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Examination of a Health Production Function: Evidence from South Asian Countries

Shapan Chandra Majumder
Department of Economics, Comilla University, Cumilla, Bangladesh

Azer Dilanchiev
Faculty of Business and Technologies, International Black Sea University, Georgia
Corresponding author: adilanchiev@ibsu.edu.ge

Hasanur Rahman
Department of Economics, Sheikh Fazilatunnesa Mujib University, Jamalpur-2000, Bangladesh

Abstract

The health production function for South Asian countries has been measured by infant mortality, neonatal mortality, maternal mortality, and life expectancy concerning social, economic, and environmental factors. The study used the panel generalized method of moments (PGMM) and panel fully modified ordinary least square (PFMOLS) methods to consider panel data from 2000 to 2019. The key findings indicate that a higher GDP per capita significantly reduces infant, neonatal, and maternal mortality and increases life expectancy. Similarly, education and health expenditures are vital in advancing health production functions in South Asian countries. Population control, the desired number of physicians, and planned urbanization help to enhance health production functions by raising life expectancy and reducing infant, neonatal, and maternal mortality rates.

Keywords: Health production function, economic factors, social factors, environmental factors, PGMM, PFMOLS

1. Introduction

The healthcare system is one of the main pillars of social well-being and economic development. Economic growth and public health expenditure substantially work as a significant reform of nations. A pivotal point to be noted is that the changes and enhancements to the health care scheme in South Asian countries are enduring progressions. Ahead of defining the health production function, we must understand production function. The production function tells us the maximum output it can construct with any given level of inputs. In short, it summarizes the associations between inputs and outputs. The health production function is defined as the rapport between health and health inputs, e.g., practitioner-provided health care, needed to produce healthcare facilities (Bloom, Canning, & Sevilla, 2004; Fayissa & Gutema, 2005).

A person's health can be maintained or improved in various ways, including through close-to-home conduct changes and the proper utilization of medical care administrations. While there is considerable medical service spending in South Asian countries, the significance of health gives solid reasoning for this degree of expenditure. However, while medical care financing and transportation are frequently wasteful, there are methods for promoting well-being and admission to medical service administrations without additional spending. To improve the effectiveness of medical care financing and conveyance, organizations have sought strategies to expand motivators for people to buy customer-coordinated healthcare coverage plans (Rosenzweig & Schultz, 1983). The government or non-government organizations (NGOs) have also attempted to connect supplier installments to execution, compensating for the productive conveyance of medical services.

Healthcare production in South Asian countries has taken place from an economic point of view. The transformation of economic power occurred several times among those countries due to regional similarity. The South Asian economy follows a market-based economic system (Dissanayake, Mahadevan, & Asafu-Adjaye, 2018; Wadud, 2009). Most countries moved from the least developed to developing countries in this region. Those countries have changed in terms of population size, income, level of development, infrastructure development, and other social and economic characteristics.

However, there is a long way to go for those countries to reach the standard of developed countries. Although the life expectancy in South Asian countries is increasing, it is still far behind developed countries (Gopalan, Misra, & Jayawardena, 2018; Muhammad, 2006). The whole mortality rate is a mirror image of life expectancy in this region. Considering the importance of health care, the study has investigated the impact of the different economic, social, and environmental factors on the health status of South Asian countries. This research aims to analyze the health production function at the macro level and is the first attempt to measure the health production functions in South Asian countries. Previous studies measured the health production function by considering infant mortality as a partial study, whereas this study considered infant mortality, neonatal mortality rate, and life expectancy to measure the health production functions in South Asian countries.

2. Literature Review

The health production function of East European countries was estimated by Fayissa and Traian (2013). Many empirical studies on health production functions are commonly performed in Western European countries and North America. Grossman's theory (1972) was utilized to estimate the health production function. However, very few empirical studies have been performed on South Asian perspectives on this issue, and this paper helps to understand the case of the health production function. A brief empirical literature review has been presented in Appendix Table 1.

3. Hypothesis Development

The hypothesis of this study has been constructed based on the social, economic, and environmental factors of health production functions. The first consideration is a negative correlation between economic factors and a health production function, meaning the H_0 is presented, and the economic factor negatively explains the health production functions in South Asian countries. Therefore, the constructed hypothesis should be rejected. Dobbins, Cockerill, and Barnsley (2001) and Kumar, Mittal, and Hossain (2008) argue against rejecting this hypothesis. The second consideration is that social factors negatively impact health production in South Asian countries. The constructed hypothesis should be rejected because health production functions have a positive impact. Yang *et al.* (2020) and Bandura (2004) also give evidence to support this hypothesis. The third consideration is that environmental factors have a negative impact on health production functions. The hypothesis should be rejected, but ecological degradation increases health vulnerability. CO_2 emissions, greenhouse gases (GHG), and urbanization negatively impact health production. Gruda (2005) and Xu *et al.* (2018) accepted this statement. Therefore, the constructed hypothesis is considered the null hypothesis.

