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RESEARCH ARTICLE

Socio-economic, macroeconomic, demographic, and environmental variables as determinants of child mortality in South Asia

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Abstract

The study empirically examines the effects of socio-economic (human capital), macroeconomic (per capita GDP), demographic (fertility rate, urbanization), and environmental variables (carbon emissions) on child mortality in South Asia. For empirical analysis, panel cointegration technique is used by using data for five South Asian countries for the period 1973 to 2015. First, it is found that the variables have unit roots at levels but are stationary at first differences, which indicates the possibility of cointegration. Cointegration test results show that long-run cointegrating relationship holds among variables. Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) methods are applied to find the parameter estimates. The results of long-run estimates show that human capital, per capita income, and urbanization reduce child mortality while high fertility rate and environmental degradation increase child mortality in the region. It is also found that trade openness, immunization, food security, and high life expectancy also decrease child mortality and that population density increases child mortality.

Keywords Child mortality · Fertility · Cointegration · South Asia

JEL classification C23 · J13

Introduction

Child mortality rate is an important indicator of socio-economic development, quality of life, and health status of a country. It is also an important component of United Nations human development index. The global child mortality under-five declined by 53% during the Millennium Development Goal (MDG) era of 1990 to 2015, which is less than the target of a two-third reduction (WHO 2015). In 1990, 12.6 million children under age of five died, which is about 35,000 under-five deaths per day. In 2016, about 20,000 less children died per day than in 1990. However, child mortality is still high which remained about 5.6 million in 2016, which is about 15,000 per day, which are largely from preventable causes. Child mortality is high in developing countries compared to developed countries. In 2016, child death rate in developing countries was 73.1 deaths per 1000 live births, which is much higher than the developed countries which is 5.3 deaths per 1000 live births. Reducing child inequality and saving more children's lives are important priorities (WHO 2018). South Asia has shown significant drop in child mortality with annual rate of reduction of 3.8% during the MDG period 1990 to 2015. However, child mortality rate is still very high in South Asian region (WHO 2015). The South Asian region accounts for 30.3% of global under-five child mortality. Globally, in 2016, the highest under-five deaths were found in India with 0.9 million deaths, which is 16% of world's total under-five death.[1] This high child mortality results in huge wastage of potential manpower.

After end of MDG era, Sustainable Development Goals (SDGs) have been agreed with the target to reduce under-

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[1] After India, under-five death rate is high in Nigeria (0.7 million deaths) and Congo (0.3 million deaths). These three countries, that is, India, Nigeria, and Congo, account for 34% of world's under-five deaths.

five child mortality to 25 deaths or less per 1000 live births by 2030. One way to achieve this target is to find the factors which are responsible for high child death. Empirically, many studies have tried to find the determinants of child mortality (see, e.g., McCord et al. 2017; Fitrianto et al. 2016; Perez-Moreno et al. 2016; Verhulst 2016; Richards and Vining 2016; Tanaka 2015; Brock et al. 2015; Liu et al. 2015; Erdogan et al. 2013; Franz and FitzRoy 2006; Grigorio et al. 2005; Shandra et al. 2004; Shehzad 2004; Hanmer et al. 2003; Frey and Field 2000). Although some studies have been done for South Asia but they are mainly conducted for individual countries, i.e., for Bangladesh (Mohammad and Tabassum 2016; Tabassum and Bari 2014; Karmaker et al. 2014; Chowdhury 2013; Quamrul et al. 2010; Mondal et al. 2009), for India (Thakur et al. 2015; Brainerd and Menon 2014; Singh et al. 2011, 2013; Subramanian et al. 2006; Claeson et al. 2000; Amonker and Brinker 1997), for Nepal (Lamichhane et al. 2017; Khadka et al. 2015; Neupane and Doku 2014; Sreeramareddy et al. 2013; Suwal 2001; Gubhaju et al. 1991), for Pakistan (Ahmed et al. 2016; Rabbani and Qayyun 2015; Aslam and Kingdon 2012; Ali 2001; Agha 2000; Bennett 1999; Mahmood and Kiani 1994; Afzal et al. 1988; Sathar 1985, 1987), and for Sri Lanka (James and Hammerslough 1983). Recently, Das et al. (2015) have done analysis for SAARC countries but they have also done analysis for indiviual countries not for the whole region using panel data. Ghimire et al. (2018) have reviewed the previous studies about perinatal mortality in South Asia and have found that the most common factors associated with perinatal mortality in South Asia are low socio-economic status, poor health care services, pregnancy and obstetric complications, lack of antenatal care, etc. Earlier studies have done work on neonatal mortality, perinatal mortality, and stillbirths and focused on medical causes of neonatal mortality and stillbirths.

