Turkish Economic Review
www.kspjournals.org
Volume 5 June 2018 Issue 2

Health and economic growth in Sudan: Cointegration and Granger causality analysis (1969-2015)

By Elwasila S. E. MOHAMED [†]

Abstract. The relationship between human health and economic growth is complex. Its analysis is further complicated by the indicators used to measure health as indirectly observed. Improved health status requires increases in supply and demand for health care services driven by both economic and non-economic factors including GDP, GDP Per capita, inflation, population, fertility rates, life expectancy at birth, morbidity and mortality rates as well as education. On the other hand, health improvements measured for example by reductions in child mortality rates and increases in life expectancy rates have proven positive effects on economic growth. This study sought to explain the interplay between the state of health and economic growth in Sudan. The study is mainly an empirical investigation employing the econometric methods of Johansen cointegration test, the vector error correction modeling (VECM) and Granger causality analysis using annual time series data for the period 1969-2015. The cointegration test shows that a long-run equilibrium relationship exists between health status and economic growth. The VECM results show that health expenditure, under-five mortality and immunization have significant positive effects on economic growth in the long run, while total investment and CO_2 emissions have no significant effect on GDP. In the short run, total investment and CO_2 emissions have significant negative effect on GDP though in two years period. In the short run, GDP is mostly and significantly affected by total health expenditure and immunization but not by the under-five mortality rates. The error correction term has the correct negative sign showing that the dependent variable GDP converges to steady state equilibrium at speed of 32%. Granger causality analysis shows a unidirectional relationship running from GDP to health expenditure, while a unidirectional relationship running from under-five mortality rate to GDP is established. CO_2 emissions are found to cause GDP with no sign of feedback effect. The study recommends that government should ensure macroeconomic stability in terms of stable growth, increase the resources to the health sector in order to achieve the under-five mortality MDG and effective coordination with donors to ensure full coverage of children immunization.
Keywords. Health, Health expenditure, Economic growth, Cointegration, VECM, Sudan.
JEL. H51, I10, F43.

1. Introduction

Sudan has been classified as lower middle income country according to the World Bank classification and definition. Gross domestic product per capita (GDPP) at current US$ was estimated at US$ 481 in 1990, increased to declined to US$ 352.5 in 2000 and in 2010 it was US$ 1451.5 increased to US$ 1806 in 2012 with an annual growth rate of 0.58%. This growth could also be attributed to secession of South Sudan resulted in a population growth rate of -3% in 2012. In 2015 GDPP was estimated at US$ 2414. Gross domestic product at current US$ was estimated at US$ 15,291.5 in 1989, declined to US$ 12,408.6 in 1990, it was US$ 12,257.4 in 2000, grown to US$ 65,634.1 in 2010. In 2015 GDP was US$ 97,156. Despite the remarkable total GDP growth since 2005,

[*†] University of Khartoum, Faculty of Economic & Social Studies, Sudan.
. +00249919268733
. elwasila.sem@gmail.com

poverty is wide spread in Sudan. The estimates from the Central Bureau of Statistics (CBS, 2009) showed that 46.5% of Sudanese live under the national poverty line defined as 103 Sudanese pounds SDG per month per head (equivalent to 44.59 US$ in 2009). In addition, recent estimates based on 2009 survey figures show that to reduce poverty and hunger by 50% by 2015, real per capita income would have to grow by 2.2% per annum given the level of inequality. Secession of South Sudan in 2011 resulted in economic downturn in 2012, with significant decline of government revenues, depreciating value of the national currency and soaring inflation, which significantly affected the welfare of a growing number of poor people. For example, the actual budget allocation for social development, including health and education, in 2012 was 2.1% of total spending and it was projected to decline to 1.9% in 2013 (AfDB, 2013).Total expenditure in health from all sources has been the lowest amongst the countries of the Eastern Mediterranean Region Office EMRO of the WHO. The low performance of Sudan in health is reflected by a low achievement in the components of the human development index (HDI). As it is well known the HDI includes main health and education status indicators together with gross national product per capita which has a proven positive relationship with the demand for health and health status of individuals in general. Thus, a low HDI score nationally or regionally indicates low performance of all other economic and non-economic factors that contribute to health throughputs and outcomes. The Sudan score in the HDI was 0.43 in 1990, increased to 0.50 in 2000, increased to 0.60 in 2010 placing Sudan as 171 out of 186 countries and as 39 out of 41 African countries. In 2015, Sudan HDI score was 0.66. The relatively low HDI scores of Sudan could be attributed to many factors including low GDP per capita, large and severe poverty, large inequality of income distribution, low spending on health by the government, lack of population access to basic services such as safe drinking water and satiation, along with long term civil war and armed conflicts brining about massive displacement and loss of livelihoods as well as high unemployment rate among the young (25%) and graduates (50%) which add to compounding poverty and inequality.