H_1: There is no correlation between economic factors and health production function.

H_2: Social factors have no impact on health production function.

H_3: There are no relations between environmental factors and health production function.

4. Methodology

The health outcome measure (infant mortality rate, neonatal mortality rate, maternal mortality ratio, and life expectancy) is specified as a function of economic (GDP per capita, health care expenditures, food production index), social (education/education expenditure, population size, physicians), and environmental (urbanization, carbon dioxide emissions) factors. Thus, a log-linear Cob-Douglas production function of the study can be written as:

$$Ln(h_{it}) = Ln(\Omega) + \sum \alpha_i \, Ln(Y_{it}) + \sum \beta_i \, Ln(S_{it}) + \sum \gamma_i \, Ln(E_{it}) + \mu_{it} \quad (1)$$

Where Ω is the initial health stock which is constant, Y_{it} shows the economic factors, S_{it} presents the social factors, E_{it} demonstrates the environmental factors of the *i* th country in period *t*, and μ_{it} presents the disturbance term. We have conducted secondary data in the study, and data were collected from the World Bank (WDI) and World Health Organization (WHO). Panel data from 2000 to 2019 was used in this study. The explanatory variables of the current study have been structured as the impact of economic, social, and environmental factors on infant mortality and presented in Model 1. An impact of economic, social, and environmental factors on neonatal mortality has been presented in Model 2. The impact of economic, social, and environmental factors on maternal mortality has been presented in Model 3. Finally, the impact of economic, social, and environmental factors on life expectancy has been presented in Model 4. The infant (Inmf), neonatal (NeoM), life expectancy (LexP), and maternal mortality (MMR) rates have been used as explained variables.

Model 1: Economic, Social, and Environmental Impact on Infant Mortality

$$Inmf = f(GDP, Thexp, FP, Edu, Phy, Pop, Urbp, CO2) \quad (2)$$

Now, the constructed econometric model is that:

$$Inmf_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 Thexp_{it} + \beta_3 FP_{it} + \beta_4 Edu_{it} + \beta_5 Phyi_t + \beta_6 Pop_{it} + \beta_7 Urbp_{it} + \beta_8 CO2_{it} + \varepsilon_{it} \quad (3)$$

where *i* means cross-section unit and *t* means time.

The log transformation has been taken in equation 3.

$$Ln(Inmf)_{it} = \beta_0 + \beta_1 Ln(GDP)_{it} + \beta_2 Ln(Thexp)_{It} + \beta_3 Ln(FP)_{It} + \beta_4 Ln(Edu)_{it} + \beta_5 Ln(Phy)_{it} + \beta_6 Ln(Pop)_{it} + \beta_7 Ln(Urbp)_{it} + \beta_8 Ln(CO2)_{it} + \varepsilon_{it} \quad (4)$$

Model 2: Economic, Social, and Environmental Impact on Neonatal Mortality

$$NeoM = f(GDP, Thexp, FP, Edu, Phy, Pop, Urbp, CO2) \quad (5)$$

Now, the constructed econometric model is that:

$$NeoM_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 Thexp_{it} + \beta_3 FP_{it} + \beta_4 Edu_{it} + \beta_5 Phyi_t + \beta_6 Pop_{it} + \beta_7 Urbp_{it} + \beta_8 CO2_{it} + \varepsilon_{it} \quad (6)$$

where *i* means cross-section unit and *t* means time.

The log transformation has been taken in equation 6.

$$Ln(NeoM)_{it} = \beta_0 + \beta_1 Ln(GDP)_{it} + \beta_2 Ln(Thexp)_{It} + \beta_3 Ln(FP)_{It} + \beta_4 Ln(Edu)_{it} + \beta_5 Ln(Phy)_{it} + \beta_6 Ln(Pop)_{it} + \beta_7 Ln(Urbp)_{it} + \beta_8 Ln(CO2)_{it} + \varepsilon_{it} \quad (7)$$

Model 3: Economic, Social, and Environmental Impact on Maternal Mortality

$$MMR = f(GDP, Thexp, FP, Edu, Phy, Pop, Urbp, CO2) \quad (8)$$

Now, the constructed econometric model is that:

$$MMR_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 Thexp_{it} + \beta_3 FP_{it} + \beta_4 Edu_{it} + \beta_5 Phyi_t + \beta_6 Pop_{it} + \beta_7 Urbp_{it} + \beta_8 CO2_{it} + \varepsilon_{it} \quad (9)$$

where *i* means cross-section unit and *t* means time.