Thus, no study has been done exclusively on South Asia as a whole region using panel data to analyze the determinants of child mortality which will lead to a decline in preventable child death in the region. Further, besides medical factors, child mortality is also affected by several macroeconomic, socio-economic, demographic, and environment-related factors. It is important to study these factors, as it will help to formulate effective policies and programs to accelerate progress to decrease child mortality in South Asia. This paper will fill this gap by examining the impact of macroeconomic, socio-economic, demographic, and environmental factors on child mortality in South Asia as whole region. Earlier studies have used simple least square estimation technique on non-stationary data which gave rise to fallacious results. In turn, the present study will examine the association between child mortality and its determinants using panel cointegration technique. The study contributes to the body of existence literature needed to devise effective policy strategies to decrease child mortality and to set the region on the path to achieve the SDG target of reducing child mortality. The study is structured as follows. "Child mortality in South Asia" discusses child mortality trends in South Asia. "Theoretical framework" provides theoretical framework. "Data and estimation of model" gives data overview and estimated results of the model along with their interpretations. Last section provides the conclusion.

Child mortality in South Asia

Child mortality has decreased in South Asia in last few decades. From 1973 to 2015, child mortality rate has decreased from an average of 182.67 deaths to 39.64 deaths under-five (per 1000 live births). Figure 1 provides child mortality rate trends in South Asia for the period 1973 to 2015. It is evident from the figure that child mortality rate has decreased in all South Asian countries. The highest child mortality rate decline is observed in Maldives and low child mortality rate decline is observed in Pakistan. Initially, Nepal had the highest child mortality rate in the region, which has declined significantly. Like Nepal, Bhutan has also declined the child mortality and Sri Lanka is the only country which had low child mortality rate throughout the time period.

Several factors have helped to reduce this decline in child mortality in South Asia. Some important factors include change in age structure, decrease in population growth rate, high women education, and better health facilities. Increase in per capita income and investment in human capital have also helped to decrease child mortality in the region. However, the main reason for decline of child mortality rate is the decline in fertility rate (births per woman). Figure 2 explains that fertility rates have significantly declined in all South Asia countries. Fertility rate is still high in Pakistan compared to other South Asian countries. Although child mortality has decreased in South Asia over time, but still it is high compared to the world. Table 1 provides the child mortality rates of different regions for the period 1990 and 2016. It is clear from this table that South Asia has the highest child mortality rate in the world after sub-Saharan Africa. Thus, there is a need to find the factors which affect child mortality in South Asia and to formulate the policies accordingly which help to reduce child mortality in the region.

Theoretical framework

The standard econometric model of household has the existence in the human capital analysis of Becker (1981). In the standard economic models of child health and household, an inter-temporal utility function is maximized such as

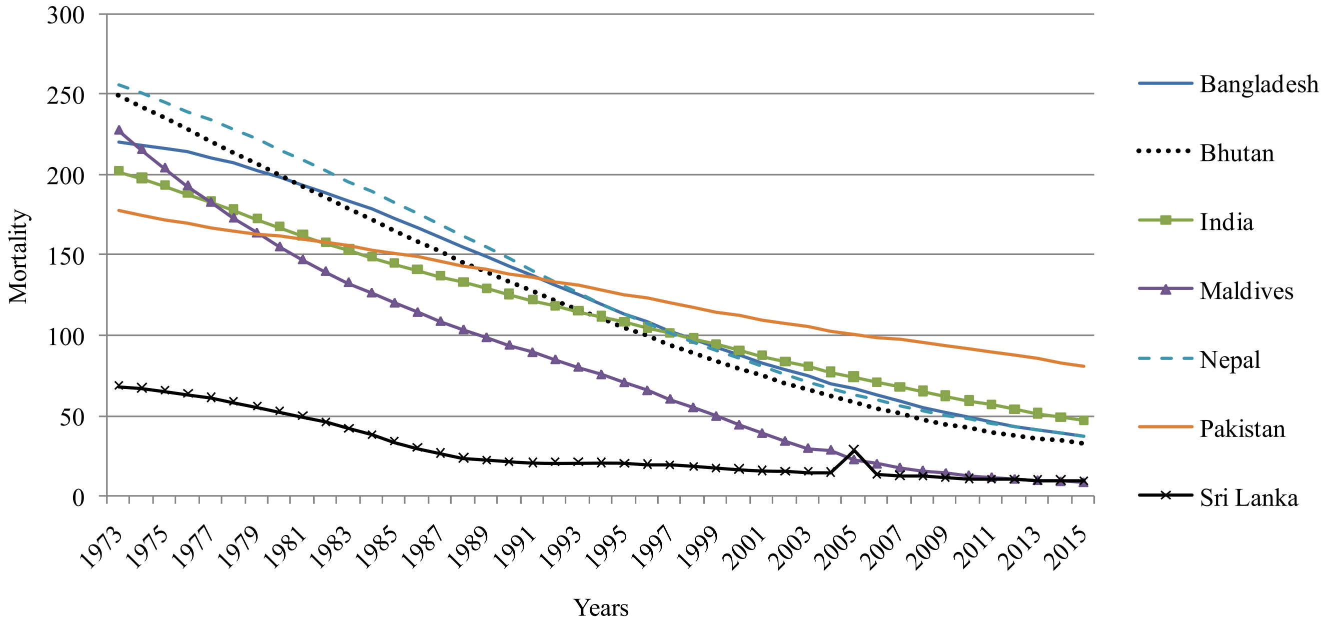

Fig. 1 Child mortality rates in South Asian countries. Source: World Bank

$$\sum_{t=1}^{T}\left(\frac{1}{1+\sigma}\right)^{t}U_t$$

where σ is the discount rate. Utility U_t is defined as

$$U_t = U(H_t, C_t) \qquad (1)$$

where H_t is child health status and C_t is consumption of other goods (non-health items). The household maximizes utility subject to the following set of constraints.

