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Influence of Government Effectiveness, Health Expenditure, and Sustainable Development Goals on Life Expectancy: Evidence from Time Series Data

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Abstract: This study investigates the influence of government effectiveness, health expenditure, and sustainable development goals (SDGs) on life expectancy in Pakistan. To accomplish this, a systematic analysis was conducted on time series data spanning from 2000 to 2020. Cointegration analysis was utilized to evaluate the long-term integration of all variables, while a comprehensive causality test was performed to investigate the short-term links among government effectiveness, health expenditure, SDGs, and life expectancy. The findings of the Johansen Cointegration test definitively confirmed the presence of long-term cointegration among all variables. In addition, the results of the Granger causality test show that there is a one-way causal relationship between government performance, health spending, and SDGs to life expectancy in the short term. The validation of both enduring and immediate connections among these factors emphasizes the crucial significance of healthcare services in Pakistan. Therefore, it is important to push for more healthcare investments and increased national budget allocations by the Pakistani government. Prioritizing the allocation of resources towards healthcare, bolstering the efficiency of the administration, and attaining SDG targets are all crucial for enhancing life expectancy in Pakistan. The study's results also carry significant policy implications, underscoring the necessity of strategically implementing health expenditure and SDG targets to enhance human capital and population well-being, as demonstrated by the increased life expectancy.

Keywords: government effectiveness; health expenditure; SDGs; life expectancy; time series data

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1. Introduction

The allocation of resources by the current economic, social, and political systems determines the health problems within and outside the healthcare sector of Pakistan. Health system indicators of Pakistan indicate that the economic, social, and political systems should allocate resources in a way that best addresses the economic, social, and environmental determinants of health in the country [1]. Pakistan has the second highest population growth rate (1.9%) in South Asia, and life expectancy at birth is the second lowest at 67 years, lower than Maldives, Sri Lanka, Bangladesh, Nepal, and India, who have life expectancies greater than 70 years. Pakistan also has one of the lowest percentages of children (81%) aged between 12–23 months who have received the measles vaccination, followed only by Afghanistan. This has resulted in Pakistan being at the top rank in the region for under-five mortality rates [2].

Life expectancy is a commonly used measure to evaluate the overall health of people globally. This metric represents the average lifespan that an individual might expect if current death rates continue. According to the World Bank, life expectancy at birth is defined as the average number of years a newborn is projected to live, considering the mortality patterns at the time of birth [3]. This metric captures the intricate interplay between environmental factors, healthcare accessibility, social structures, cultural influences, economic conditions, and genetic predispositions. Most notably, the upward trend in life expectancy can be attributed to improvements in living standards, a broader range of lifestyle options, and enhanced educational prospects [4]. These factors emphasize the complex interactions that influence population health outcomes and the need to tackle numerous environmental and socioeconomic problems in order to boost longevity and general well-being.

A discernible pattern can be seen throughout the dynamic geography of Asia and the Pacific: a growth in the average life expectancy at birth over time. Significant development has been shown by the region average, which rose from roughly 68.6 years in 2000 to 74.2 years in 2019, indicating significant development. This increasing tendency is highlighted by the outstanding accomplishments in countries like Timor-Leste, Bhutan, and Cambodia, which have seen increases of 10.9 years, 11.4 years, and 11.4 years, respectively, since the turn of the millennium [5,6]. This upward trajectory in life expectancy is driven by multiple factors, including improved living conditions, easier access to healthcare services, better dietary intake, and enhanced water and sanitation facilities. Furthermore, a growing emphasis on education also contributes considerably to this rapid improvement, fostering a population equipped with knowledge to lead healthy lives.

Despite notable improvements, the region's life expectancy lags behind its global counterparts. Pakistan's life expectancy trend shows a transformative journey from a modest 44.93 years in 1960 to a gradual increase up to 66.27 years by 2020, representing remarkable growth over decades [3]. Pakistan's history has been characterized by periodic transitions oscillated between periods of dictatorship and democratic governance, forming three eminent social factions: the military, the bureaucrats or civil servants, and the politicians. As a result, the governing class has frequently ignored the social sector when formulating and enforcing policies, which has hindered sustainable development in healthcare. In spite of this, building a strong healthcare system is still an inspirational goal [1]. The data from UNICEF's social expenditure division highlights this discrepancy. Specifically, the central government of Pakistan allocates a mere 0.6% of its GDP to social assistance, 2.8% to education, and 0.7% to health. These figures highlight the necessity for increased investment in critical social services [7,8]. Economic growth in Pakistan has been slow in comparison to some of its neighboring countries but was consistent between 1970 and 1990 with an average annual growth rate of 3%, which unfortunately declined to 1.7% from 1990 to 2009. Encouragingly, Pakistan experienced a resurgence in economic growth, reaching a peak of 6.2% in 2018. Allocating a mere amount of GDP to health, education, and social assistance is insufficient. Sustainable development requires strategic investments in healthcare, education, and social welfare programs. Pakistan can endeavor to achieve equitable and inclusive progress for its inhabitants by giving priority to these areas [9].

Pakistan started a transformative journey to align its national development trajectory with the global imperative of sustainable development by incorporating the sustainable development goals (SDGs) into its national vision by formally adopting it in 2016, demonstrating its commitment to tackling urgent environmental and socioeconomic problems [3]. Even though Pakistan has made impressive strides in a number of areas, it still lags behind its peers in implementing the SDGs. The 2019 Voluntary National Review (VNR) showcased accomplishments in several areas. However, this excellent improvement is contrasted with ongoing issues in critical sectors, including education, healthcare, energy availability, and water and sanitation [10]. In-depth research reveals that Pakistan's performance, as measured by the SDG indices is below the median for emerging markets and developing economies [11]. Addressing these disparities requires concerted efforts to rectify structural deficiencies and strengthen institutional capacities. As Pakistan experiences significant population growth, it stands at a critical juncture. Urgent revitalization of strategies is essential to accelerate progress toward SDGs attainment [12,13].