Increasing demand for health and health care services in Sudan is driven by both economic and non-economic factors chief among them being GDP, GDPP, inflation, population, fertility rates, life expectancy at birth, morbidity and mortality rates mainly from communicable diseases but also increasing prevalence of non-communicable diseases, as well as education. On the other hand, achievements in health improvements measured for example by reductions in child mortality rates, declines in maternal mortality ratio, declines in fertility rates, and increases in overall life expectancy is expected to have positive effects on economic growth in the long run. Against this background, this study sought to explain the interplay between the state of health and economic growth in Sudan. The study is mainly an empirical investigation which employs the econometric techniques of the Augmented Dickey-Fuller (ADF) unit root test for stationary of the time series, Johansen cointegration test, the vector error correction modeling (VECM), and Granger causality analysis.

2. Objectives

i. Investigate the dynamic interplay and causal relationships between economic growth and the state of health in Sudan.
ii. Draw some policy implications and recommendations for how to strengthen the role of health on economic growth and vice versa.

3. Literature review and theoretical framework

The WHO defines health as state of complete physical, metal and social wellbeing and not merely the absence of disease of infirmity. This could never be fully operationalised a definition, but it is a moral guidance for governments to

strive constantly to improve the health of population through various means and policies. The state of health of individuals and of the population in general is influenced by genetic and environmental factors, cultural and socioeconomic conditions, as well as the health care services that are available to prevent and to treat illness and diseases. Some of these factors are under control of governments and individuals and some of them are beyond the control of individuals. Nevertheless, governments invest in health as investment good for the sake of improving productivity of people and for social welfare improvement in general. Government expenditure on health care partially determines availability of health care services which in turns determines accessibility to health care services particularly by the poor people. But, government expenditure on health care affects the status of health of population with a complicated transmission mechanism and interplay of cultural, environmental, economic, population and demographic factors which need to be taken in account when planning the optimal amounts of health expenditures. Good or improved health then affects both productive and non-productive activities pursued by individuals and in this sense individuals demand health as a production and consumption good. Assuming that health expenditure would be reflected into good health, productivity of individual will be higher, which positively affects GDP and hence GDP per capita given population growth rates. Improved GDP per capita feedbacks positively into individual's ability to spend and invest in health care and health and collectively improved health status of the society. This comes in the context of human capital theory which states that poor countries remain poor because of low GDP and GDP per capita, hence low consumption and saving and low investment in health, thus low health level, and as a result low productivity and again low GDP and GDP per capita. This gives about the vicious cycle of low levels of GDP per capita and low health levels however health is measured. Thus, one way to break such viscous cycle is to enhance growth of income with equity in order to increase savings and spending on health services in expectations of health improvement and therefore productivity and incomes once again.

The contribution of health care on health is much debated and the outcomes are yet not conclusive. Plümper & Neumayer (2013) argue that open, fair, and equitable access to health care for all citizens will lower overall mortality rates by enabling the very poor and chronically ill to satisfy their demand for necessary health care. But as the authors noted access to health care by all citizens will also result in higher costs, not least by also increasing demand for irrelevant, unnecessary, and inefficient health care. However, they acknowledge that this undesirable demand and its associated costs can be reduced by increasing out-of-pocket contributions paid for by patients. Yet, if the freed-up resources are used for more life-saving measures, then higher out-of-pocket contributions will lower overall mortality rates though this effect depends on what happens to total health spending. Their theoretical arguments are confirmed by an econometric analysis of aggregate mortality rates in OECD countries over the period 1984 to 2007. Farahani, Subramanian & Canning (2009) used the second National Family Health Survey (NFHS-2) of India to estimate the effect of state public health spending on mortality across all age groups, controlling for individual, household, and state-level covariates using a state's gross fiscal deficit as an instrument for its health spending. Their study shows a 10 % increase in public spending on health in India decreases the average probability of death by about 2%, with effects mainly on the young, the elderly, and women. They also indicate that other major factors affecting mortality are rural residence, household poverty, and access to toilet facilities. Such positive health outcomes should promote economic growth.

