2014) found that the availability of food and the level of education significantly affected life expectancy in Oman. Audi and Ali

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(2016) found that life expectancy was significantly affected by the availability of food, environmental degradation, education, income, and population growth.
Ogungbenle et al. (2013) found No causal relationship between life expectancy and either health expenditure or economic growth; however, a bidirectional causality was observed from health expenditure to economic growth. Musgrave (1996) found no association between child mortality and health expenditure. in low-income countries. Nixon and Ulmann reported that between 1980 and 1995, healthcare expenditure and the number of physicians contributed to improvements in infant mortality; however, healthcare expenditure exerted a lesser impact on life expectancy across different nations. Zakar and Wunnva (1997), found that GNP healthcare spending did not significantly explain infant mortality but was associated with other health indicators. In Uganda, Seewananyana and Younger (2004) projected that healthcare expenditure, particularly on vaccination programs, would positively influence infant mortality rates by 2015.
Wang (2002) showed that public health spending in lower income countries significantly reduced child mortality. Harttgen and Misselhorn (2006) highlighted the importance of health infrastructure and socioeconomic factors, which greatly influence health, as shown in many child mortality studies (e.g., Preston, 1975, 1985; Hobcraft et al., 1984; Hill, 1989). Bhargava et al. (2001) noted that lagged life expectancy, alongside other demographic factors, was crucial for economic growth. Chakraborty (2004) developed a model linking life expectancy with capital accumulation, providing evidence that longer life expectancy drives economic growth. Govdeli et al. (2019) evaluated E7 nations for the period from 1992 to 2016 and established a correlation between economic growth and population life expectancy. Shahbaz et al. (2017) reported similar positive correlations within sub-Saharan Africa. Furthermore, Shahbaz et al. (2017) also analyzed the case of Pakistan, demonstrating that enhancements in health infrastructure and governmental interventions were essential to sustain both life expectancy and economic growth. The positive impact of life expectancy on the economy was additionally evidenced by Biyase and Maleka (2019), who examined regions in Southern Africa between 1985 and 2017. Acemoglu and Johnson (2006, 2007) explored the relationship between life expectancy and economic growth in a sample of 47 countries and identified an insignificant negative correlation. Leung and Wang (2006) employed a neoclassical growth model to argue that increases in life expectancy detracted from income per capita due to rising dependency ratios. Ecevit (2013) investigated the influence of life expectancy on economic growth in 21 OECD countries, concluding that life expectancy is a significant determinant of economic growth, with a unidirectional causal effect from life expectancy to real per capita GDP. Likewise, Mahumud (2013) observed that higher life expectancy corresponded with higher GDP per capita in Bangladesh.
Acemoglu and Johnson's 2007 study did not find a positive link between economic growth and life expectancy at birth. Instead, it suggests healthcare improvements may cause population increases that lower average income. Barro and Lee (2010) also found a negative correlation between life expectancy and growth in high-income countries. Conversely, research by Schultz and Tansel (1992), Strauss and Thomas

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(1998), Schultz (1999a, 1999b), Savedoff and Schultz (2000), and Schultz (2002) shows health improves productivity, leading to economic growth. The debate on whether life expectancy impacts economic development remains complex. Researchers like Gallup and Sachs (2000) and Alleyne and Cohen (2002) assert it does. Many studies show a positive correlation between increased life expectancy and economic growth (Gallup and Sachs, 2000; Barro and Sala-I-Martin, 1995; Mayer, 2001; Bloom et al., 2001, 2003; Akram et al., 2008; Cervellati and Sunde, 2010; Ngangue and Kouty, 2015), but others suggest it may be negative (Acemoglu and Johnson, 2006, 2007). The research findings are inconclusive, with some indicating a positive effect (Bloom, Canning, and Sevilla, 2004; Zhang and Zhang, 2005; Lorentzen et al., 2008) and others a very small positive impact (Shastry and Weil, 2003; Weil, 2007; Ashraf et al., 2008). Some studies propose a U-shaped relationship between life expectancy and economic development (Hansen, 2013; Cervellati & Sunde, 2011; Desbordes, 2011).

Research Methodology

The primary goal of this study is to analyze life expectancy differentials in Pakistan using time series data.