$$H_t = H(M_t, T_M, Z_t) \qquad (2)$$

$$C_t = C(N_t, T_N, V_t) \qquad (3)$$

$$Y_t = I_t + w_t T_{HR} \qquad (4)$$

$$T_M + T_N + T_{HR} = T \qquad (5)$$

where M_t is vector of material inputs, T_M is time spent on health investment, and Z_t is a set of other factors which affect health production function. N_t is a set of inputs which affect the consumption of non-health items,

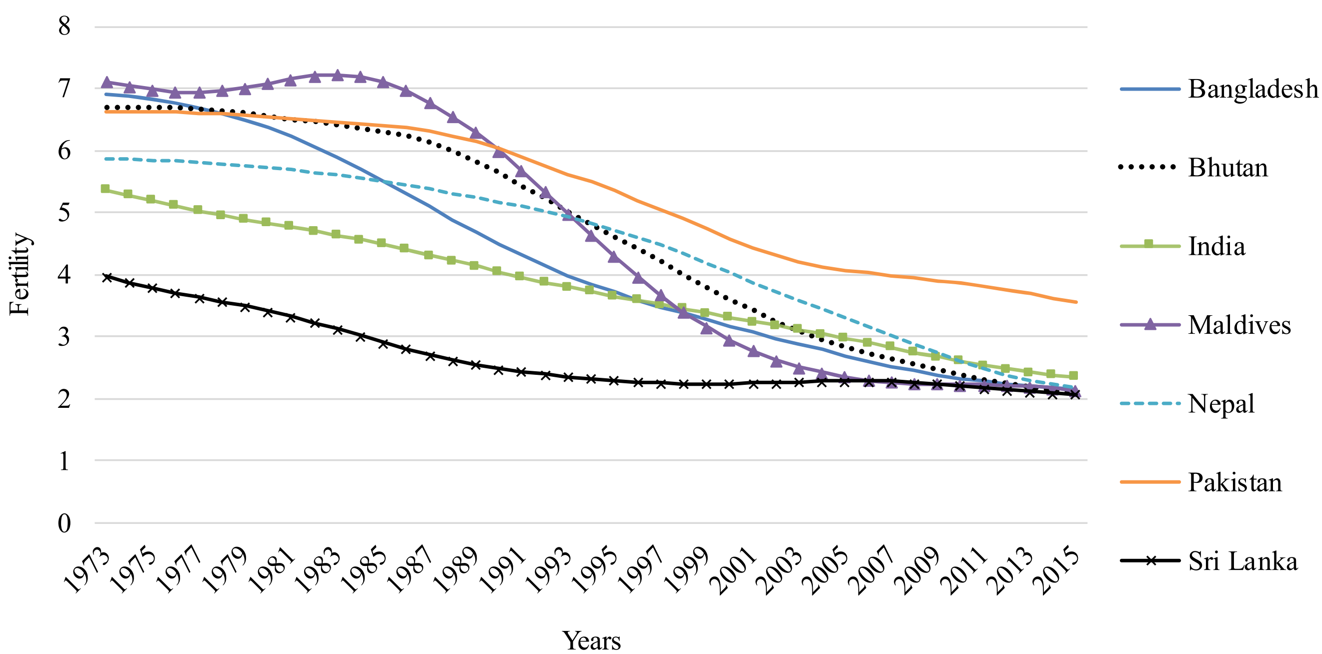

Fig. 2 Fertility rates in South Asian countries. Source: World Bank

T_N is time spent on consumption of non-health items, and V_t is a set of other variables which affect C_t. Y_t is total income, I_t is unearned income, w_t is wage rate, and T_{HR} is time or hours of work. Equation (2) represents "production function" for child health.

Consumers maximize their utility function subject to resource constraint, including both budget and time constraints. Thus, the budget constraint Eq. (4) can be expressed as follows:

$$Y_t = I_t + w_t T_{HR} = P_{Mt} M_t + P_{Ct} C_t \tag{6}$$

where P_{Mt} is price of material inputs and P_{Ct} is price of C_t (i.e., non-health items). The budget constraint equation equates the non-wage (I_t) and wage earnings ($w_t T_{HR}$) to the spending on health care services ($P_{Mt} M_t$) and other commodities ($P_{Ct} C_t$). Time constraint Eq. (5) implies that total time (T) is split into time spent on leisure (T_L), time spent on health investment (T_M), and time spent on earning wage (T_{HR}).