Filmer, & Pritchett (1999) use cross-national data to examine the impact of both public spending on health and non-health factors in determining child (under-5) and infant mortality. They find that the impact of public spending on

health is quite small, with a coefficient that is typically both numerically small and statistically insignificant at conventional levels indicating that independent variations in public spending explain less than one-seventh of 1% of the observed differences in mortality across countries. Their estimates imply that for a developing country at average income levels the actual public spending per child death averted is $50,000–100,000. They argue that these estimates contrast to the typical range of estimates of the cost effectiveness of medical interventions to avert the largest causes of child mortality in developing countries, of $10-4000. Nevertheless, they show that whereas health spending is not a powerful determinant of mortality, 95% of cross-national variation in mortality can be explained by a country's income per capita, inequality of income distribution, extent of female education, level of ethnic fragmentation, and predominant religion. Baurne (2012) using both infant mortality rates IMR and child mortality rate CMR as indictors of aggregate health level finds that IMR is influenced by health care utilization with a negative coefficient of -0.004 and GDP with a negative coefficient of -1.96, and these two factors account for 55% of the variance in IMR, while CMR is found to be correlated with log poverty with a positive coefficient of 0.22 and GDP per capita with a negative coefficient of -2.66. Their study generally shows that during economic recession IMR and CMR decline and the opposite is true in periods of economic growth. Zakir, & Phanindra (1999) empirically tests for factors affecting infant IMR based on a cross-sectional model covering 117 countries for the year 1993. Their results show that fertility rates, female participation in the labour force, per capita GNP, and female literacy rates significantly affect IMR. Government expenditure on health care was found as playing no major role in determining IMR. One reason for the ineffectiveness on health expenditure on aggregate health outcome measures is possibility that not all health expenditure is necessarily reflected in increase in the quantity consumed of health care. One reason could be inflation rate and population growth. For example, Virts & Wilson (1984) examined the contribution of health care price inflation to rising health care spending in the USA using the National Hospital Input Price Index and the National Nursing Home Input Price Index applied to the hospital and nursing home sectors respectively. They find that change in price account for a significant portion of changes in health care spending to the amount of 63 percent in 1965-81, 45.0 percent in 1965-72 and for 68 percent in 1972-81. Population growth accounted for 9.0%, 9.2%, and, 9.0% for the period 1965-81, 1965-72 and 1972-81 respectively. Meanwhile per capita use increases was found to account for 27.4%, 45.8% and 22.5% for the period 1965-81, 1965-72 and 1972-81 respectively.

A fact is that health expenditure in both high income and low income countries has been in increasing trends as percentage of GDP as well as per capita. For example, Getzen (2014) states that expenditures on health care have increased rapidly in all developed Organization for Economic Cooperation and Development countries over the last five decades, with total spending rising more than 1,000% in most countries manly due to inflation, demography, technology and income. However, with examples from developed countries the author demonstrates that the effect of GDP on health expenditure varies with long time and lags. On the other side of the story of relationship, the same could be true for the feedback effect from health expenditure to GDP growth. The well known and widely quoted and debated argument has been the inverse relationship between income and mortality was that of Preston (1975). The widely and generally agreed argument is that good health measured generally through decline in mortalities or conversably as increases in life expectancy has a proven positive effect on economic (Barro, 1996; 2013; Sachs & Warner, 1997; and Weil, 2013). The relationship is even found to be dynamically positive in that good health enhances economic growth and enhanced economic growth feeds back positively to improve health although income growth may have negative effect on health in the short run (Weil, 2005). Sachs & Warner (1997) used the life expectancy as

indicator of health status and found quadratic relationship between health and economic growth. Their study concludes that human capital in terms of health increases economic growth but at a decreasing rate. Bloom, Canning & Sevilla (2004), estimated a neoclassical production function involving economic growth, work experience and health using the 2SLS method. They show that good health has a positive, sizable and statistically significant effect on aggregate output even when experience of workforce is controlled for. Their study finds that improvement of one year in life expectancy result in an increase of output by 4 percent. Yet, the authors acknowledge that aggregate data exhibit a great deal of multicolinearity where capital intensity, education level, and health status all tend to move together. According to Getzen (2014), the strong long run and cross-sectional connection between GDP and mortality made it seem like "common sense" that a similar short-run relationship should hold. Using a panel of 91 countries over the period 1960-2005, Pablo, *et al.,* (2017) find that the marginal effect of the change in health status in the long-term income lies between 2.6% in the growth accounting models and 8.3% when using Barro regressions type model. Such theoretical and empirical complexities of the relationship between health and economic growth give a rationale for using dynamic cointegration and error correction techniques in investigating the relationship between human health and economic growth, which our study intends to do.