Governments all throughout the world are focused on the critical and urgent issue of healthcare. It routinely commands attention in international forums, which is indicative of its crucial role in global development. Notably, life expectancy plays a crucial role in the human development index (HDI), highlighting the inextricable connection between well-being and health. The Millennium Development Goals (MDGs) emphasized the importance of achieving universal health and well-being, highlighting the need for fair access to health-care and favorable health outcomes [14]. The responsibility for achieving health equity was smoothly transferred from the MDGs to the SDGs, highlighting the ongoing dedication to this crucial objective. This continuity demonstrates the acknowledgment of persistent health inequalities and the urgent need to intensify efforts to attain comprehensive health outcomes for all [15,16].

The interconnectedness between health and other dimensions of sustainable development necessitates coordinated and multisectoral approaches to tackle health inequalities effectively. Similar to findings in Latin America, where democratic governance and digital transformation are shown to significantly impact development outcomes, effective governance in Pakistan plays a crucial role in enhancing life expectancy and achieving sustainable development [17]. Furthermore, the evaluation of indicators for benchmarking and monitoring progress towards the SDGs is critical for creating healthy and sustainable societies [18]. This underscores the significance of robust indicator systems in assessing the impact of SDGs on life expectancy in Pakistan.

Life expectancy is influenced by a number of important factors, including government effectiveness, health care spending, and the achievement of SDGs. There is limited research that explicitly examined the causal pathways through which government effectiveness, healthcare expenditures, and SDGs achievements translate into improved life expectancy. To investigate these mechanisms, more thorough research is required. Even with a great deal of research, there are still unanswered questions. By analyzing time series data, researchers can uncover valuable insights into the interplay between policy, investment, and health outcomes. This investigation thus aims to shed light on how these factors shape the well-being and life expectancy for the population of Pakistan. Specifically, this study seeks to determine the relationship between health expenditures and life expectancy, the impact of SDGs on life expectancy, and the relationship between government effectiveness and life expectancy (Figure 1). With the help of these objectives, this study intends to offer a comprehensive understanding of the factors influencing change in life expectancy in the Pakistani population. Unravelling these dynamics is essential for informed decision-making and targeted interventions to enhance public healthcare and promote sustainable development.

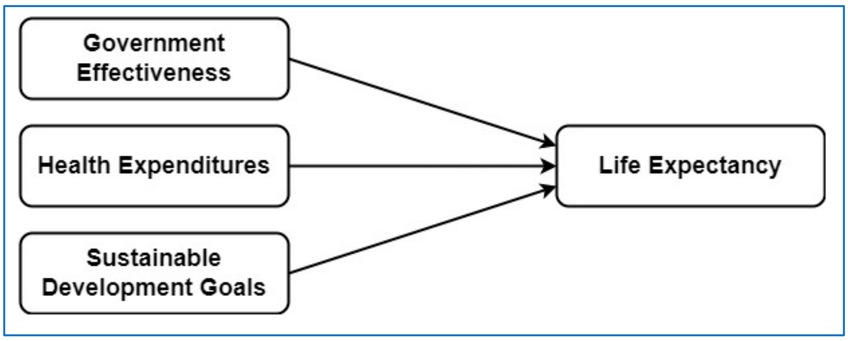

Figure 1. Conceptual model of the study used to explore the objectives of the research.

1.1. Objectives

The objectives of this study are to:

1. Determine the impact of government effectiveness on life expectancy.
2. Investigate the impact of health expenditure on life expectancy.
3. Explore the effect of SDGs on life expectancy.

1.2. Research Questions

This work addresses the following questions:

1. What is the impact of government effectiveness on life expectancy?
2. What is the impact of health expenditure on life expectancy?
3. What is the impact of SDGs on life expectancy?

The selection of these specific objectives is grounded in the critical importance of understanding the multifaceted determinants of life expectancy in Pakistan. In addition, lessons learned from Pakistan can be applicable to other countries facing similar challenges, contributing to the broader international efforts to improve health outcomes and well-being.

2. Materials and Methods

The aim of this study includes the analysis of annual time-series data from Pakistan from 2000 to the most recent accessible year (2022). This extensive timeframe provides a comprehensive dataset required to achieve the study's objectives. By investigating trends and patterns over such a long period of time, this study hopes to provide strong insights into the dynamics and phenomena under inquiry, allowing for a full grasp of the subject matter at hand. Using data from this extended period enables the inclusion of numerous socioeconomic, political, and environmental elements that may have influenced the results under consideration, hence increasing the validity and dependability of the study findings. The data on life expectancy, government effectiveness, and health expenditure per capita (current USD) were sourced from the World Bank open data portal [17,19], while data on the SDGs index were obtained from the sustainable development report [13]. This work predicts life expectancy by government effectiveness percentile rank, health expenditure per capita (current USD), and SDGs index. The analysis was performed using EViews version 11.

The analysis started using the unit root test to confirm the stationarity of the examined series. Stationarity is essential because it indicates a consistent probability distribution throughout time. The augmented Dickey–Fuller (ADF) test, developed by Dickey and Fuller in 1979 and 1981, has become the most used method for evaluating the presence of unit roots. This test, which is an expansion of the Dickey–Fuller (DF) method, uses the ordinary least squares (OLS) estimator to determine if there are unit roots in the series.

After completing the initial phase, the attention turned to investigating possible long-term connections between important factors, including the SDG index, health expenditure per capita, government effectiveness percentile rank, and life expectancy at birth. The study explored the presence of their existence and the direction of causality. In addition, the effect of sudden changes in the independent variables on life expectancy was investigated using impulse response function analysis. The purpose of doing unit root tests, such as the ADF test, was initially to achieve this objective. Later, the Autoregressive Distributed Lag (ARDL) and Vector Autoregression (VAR) models were used to determine cointegration.