By substituting Eqs. (2) and (3) into Eq. (1), we obtain utility function as follows:

$$U_t = U(H(M_t, T_M, Z_t), C(N_t, T_N, V_t)) \tag{7}$$

By combining Eqs. (5) and (6), we get the combined budget and time constraint Eq. (8):

$$I_t + w_t (T - T_M - T_N) = P_{Mt} M_t + P_{Ct} C_t \tag{8}$$

Or

$$I_t + w_t T = (P_{Mt} M_t + w_t T_M) + (P_{Ct} C_t + w_t T_N)$$

The representative individual maximizes the utility function (7), subject to the budget constraint (8). Following the notion of the Marshallian system, we can write the utility maximization problem as follows:

Max

$$U_t = U(H(M_t, T_M, Z_t), C(N_t, T_N, V_t))$$

$s.t.$

$$w_t T + I_t = (P_{Mt} M_t + w_t T_M) + (P_{Ct} C_t + w_t T_N)$$

In Lagrange form, this maximization problem can be written as follows:

$$\mathcal{L} = U(H(M_t, T_M, Z_t), C(N_t, T_N, V_t)) + \lambda (w_t T + I_t - (P_{Mt} M_t + w_t T_M) - (P_{Ct} C_t + w_t T_N)) \tag{9}$$

The first-order conditions (FOCs) are as follows:

$$\frac{\partial \mathcal{L}}{\partial M_t} = U_H \left(\frac{\partial H}{\partial M_t} \right) - \lambda P_{Mt} = 0 \tag{10}$$

$$\frac{\partial \mathcal{L}}{\partial T_M} = U_H \left(\frac{\partial H}{\partial T_M} \right) - \lambda w_t = 0 \tag{11}$$

$$\frac{\partial \mathcal{L}}{\partial N_t} = U_C \left(\frac{\partial C}{\partial N_t} \right) - \lambda P_{Ct} \left(\frac{\partial C}{\partial N_t} \right) = 0 \tag{12}$$

$$\frac{\partial \mathcal{L}}{\partial T_N} = U_C \left(\frac{\partial C}{\partial T_N} \right) - \lambda w_t = 0 \tag{13}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = w_t T + I_t - (P_{Mt} M_t + w_t T_M) - (P_{Ct} C_t + w_t T_N) = 0 \tag{14}$$

The above equations can alternatively be written as follows:

$$U_H \left(\frac{\partial H}{\partial M_t} \right) = \lambda P_{Mt} \tag{15}$$

$$U_H \left(\frac{\partial H}{\partial T_M} \right) = \lambda w_t \tag{16}$$

$$U_C \left(\frac{\partial C}{\partial N_t} \right) = \lambda P_{Ct} \left(\frac{\partial C}{\partial N_t} \right) \tag{17}$$

$$U_C \left(\frac{\partial C}{\partial T_N} \right) = \lambda w_t \tag{18}$$

$$w_t T + I_t = (P_{Mt} M_t + w_t T_M) + (P_{Ct} C_t + w_t T_N) = 0 \tag{19}$$

Solving Eqs. (15) through (19) and applying some algebra, we can obtain the demand function for material inputs M_t as follows:

$$M_t^* = M^*(P_{Mt}, P_{Ct}, w_t, I_t, Z_t, V_t) \tag{20}$$

By putting this equation into child health equation, we get

$$H_t = H(M_t^*, T_M, Z_t)$$

or

$$H_t = H(M^*(P_{Mt}, P_{Ct}, w_t, I_t, Z_t, V_t), T_M, Z_t) \tag{21}$$

The factors which affect child health (measured by child mortality) are the price of the material inputs (P_{Mt}), the price of other consumption commodities (P_{Ct}), the wage rate (w_t), and non-wage income (I_t). Employment has direct link with wage rate; therefore, wage rate will be proxied by employment status. There are also other important exogenous factors which affect child health such as human capital (HK), per capita GDP (Y), fertility rate (FER), urbanization (URB), and carbon dioxide emission

Table 1 Child mortality under-five by UNICEF region

	1990	2016	Change (%) 1990–2016	Annual rate of reduction (%)
Sub-Saharan Africa	181	78	− 56.91	3.2
Middle East and North Africa	66	24	− 63.64	3.9
South Asia	129	48	− 62.79	3.8
East Asia and Pacific	57	16	− 71.93	4.8
Latin America and Caribbean	55	18	− 67.27	4.4
North America	11	6	− 45.45	2.0
Europe and Central Asia	31	10	− 67.74	4.5
World	93	41	− 55.91	3.2

Source: UNIGME (2017)

(CE). Therefore, we will estimate the following augmented version of our model:

$$H_t = H(HK, Y, FER, URB, CE) \tag{22}$$

If child health (H) is measured by child mortality (CM), then the above model in econometric form can be expressed as follows:

$$cm_{it} = \alpha_0 + \alpha_1 hk_{it} + \alpha_2 y_{it} + \alpha_3 fer_{it} + +\alpha_4 urb_{it} + \alpha_5 ce_{it} + \varepsilon_{it} \tag{23}$$

where $i = 1\ldots5$ represents cross-sectional units and $t = 1973\ldots2015$ is time period. The lowercase letters indicate that the variables are taken in natural logarithm form. The theoretical justification of the variables is given below turn by turn:

- *Human capital*: Parents' education helps to reduce child mortality as educated parents have better knowledge of child health (Hobcraft et al. 1984; Mohammad and Tabassum 2016; Perez-Moreno et al. 2016). They also use health care services in a better way. They prefer small family size and increase family resources, which, in turn, positively affect the health of family members. It helps to decrease child mortality. A substantially lower level of mortality is experienced in children with the most educated parents than children born into households where neither parent is educated. So there exists a negative relation between parents' education and child death (Currie 2009). Thus, the coefficient α_1 is expected to be negative, i.e., $\alpha_1 < 0$.
- *Income level*: Income decreases child mortality because when income increases, living standard also increases so people are extra worried about quality of life including quality of their children (Perez-Moreno et al. 2016; Tanaka 2015; Erdogan et al. 2013). Therefore, they focus more on quality of children not on quantity of children. They will spend more income on their education and health, which will help to reduce child mortality (O'Hare et al. 2013). Thus, the coefficient α_2 is contemplated to be negative, i.e., $\alpha_2 < 0$.
- *Fertility*: Fertility positively affects child mortality because high fertility decreases birth interval which directly affect mother's health and child's health also (Sachs and Malaney 2002; Bongaarts 1987; Verhulst 2016; Richards and Vining 2016; Hanmer et al. 2003). High fertility rate accelerates population growth, which decreases development process in the country, and the benefits of development do not reach to the people. It adversely affects the standard of living of the people. In turn, low fertility rate decreases population growth, which leads to high economic welfare. It improves quality of life and hence decreases child mortality (LeGrand and Phillips 1996). Empirical literature has shown that high fertility increases child mortality (McCord et al. 2017). The coefficient of fertility is contemplated to be positive, i.e., $\alpha_3 > 0$.
- *Urbanization*: Urbanization also helps to reduce child mortality as better preventive and curative health services like hospitals, safe filtered and chlorinated drinking water, better sewerage and sanitation systems, draining swamps, pasteurized milk, and vaccination facilities are easily available in urban areas (Shehzad 2004; Hanmer et al. 2003; Matteson et al. 1998). Hospitals help in curing different kinds of children diseases like cholera, diarrhea, and malaria. Thus, child mortality is less in urban areas than in rural areas due to better health facilities (Agha 2000). The coefficient of urbanization is expected to take negative value, i.e., $\alpha_4 < 0$.
- *Environment quality*: Children are vulnerable to polluted environment as lack of adequate sanitation, impure water, contaminated hazards, ultraviolet radiation, disease vectors, and degraded ecosystems are all major environmental risk elements for children. Pollution and environmental hazards like carbon emission are major contributors to illnesses, disability, childhood deaths from acute respiratory disease, physical injuries, diarrheal diseases, poisonings, insect-borne diseases, and prenatal infections (Fitrianto et al. 2016). The greater the carbon dioxide emission, the greater the child mortality because it causes

air pollution that increases diseases among children like respiratory illness and asthma which do not let children to celebrate their fifth birthday (Chay and Greenstone 2003). Thus, the coefficient α_5 is expected to take a positive sign, i.e., $\alpha_5 > 0$.

Data and estimation of model

Data overview

Annual data is collected for five South Asian countries which include Bangladesh, India, Nepal, Pakistan, and Sri Lanka for the period 1973 to 2015. Afghanistan, Bhutan, and Maldives are not included in the analysis due to unavailability of data for all variables for these countries. Child mortality is child death rate under-five years (per 1000 live births). Human capital is an index of years of schooling and rate of returns to education. Income is measured by per capita GDP. Fertility rate is average number of children born to a woman in her life span. Urbanization is percentage of population living in urban areas. Environmental degradation is proxied by carbon emission (metric tons per capita). Data is taken from Penn World Table (PWT), Food and Agriculture Organization (FAO), and World Development Indicators (WDI) of World Bank.

Table 2 provides the summary statistics of all variables. All dispersion indicators, i.e., standard deviation, quartile deviation, and interquartile range, show that per capita income has the largest variation in the data followed by child mortality rate. Urbanization also has high variation in the data. Mean value of mortality rate indicates that in South Asia, infant death rate is 105.82 deaths per 1000 live births under age of 5 during 1973 to 2015 and this death rate ranges between 10 and 256.2 deaths. Mean value of fertility rate shows that in South Asia, on average, a woman has given birth to 4.08 children during 1972 to 2013 and this birth rate ranges between 1.92 and 6.90 births. All other variables have the same interpretation. Table 3 presents correlations among variables. Human capital, income, and urbanization are negatively correlated with child mortality, which implies that when human capital, income, and urbanization increase, child mortality decreases. In turn, fertility has positive correlation with child mortality. It indicates that when fertility increases, child mortality will also increase. These results corroborate theoretical justifications of the selection of the variables.

Estimated results

Cross-sectional dependence test

Examining cross-sectional dependence in panel model is important because in last few decades, child mortality rates of the countries have decreased, which entails strong linkages between cross-sectional units. Literature has highlighted variety of tests for cross-section dependence in panel data, e.g., Breusch and Pagan (1980) LM test, Pesaran (2004) scaled LM test, Baltagi et al. (2012) bias-corrected scaled LM test, and Pesaran (2004) CD test.