The log transformation has been taken in equation 9.

$$Ln(MMR)_{it} = \beta_0 + \beta_1 Ln(GDP)_{it} + \beta_2 Ln(Thexp)_{It} + \beta_3 Ln(FP)_{It} + \beta_4 Ln(Edu)_{it} + \beta_5 Ln(Phy)_{it} + \beta_6 Ln(Pop)_{it} + \beta_7 Ln(Urbp)_{it} + \beta_8 Ln(CO2)_{it} + \varepsilon_{it} \quad (10)$$

Model 4: Economic, Social, and Environmental Impact on Life Expectancy

$$LexP = f(GDP, Thexp, FP, Edu, Phy, Pop, Urbp, CO2) \quad (11)$$

Now, the constructed econometric model is that:

$$LexP_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 Thexp_{it} + \beta_3 FP_{it} + \beta_4 Edu_{it} + \beta_5 Phyi_t + \beta_6 Pop_{it} + \beta_7 Urbp_{it} + \beta_8 CO2_{it} + \varepsilon_{it} \quad (12)$$

where *i* means cross-section unit and *t* means time.

The log transformation has been taken in equation 12.

$$Ln(LexP)_{it} = \beta_0 + \beta_1 Ln(GDP)_{it} + \beta_2 Ln(Thexp)_{It} + \beta_3 Ln(FP)_{It} + \beta_4 Ln(Edu)_{it} + \beta_5 Ln(Phy)_{it} + \beta_6 Ln(Pop)_{it} + \beta_7 Ln(Urbp)_{it} + \beta_8 Ln(CO2)_{it} + \varepsilon_{it} \quad (13)$$

Where β_0 is the intercept term of the model and β_1 to β_8 are the slope coefficients, *t* represents time and *i* represents cross-section unit (individual country). The term ε represents the residual of estimated models. This research also employs infant, neonatal, and maternal mortality rates and life expectancy as the dependent variable to evaluate the health production function.

Table 1: Description of variables

Variables	Details
Inmf	Mortality rate, infant (per 1,000 live births)
NMR	Neonatal Mortality Rate (per 1,000 live births)
MMR	Maternal Mortality Ratio (per 100,000 live births)
GDP	GDP per capita (current US$)
Eduexp	Government expenditure on education, total (% of GDP)
FP	Food Production Index (2004-2006 = 100)
Phy	Physicians (per 1,000 people)
Urbp	Urban population (% of the total population)
CO_2	CO_2 emissions (metric tons per capita)
Pop	Population, total
Lexp	Life expectancy at birth, total (years)
Thexp	Current health expenditure (% of GDP)

Source: WDI (2020).

4.1 CIPS Panel Unit Root

The current study considers the Cross-sectional Augmented Dickey-Fuller (CADF) and Cross-sectional augmented Im, Pesaran, and Shin (CIPS) unit root tests to determine the order of integration of the consequent variables. The CADF and CIPS statistics are proposed by Pesaran (2007). CADF and CIPS test statistics can be considered from the following regressions:

$$\Delta X_{it} = \alpha_i + \beta_i X_{i,t-1} + \delta_i T + \sum_{j=1}^{k} \varphi_{ij} \, \Delta X_{i,t-j} + \varepsilon_{it} \tag{14}$$

where $i=1, 2, \ldots, N$ denotes the cross-sectional member; $t=1, 2, \ldots, T$ indicates the time period, X_{it} means the analyzed variable; α is constant, T means time trends, and ε_{it} is the error term.

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \tag{15}$$

where, $CADF_i$ is cross-sectional augmented Dickey-Fuller test statistic for the i th cross-sectional unit.

4.2 Cointegration Test

The cointegration equation can be presented in the following manner:

$$Z_{it} = \delta_i + \beta V_{it} + \varepsilon_{it} \tag{16}$$

Here, δ_i and βV_{it} present the parameter and the residual term, respectively, presented by ε_{it}. Kao (1999) suggests the cointegration technique concerning ADF test, and the estimation process follows the equation 14.

$$\varepsilon_{it} = \alpha \varepsilon_{it-1} + \sum_{k=1}^{m} \theta_j \, \Delta\hat{\varepsilon}_{i,t-j} + \epsilon_{it} \tag{17}$$

The parameter of and the residual term are uncorrelated. Therefore, the null hypothesis for cointegration is that no cointegration relationship exists among the series. This study aimed to reject the null hypothesis.