Theoretical framework

Examining life expectancy through the lens of infrastructure development is complex because many factors influence it. The research discusses infrastructure's impact on life expectancy, noting variation in quality, accessibility, and coverage across regions (S. Zuberi, 2006). We will explore infrastructure's role in shaping economic and public health effects on life expectancy.

Infrastructure development influences socioeconomic factors and can boost economic growth and income while reducing poverty, indirectly improving life expectancy. Regression models, similar to those in previous studies (Yang et al., 2009; Pickett, 2001; Mahmood & Asif., 2024), analyze the relationship between infrastructure and life expectancy. This analysis is based on a time-series dataset from the Economic Survey of Pakistan from 1991 to 2023.

Econometric representation

Grossman (1972b) constructed a theoretical health production function that associates the outcome of health with inputs of health care, as shown:

$$H = f(X) \qquad (1)$$

Here, the health output of an individual in this model is captured by H. At the same time, X denotes non-medical elements like environmental factors that can constitute the health inputs in the production function (Fayissa & Traian, 2013). For exercising theoretical coherence, the components of vector X can also be related to environmental factors (Fayissa & Gutema, 2005; Rayhan et al., 2019), as provided below.

$$H = f(ENV) \qquad (2)$$

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In Equation (2), H represents health outcomes, while ENV refers to the vector of environmental factors, therefore, an individual's health status can be influenced by a range of environmental factors (Rayhan et al., 2019). We can write eq 2 as

$$H = f(en_1, en_2, en_3, \text{-----}\ en_n) \qquad (3)$$

In Equation 3, "h" is the individual's health status proxies by mortality rate, $en_1, en_2, en_3,$ ----- en_n) = ENV and "n" is the number of variables in the group. Using calculus, Equation (3) can
be converted into its explicit form and written as:

$$h= \Omega \Pi en^{\alpha} \qquad (4)$$

α represents elasticity in eq 4.

For empirical research of this work, the environmental variable is confined to carbon emissions. The following equation is derived from (4) after it was logarithmically transformed and rearranged:

$$\ln h= \ln\Omega þ\ X + \sum\alpha_i(\ln en i) \qquad (5)$$

In Equation (5), Ω shows the estimate of the initial health stock of the region.

3.3: Model

Life expectancy = Infrastructure for Healthcare + income level + health staff+ environmental quality+ health expenditure+ roads network

Econometric Representation and Tests used in the analysis

Testing unit root

To proceed with the analysis, we need to check for the stationarity of the data (Verbeek, 2008). We have used the augmented dicky fuller (Dickey & Fuller, 1979, 1981) test for checking stationarity. The general form of ADF is written as:

$$\Delta\gamma_t = \alpha_0 + \alpha_1\gamma_{t-1} + \sum_{i=1}^{n}\Delta\alpha\gamma_i + u_t \qquad (6)$$

$$\Delta\gamma_t = \alpha_0 + \alpha_1\gamma_{t-1} + \sum_{i=1}^{n}\Delta\alpha\gamma_i + \delta_t + u_t \qquad (7)$$

Here γ_t represents the time series Δ ; represents the operator of the first difference, while α_0 is the constant. Additionally, t is used for a linear time trend, and n shows the maximum lags of the dependent variable. Here, u is the error term, as is this term used in other regression models.

ARDL or Auto Regressive Distributive Lag Model and Bound tests

This study used ARDL as a test statistic for checking the relationship between independent variables and the dependent variable. The test gives evidence for both the long run and the short run. This method has been introduced by Pesaran et al., (1996) and developed again by Pesaran et al., 2(001). This method is used extensively by researchers. (Rehman et al., 2011) and (Kashif & Muhammad, 2013), it was introduced by Pesaran et al. (1996) and developed again by Pesaran et al. (2001), to name a few. The precondition for ARDL is that some variables are

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stationary at level and some at first difference. However, it cannot be used in the acse when the variables are stationary at second difference. ARDL also provides flexibility to use variables with different lags (Pesaran et al., 2001). Another advantage of ARDL is that it can be applied to samples with fewer observations and does not require associated outcomes (Akel & Gazel, 2014). There is this corresponding error correction which makes the corresponding outcomes and data statistically trustworthy.