Consider the traditional panel data model:

$$y_{it} = \alpha_i + \beta'_{it} x_{it} + u_{it} \tag{24}$$

For $i = 1\ldots N$ and $t = 1\ldots T$ where β is a $K\ x\ 1$ vector of parameters, x_{it} is a $K\ x\ 1$ vector of regressors, and α_i is time-invariant individual nuisance parameters. The null hypothesis of no cross-section dependence may be expressed as follows.

$$H_0 : \rho_{ij} = Corr\left(\mu_{it}, \mu_{jt}\right) = 0 \text{ for } i \neq j.$$

where ρ_{ij} is correlation coefficient between the disturbances in cross-section units i and j. The null hypothesis states that there is no cross-sectional dependence. The results of various cross-sectional dependence tests are provided in Table 4. The null hypothesis is rejected at conventional significance levels, which indicates the presence of cross-sectional dependence.

Panel unit root test

Since cross-section units are not independent, we cannot apply first-generation panel unit root tests to test the stationarity of the variables as these tests do not take into account cross-sectional dependence. We will apply second-generation panel unit root test of Pesaran (2007).

Table 2 Descriptive statistics of the variables

	Mean	Minimum	Maximum	Standard deviation	Quartile deviation	Interquartile range
Mortality rate, under-5 (per 1000 live births)	105.82	10	256.20	62.53	50.12	100.25
Human capital	1.70	1.04	2.89	0.50	0.29	0.58
Fertility rate (births per woman)	4.08	1.92	6.90	1.44	1.27	2.54
Per capita GDP (constant 2010 US$)	828.26	273.05	3637.53	619.00	283.88	567.76
Urbanization (% of total population)	21.82	4.19	38.75	8.36	5.45	10.89
Carbon emissions (metric tons per capita)	0.45	0.020	1.63	0.36	0.26	0.53

Table 3 Correlation matrix

	Child mortality	Human capital	Fertility	Income	Urbanization	Carbon emissions
Child mortality	1					
Human capital	− 0.94 (− 41.99)***	1				
Fertility	0.89 (29.52)***	− 0.86 (− 24.61)***	1			
Income	− 0.87 (− 26.11)***	0.92 (33.66)***	0.74 (15.98)***	1		
Urbanization	− 0.19 (2.91)***	0.34 (5.27)***	− 0.26 (− 4.01)***	0.47 (7.75)***	1	
Carbon emissions	− 0.38 (− 6.02)***	0.51 (8.71)***	− 0.41 (− 6.54)***	0.69 (13.80)***	0.87 (27.97)***	1

t values are given in parentheses

****t* value is statistically significant at 1% level

Pesaran (2007) provides the following cross-sectionally augmented Dickey-Fuller (CADF) unit root test:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + c_i \overline{y}_{t-1} + d_i \Delta \overline{y}_t + \upsilon_{it} \tag{25}$$

where $\overline{y}_{t-1} = (1/N)\sum_{i=1}^{N} y_{i,t-1}$, $\Delta\overline{y}_t = (1/N)\sum_{i=1}^{N} \Delta y_{i,t}$, and υ_{it} is the regression error, which are assumed to be not serially correlated. This test is based on the *t* ratio of the OLS estimate $\hat{\rho}_i$. Pesaran (2007) suggests the following augmented version of IPS test:

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

where $CADF_i$ is the statistics of the *i*th cross-section unit provided by the *t* ratio of $\hat{\rho}_i$ in the above regression.

If the residuals are serially correlated, more lags of $\Delta y_{i,\ t}$ and $\Delta\overline{y}_t$ need to be incorporated in the regression. For an $AR(p)$ process, the following CADF regression will be estimated:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + c_i \overline{y}_{t-1} + \sum_{j=0}^{p} d_{i,j} \Delta \overline{y}_{t-j} + \sum_{j=0}^{p} \beta_{i,j} \Delta y_{i,t-j} + \upsilon_{i,t} \tag{26}$$

Table 5 provides the panel unit root results, which reveal that all variables are not stationary at levels but they are stationary at their first differences. This finding reveals the possibility of cointegration among variables.

Table 4 Cross-section dependence (CD) test

Test	Statistics	*p* value
Breusch-Pagan LM	134.5589***	0.0000
Pesaran scaled LM	26.7342***	0.0000
Bias-corrected scaled LM	26.6747***	0.0000
Pesaran CD	− 3.4926***	0.0005

***The value is statistically significant at 1% level

Panel cointegration test

We have used Pedroni (1999, 2004) panel cointegration test to test cointegration. Table 6 provides the panel cointegration results. Three out of four statistics reject the null hypothesis of no cointegration, which implies that cointegration exists among variables, i.e., long-run relationship holds between all variables.