The international commitment to improvement of health has been prominent since 2000 with the signing of the millennium development goals MDGs agreed to be met by 2015 and further emphasized by moving forward into the sustainable development goals SDGs since 2015. In addition to eradication of poverty and hunger, health improvement targets were well emphasized in the MDGs and the SDGs. Major health targets in the MDGs was to reduce under-five mortality rates by two third between 1990 and 2015, and maternal mortality ratio MMR by 75% between 1990 and 2015. Statistics show that since 1990 global maternal death has been declining but with too slow rate of decline to meet that target in low income countries. On average, global MMR declined by 44 percent, from 385 maternal deaths per 100,000 live births in 1990 to 216 in 2015 (Alkema *et al.,* 2015 and Black *et al.,* 2016). It has also been shown that regional MMRs for 2015 ranged from 12 deaths per 100,000 live births in high-income regions to 546 in low income region of sub-Saharan Africa and that, in order to achieve the maternal health SDGs countries need to reduce their MMRs at an annual rate of at least 7.5% (Alkema *et al.,* 2015). The simple conclusion from these estimates is that economic growth has a positive influence on MMR. Thus, targeting reduction of infant or under-five mortality rate by national governments requires economic growth which enables sufficient expenditure financed by the government itself and the private sector. However, as discussed above, the association between government expenditure on health and under-five mortality rates could be positive or negative, or nonexisting statistically speaking. Furthermore, under-five mortality rate defined as death per 1,000 children in a year further complicates the interplay between health care expenditure and population factors. Higher rates of CMR or slower rates of reducing it may in part reflect low economic growth or health damaging growth and/or lower or ineffective government expenditure on health care or both as well as lack of other determinant of child health such as access to safe drinking water and sanitation and essential immunization.

In Sudan, communicable diseases have been the main causes of morbidity and mortality mainly from parasitic diseases such as malaria, and tuberculosis, diarrhoeal diseases, respiratory infections, and schistosomiasis which is the most prevalent parasitic disease in Sudan, with 24 million people at risk, 5 million cases of infection and a prevalence rate of 20%. Sudan is prone to epidemics of other diseases such as meningococcal meningitis, viral haemorrhagic fevers, cholera, resulting from poor reporting, environmental factors and inadequate health services which all have major effects on population health including

women and children. Although the country is at an early stage of a generalized HIV/AIDS epidemic the national health policy and strategy give priority to the control and prevention of HIV/AIDS. The incidence of HIV/AIDS increased from an estimated 1.6% in 2002 to around 2.3% in 2010 and remains around 1.6% through 2012-2015 (WHO, 2015). Non-communicable diseases prevalent in Sudan includes cancers especially breast cancer, heart and cardiovascular disease, and diabetics. In Sudan poverty is widespread, is severe and wide spread especially in rural areas where the majority of people live and rural poverty was estimated at 67 percent with considerable variation between and within states (CBS, 2009). The Gender Inequality Index for Sudan was estimated at 0.604, ranking 171 out of 186, and 58% of females above 15 are illiterate. 40% of the population is under 15 years of age with a life expectancy is 62 years in 2012 increased to round 64 years in 2015. Only 61% of the population has access to safe water sources and 27% has access to sanitation. The average health indicators in terms of maternal and child mortality trends mask significant urban–rural and regional disparities with some states underserved, reflecting economic disparities in terms of GDP per capita across states.

Sources of financing health in Sudan are diverse. They include public and government including donor finance, private or individual finance. Government health expenditure is financed by the government revenues which include taxes, and non-tax revenues as well as Zakat and since 1994 also through health insurance. Government finance and expenditure on health care flows to different levels spatially at the centre and throughout the states governments. Government finance is also channeled to primary healthcare, secondary and tertiary health care levels. The government at the federal and state level also contributes to the social health insurance schemes run by the National Health Insurance Fund (NHIF) and one of the most insurance schemes at the states level is Health Insurance Corporation Khartoum State (HIKS). Despite such diverse funding sources, the health sector of Sudan is considered underfunded (WHO, 2015). Total health expenditure as percentage of GDP has been in a declining trend from 3.91%, to 3.98%, to 3.23%, and to 3.18%, in 1990, 1995, 2000 and 2005 respectively. More recently, it has increased from 7.97% in 2010 to 8.59% in 2015. As a result Sudan has been slow in achieving the health-sector MDGs including under-five and maternal mortality rates. Sudan receives non-negligible amounts of external resources for health which as percent of total health expenditure on health amounted to 0.32 percent in 1995, increased to 6.86 percent in 2005 but declined sharply to 2.8 per cent in 2011 with a maximum of 8.76 percent in 2006 and it was only about 2.46 percent in 2015 (World Bank, 2017). Out-of-pocket health expenditure as percent of total expenditure on health was 80.82 percent in 1995, declined to 62.76 percent in 2005, but increased to 69.58 per cent in 2011, and it was about 73 percent in 2015. Out-of-pocket health expenditure as percent of private expenditure on health was 95.35 percent in 1995, declined slightly to 91.88 percent in 2005 but increased to 96.52 percent in 2011 and it was around 94.78 percent in 2015. Such contributions make out-of-pocket impoverishing and catastrophic. Private health expenditure as percentage of GDP slightly decreased from 2.93 percent in 1995 to 2.59 percent in 2005, but increased substantially to 6.01 in 2011, and it was around 5.24 percent in 2015. Public health expenditure as percentage of GDP was 0.54 percent in 1995, increased to 1.73 percent in 2005 and to 2.38 percent in 2011, and it was around 3.76 percent in 2015. Given such patterns and magnitudes of expenditure on health Sudan performance in major health indicators is poor in absolute terms, relative to other countries and in the context of the health MGDs. In response to such mounting health challenges, the Sudan government has developed a 25-year long term and a 5- year medium term strategic plan since 2002 and in cooperation with the WHO for strengthening the health sector. The 25-year plan (2003–2027) gives priority to reforming and rebuilding the health system based on fair financing, and aims to reduce the burden of diseases, promote healthy lifestyles, develop and retain human