ARDL error correction model can be expressed as

$$\Delta LE_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i}\, \Delta LE_{2,t-i} + \sum_{i=0}^{k} \beta_{2i}\, \Delta TS_{t-i} + \sum_{i=0}^{k} \beta_{3i}\, \Delta GDP_{t-i} + \sum_{i=0}^{k} \beta_{4i}\, \Delta HS_{t-i} + \sum_{i=0}^{k} \beta_{5i}\, \Delta HInf_{t-i} + \sum_{i=1}^{k} \beta_{6i}\, \Delta CO_{2,t-i} + u_t \quad (8)$$

To test long-run relationships, the following equation is used:

$$LE_{2t} = \beta_0 + \sum_{i=1}^{k} \beta_{1i}\, \Delta LE_{2,t-i} + + \sum_{i=0}^{k} \beta_{2i}\, \Delta TS_{t-i} + \sum_{i=0}^{k} \beta_{3i}\, \Delta GDP_{t-i} + \sum_{i=0}^{k} \beta_{4i}\, \Delta HS_{t-i} + \sum_{i=0}^{k} \beta_{5i}\, \Delta HInf_{t-i} + \sum_{i=1}^{k} \beta_{6i}\, \Delta CO_{2,t-i} + u_t \quad (9)$$

To test for cointegration, we have developed the following hypothesis

H_0: There is no cointegration: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$
As against
H1: There is cointegration: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq 0$

If there is evidence of cointegration, an ECM model is used to describe the short-term interaction of the study's variables.

$$\Delta LE_{2t} = \beta_0 + \sum_{i=1}^{m} \Delta LE_{2,t-i} + \sum_{i=0}^{k} \beta_{1i}\, \Delta TS_{t-i} + \sum_{i=0}^{k} \beta_{2i}\, \Delta GDP_{t-i} + \sum_{i=0}^{k} \beta_{3i}\, \Delta PR_{t-i} + \sum_{i=0}^{k} \beta_{4i}\, \Delta HS_{t-i} + \sum_{i=0}^{k} \beta_{5i}\, \Delta Hinf_{t-i} + \sum_{i=0}^{k} \beta_{6i}\, \Delta CO2_{t-i} + ECT_{t-1} + u_t \quad (10)$$

Results

Stationarity Test for Variables

Table 4.1 presents the results of the Augmented Dickey-Fuller test for the variables used in the analysis. Most of the variables are stationary at first difference, while one variable is stationary at level. This mix of variables is suited for a regressive distributive lag model for analysis.

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Table No. 4.1: Dickey–Fuller Test for Checking Stationarity

Variable name	Stationarity order	Test statistic	critical value			*P-value*
		Z(t)	1%	5%	10%	
ln_LE_Total	Level	-1.297	-4.316	-3.572	-3.223	0.8886
ln_LE_Total	I(1)	-3.677	-4.334	-3.580	-3.228	0.0239
ln_LEM	Level	-2.791	-4.316	-3.572	-3.223	0.2002
ln_LEM	I(1)	-5.691	-4.325	-3.576	-3.226	0.0002
ln_LEFM	Level	-2.620	-4.316	-3.572	-3.223	0.2723
ln_LEFM	I(1)	-5.698	-4.325	-3.576	-3.226	0.0000
ln_CO2	Level	-1.570	-4.316	-3.572	-3.223	0.8039
ln_CO2	I(1)	-5.154	-4.325	-3.576	-3.226	0.0001
lnDE	Level	-3.112	-4.316	-3.572	-3.223	0.1034
lnDE	I(1)	-5.859	-4.325	-3.576	-3.226	0.00011
lnNDE	Level	-2.310	-4.316	-3.572	-3.223	0.4283
lnNDE	I(1)	-7.333	-4.325	-3.576	-3.226	0.0001
ln_TE	Level	-2.812	-4.316	-3.572	-3.223	0.1927
ln_TE	I(1)	-7.801	-4.325	-3.576	-3.226	0.0001
ln_GDPcurrent	Level	-1.595	-4.316	-3.572	-3.223	0.7943
ln_GDPcurrent	I(1)	-5.707	-4.325	-3.576	-3.226	0.00001
ln_transportServices	Level	-3.431	-4.316	-3.572	-3.223	0.0474.
ln_transportServices	I(1)	-7.801	-4.325	-3.576	-3.226	0.0012
ln_healthSTAFF	Level	-3.209	-4.316	-3.572	-3.223	0.0826
ln_healthSTAFF	I(1)	-5.343	-4.325	-3.576	-3.226	0.0002
ln_health_INF	Level	-1.876	-4.316	-3.572	-3.223	0.6671
ln_health_INF	I(1)	-5.808	-4.325	-3.576	-3.226	0.0002