Estimated results

To get long-run parameter estimates, we have estimated our model using Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) techniques. Table 7 provides the estimated results. The results reveal that human capital has statistically significant negative impact on child mortality. Estimated value of the coefficient shows that if human capital increases by 1%, child mortality will decrease by 0.337% in FMOLS estimations. It validates the hypothesis that human capital helps in reducing infant child mortality in long run (Richards and Vining 2016; Aslam and Kingdon 2012; Khadka et al. 2015; Tanaka 2015). As was theoretically expected, fertility rate appears with statistically significant positive coefficient. It indicates that high fertility rate increases child mortality in South

Table 5 Pesaran (2007) panel unit root test results

	Level		First difference
cm_{it}	− 0.675	Δcm_{it}	− 2.400***
hk_{it}	− 1.999	Δhk_{it}	− 5.695***
fer_{it}	− 0.482	Δfer_{it}	− 3.209***
y_{it}	− 1.851	Δy_{it}	− 5.787***
urb_{it}	− 1.288	Δurb_{it}	− 5.998***
ce_{it}	− 1.229	Δce_{it}	− 5.883***

For level and first difference series, critical values for 1% are − 2.410 and − 2.360, respectively

***A rejection of the null hypothesis at 1% level

Asia. The value of coefficient shows that when fertility rate increases by 1%, child mortality increases by 0.539% (0.642) in FMOLS (DOLS) estimations. These results support the findings of Richards and Vining (2016) and Oloo (2005).

Income has statistically significant negative impact on infant mortality. It implies that higher level of income increases standard of living and brings about better medical facilities, which helps to reduce child mortality. The estimated result implies that 1% increase in per capita GDP will decrease child death rate by 1.444% (1.119) in FMOLS (DOLS) estimates. These results support the findings of Perez-Moreno et al. (2016), Brock et al. (2015), Richards and Vining (2016), McCord et al. (2017), and Erdogan et al. (2013). High income means high potential to sustain high-quality childbearing. Therefore, it increases demand for fewer but healthy children. The coefficient value of urbanization is negative and statistically significant. It shows that 1% increase in urbanization will decrease child mortality rate by 0.071% (0.228) in FMOLS (DOLS) estimation. It means that urbanization reduces child mortality because better health facilities are available in urban areas compared to rural areas (Matteson et al. 1998). Finally, carbon emission has statistically significant positive effect on infant mortality, which indicates that carbon emission adversely affects child health through different diseases. Estimated value of the coefficient suggests that 1% increase in carbon emission will increase child death by 1.254% (1.029) in FMOLS (DOLS) estimations. High values of R^2 and adjusted R^2 imply that the regression models fit the data well.

Robustness analysis

Theory has highlighted some other determinants of child mortality. For robustness analysis, we have taken trade openness, immunization, population density, food security, and life expectancy as some other possible determinants of infant mortality. Trade openness helps in increasing states' revenues which increases government spending on health-related projects which helps to decrease child death rate. It also generates employment which increases per capita income which helps to decrease child mortality (Herzer 2017). The impact of immunization on child mortality is expected to be negative. Children who are immunized against diseases like diphtheria, pertussis (or whooping cough), tetanus (DPT), and measles live a healthy life. Densely populated areas produce infectious diseases, which adversely affects the child's health and hence increases child mortality (Root 1997). Food security helps to reduce child mortality as availability of food decreases malnutrition which improves health of children and decreases infant mortality (Pelletier et al. 1995; Pelletier and Frongillo 2003).

Table 6 Pedroni panel cointegration test

	Statistic	Prob.
Panel v-Statistic	− 1.40756	0.9204
Panel rho-Statistic	− 3.6787	0.0001*
Panel PP-Statistic	− 7.32677	0.000*
Panel ADF-Statistic	− 3.16068	0.0008*

*The value is statistically significant at 1% level

Table 7 Estimated results (1973–2015)

Variables	FMOLS	DOLS
Human capital	− 0.337*** (− 41.886)	− 0.288 (− 0.922)
Fertility	0.539*** (68.103)	0.642*** (5.560)
Income	− 1.444*** (− 202.329)	− 1.119*** (− 7.763)
Urbanization	− 0.071*** (− 26.138)	− 0.228* (− 1.834)
Carbon emissions	1.254*** (125.591)	1.029*** (6.075)
R^2	0.991	0.997
Adjusted R^2	0.990	0.995
S.E. of regression	0.078	0.053
Observations	200	200

t values are given in parentheses

*** (*) show that value is statistically significant at 1% (10%) level

Estimated results of robustness analysis are provided in Table 8. Human capital, fertility, income, and carbon emissions maintain their signs and significance levels. As was theoretically expected, trade openness, measured by exports plus imports as percentage of GDP, has negative impact on child mortality. FMOLS result suggests that 1% increase in trade openness will decrease child mortality by 0.146% (column 2). The same results hold when the model is estimated by DOLS. This result supports the findings of Frey and Field (2000), and Herzer (2017) that trade liberalization reduces child mortality. The effect of immunization on child morality is negative both in FMOLS and DOLS estimations. This result supports the findings of Hanmer et al. (2003), Mondal et al. (2009), and Richards and Vining (2016) that immunization decreases child mortality. Statistically significant coefficient of immunization implies that 1% increase in immunization will decrease child mortality rate by 0.036% (0.035) in FMOLS (DOLS) estimations. Immunization decreases child mortality as availability of antibiotics and vaccination improve child's health and decrease child's death rate.