During the third phase, the inquiry was broadened to examine the presence and direction of causation by employing the vector error correction model (VECM). The Johansen and Juselius technique were used to establish cointegration among the variables. The Granger causality test was used to analyze short-term causal relationships among the variables. This test assesses the direction and presence of causality. The study used impulse response function analysis to examine the influence of government efficacy, healthcare expenditure, and the SDGs index on life expectancy. Utilizing the VECM provided a detailed comprehension of how the model reacts to certain shocks over time. The analysis was performed using EViews version 11. Multiple regression analysis was utilized to examine the relationship between government effectiveness, health care expenditure, and SDGs with life expectancy (Figure 2). Equation (1) models this study.

$$Y = \beta_o + \beta_1\, x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon, \quad (1)$$

where Y is the response variable (life expectancy at birth), β_o is the intercept (constant term), β_1, β_2 and β_3 are the regression coefficients, x_i (i = 1, 2, 3) are the explanatory variables, and ε is the error term.

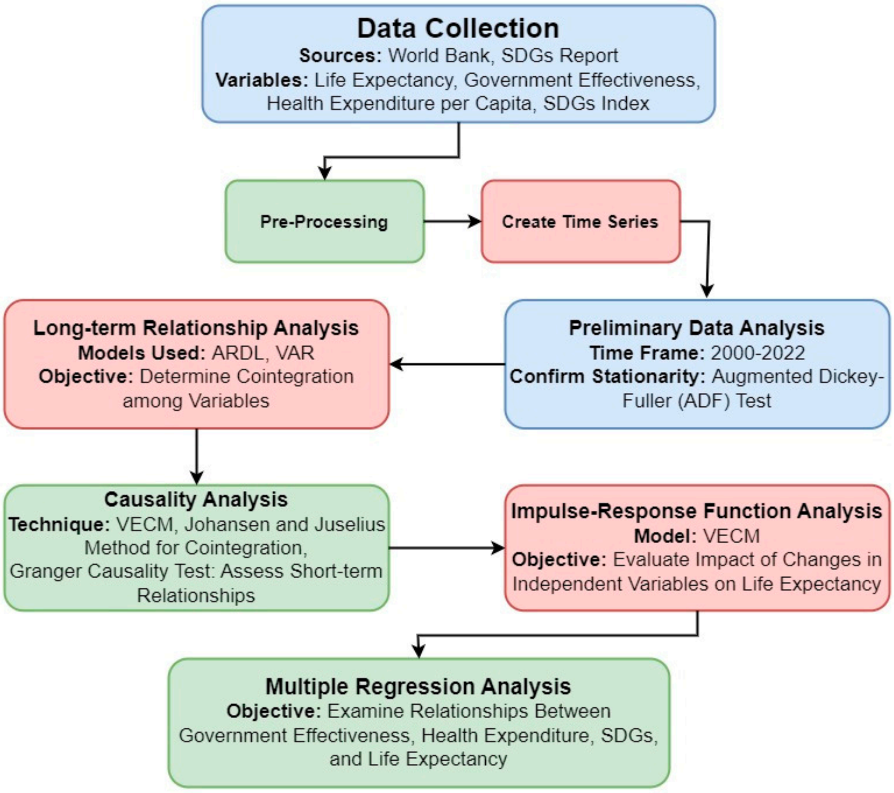

Figure 2. Flow chart of the methodology used for the study.

3. Results

Table 1 provides descriptive statistics such as mean, standard deviation (SD), and the total number used to calculate these statistics. These metrics provide an overview of the data's central tendency, variance, and sample size. The average life expectancy in the dataset was 64.43 years, with a standard deviation of ±1.47 years. This means that, on average, people in the population may expect to live for 64.43 years, with a variance of about 1.47 years around this average number. These statistics provide fundamental insights into life expectancy distribution and characteristics within the examined population, allowing for additional research and interpretation.

Table 1. Results of descriptive statistics for the study variables.

Variable	No. of Observations	Mean	SD	Range	Mini	Max
Government Effectiveness	21	30.86	6.34	19.4	22.6	42
Life Expectancy	21	64.43	1.47	4.7	62.1	66.8
Health Expenditures	21	26.86	9.39	30	13.4	43.4
SDGs	23	55.11	2.26	6.3	52.8	59.1

The health expenditure was about USD 26.86 ± USD 9.39; the government effectiveness was about 30.86 ± 6.34 percentile rank, and the SDGs index was about 55.11 ± 2.26 SDG index. Life expectancy ranged from a minimum of 62.10 years in 2000, 62.42 in 2001, and 62.63 in 2002 to 66.48 in 2018, 66.76 in 2019, and 66.269 in 2020. Life expectancy's mean was 64.43 years with an SD of 1.47. The difference between Pakistan's highest and lowest life expectancy is 4.167 years. The mean percentage of government effectiveness was 30.86 percentile rank with an SD of 6.34. The health expenditure per capita's mean (SD) was USD 26.86 (USD 9.39), while the mean (SD) of SDGs was 26.86 SDGs index (2.26).

3.1. Trend Analysis

Figure 3 shows the relationship between government effectiveness, health expenditure, SDGs, and life expectancy over the study period. The figure shows that life expectancy in Pakistan increased from 62.01 years in 2000 to 69.68 years in 2023. The government's effectiveness decreased from 2000 to 2002, but then from 2002, it started to rise to its peak in 2006. After 2006, government effectiveness started to fall to its lowest in 2009. Then, again, there was a rise in government effectiveness from 2019 to 2022. Health expenditure and SDGs both were exponentially increasing from 2000 to 2022.