resources, and introduce advanced technology, while assuring equity, quality and accessibility of health services. The focus of the 5-year health sector strategy (2007–2011), in line with 25-year plan and national health policy, was on ensuring the provision of health care to the citizens of Sudan, especially poor and vulnerable populations (Federal Ministry of Health, 2002). This means that there is a need for major increases in health expenditure, financed by the government, privately and from external donor sources for the purpose of health care and health improvement and arguably enhancement of economic growth.

4. Methodology and models

4.1. Definition and measurement of variables

This study is mostly empirical, though it highlights some of the theoretical links between economic growth and health through health inputs and output indictors. The study asserts that the relationship run from health to economic growth rather than the other way around. The study covers the period of forty seven years spanning from 1969 to 2015 using annual time series data processed from the World Bank World Development Indicators WDIs (World Bank, 2017) and supplemented by statistics from national sources and WHO sources. This is relatively a long period which gives reliable results of the fitted model of health and economic growth. Also this period is chosen because over which the economy of Sudan has been witnessed three remarkable changes. First for the first time since independence in 1956 Sudan has started to devalue the national currency against the US dollars. In 1977 the exchange rate was 1.35 US$ per one SDG and continuously devaluated since 1978. Since then the value of the SDG has been decreasing against the US$ and particularly since 2012 with the secession of South Sudan and the implied loss of oil revenues. Second since 1992, the government of Sudan has liberalized the economy with full liberalization of prices of goods and services under a market oriented economy management including decentralized health care system. Third, since 1999 the government revenues have been increasing due to extraction and exportation of oil as well as government tax revenues and since 2013 increasing revenues from extraction of gold. In particular, over this period, the health care sector has been witnessing major deregulation changes with federal federalism as well with cut in government finance as an easy option the ease the pressure on the government deficit which has been in an increasing deficit since 1978. Indeed, the macroeconomic management and the performance of the economy have profound effects on the functioning and finance of the health care system and health outcomes. A government planned and supported health care system functions differently compared with a market oriented health care system given the stage of development with implication of economic growth. The performance of the economy as measured by the GDP determines the willingness and ability of the government and individuals to invest in health care and health. In addition, government spending on health is directly and indirectly linked to by population and demographic factors such the number of people, under-five mortality rates life expectancy and education levels. Therefore, the models built seek to explain the behaviour of economic growth measured by GDP and health inputs measured by total health expenditure (THE) and child immunization (IMZ) and the state of health measured by under-five mortality rates. Total investment (TIV) is also included as economic variable defined as private and public investment which operates at as control variable in determining the interrelationship between health and economic growth in Sudan. The study also includes the state of the environment measured by carbon dioxide emissions per capita (CO_2P) which has proven relationship with economic growth, energy sources and mortalities and government policies.

4.2. Specification of econometric models

Empirically, the study employs the econometric techniques of the Augmented Dickey-Fuller (ADF) unit root to test for stationarity, Johansen cointegration test, the vector error correction modeling (VECM) and testing for causality using the standard Granger method. Economic growth is presented by GDP as the dependent variable, explained by total investment TIV, health care factors represented by throughput in terms of total health expenditure THE and output in terms of under-five mortality UMR as well as immunization IMZ which is thought to affect UMR. Environment is represented by carbon dioxide emissions CO_2 per capita reflecting source and levels of energy use where higher energy use is expected to associate with economic growth, but also the state of the environment reflected in externalities associated with CO_2 emissions is expected to have a major negative influence on the state of health. Thus, a general linear model of economic growth is written as:

$$GDP = f(THE, TIV, UMR, CO_2, IMZ) \quad (1)$$

The econometric model to be estimated can be written as follows:

$$GDP = \alpha + \beta_1 THE + \beta_2 TIV + \beta_3 UMR + \beta_4 CO_2, \beta_5 IMZ + \mu \quad (2)$$

The coefficient α is the constant (intercept) in the relationship between GDP and its explanatory variables. $\beta_1, \beta_2, \beta_3, \beta_4, and\ \beta_5$ are the coefficients of THE, TIV, UMR, CO_2, and IMZ respectively. μ is error term.