4.3 Description of PGMM Analysis

The current study used a multivariate regression analysis while considering the panel generalized method of moments (PGMM). Griliches and Hausman (1986) first introduced GMM methods to analyze panel data in sequential econometric approaches. In the case of cross-sectional dependency and endogeneity analysis in panel estimation, PGMM is one of the best methodologies to estimate the desired results. Moreover, the GMM method has been used by other researchers, e.g., Khadaroo and Seetanah (2009), Alege (2016), Farla, De Crombrugghe, and Verspagen (2016), Ozturk (2016), and Ayadi (2020).

5. Results Discussion

5.1 Descriptive Statistics

The results of descriptive statistics have been presented in Table 2, where mean, median, maximum, minimum skewness kurtosis, and Jarque-Bera statistics tools have been used to represent the selected variable's descriptive statistics. For simplicity, we have used the log transformation of each variable. The variable LNINMF shows that the mean and median values are 3.34 and 3.52, respectively. The variable is negatively skewed, and its skewness value is -0.82, whereas a kurtosis value is 2.54. The Jarque-Bera statistics have been significant at the 1% level of this variable. The descriptive statistics of variable LNMMR show that the mean and median values are 6.74 and 7.86, respectively. The maximum value of this variable is 11.55, and the minimum value is 1.61. The variable is negatively skewed, and its skewness value is -0.23, whereas a kurtosis value is 1.61. The Jarque-Bera statistics have been significant at the 1% level of this variable.

Table 2: Descriptive Statistics

Variables	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
LNINMF	3.34	3.52	4.20	1.81	0.67	-0.82	2.45	16.93***
LNLEXP	4.24	4.23	4.37	4.11	0.07	0.23	2.00	6.97**
LNMMR	6.74	7.86	11.55	1.61	3.21	-0.23	1.61	12.12***
LNNMR	2.96	3.20	3.81	1.46	0.69	-0.83	2.27	18.80***
LNGDP	7.23	7.13	9.27	5.44	0.91	0.32	2.48	3.88
LNHEXP	1.49	1.50	2.44	0.65	0.41	0.11	2.23	3.61
LNEDU-EXP	1.30	1.29	3.32	0.40	0.63	1.68	6.43	130.81***
LNFP	4.64	4.64	4.98	4.15	0.20	-0.41	2.65	4.46*
LNPHY	-0.59	-0.57	1.52	-3.77	0.83	-0.69	6.09	65.17***
LNPOP	16.34	16.81	21.04	12.51	3.40	0.26	1.48	14.74***
LNURBP	3.30	3.40	3.73	2.60	0.30	-0.74	2.25	15.48***
$LNCO_2$	-0.31	-0.15	1.11	-2.32	0.84	-0.52	2.86	6.26**

*, **, and *** present 10%, 5% and 1% significance levels, respectively.

Moreover, the variable LNLEXP shows that the maximum and minimum values are 4.37 and 4.11, respectively. The mean value of this variable is 4.24, and the median is 4.23. The variable is positively skewed, and its skewness value is 0.23, whereas kurtosis values are 2.00. The Jarque-Bera statistics have been significant at the 5% level of this variable. The mean value of LNGDP is 7.23, the mean value of LNFP is 4.64, and the mean value of LNURBP is 3.30. In addition, the median value of LNGDP is 7.13, the median value of LNFP is 4.64, the median value of LNURBP is 3.40, and the median value of CO_2 is -0.15. Whatever the results of descriptive statistics state, consistent results for each variable are significant with the unique volume to estimate the desired results.

5.2 Cross-Section Dependence Test and CIPS Unit Root

At the early stage of result estimation, we tested the cross-section dependence (CD) proposed by Pesaran (2004). The CD test is essential to a panel study to estimate the CIPS unit root test. The result of CD statistics has been considered Pesaran CD (statistics), where the null hypothesis (H_0) assumes there is no cross-sectional dependence among the estimations. The results of Pesaran CD (statistics) showed that the variables have cross-sectional dependence, and the results rejected the null hypothesis (H_0). The statement argues that CIPS has estimated a second-generation estimation of panel analysis, the unit root test.