Looking at the trends, one can observe in Figure 3 that the government effectiveness has a negative trend with larger variation around the trend. The last decade showed a significant downfall from its mean, but in the end (2021–2022), it witnessed a significant increase. Life expectancy in Pakistan showed a persistent rise with a stable positive trend. The negative association between life expectancy and government effectiveness can be perceived by trend analysis. Health expenditure and SDGs both show positive trends with a lesser variation. The least variation can be seen in life expectancy, where individual observations lie on the trend line, which means that the individual observations justify the mean and its consistency. A positive association can be observed between life expectancy and health expenditure as well as with SDGs.

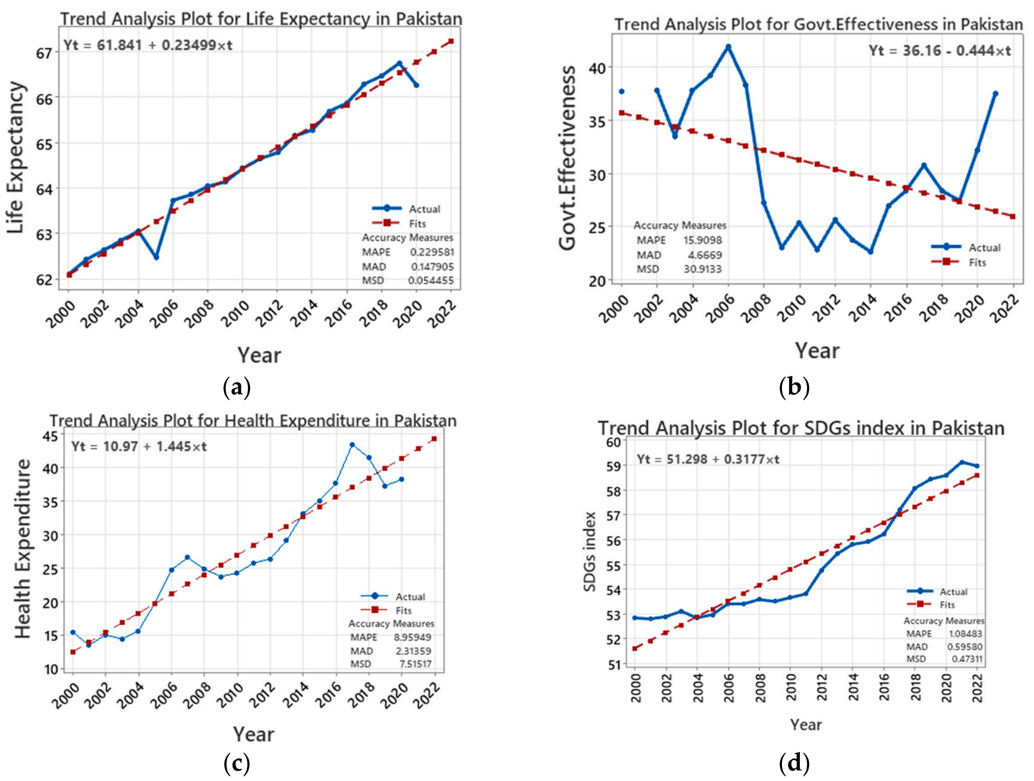

Figure 3. Trend behavior of the factors: (**a**) life expectancy; (**b**) government effectiveness; (**c**) SDGs; (**d**) health expenditure.

The ADF test, which uses the OLS estimator, is an important technique for determining the presence of a unit root in time series data. The results of this test, shown in Table 2, give information on the stationary qualities of the variables under consideration. The results show the amounts and trends of the variables' intercept types, providing insight into their underlying properties. At the beginning of the analysis, the stationarity test demonstrated that the variables in the econometric model are not stationary. This is because the null hypothesis of a unit root cannot be rejected for any of the variables when tested at the appropriate levels. Thus, variables follow consistent patterns throughout time rather than fluctuate around a steady mean. This basic understanding of the variables' behavior is essential for ensuring the validity and reliability of the ensuing econometric analysis.

Table 2. Augmented Dickey–Fuller test.

Variables	At Level				1st Difference			
	With Constant	Probability	Trend and Intercept	Probability	With Constant	Probability	Trend and Intercept	Probability
LE	−1.180	0.680	−2.556	0.301	−10.023	0.000	−10.034	0.000
GE	−1.737	0.409	−1.442	0.842	−9.386	0.000	−9.432	0.000
SDG	−0.115	0.944	−2.167	0.501	−2.880	0.052	−2.854	0.182
HE	−0.804	0.813	−2.622	0.272	−3.348	0.016	−3.368	0.062

Note: Probability is based on MacKinnon (1996) one-sided *p*-values.

In the second stage of analysis, the differenced components were tested, resulting in the rejection of the hypothesis. The initial findings for all variables show stationarity, showing that the series is integrated with order one, defined as I (1) in econometric jargon. After determining the integrated order of the variables, the next step was to investigate the presence of long-term correlations between critical factors such as health spending and the SDGs. The cointegration test was used to evaluate these relationships, with the null hypothesis assuming no cointegration and the alternative hypothesis implying cointegration. The Johansen cointegration test, which uses statistics like trace and eigenvalue, is the principal approach for evaluating the cointegration test [18,20]. These statistical measures provide information about the presence and intensity of long-term relationships between variables, setting the groundwork for future analysis and interpretation. Before beginning the cointegration test, the optimum lag number must be chosen to examine the cointegration's presence. Table 3 shows the optimum lag length results. There are multiple selection criteria in the table. The Akaike information criterion (AIC) was used to determine the ideal lag duration. According to AIC, the best lag length is five.

Table 3. Optimal lag length selection.