MacKinnon approximate p-value for Z(t).
H0: Random walk with or without drift

ARDL model for life expectancy

Table 4.2 shows the ARDL model's estimated coefficients for life expectancy, in first difference, indicating short-run effects. A 1% increase in past life expectancy (d_LE_Total) decreases current life expectancy by 0.679%, which is significant. The second and third lags are insignificant, so effects diminish after the first lag. The first lag strongly negatively impacts current life expectancy, meaning higher past life expectancy reduces it. Similarly, the effect of health staff shows a negative relation. Results indicate a one percent increase in health staff in the previous year reduces life expectancy by 19.86%, while a 1% increase two years ago raises it by 18.46%. The third lag is highly significant but negative, decreasing life expectancy by 35% if staff increased three years ago. A 1% rise in health infrastructure weakly decreases life expectancy by 10.57%. The first lag is insignificant, but a 1% increase in infrastructure two years ago raises current life expectancy by 12.8%. An increase three periods ago boosts current expectancy by 28.34%, which is highly significant.

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Using CO2 as a proxy for environmental degradation, results show a 1% rise in CO2 decreases life expectancy by 5%, with insignificant effects in one lag but a positive significant effect in the second lag, indicating that in Pakistan, increased CO2 from economic activity may raise life expectancy by 4.4%. Overall, current CO2 emissions negatively affect life expectancy, though second lag results show a positive effect. A 1% increase in current GDP raises life expectancy by 3.42%, with significant positive effects in lags two and three, indicating higher GDP correlates with higher life expectancy across periods. Transport services, representing connectivity networks, show no short-term effect, but a strong positive impact in the first two lags. A 1% increase boosts life expectancy by 1.32% and 1.06% at 5% significance. Improvements in past transport facilities significantly enhance life expectancy.
The model fitness statistics show a significant F value (5.45*) showing a statistically significant model and implying that independent variables have a joint and significant effect on life expectancy. The adjusted R value shows that these variables explain almost 77% of the variation in life expectancy. A lower RMSE value also supports a good model.

Table No. 4.2: ARDL model for life expectancy

d_LE_Total	**Coefficient**	**Std. err.**	**t**	**P>t**	**[95% conf. interval]**	
d_LE_Total						
L1.	-.6791688	.1533061	-4.43	0.003	-1.04168	-.3166574
L2.	-.1799508	.145452	-1.24	0.256	-.5238901	.1639886
L3.	.1648866	.1313691	1.26	0.250	-.1457519	.4755251
d_ln_healthSTAFFD						
-.	7.846755	6.802272	1.15	0.287	-8.238062	23.93157
L1.	-19.86029	7.596705	-2.61	0.035	-37.82364	-1.896938
L2.	18.46229	7.999928	2.31	0.054	-.4545335	37.37912
L3.	-35.57139	5.810517	-6.12	0.000	-49.31108	-21.8317
d_ln_health_INF						
-.	-10.57262	4.564252	-2.32	0.054	-21.36536	.2201192
L1.	-2.861394	3.431298	-0.83	0.432	-10.97512	5.252337
L2.	12.81246	4.63328	2.77	0.028	1.856491	23.76842
L3.	28.43851	5.590907	5.09	0.001	15.21812	41.65891
d_ln_CO2						
-.	-5.150763	1.334885	-3.86	0.006	-8.307265	-1.994261
L1.	-2.258629	2.015288	-1.12	0.299	-7.024026	2.506769
L2.	4.408922	1.458284	3.02	0.019	.9606293	7.857215
d_ln_GDPcurrent						
-.	3.421129	.5522889	6.19	0.000	2.115173	4.727085
L1.	2.221781	.7292895	3.05	0.019	.4972858	3.946277
L2.	.9171538	.4640673	1.98	0.089	-.1801909	2.014499
L3.	2.327629	.5984441	3.89	0.006	.9125336	3.742724
d_ln_transportSer~s						