Population density has statistically significant positive coefficient which indicates that population density increases child mortality rate in South Asia. Estimated value of coefficient implies that 1% increase in population density increases child mortality rate by 0.430% (0.961) in FMOLS (DOLS) estimation. Food security, proxied by availability of protein, shows negative effect on child mortality. Estimated value of the coefficient of protein indicates that 1% increase in the

Table 8 Fully Modified OLS and Dynamic OLS estimation (1973–2015)

	FMOLS (1)	FMOLS (2)	DOLS (3)	DOLS (4)
Human capital	− 0.151 (− 0.836)	− 0.395 (− 13.793)***	− 1.374 (− 3.926)***	− 1.719 (− 5.563)***
Fertility	1.999 (18.592)***	1.384 (87.490)***	2.150 (11.342)***	0.988 (9.753)***
Income	− 0.057 (− 0.636)	− 0.965 (− 37.993)***	− 0.357 (− 3.279)***	− 0.704 (− 4.840)***
Carbon emissions	0.385 (3.356)***	0.701 (12.007)***	0.728 (5.015)***	1.186 (6.432)***
Trade openness	− 0.006 (1.139)	− 0.146 (− 51.443)***	− 0.006 (− 2.950)***	− 0.005 (− 3..601)***
Immunization	− 0.036 (− 1.707)*	− 0.006 (− 2.118)**	− 0.035 (− 3.264)***	− 0.019 (− 2.499)**
Population density	0.430 (3.416)***		0.961 (8.157)***	
Food security (protein)	− 0.005 (− 2.015)**		− 0.005 (− 0.984)	
Life expectancy		− 2.221 (− 17.477)***		− 2.024 (− 10.390)***
R^2	0.813	0.939	0.998	0.997
Adjusted R^2	0.806	0.938	0.994	0.994
S.E. of regression	0.353	0.19	0.056	0.58

t values are given in parentheses

*** (*) implies that the value is statistically significant at 1% (10%) level

availability level of protein will decrease child death rate by 0.005% both in FMOLS and in DOLS (Ren 1995). Life expectancy is also considered an important factor that affects mortality rate. Therefore, model is also estimated by including life expectancy variable. The results show that life expectancy has statistically significant negative impact on child mortality. It indicates that when life expectancy increases, child mortality decreases. The values of coefficient imply that 1% increase in life expectancy will decrease child death by 2.221% (2.024) in FMOLS (DOLS) estimations (Cutler et al. 2006). Again, high values of R^2 and adjusted R^2 imply that the regression models fit the data well.

Conclusion

The study empirically examines the effects of socio-economic (human capital), macroeconomic (per capita GDP), demographic (fertility rate, urbanization), and environmental variables (carbon emissions) on child mortality in South Asia. Panel data is used for five South Asian countries, i.e., Bangladesh, India, Nepal, Pakistan, and Sri Lanka, for the period 1973 to 2015. First, it is found that all variables have unit roots at levels but they become stationary at first differences. Second, it is found that the variables have long-run cointegrating relationship. Finally, FMOLS and DOLS techniques have been used to find the long-run estimates of the variables. The results show that human capital, per capita income, and urbanization have statistically negative effect on child mortality; that is, child mortality decreases with the increases in education, income level, and urbanization. In turn, high fertility rate and carbon emissions have statistically significant positive effect on child mortality, which implies that child mortality increases with the increase on fertility rate and carbon emissions. The results of robustness analysis show that trade openness, immunization, food security, and high life expectancy decrease child mortality while population density increases child mortality.

The study has some important policy implications. Human capital decreases child mortality. In South Asia, illiteracy rate is very high. Thus, there is a need to invest in education, especially in female education. As a result, people will care about child health and they will prefer quality over quantity of children. It will help to decrease child mortality. High fertility rate also increases child mortality. In South Asia, fertility rate is very high because people use their children as a financial instrument to secure their old-age (Zakaria et al. 2017). Thus, to decrease fertility rates in South Asian countries, government should develop capital market and should provide people new financial instruments for their old-age security. Further, social security benefits should be provided to people to discourage high child birth rate. It will help to decrease child mortality. High per capita income decreases child mortality. Thus, by increasing economic growth, governments can reduce fertility rate in the region. Child mortality rate is less in urban areas due to better health facilities. If governments provide such facilities to rural areas, it will decrease child mortality rate in rural areas also. Further, governments should take steps to increase trade openness as it also helps to reduce child mortality. Governments should expand immunization program to reduce child mortality. High population density increases child mortality. To avoid the problem of population density in urban areas, government should provide all facilities to rural areas as well. Governments should also take steps for the availability of adequate food for children as food security helps to decrease child mortality.

An important limitation of the study is that it has excluded Afghanistan, Bhutan, and Maldives from the analysis due to non-availability of data for these countries. Future work can be extended by taking data of these countries. Further, future work can also be extended by incorporating some other variables like health expenditures, domestic and foreign investment, and financial development.

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