Lag	AIC	HQ	SC	FPE
0	0.264	0.312	0.383	1.53×10^{-5}
1	−3.227	−2.988 *	−2.631 *	4.67×10^{-7}
2	−2.957	−2.527	−1.885	6.13×10^{-7}
3	−2.782	−2.161	−1.233	7.36×10^{-7}
4	−2.909	−2.097	−0.884	6.58×10^{-7}
5	−3.847 *	−2.844	−1.346	2.64×10^{-7} *
6	−3.529	−2.335	−0.552	3.76×10^{-7}
7	−3.252	−1.867	0.202	5.22×10^{-7}
8	−3.061	−1.485	0.869	6.78×10^{-7}

* Lag length is based on SIC (Schwarz information criterion); AIC = Akaike's information criterion; HQ = Hannan-Quinn criterion; SC = Schwarz criterion; FPE = final prediction error.

Table 4 provides the cointegration test results of the eigenvalue and trace statistics. The null hypothesis is H0:r = 0, which indicates no cointegration among factors, and if it is rejected, then continue for H0:r = 1 and henceforth. Where H0:r = x is going to be accepted, it will declare the number of cointegrating equations in the VECM system. The results following the maximum eigenvalue and trace test reveal that there are two cointegrating equations, meaning the long-run association exists among variables. This case confirms the suitability of VECM for the estimation. Normally, VAR and VECM do not confer the dependency of one variable and take all variables as dependent, but herein, in this study, there is only one dependent variable; therefore, while applying VECM, one cointegration may be selected for analysis.

Table 4. Cointegration test result.

	Eigenvalue			Trace		
H_0: Rank	**Statistic**	**0.05 Critical Value**	***p*-Value**	**Statistic**	**0.05 Critical Value**	***p*-Value**
0	66.753	27.584	0.000	97.471	47.856	0.000
1	22.837	21.131	0.028	30.717	29.797	0.039
2	5.501	14.265	0.678	7.880	15.495	0.478

The cointegration test also provides the normalized cointegrating coefficients shown in Table 5. According to the results, the estimated normalized cointegrating equation (*NCE*) can be written as follows.

$$NCE = LE + 0.029GE - 2.493LNHE - 0.159SDG, \quad (2)$$

Table 5. Normalized cointegrating coefficients (standard error in parentheses).

Cointegrating Equation(s)		**Log-Likelihood**	**550.6572**
LE	GE	LNHE	SDG
1.000000	0.029	−2.493	−0.159
	(0.004)	(0.184)	(0.037)

In the NCE equation, the signs of the coefficient are interpreted as the reverse. These coefficients explain the long-run impact of independent variables on dependent variables. LE is the target variable. While GE has a negative impact on LE, as the sign is positive, the rise in GE will cause a decline in LE. The same association was already witnessed in trend analysis as well. Log HE shows negative signs, but here it explains the positive impact of LE as well as SDGs also having a positive impact on LE. An increase in HE and SDGs will cause an increase in LE. All coefficients are statistically significant as the respective standard error was less than half of the coefficient, nullifying the null hypothesis at a five percent significance level.

Error correction coefficients give the estimates showing the speed of adjustments in the long run. It means when any disturbance deviates from the dependent variable's mean, that shock is reversed at a certain speed, and long-run adjustment takes place. By virtue of the nature of this reversal, the sign of error correction needs to be negative. The following Table 6 shows the E-views outcome of the system estimation carrying error correction terms and the short-run impact of the factors on LE.

The co-integrating vector in this study can be defined and expressed as follows.

$$\hat{\beta}_1 LE_{t-1} + \hat{\beta}_2 LNHE_{t-1} + \hat{\beta}_3 GE_{t-1} + \hat{\beta}_4 SDG_{t-1} + \varepsilon, \quad (3)$$

For precision, it can be written as follows.

$$\sum \hat{\beta}_i \psi_{it-1} + \varepsilon, \quad (4)$$

Table 6. Error correction results.

	Coefficient	**Std. Error**	***t*-Statistic**	**Prob.**
CointEq1	−0.101	0.019	−5.446	0.000
D(LE(−1))	0.361	0.094	3.851	0.000
D(LE(−2))	0.042	0.107	0.393	0.695
D(LE(−3))	0.042	0.107	0.393	0.695
D(LE(−4))	−0.587	0.093	−6.340	0.000
D(GE(−1))	0.021	0.011	1.912	0.060
D(GE(−2))	0.002	0.013	0.168	0.868
D(GE(−3))	0.002	0.013	0.168	0.868
D(GE(−4))	0.004	0.011	0.404	0.687
D(LNHE(−1))	−0.705	0.534	−1.320	0.191
D(LNHE(−2))	−0.285	0.647	−0.440	0.661
D(LNHE(−3))	−0.285	0.647	−0.440	0.661
D(LNHE(−4))	0.333	0.518	0.642	0.523
D(SDG(−1))	−0.024	0.120	−0.197	0.844
D(SDG(−2))	−0.010	0.160	−0.063	0.950
D(SDG(−3))	−0.010	0.160	−0.063	0.950
D(SDG(−4))	0.472	0.133	3.538	0.001
C	0.036	0.010	3.718	0.000
R-squared	0.769	Mean dependent var		0.048
Adjusted R-squared	0.709	S.D. dependent var		0.085
S.E. of regression	0.046	Akaike info criterion		−2.876
Sum of Squared Residuals	0.140	Schwarz criterion		−2.591
Log-likelihood	149.349	Hannan–Quinn critter		−2.761
F-statistic	12.912	Durbin–Watson stat		2.060
Prob(F-statistic)	0.000			

As the LE is the dependent variable in the model, therefore $\hat{\beta}_1$ is by default estimated as 1 and the rest of its estimated form is:

$$LE_{t-1} + (-2.629)LNHE_{t-1} + 0.023GE_{t-1} + (-0.131)SDG_{t-1} + (-49.517), \quad (5)$$

This co-integration vector shows long-run equilibrium among all factors of the model. In the short run, there may be variation, and different shades of the results may be expected. By using the expression, $\sum \hat{\beta}_i \psi_{it-1} + \varepsilon$, the VECM system can be generated for short-run innovations as follows.