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-.	.2354965	.3399419	0.69	0.511	-.5683385	1.039331
L1.	1.324683	.2565993	5.16	0.001	.7179222	1.931444
L2.	1.062573	.2335421	4.55	0.003	.5103341	1.614813
_cons	1.454704	.8462745	1.72	0.129	-.5464173	3.455825

ARDL(3,3,3,2,3,2) regression Sample: 1995 thru 2023
Number of obs = 29 F(21, 7) = 5.45
R-squared = 0.9423 Prob > F = 0.0141
Adj R-squared = 0.7694 Root MSE = 0.1636
Log likelihood = 31.966801

Diagnostic tests

Table 4.3 shows that multicollinearity is not a severe issue in the current model. Table 4.4. and 4.5 show no serial autocorrelation and Heteroskedasticity. Table 4.6 confirms the normality assumption as well.

Table No. 4.3: Checking for Multicollinearity

Variable	VIF	1/VIF
d_ln_CO2		
L1.	8.86	0.112907
d_ln_GDPcu~t		
L1.	5.83	0.171609
d_ln_trans~s	5.50	0.181908
d_ln_CO2		
L2.	4.90	0.204087
d_ln_healt~D		
L2.	4.32	0.231476
d_ln_heal~NF		
L3.	3.91	0.255716
d_ln_healt~D		
L1.	3.84	0.260456
d_ln_GDPcu~t		
L3.	3.83	0.261372
d_ln_CO2	3.69	0.270711
d_ln_GDPcu~t	3.60	0.277776
d_ln_healt~D	3.50	0.285675
d_ln_trans~s		
L1.	3.14	0.318110
d_ln_heal~NF	2.85	0.350768
d_LE_Total		

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L1.	2.81	0.356167
d_ln_healt~D		
L3.	2.67	0.374473
d_ln_heal~NF		
L2.	2.64	0.378412
d_LE_Total		
L2.	2.58	0.387967
d_ln_trans~s		
L2.	2.46	0.406972
d_ln_GDPcu~t		
L2.	2.36	0.423641
d_LE_Total		
L3.	2.09	0.478598
d_ln_heal~NF		
L1.	1.83	0.545496

Mean VIF 3.68

Table No. 4.4: Breusch–Godfrey LM test for autocorrelation

lags(p)	chi2	df	Prob > chi2	
1	0.145	1	0.7030	

H0: no serial correlation

Table. 4.5: Breusch–Pagan/Cook–Weisberg test for heteroskedasticity

chi2(1) = 0.13
Prob > chi2 = 0.7166

Table No. 4.6: Cameron and Trivedi's decomposition of IM-test

Source	**chi2**	**df**	**P value**
Heteroskedasticity	29.00	28	0.4125
Skewness	16.48	21	0.7422
Kurtosis	1.29	1	0.2556
Total	46.77	50	0.6038

Test for Normal Data and Stability

Table 4.7 confirms the results of Table 4.6 about normality and provides evidence that the data are normal based on the Shapiro-Wilk W test for normality. Additionally, the CUSUM graph shows a stable model.

Table No. 4.7: Shapiro–Wilk W test for normal data

Variable	**Obs**	**W**	**V**	**z**	**Prob>z**
residuals	30	0.98251	0.556	-1.214	0.88757

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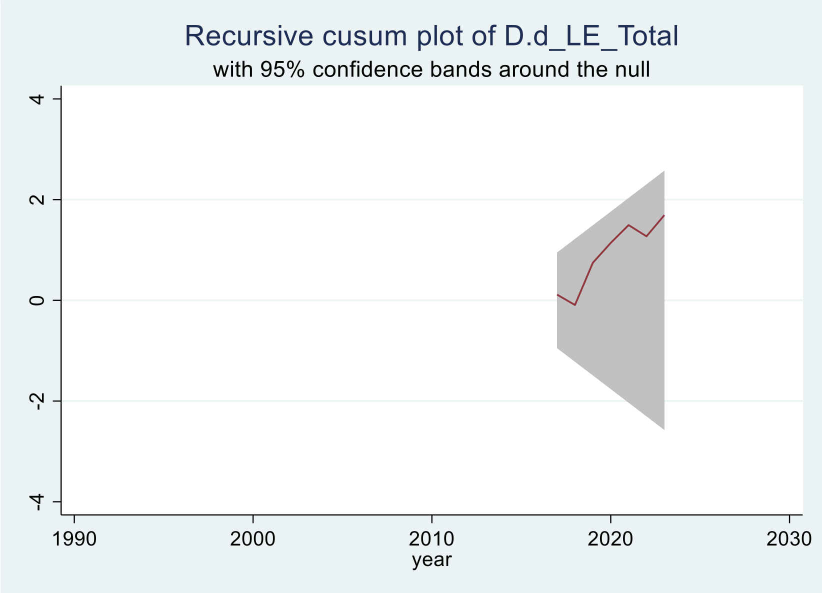