Table 3: Results of Cross-Section Dependence Test

Variables	Pesaran CD (Statistics)
Inmf	20.26***
NMR	19.81***
MMR	17.76***
GDP	19.91***
Eduexp	2.01**
FP	8.22***
Phy	13.22***
CO_2	16.18***
Urbp	15.01***
Pop	20.04***
Lexp	20.17***
Thexp	2.70***
** and *** present 5% and 1% significance levels, respectively.	

Table 4: CIPS Test Results of the Second-generation Panel Unit Root Model

Tests	CIPS	
Variables	Level I(0)	1st diff. I(1)
LNINMF	-0.403	-2.308**
LNLEXP	-2.082	-4.896*
LNMMR	-0.159	-4.020*
LNNMR	-0.846	-2.480**
LNPHY	-1.619	-4.876*

LNPOP	-2.181	-2.394*
LNURBP	-0.390	-2.974*
LNHEXP	-2.072	-4.920*
LNGDP	-2.165	-4.345*
LNCO2	-1.555	-4.325*
LNEDUEXP	-2.014	-5.119*
LNFP	-2.154	-4.731*

(Notes: The optimal lags are estimated based on Schwarz Information Criterion (SIC); the test statistics are determined based on both constants and level through the null hypothesis to the alternative hypothesis of data stationarity; P-values for the statistical significance of the coefficients are * and **, representing 1% and 5% levels, respectively).

The results of the CIPS unit root have been presented in Table 4. The developed null hypothesis assumes the variables have a unit root. Through the result of the CIPS test, the variables are not stationary at a level, and there is no evidence to reject the null hypothesis. After taking the first difference, we see that the variables are stationary, and the dimension of the level of integration of the data series is I(1). All the variables are not stationary at level I(0), but taking the 1st difference, the variables are stationary, meaning the evidence of I(1). The results of the second-generation panel series argued for the need to run further models of this study, e.g., GMM and FMOLS, to achieve the study objectives. In this study, we have estimated the GMM model to know the marginal effect of each independent variable on the dependent variable. The FMOLS method was used to estimate the long-run coefficient of each selected factor.

5.3 Panel Cointegration Test

The panel cointegration test run by Kao (1999) to estimate the long-run relationship among the variable t-stat of Kao (1999) has been considered. The results of cointegration are presented in Table 5.

Table 5: Results of Kao Residual Cointegration Test

Test		t-Statistic	Prob.
Model 1	ADF	-3.47571	0.0003
Model 2	ADF	-3.48072	0.0003
Model 3	ADF	-3.87617	0.0001
Model 4	ADF	-3.33475	0.0004
Null Hypothesis: No cointegration.			

The ADF test has been considered to determine the Kao technique. The t-stat of the ADF test for Model 1 is -3.47, Model 2 is -3.48, Model 3 is -3.87, and Model 4 is -3.33, where the probability is 0.00, meaning that we reject the null hypothesis at a 1% level of significance. Concerning the cointegration strategy results, Kirikkaleli (2016) found a long-run connection between the selected variables. Similar to Streimikiene and Kasperowicz (2016) and Cho and Ramirez (2016), this investigation connected with the FMOLS to break down the long-run impact. To estimate the long-run relationship, the Kao test is much more effective in panel series (Ssali, Du, Mensah, & Hongo, 2019; Wang, Wang, Ma, & Gong, 2011). The results conclude that residuals of variables have cointegration in the long run, rejecting the null hypothesis.

5.4 Panel Generalized Method of Moments (PGMM)

Table 6 presents that, for the estimated four models with an infant, neonatal, maternal mortality rates and life expectancy for the PGMM method, the board weight output shows the marginal effect of independent variables on the dependent variable. Through the results of the PGMM method, Model 1 indicates that GDP has a significant impact on reducing infant mortality in South Asian countries. The coefficient of GDP is 0.31, which is negative. That means a 1% increase in GDP can reduce infant mortality by 0.31% in Model 1, neonatal mortality by 0.20% in Model 2, and maternal mortality by 0.25% in Model 3.

Table 6: Results of PGMM Analysis

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	LNINMF	LNNMR	LNMMR	LNEXP
LNGDP	-0.31***	-0.20***	-0.25***	0.02***
LNFP	0.17***	0.26***	-0.08	0.02***
LNEDUEXP	-0.05***	-0.04***	0.06***	0.002*
LNHEXP	0.16***	0.18***	-0.12*	0.02***
LNPOP	-1.15***	-1.07***	0.52***	0.06***
LNURBP	-0.54***	-0.76***	-1.85***	0.16***
LNPHY	-0.02*	-0.01	-0.01	0.00
LNCO2	-0.10***	-0.11***	-0.07	-0.002
C	25.06***	22.88***	6.64***	2.41***

*, **, and *** present 10%, 5%, and 1% significance levels, respectively.