This general model will later be specified as a VECM in order to assess the direction of causality between health and economic growth.

5. Estimations and presentation of results

5.1. Descriptive statistical analysis

The study starts with descriptive statistical analysis. Table (1) presents the main descriptive statistics of the variables used in the study on their actual values.

Table 1. *Descriptive statistics*

	GDP	THE	TIV	UMR	CO_2	IMZ
Mean	2,130	4.542	5342.096	118.550	0.244	43.24
Median	1,230	4.030	1815.908	122.980	0.216	52.84
Maximum	97,100	8.620	26667.35	155.880	0.382	95.16
Minimum	1,850	2.830	237.1590	68.1600	0.113	0.77
Std. Dev.	2,230	1.823	6878.856	26.421	0.083	35.56
Skewness	1.485	1.372	1.574	-0.388	0.369	-0.034
Kurtosis	3.819	3.407	4.368	1.872	1.624	1.455
Jarque-Bera	18.576	15.061	23.067	3.672	4.776	4.686
Probability	0.00009	0.0005	0.00001	0.1594	0.0912	0.096
Observations	47	47	47	47	47	47

As from table (1), GDP, THE and TIV are not normally distributed as indicated by Jarque-Bera stat. and the associated probability values with kurtosis constituting the non-normality. Since the variables in the study are interrelated with dynamic interplay among them, we initially tested for multicolinearity through a test for simple correlation between the variables of study and the results are presented in table (2).

Table 2. *Correlation matrix*

	GDP	THE	TIV	UMR	CO2P	IMZ
GDP	1					
THE	0.90	1				
TIV	0.98	0.88	1			
UMR	-0.87	-0.77	-0.87	1		
CO2P	0.55	0.53	0.60	-0.31	1	
IMZ	0.77	0.67	0.78	-0.95	0.22	1

The main diagonal entries indicate correlation of the variable itself while entries off the main diagonal show pair-wise correlations that exist between the included variables. As a rule of thumb, a correlation statistic greater than 0.80 indicates significant correlation between the pair of variables. A positive correlation exists between GDP, THE and TIV but GDP is negatively correlated with UMR. There is a positive correlation between TIV and THE but negative correlation between UMR and IMZ. Such high degree of correlation makes it difficult to disentangle the separate effect of each explanatory variable. From the correlation matrix it is clear that there is multicolinearity problem among some of the variables which indicates the complexity of the interplay between the economic, population and environmental factors taken collectively in explaining a complex relationship as of health and economic growth in the context of Sudan as a lower middle income country.

5.2. Econometric analysis

5.2.1. Stationarity and cointegration of variables

A first step of a reliable econometric analysis is to investigate the characteristic of time series data. For reliable estimation, it is a requirement that time series data should be stationary. Stationarity of time series included in this study is tested through the conventional ADF unit root test. The data were converted into logarithms in order to bring them to a common base, reduce their variability and enable direct estimation of elasticities in the subsequent estimations. Applying the ADF unit root test all variables are found to be nonstationary at level but the first differencing makes all of them stationary as presented in table (3).

Table 3. *ADF unit root test: at level I(0) and first difference I(1)*

Variable	ADF Test Statistic Value I(0)	5% Mackinnon Critical Value I(0)	ADF Test Statistic Value I(1)	5% Mackinnon Critical Value I(1)	Order of Integration
L(GDP)	-0.836	-2.927	-5.7180*	-2.928	I(1)
L(THE)	-1.014	-2.927	-7.080*	-2.928	I(1)
L(TIV)	-0.761	-2.927	-5.910*	-2.928	I(1)
L(UMR)	2.689	-2.928	-9.451*	-2.928	I(1)
L(CO_2)	-1.043	-2.928	-8.394*	-2.928	I(1)
L(IMZ)	-1.550	-2.928	-3.248*	-2.928	I(1)

5.3. Cointegration of variables under study

Johansen cointegration method is employed at lag length of 1 2, with the assumption of constant and no trend. The results show that a long run equilibrium relationship exist amongst the variables of the study as it turns out that there exist two cointegrating equations using the trace statistic, while there is only one cointegrating equation when using the maximum Eigen value as shown in table (4).