Figure 4.1: Cusum plot for model stability

ARDL Bound test for Long-Run Relationship

According to Table 4.9, for I(0) (level), the lower bound shows no evidence of cointegration (2.26 to 3.41). For I(1) (upper bound), the value (3.35 to 4.68) shows that cointegration exists. The F statistic value of 14.385 is well above the upper bound (I(1)) at all significance levels from 01 to 0.01. Therefore, we reject H0 of no cointegration and conclude that there is a strong long-run relationship in the model. In the second case, where the test statistic is the t statistic, the value of -7.283 provides no evidence of cointegration in the lower bounds (-2.57 to -3.43), while there is strong evidence of cointegration in the upper I(1) bounds (-3.86 to -4.79), suggesting a long-run relationship between the model variables. Since the t value of -7.28 is lower than the highest critical value of -4.79, we accept the presence of cointegration. To conclude, both the t value and the F value statistics give strong evidence to reject the null hypothesis of no cointegration and accept the alternative of a long-run relationship. In other words, the model's independent variables jointly shape the long-run behavior of life expectancy.

Table No. 4.8: Pesaran/Shin/Smith (2001) ARDL Bounds Test

[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]	
	L_1	L_1	L_05	L_05	L_025	L_025	L_01	L_01
k_5	2.26	3.35	2.62	3.79	2.96	4.18	3.41	4.68

H0: no levels relationship F = 14.385

Table No. 4.9 Pesaran/Shin/Smith (2001) ARDL Bounds Test

	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]
	L_1	L_1	L_05	L_05	L_025	L_025	L_01	L_01

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k_5	**-2.57**	**-3.86**	**-2.86**	**-4.19**	**-3.13**	**-4.46**	**-3.43**	**-4.79**

t = -7.283

Estimation of Long-run and Short-run Coefficients for Life Expectancy through Error Correction Model

Table 4.10 shows ARDL model estimates for long and short run using error-correction. The ECM adjustment term is -1.69 (p=.00001), meaning about 169% of deviations are corrected within a year. The negative coefficient confirms cointegration, and its large magnitude indicates rapid correction toward equilibrium. As per the long-run impact of variables on life expectancy, the health staff coefficient is insignificant, indicating no long-term effect. However, health infrastructure significantly boosts life expectancy; a 1% increase raises it by 16.42% (p=0.009). CO2 emissions negatively affect life expectancy, but evidence is weak at 10% significance. Higher current GDP correlates with longer life expectancy; a 1% GDP increase raises it by 5.25% (p=0.001). Better transport services also improve life expectancy; a 1% increase leads to a 1.55% rise.

Short-run coefficients show variable immediate effects, detailed in Table 4.12. Lagged life expectancy has no significant short-term impact (p=0.94, 0.250). Health staff positively affects life expectancy by 36.97 short-term (p=0.02), with weak evidence at first lag and a strong effect of 35.57 at second lag (p=0.0001), indicating a short-term positive impact persisting into the second lag. Conversely, health infrastructure negatively impacts life expectancy in the short run (-38.39, -41.25,-28.44), possibly due to infrastructural unpreparedness or reallocated funds. However, infrastructure shows a strong positive long-term effect, offsetting initial negatives over time, with long-term benefits appearing after delays despite early disruptions.

Environmental degradation and CO2 emissions have minimal but negative short-term effects on life expectancy, confirmed by a -3.02% initial lag. Higher CO2 emissions decrease expectancy. A 1% short-term GDP growth reduces life expectancy by -5.47%, with -3.24% and -2.33% in the first and second lags. Long-term GDP growth positively affects life expectancy, as initial pollution and inequality harm health, but over time, better lifestyles increase expectancy. Transport services initially reduce life expectancy by 2.39% and 1.06% (first lag) for a 1% increase, but have a positive long-term effect. Construction of transport infrastructure causes short-term disruptions, though it ultimately improves quality of life and longevity.