Model 4 has determined that increasing GDP helps increase life expectancy in South Asian countries. Education expenditure has a significant impact on reducing infant mortality and neonatal mortality, but it does not significantly reduce maternal mortality. The importance of education for social standards has been analyzed by Yun and Yusoff (2019) and Likhitcharoen-korn (2015). Moreover, education expenditure enhances the quality of life, raising life expectancy. A 1% increase in education expenditure increases the life expectancy rate by 0.02%, which is significant at the 1% level. Food production helps reduce maternal mortality and positively impacts life expectancy in South Asian countries. An important variable is health expenditure, which shows that health expenditure significantly impacts reducing maternal mortality, while insufficient health expenditure has a positive effect on infant and neonatal mortality. Inadequate management is another reason for the health sector's inefficiency (Rahman, Majumder, & Rana, 2020).

Increasing the number of physicians can contribute to reducing infant, neonatal, and maternal mortality rates. Additionally, the presence of physicians helps raise the life expectancy rate, but this contribution is tiny because of the considerable population with a lower number of physicians and a lack of healthcare institutions. The PGMM estimation determined that urbanization significantly reduces infant, neonatal, and maternal mortality rates. Due to the increase in GDP and per capita income, industrialization in South Asian countries enhances urban expansion (Sarker *et al.,* 2018). The migration from urban to rural areas was increased by the pull factor rather than the push factor in South Asian countries. In that case, if urbanization increases by 1%, it will help reduce infant mortality by 0.54% in Model 1, 0.76% in Model 2, and 1.85% in Model 3. A 1% rise in urbanization facilitates a rise in life expectancy by 0.16% in South Asia. Population control reduces infant and neonatal mortality rates but does not work for maternal mortality. Model 3 indicates that maternal mortality will increase with an increase in population.

The variable CO_2 explains that there is no positive impact on the rising infant, maternal, and neonatal mortality rates in South Asian countries. It is a consequence that CO_2 emissions reduce life expectancy; the PGMM results indicated a 1% rise in CO_2 emissions lessens life expectancy by 0.002%, but this result is not significant. According to Ratisurakarn (2019), forest area and investment in forests can reduce CO_2 emissions, helping to increase the quality of life. The overall estimation has covered the social, economic, and environmental impact on the health production function, measured by considering infant, neonatal, and maternal mortality rates and life expectancy rates.

5.5 Panel Fully Modified Least Squares (PFMOLS)

The factors' long-run relationship is inspected by utilizing the FMOLS strategy. The FMOLS strategy was presented by Phillips and Hansen (1990) and further changed by Pedroni (2001). This method was used since it represents endogeneity and autocorrelation issues and gives powerful outcomes. We examined how appraisals taken a long time ago for the PFMOLS, and the consequences of PFMOLS, have been accounted for independently for each model in Table 7. The long-run beta value is determined using two unique methodologies, which are exceptionally comparable and significant at the 1% and 5% levels. Table 7 clarifies that, for the estimated four models with the infant, neonatal, and maternal mortality rates and life expectancy for the PFMOLS technique, the board gauge output presumes the long-run effect of independent variables on the dependent variable.

Table 7: Results of PFMOLS Analysis

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	LNINMF	LNNMR	LNMMR	LNEXP
LNGDP	-0.32***	-0.18***	-0.25***	0.03
LNFP	0.19***	0.27***	-0.07	0.02**
LNEDUEXP	-0.05***	-0.05***	0.07***	-0.002
LNHEXP	0.24***	0.22***	-0.23**	0.03***
LNPOP	-1.12***	-1.04***	0.57***	0.07***
LNURBP	-0.48***	-0.77***	-1.96***	0.16***
LNPHY	-0.02	-0.004	-0.01	0.00
LNCO2	-0.13***	-0.14***	-0.04	-0.002

** and *** present 5% and 1% significance levels.

Model 1 estimates the impact on infant mortality where GDP has a negative coefficient, which means a 1% increase in GDP helps to reduce infant mortality by 0.32% in Model 1, 0.18% in Model 2, 0.25% in Model 3, and 0.03% increase in the case of life expectancy in South Asia. A similar kind of effect has been shown by education expenditure. Education is the social and economic factor that increases health production by reducing the mortality rate and increasing the life expectancy ratio. A 1% increase in education spending reduces infant mortality by 0.05% in Model 1, 0.05% in Model 2, 0.07% in Model 3, and 0.002% in the case of life expectancy. Quality of education helps raise life expectancy and reduce neonatal and infant mortality rates in South Asia (Bhutta *et al.,* 2004; Zakaria, Tariq, & Ul Husnain, 2020).