$$\Delta LE = \nu_1 + \alpha_1 \left(\sum \hat{\beta}_i \psi_{it-1} + \varepsilon\right) + \sum_{i=1}^{4} \theta_{1i} \Delta LE_{t-i} + \sum_{i=1}^{4} \gamma_{1i} \Delta LNHE_{t-i} + \sum_{i=1}^{4} \vartheta_{1i} \Delta GE_{t-i} + \sum_{i=1}^{4} \sigma_{1i} \Delta SDG_{t-i}, \quad (6)$$

$$\Delta LNHE = \nu_2 + \alpha_2 \left(\sum \hat{\beta}_i \psi_{it-1} + \varepsilon\right) + \sum_{i=1}^{4} \theta_{2i} \Delta LE_{t-i} + \sum_{i=1}^{4} \gamma_{2i} \Delta LNHE_{t-i} + \sum_{i=1}^{4} \vartheta_{2i} \Delta GE_{t-i} + \sum_{i=1}^{4} \sigma_{2i} \Delta SDG_{t-i} \quad (7)$$

$$\Delta GE = \nu_3 + \alpha_3 \left(\sum \hat{\beta}_i \psi_{it-1} + \varepsilon\right) + \sum_{i=1}^{4} \theta_{3i} \Delta LE_{t-i} + \sum_{i=1}^{4} \gamma_{3i} \Delta LNHE_{t-i} + \sum_{i=1}^{4} \vartheta_{3i} \Delta GE_{t-i} + \sum_{i=1}^{4} \sigma_{3i} \Delta SDG_{t-i} \quad (8)$$

$$\Delta SDG = \nu_4 + \alpha_4 \left(\sum \hat{\beta}_i \psi_{it-1} + \varepsilon\right) + \sum_{i=1}^{4} \theta_{4i} \Delta LE_{t-i} + \sum_{i=1}^{4} \gamma_{4i} \Delta LNHE_{t-i} + \sum_{i=1}^{4} \vartheta_{4i} \Delta GE_{t-i} + \sum_{i=1}^{4} \sigma_{4i} \Delta SDG_{t-i} \quad (9)$$

For simplification only, the first equation is estimated as the dependent variable here is LE only, and the estimated result of VECM for the said equation is given in Table 6.

The cointegration equation, first row in Table 6, indicates the speed of adjustment, and as mentioned earlier, it is negative and found significant at a 1% significance level. The speed of 0.101 percent may adjust any short-run deviation that comes through the factors or predictors in the long run. GE is found significant in the short run but at a 10 percent significant level in the first lag only. SDGs were found to be significant in the fourth lag at a one percent significant level in the short run. Log HE was not found significant in the short run at all, but in the long run, they were found significant at 5%.

Table 7 reports the basic diagnostic test, where the LM (Lagrange Multiplier) test is done to see the serial autocorrelation with the null hypothesis of no autocorrelation. The Breusch–Pagan–Godfrey test talks about the presence of heteroscedasticity with the null hypothesis of no heteroscedasticity. Both null hypotheses cannot be rejected in the results because the p-value is more than 0.05 for both tests. Therefore, no sign of heteroscedasticity and autocorrelation is witnessed.

Table 7. Diagnostic check.

Breusch–Godfrey Serial Correlation LM (Lagrange Multiplier)Test			
F-statistic	1.672	Prob. F(2.64)	0.194
Obs*R-squared	3.718	Prob. Chi-Square(2)	0.156
Heteroskedasticity Test: Breusch–Pagan–Godfrey			
F-statistic	1.868	Prob. F(20.63)	0.149
Obs*R-squared	5.418	Prob. Chi-Square(3)	0.143
Scaled explained SS	3.623	Prob. Chi-Square(3)	0.305

Some authors have proved that cointegration does not reveal causality among variables, but there is always a bidirectional causality in economics. Therefore, the researchers recommend using the Granger causality test, a reliable approach for determining causal linkages between two variables [21]. The Granger causality test was used in this study, and the results are shown in Table 8, with the goal of testing hypotheses about the directional causality of variables in the context of short-term connections.

Table 8. Granger causality test result.

Null Hypothesis	**Chi-sq**	**Probability**
Health expenditure does not Granger cause government effectiveness	1.123073	0.9520
Health expenditure does not Granger cause SDGs	1.690196	0.8901
Health expenditure does not Granger cause life expectancy	0.482258	0.9928
Government effectiveness does not Granger cause health expenditure	3.658466	0.5996
Government effectiveness does not Granger cause SDGs	0.304858	0.9976
Government effectiveness does not Granger cause life expectancy	0.595516	0.9882
SDGs do not Granger cause health expenditure	4.241053	0.5153
SDGs do not Granger cause government effectiveness	2.190664	0.8222
SDGs do not Granger cause life expectancy	2.629816	0.7568
Life expectancy does not Granger cause health expenditure	39.89976	0.0000
Life expectancy does not Granger cause government effectiveness	12.64663	0.0269
Life expectancy does not Granger cause SDGs	11.10574	0.0493

The chi-square value is used to determine test results and is a key measure of directional influence. Table 8 displays the results of the Granger causality test for Pakistan, emphasizing variables linked with the chi-squared value. The chi-square test result and the corresponding p-value decisively reject the null hypothesis, confirming the absence of directional causality between health expenditure per capita and GDP per capita. Furthermore, there is no clear association between healthcare spending per capita and government effectiveness. As a result, a rise in health expenditure has no substantial impact on government effectiveness, emphasizing its insignificance in boosting governmental efficacy—a finding supported by earlier research.

An impulse response function analysis based on the vector error correction model (VECM) was carried out to explore the dynamics of the model's response to specific shocks. This analytical approach provides insights into the dynamic influences exerted by various shocks on the model, which enriches our understanding of its response dynamics.