Table No. 4.10: Estimation of Long-run and Short-run coefficients through Error Correction Model

D.d_LE_Total	**Coefficient**	**Std. err.**	**t**	**P>t**	**[95% conf. interval]**	
ADJ						
d_LE_Total						
L1.	-1.694233	.2326398	-7.28	0.000	-2.244339	-1.144127
LR						
d_ln_healthSTAFFD	-17.18927	10.18183	-1.69	0.135	-41.26548	6.886939

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d_ln_health_INF	16.41861	4.638794	3.54	0.009	5.449606	27.38762
d_ln_CO2	-1.77099	.9423045	-1.88	0.102	-3.999186	.4572064
d_ln_GDPcurrent	5.245851	.9097262	5.77	0.001	3.09469	7.397011
d_ln_transportSer~s	1.548047	.3810232	4.06	0.005	.6470708	2.449024
SR						
d_LE_Total						
LD.	.0150642	.206297	0.07	0.944	-.4727507	.502879
L2D.	-.1648866	.1313691	-1.26	0.250	-.4755251	.1457519
d_ln_healthSTAFFD						
D1.	36.96939	12.31297	3.00	0.020	7.853846	66.08493
LD.	17.1091	9.186141	1.86	0.105	-4.612677	38.83087
L2D.	35.57139	5.810517	6.12	0.000	21.8317	49.31108
d_ln_health_INF						
D1.	-38.38957	8.536371	-4.50	0.003	-58.57488	-18.20426
LD.	-41.25097	8.241549	-5.01	0.002	-60.73913	-21.7628
L2D.	-28.43851	5.590907	-5.09	0.001	-41.65891	-15.21812
d_ln_CO2						
D1.	-2.150294	1.412477	-1.52	0.172	-5.490272	1.189684
LD.	-4.408922	1.458284	-3.02	0.019	-7.857215	-.9606293
d_ln_GDPcurrent						
D1.	-5.466564	1.426773	-3.83	0.006	-8.840346	-2.092783
LD.	-3.244783	.8524131	-3.81	0.007	-5.26042	-1.229146
L2D.	-2.327629	.5984441	-3.89	0.006	-3.742724	-.9125336
d_ln_transportSer~s						
D1.	-2.387257	.3935117	-6.07	0.001	-3.317764	-1.456749
LD.	-1.062573	.2335421	-4.55	0.003	-1.614813	-.5103341
_cons	1.454704	.8462745	1.72	0.129	-.5464173	3.455825
ARDL(3,3,3,2,3,2) regression						
Sample: 1995 thru 2023			Number of obs = 29			
R-squared = 0.9758			Adj R-squared = 0.9033			
Log likelihood = 31.966801			Root MSE = 0.1636			

Discussion

The average life expectancy is 66 years for females and 62 for males, with an overall of 63, based on data from 1990-2023. Previous studies (1990-2015) reported 67 years, while 2022 data shows 69 years. The maximum total life expectancy is 67, indicating a decrease in Pakistan's average lifespan.

The long-run impact of the independent variables on life expectancy shows no long-run effect of health staff on life expectancy. These long-run results are opposite to those of Yavari and Mehrnoosh (2006), who report a positive relationship between the two variables. However, the short-run results confirm their outcomes. These short-run results also confirm previous studies on health service and life expectancy (Kakwani,

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1993; Gerring et al., 2005; Grosse & Aufiey, 1989; Preston, 1980; Lake & Baum, 2001; Navarro et al., 2006; Franco et al., 2004; Mahfuz, 2008; Shen & Williamson, 1997; WHO, 2005). Some studies, such as Poikolainen & Eskola (1988), Navarro et al. (2006), Halicioglu (2010), Wolfe (1986), Preston (1976), Hertz et al. (1994), Cumper (1984), and Lake & Baum (2001), have attributed higher life expectancy to maternal care and spending on health service delivery, which indirectly supports the results.