This estimation also shows population control helps reduce infant mortality. If the population is controlled by 1%, it will reduce infant mortality by 1.12% in Model 1 and 1.14% in Model 2. However, in Model 3, the population positively impacts maternal mortality, and in Model 4, population control helps raise life expectancy by 0.07%. Since the last decade, South Asian countries have had a consistent population growth rate, significantly impacting infant mortality rates by raising social awareness and security. The number of physicians has a negative coefficient, which indicates that a 1% increase in physicians or medical consultants helps reduce infant mortality by 0.02% in Model 1, neonatal mortality by 0.004%, and maternal mortality by 0.01%. Model 4 indicates that the number of physicians does not significantly increase life expectancy in this region because of the high population, lack of physicians, and lack of social infrastructure, e.g., hospitals.

Food production significantly reduces maternal mortality rates, but the coefficients of infant and neonatal mortality are positive because of massive food demand and insufficient food production. Due to poverty, working mothers cannot care for their babies properly. Environmental degradation is a critical issue in social life (Devkota, Phuyal, & Shrestha, 2021). In the case of CO_2 emissions, there is no positive impact on the infant, neonatal, or maternal mortality rates, but they negatively impact life expectancy. In South Asian countries, if CO_2 emissions increase by 1%, life expectancy is reduced by 0.002%, as presented in Model 4, with results similar to Mohmmed *et al.* (2019) and Murthy, Shaari, Mariadas, and Abidin (2021).

Economic dualism and demographic transition help to increase urbanization, and controlled or planned urbanization increases the quality of life and health. If urbanization rises by 1%, it will help to reduce infant mortality by 0.48% in Model 1, neonatal mortality by 0.77% in Model 2, and maternal mortality by 1.96% in Model 3. A 1% rise in urbanization helps raise life expectancy by 0.16%. Planned urbanization increases the quality of life by raising per capita income, education, and more, helping to reduce mortality rates (Santana, Costa, Marí-Dell'Olmo, Gotsens, & Borrell, 2015; Sato & Yamamoto, 2005; Yuan *et al.,* 2018).

6. Conclusion

According to PGMM estimation, an increase in GDP significantly improves health production function, where a 1% increase in GDP can reduce infant mortality by 0.31% (Model 1), neonatal mortality by 0.20% (Model 2), and maternal mortality by 0.25% (Model 3). Model 4 determined that an increase in GDP helps to increase life expectancy. Education expenditure and health expenditure also play an essential role in the developed health production function. Urbanization or rural-urban migration has an impact on the health production function. If urbanization increases by 1%, it will help reduce infant mortality by 0.54% in Model 1, 0.76% in Model 2, and 1.85% in Model 3. A 1% rise in urbanization facilitates raising life expectancy by 0.16% in South Asian countries.

Moreover, significant findings from PFMOLS methods show that a 1% increase in education expenditure reduces infant mortality by 0.05% in Model 1, 0.05% in Model 2, and 0.07% in Model 3, which is positive, and a 0.002% increase in life expectancy. In Model 1, a 1% increase in physicians or medical consultants reduces infant mortality by 0.02%, neonatal mortality by 0.004%, and maternal mortality by 0.01%. GDP, urbanization, and health expenditure are essential in South Asian countries' advanced health production functions. The current study ensures that it is the first step to measure the health production function in economic, social, and environmental aspects in South Asian countries, considering Grossman's theory (1972). This study suggests that increasing the GDP per capita is necessary based on the empirical findings because it significantly raises life expectancy and helps reduce infant, neonatal, and maternal mortality rates. The increasing trend of education expenditure significantly impacts developing health production functions.

Health expenditure should be increased because of the large population in the study area. The population density in Bangladesh, India, and Pakistan is higher than in other countries; therefore, a case-control of the people must be needed. Proper management of urban resources and population distribution in rural-urban migration can help to increase health production function by increasing the availability of modern facilities in daily life. Healthcare spending should be increased, particularly in the rural sector, where community clinic facilities are essential in maintaining rural healthcare services. The authorities should emphasize that healthcare facilities need access to good governance in this sector. Planned urbanization and urban facilities help to improve the quality of life. Environmental sustainability should be a concern for stakeholders in each country, especially in developing countries. Governments should take action to maintain environmental quality. The overall contribution of this study can open new doors for stakeholders through emphasis, awareness, and policy coordination.