3.2. Impulse Response

The impulse response function gives a glance view of contemporaneous short-run innovations or shocks on the dependent variable. Keeping the dependent variable last for VECM, the following recursive structure explains the first contemporaneous effect on the later variable without considering the reverse effect. Impulse response functions are shown in Figure 4.

The last row of Figure 4 presents the variations of the impulse response of life expectancy introduced by government effectiveness, SDGS, and health expenditure. The results of the impulse response function, that considered 10 lag periods in the model, showed that health expenditure had a positive short-run impact. However, in the fourth lag, it seems insignificant. Similarly, SDGs also seem to have a positive shock in the fourth lag, and the result can be cross-verified from Table 6. Regardless of the significance, the shocks fizzle out later, which validates the convergence of the factors in the long run as a result of the error correction term.

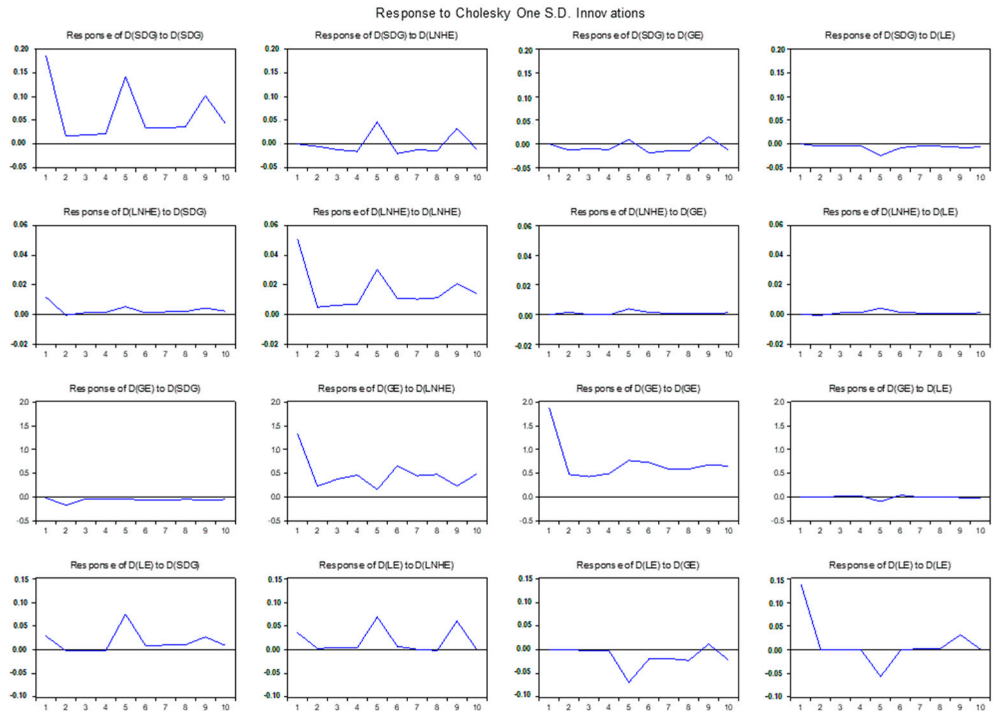

Figure 4. Impulse response function. The figure depicts response to Cholesky one standard deviation innovations.

4. Discussion

The major goal of this study was to investigate the impact of health spending, the SDGs, and government effectiveness on life expectancy in Pakistan by using data from 2000 to 2020, aimed to determine the correlations between these crucial variables.. Our findings showed that all variables studied in the econometric analysis have integration of order one, implying that they are integrated as first differences. This critical discovery validating the long-term association between health expenditure, SDGs, government effectiveness, and life expectancy in Pakistan. By establishing this long-term relationship, this study emphasizes the interdependence of healthcare investment, SDGs, government efficacy, and life expectancy outcomes. These findings contribute to the diverse knowledge of the complex elements that influence population health dynamics, giving useful insights for policymakers, healthcare practitioners, and researchers [22,23].

Analyzing the individual cointegration coefficients, this study found mixed results: GE was found significant in the short run but at a 10 percent significance level in the first lag only. SDGs were found to be significant in the fourth lag at a one percent significance level in the short run. Log HE was not found significant in the short run at all, but in the long run, it was found to be significant at five percent. Furthermore, the findings of this study showed that health expenditure, SDGs, and government effectiveness all have a considerable positive impact on life expectancy in Pakistan. While health expenditure and SDGs had positive and statistically significant effects on life expectancy, the influence of government effectiveness was mixed. These findings highlight the critical importance of public healthcare spending in improving life expectancy in Pakistan. The positive relationship between health expenditure and life expectancy showed that increasing investment in healthcare infrastructure can result in substantial improvements in public health. As countries' economies grow, spending on healthcare infrastructure often increases. As a result, healthcare services become more accessible and of higher quality. This favorable relationship between economic growth and healthcare infrastructure development emphasizes the significance of substantial healthcare investments in promoting population health and lifespan [24].

In addition, the variation in government effectiveness does not seem consistent with Pakistan's life expectancy performance [25]. This depicts the need for policy measures that may result in smooth and consistent government effectiveness but with a positive trend. Our cointegration results showed that government effectiveness was significant with negative signs. The role of effective government extends to individuals and their life expectancies, with research revealing diverse effects on global life satisfaction and life expectancy. According to research, governance characteristics might impact overall life. The significance of different aspects of efficient governance is often established by the degree of advancement in a society. However, it is commonly acknowledged that people's happiness plays an important part in determining life expectancy, and happiness is frequently acquired through access to quality services. Increased government investment in healthcare is an important means of financial assistance by subsidizing medical bills and improving healthcare accessibility, particularly for low-income and marginalized populations. This financial aid serves to ease the burden of healthcare bills, allowing patients to access necessary medical services without financial constraints [26].