Table 4. *Unrestricted cointegration rank test: Trace and Max-Eigen statistics*

Null Hypotheses	Eigen Value	Trace Statistic	0.05 Critical Value	Prob.**	Max-Eigen Statistic	0.05 Critical Value	Prob.**
r = 0	0.794	139.638	95.754	0.0000*	69.558	40.078	0.0000*
r ≤ 1	0.491	70.080	69.819	0.0477*	29.703	33.877	0.1454
r ≤ 2	0.332	40.377	47.856	0.2093	17.751	27.584	0.5159
r ≤ 3	0.257	22.626	29.797	0.2650	13.056	21.131	0.4471
r ≤ 4	0.169	9.570	15.495	0.3153	8.124	14.265	0.3663
r ≤ 5	0.032	1.446	3.841	0.2291	1.446	3.841	0.2291

Notes: Trace test indicates 2 cointegrating equation while Max-Eigen value test indicates 1 cointegrating equation at the 0.05 level; * denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values

The cointegration equation one is chosen to represent the model with minimum log likelihood of 255.1943 is represented as follows:

$$\begin{array}{lccccc} LGDP = -0.05LTIV + 1.58LTHE + 6.95LUMR - 0.18LCO_2 + 0.17LIMZ & & & & & \\ Std. & (0.1116) & (0.2753) & (0.1724) & (0.2024) & (0.0621) \\ t.stat. & [0.4912] & [5.7320] & [6.4850] & [-0.8870] & [2.6706] \end{array} \quad (3)$$

The cointegration equation states that investment surprisingly has a positive but statistically insignificant effect on economic growth, while health expenditure, under-five mortality and immunization have positive and statistically significant effect on economic growth.

An unrestricted autoregressive VAR model on equation (2) is estimated at a lag length of 2, showing that investment surprisingly has a negative and statistically significant effect on economic growth in one period time. Total health expenditure has a negative effect on economic growth in one year period, under-five mortality rates and immunization coverage have no statistically significant effects on output growth, despite the correct expected signs of relationships, and CO_2 emissions have no significant effect on economic growth as presented in table (5).

Table 5. *Summary results of unrestricted VAR*

Variable	Coefficient	Std. Errors	t. stat.	P. Values
$L(GDP)_{t-1}$	0.87	0.2034	4.2698	0.0000***
$L(GDP)_{t-2}$	0.19	0.2318	0.8122	0.4177
$L(THE)_{t-1}$	-0.54	0.2188	-2.4503	0.0152**
$L(THE)_{t-2}$	0.03	0.2047	0.1540	0.8778
$L(TIV)_{t-1}$	-0.17	0.0948	-1.7419	0.0831*
$L(TIV)_{t-2}$	0.0001	0.1001	0.0013	0.9990
$L(UMR)_{t-1}$	-0.84	1.0233	-0.8203	0.4131
$L(UMR)_{t-2}$	-0.86	1.0144	-0.8510	0.3958
$L(CO_2)_{t-1}$	-0.07	0.1951	-0.3638	0.7164
$L(CO_2)_{t-2}$	0.10	0.1917	0.5005	0.6173
$L(IMZ)_{t-1}$	-0.24	0.2018	-1.2112	0.2273
$L(IMZ)_{t-2}$	0.17	0.1939	0.8647	0.3883
C	9.16	4.1641	2.2008	0.0289**

Notes: R-squared = 0.98; Adj. R-squared = 0.97; SSR = 0.88836; SER = 0.1666; F. Stat. = 109.4648; LL. 24.4611; AIC = -0.5094; SC = 0.0125

***, **, * indicates significance at 1%, 5% and 10% level respectively

The estimated unrestricted VAR has a high goodness of fit indicated by adj. R-squared of 97% but it shows poor power of individual explanatory variables. This also gives rationale for estimating a VECM. From the estimated unrestricted VAR, the lag order of 2, to be used in the estimation of the VECM, is selected according to LR criterion as presented in table (6).

Table 6. *VAR lag order selection criteria*

Lag	Log L	LR	FPE	AIC	SC	HQ
0	-83.80970	NA	2.39e-06	4.082259	4.325558	4.172486
1	202.4565	481.4476	2.78e-11	-7.293475	-5.590385*	-6.661887*
2	246.5069	62.07105*	2.12e-11	-7.659403	-4.496522	-6.486454
3	290.2341	49.69001	1.92e-11*	-8.010640*	-3.387967	-6.296330

Note: * indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

5.4. Specification and estimation of VECM

Toda & Philips (1993) suggested that if a long-term relationship exists, then the direction of causality can be determined by the error correction model. The VECM for this study is generally specified as follows:

$$dLGDP = \alpha + \beta_q \sum_{i=1}^{j} dLGDP_{t-i} + \beta_2 \sum_{i=1}^{j} dLTHE_{t-1} + \beta_3 \sum_{i=1}^{j} dLTIV_{t-1}$$
$$+ \beta_4 \sum_{i=1}^{j} dLUMR_{t-1} + \beta_5 \sum_{i=1}^{j} dLCO_{2t-1} + \beta_6 \sum_{i=1}^{j} dLIMZ_{t-1} + \phi \sum_{i=1}^{jt} ECT_{t-1} + \varepsilon_t \quad (4)$$

where J is the lag length and d is difference operator. The VECM is estimated at a lag length of 2 and the results of the model are summarized in table (7).