In the case of health infrastructure, there is a significant negative effect on life expectancy in the short run, and the effect remains negative in the first and second lags. It may be because infrastructure is not ready in the short run. However, health infrastructure has a strong positive effect in the long run; hence, its short-run negative effects can be ignored for better long-run benefits. The positive effect of health infrastructure agrees with previous research (e.g., Preston, 1975, 1985; Hobcraft et al., 1984; Hill, 1989; Wang (2002); Farhadi (2014), Amaghionyeodi (2009), Allin et al. (2010), and Kim et al. (2017) and Craigwell et al. (2012). The results do not confirm the outcomes of Ogungbenle et al. (2013), which found no evidence of causality between life expectancy and health infrastructure. However, some lag differences in Canning and Pedroni (2008)'s results confirm that infrastructure has different lag effects.

Environmental degradation or CO2 emissions have been found to have no significant effect on life expectancy in the short run. However, the effect is negative, and one can say that a bad environment reduces life expectancy. CO2 was not found significant by ŞENTÜRK and Ali (2021) in the case of Turkey, and Ahmad (2014) in the case of Oman. However, the current negative impact results confirm the outcomes of Audi and Ali (2016). Kulunk. Results confirm the outcomes of Hafeez et al. 2023) that Pakistan's life expectancy has fallen due to CO2 emissions.

The effect of GDP growth in the long run is significantly positive. The results are similar to those of ŞENTÜRK and Ali (2021) , Yavari and Mehrnoosh (2006) , Audi and Ali (2016), Diana Bowser (2019), Regidor et al. (2003), Dao (2008), and Hill & Jorgensen (2018). The outcomes are also consistent with the findings of Regidor et al. (2003), Dao (2008), Grzywacz (2015), and Hill and Jorgensen (2018). Some studies, such as Ahmad (2014), did not find evidence of a relationship between life expectancy and income in the case of Oman, while no direct relationship could be proved, as was found by Dimitrios Varvarigos (2008). The current study's results can be ascribed to short-run negative effects of GDP growth that may be explained by the initial stages of growth in which pollution, inequality, and stress account for negative health effects, but the long-run improvements in lifestyle result in an increase in life expectancy.

The link between economic growth and life expectancy is complex. Many studies show a direct correlation (Gallup and Sachs, 2000; Barro and Sala-I-Martin, 1995; Mayer, 2001; Bloom et al., 2001, 2003; Akram et al., 2008; Cervellati and Sunde, 2010; Ngangue and Kouty, 2015), while others suggest it may be negative (Acemoglu and Johnson, 2006, 2007). Research results are inconclusive: some find a positive effect (Bloom, Canning, and Sevilla, 2004; Zhang and Zhang, 2005; Lorentzen et al.,

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2008), others say the positive effect is small (Shastry and Weil, 2003; Weil, 2007; Ashraf et al., 2008). This study shows different short-term and long-term outcomes, indicating that positive health effects mainly manifest over the long run rather than immediately with economic growth.

Results suggest better transport services improve life expectancy overall, with a 1% increase boosting it by 1.55% in the long run. Short-term effects are negative, with a 1% increase decreasing life expectancy by 2.39% and 1.06% (first lag). Long-term effects are positive, supporting research on transport infrastructure's benefits (Arvin et al., 2015; Phang, 2003; World Development Report, 1994; Bhatta & Drennan, 2003; Lakshmanan, 2007), as well as findings by Cantos et al. (2005) and Fidelis et al. (2026). Infrastructure development has social and economic impacts, leading Crafts (2009) to recommend government funding. Construction requires destruction that temporarily hampers commuting, but once operational, it improves quality of life and life expectancy.

Conclusion

Variables like health infrastructure, staff, environment, transport, and income influence life expectancy. Past increases have little effect now. Health staff boost life expectancy short-term across many lags, especially in Pakistan, lasting into the second lag. Short-term infrastructure increases negatively impact life expectancy initially due to service disruption but have positive long-term effects. Environmental issues like CO2 emissions don't significantly affect life expectancy in the short term, but long-term environmental degradation reduces it. GDP growth may lower life expectancy in the short term but increase it in the long term, likely due to developmental spending.

Transport services show a strong negative short-term impact but a positive long-term effect. Construction disruptions hinder short-term mobility, but once operational, they improve quality of life and life expectancy. Increasing health staff and infrastructure is crucial for Pakistan's life expectancy. While short-term GDP effects are discouraging, long-term benefits are significant. Environmental degradation reduces life expectancy, but improved road networks and transportation yield positive outcomes.

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