Our results highlight the importance of SDGs, health spending, and an effective government in improving life expectancy in Pakistan. Just as business structure is crucial for managing corporate cash holdings and maintaining financial stability, so too are efficient resource allocation and expenditure management. Like businesses, governments must effectively manage their resources in order to fulfill their goals. Significant global economic disruptions brought about by the COVID-19 epidemic have had a considerable impact on financial performance in developing economies [27]. The efficacy of government and health spending have been impacted in a cascade manner by these disturbances, which has an impact on public health outcomes. In order to maintain progress toward the SDGs and safeguard improvements in life expectancy, strong health systems and resilient governance structures are essential. This is demonstrated by the volatility and systemic shocks that occurred during the pandemic years.. However, despite Pakistan's progress towards health and prosperity, the country faces a number of domestic and international challenges. Political instability, repeated catastrophic flooding, and pandemics like COVID-19 substantially impacted the country's health landscape and development trajectory. In addressing these difficulties, Pakistan must deal with the twin burden of infectious diseases as well as rising rates of non-communicable diseases. Prioritizing these critical areas holds the key to strengthening Pakistan's ability to attain universal health coverage, meet its SDGs, and ultimately improve overall health outcomes. Pakistan can pave the way to a healthier and more resilient future by focusing on controlling infectious diseases, managing the rising prevalence of noncommunicable diseases, and dealing with the complications of health emergencies.

A number of other studies have also looked at the factors that influence health outcomes in Pakistan, with particular attention to the objectives of sustainable development, government effectiveness, and healthcare spending. Our findings on the impact of economic determinants on life expectancy are consistent with those of Abbas et al. (2024), who explored these factors in the context of sustainable development in Sino-Pak from 1965 to 2020 [28]. While our study focuses specifically on government effectiveness and health expenditure, the broader context provided by Abbas et al. highlights the significant role that sustainable development practices play in influencing life expectancy outcomes. Government expenditure on social safety, education, and health has a positive effect on the growth of human capital, as Kousar et al. (2023) have shown [29]. This is consistent with our findings that health spending increases life expectancy. Our findings provide credence to the idea that strategic health investments are essential for raising population health outcomes and promoting the development of human capital. They therefore have proposed that the Pakistani government ought to devote a larger portion of its budget on social protection, health, and education initiatives to improve its human capital.

Our examination of the connection between life expectancy and public health spending is consistent with the results of Ullah et al. (2021), who have shown that public healthcare spending considerably raises life expectancy both in the short-run and long-run and lowers mortality rates using the Quantile Autoregressive Distributed Lag model [30]. Their analysis highlights the crucial influence that health spending has on health outcomes, which our research further substantiates by demonstrating a direct link between health spending and life expectancy. Abbas et al. (2022) offer a useful framework for comprehending the larger context of our findings through their investigation of the influence of socio-economic variables and state capability on health quality and access [31]. In order to improve health outcomes, our study goes beyond their research by focusing on the relationship between government efficacy and life expectancy. This emphasizes the significance of strong state capacity and efficient governance.

In this study, life expectancy was used as a main indication of health outcomes; however, future research should investigate additional variables to examine health outcomes more thoroughly. Beyond life expectancy, numerous socioeconomic factors influence general health and well-being. Variables such as education, economic disparity, unemployment rates, and lifestyle choices substantially impact life expectancy and demand further examination. Thus, future studies should investigate the complex links between these socioeconomic characteristics and life expectancy. Understanding the multiple effects of education, income distribution, work possibilities, and lifestyle factors might help develop strategies for improving population health and longevity. It is especially important to perform such studies in poorer nations, where socioeconomic inequities and healthcare issues are often more severe. Researchers can use the interplay of socioeconomic determinants and life expectancy in various situations to drive targeted interventions and policies to improve health outcomes and support equitable development.

5. Conclusions

The current study investigated the impact of government effectiveness, health expenditure, and SDGs on life expectancy in Pakistan. The study contributes to the body of literature by studying the impact of government effectiveness, health expenditure, and SDGs on life expectancy in Pakistan. The results confirmed the positive impact of health expenditure and SDGs on life expectancy in Pakistan. The results also revealed the negative effect of government effectiveness on life expectancy.

Given the enormous positive impact of health expenditure and SDGs on life expectancy, the government must aggressively facilitate and strengthen healthcare and the whole health system. This includes providing sustained assistance through productive health spending as well as implementing suitable and timely policies. To properly meet healthcare demands, it is critical to strengthen the health system's core pillars, which require an increase in the number of medical staff, especially doctors.

Furthermore, incorporating patients' voices into the creation of health policies is critical to ensuring productive outcomes at the lowest expense. Integrating patient viewpoints allows policymakers to modify healthcare programs to fit the population's needs and preferences better, thereby improving healthcare delivery and outcomes. Protecting the environment is critical for reducing disease incidence and healthcare costs. Environmental degradation is known to worsen health concerns. Thus, Pakistan must prioritize measures targeted at increasing renewable energy consumption and environmental sustainability. Pakistan may reduce environmental degradation and create healthier living circumstances by shifting to renewable energy sources, decreasing the pressure on healthcare systems, and boosting overall well-being.

6. Limitations and Future Directions

Although this study offers insightful information, the study also has a couple of limitations. Firstly, the study used secondary data, which may not fully capture all the subtleties and real-time changes in the healthcare sector. Secondly, the study is limited to Pakistan, and in some contexts the results may not be generalizable to other countries with different socio-economic and political contexts.

Future studies should consider a comparative analysis including multiple countries to offer a more comprehensive viewpoint on how government effectiveness, health spending, and SDGs affect life expectancy. Accurately capturing the dynamic nature of these linkages would also be made possible by longitudinal studies that collect data in real-time. Moreover, investigating the contribution of particular health policies and initiatives to increased life expectancy may offer policymakers useful information. In addition, numerous other socioeconomic factors that influence general health and well-being such as education, economic disparity, unemployment rates, and lifestyle choices may also be investigated.

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