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Appendix Table 1: Literature Review on Health Production Functions

Name of Author	Type of Data, Country & Duration	The framework of the Study	Variables	Results
Haseeb et al. (2019)	Panel Data, Asian countries, 2009-2018	ARDL approach	Env. pollution, GDP, Health care, energy, R&D	There is long-run association among the variables.
Rayhan et al. (2019)	Panel Data, South Asian Countries, 1995-2015	Pooled OLS, Fixed & Random Effect Model	Life Expectancy, Economic (Health Expenditure Per Capita & Food Production Index), Social (Education & Access to Improved Water Sources) & Environment (Urbanization Rate)	The impact of health expenditure per capita, education, access to improved water sources, and urbanization on life expectancy are statistically significant positive in South Asian countries, but the impact of the food production index is statistically significant negative.
Rahman et al. (2018)	Panel Data, (SAARC) and ASIAN 15 countries, 1995-2014	Panel Generalized Method of Moments (GMM)	Public and private health expenditure, private, GDP, sanitation, life expectancy, death rate, and infant mortality rate	Health expenditure and GDP reduce the infant mortality rate.
Bayati et al. (2016)	Panel Data, 22 Eastern Mediterranean Regions, 2004-2011	Fixed Effect Method	Maternal Mortality Rate, Social (Fertility Rate, Urbanization, Female Education), Economic (GDP Per Capita), Health Indicators (Health Expenditure, Skilled Health Personnel, Primary Health Care Center)	The model's evaluation revealed a negative and significant relationship between GDP per capita, health spending, female literacy, skilled birth attendance, and maternal mortality rate.

Bayati et al. (2013)	Panel Data, East Mediterranean Region (21 Countries), 1995-2007	Fixed Effect Model	Life Expectancy, Economic (Income Per Capita, Health Expenditure, Food Availability & Employment Ratio), Social (Education, Vaccine), & Environment (Urbanization & CO_2)	Factors like income per capita, schooling index, food availability, level of urbanization, and employment ratio, were specified as determinants of health status, proxied by life expectancy at birth, to estimate the health production function. The elasticity of life expectancy with respect to the employment rate was a notable finding, and its significance level differed between males and females.
Kenkel (1995)	Panel Data, 21 EMR countries, 1995 – 2007	Panel data model (fixed effect)	Food, GDP, Education, Urbanization, Life expectancy	Food, GDP, and Education accelerate life expectancy.
Narayan et al. (2010)	Panel Data, 5 Asian countries, 1974–2007	OLS Regression	Economic growth and health	Economic growth accelerates health production.
Kabir (2008)	Panel Data, 91 Developing Countries,	Multilevel Regression and Causality Analysis	Life Expectancy, Economic (GDP Per Capita, Per Capita Public and Private Healthcare Expenditure, Urbanization, Fertility Rate & Medical Care Inputs) & Non-economic Factors (Nutritional Status, Safe Water, Location)	The majority of explanatory variables were statistically insignificant, implying that relevant socio-economic factors such as per capita income, education, health expenditures, access to safe water, and urbanization are not always considered influential in determining life expectancy. In developing countries, life expectancy is low.

Gilligan & Skrepnek (2015)	Cross-sectional Time Series (Panel Data), Eastern Mediterranean Region (21 Countries), 1995-2010	Multilevel mixed-effects linear model	Life Expectancy, Infant Mortality Rate, Population, Health Expenditure, GDP Per Capita, Adult Literacy Rate, Urbanization, Water, Physician, Average Vaccination Rate, Malnourished	GDP per capita, urbanization and vaccination were significant and influencing determinants of life expectancy in the study countries.
Fattahi (2015)	Panel Data, Developing Countries, 1995-2011	GMM estimation	Health Expenditure, CO_2, Urbanization, Government exp., Unemployment rate, Education	Urbanization and CO_2 create health vulnerability where education and govt. expenditure positively impact the health production function.
Amiri & Gerdtham (2013)	Panel Data, 180 Countries, 1990-2010	DEA analysis	Infant, maternal mortality rate, GDP	GDP support to reduce infant and maternal mortality.
Magdalena et al. (2021)	Primary data, 34 provinces, Indonesia	Multivariate Analysis	Child Labor, Poverty, Inequality, Health	Economic determinants are mostly responsible to increase child labor and child health vulnerability.
Rahman (2011)	Time series, Bangladesh, 1978-2007	ECM methodology	Education, health Exp. and GDP	Education and health expenditure increase the human and physical capital.

Source: Authors' Selection.