Table 7. *Summary results of estimated VECM*

VECM Short Run Dynamic Coefficients					VECM Long Run Coefficients			
Variable	Coefficient	St. Error	t. Stat.	P. value	Variable	Coefficient	St. Error	t. Stat.
ECT_{t-1}	-0.32	0.04104	-7.7834	0.0000***	$L(GDP)_{t-1}$	1.000		
$d(L(GDP)_{t-1}$	-0.09	0.11733	-0.7788	0.4371	$L(TIV)_{t-1}$	-0.05	0.1116	-0.4912
$d(L(GDP)_{t-2}$	0.12	0.11497	1.0190	0.3096	$L(THE)_{t-1}$	1.58	0.2753	5.7320***
$d(L(TIV)_{t-1}$	-0.008	0.05704	-0.1382	0.8902	$L(UMR)_{t-1}$	6.95	1.0724	6.4850***
$d(L(TIV)_{t-2}$	-0.19	0.05996	-3.1746	0.0018***	$L(CO_2)_{t-1}$	-0.18	0.2024	-0.8870
$d(L(THE)_{t-1}$	0.07	0.13675	0.4891	0.6254	$L(IMZ)_{t-1}$	0.17	0.0621	2.6706**
$d(L(THE)_{t-2}$	0.48	0.13282	3.5904	0.0004***	C	-58.96		
$d(L(UMR)_{t-1}$	0.16	0.78321	0.2097	0.8341				
$d(L(UMR)_{t-2}$	0.51	0.69117	0.7450	0.4572				
$d(L(CO_2)_{t-1}$	-0.30	0.13976	-2.1461	0.0332**				
$d(L(CO_2)_{t-2}$	-0.82	0.13610	-6.0354	0.0000***				
$d(L(IMZ)_{t-1}$	0.18	0.11394	1.5580	0.1210				
$d(L(IMZ)_{t-2}$	0.22	0.10461	2.1085	0.0364**				
C	0.06	0.03041	1.9111	0.0576*				

Notes: R-squared = 0.78; Adj. R-squared = 0.68; SSR = 0.327; SER = 0.1044; F. stat. = 8.0296; LL. 45.415; AIC = -1.427937; SC = -0.86024; DW = 2.02
VECM Diagnostic Tests
Autocorrelation: χ^2 = 65.750, P(0.4855)
Residual Heteroskedasticity: χ^2 = 543.19, P(0.5259)
Normality: JB. = 36.42, P(0.0003)
Functional Form: Stability: Specification imposes 5 roots, none is out the unit circle
***, **, * indicate significance at 1%, 5% and 10% level respectively.

The estimated VECM is represented by the following equation.

$$dLGDP = -0.32LGDP_{t-1} + 1.58LTHE_{t-1} - 0.05LTIV_{t-1}$$
$$+ 6.95LUMR_{t-1} - 0.18LCO_{2t-1} + 0.17LIMZ_{t-1} - 0.09dlGDP_{t-1}$$
$$+ 0.12dLGDP_{t-2} + 0.07dLTHE_{t-1} + 0.48dLTHE_{t-2} - 0.008dLTIV_{t-1}$$
$$- 0.19dLTIV_{t-2} + 0.16dLUMR_{t-1} + 0.51dLUMR_{t-2} - 0.30dLCO_{2t-1}$$
$$- 0.82dLCO_{2t-2} + 0.18dLIMZ_{t-1} + 0.22dLIMZ_{t-2} + 0.06 \quad (5)$$

Standard errors, t. stat. and probability values corresponding to the estimated VECM were shown in table (7). The VECM results show that health factors represented by health expenditure, under-five mortality and immunization have significant positive effects on economic growth in the long run with the expected correct signs of coefficients, while total investment and CO_2 emissions and have no significant effect on GDP in the long run. In the short run, total investment and CO_2 emissions have significant negative effect on GDP though mostly in two years period. Also, in the short run GDP is mostly and significantly affected by total health expenditure and immunization but not by the under-five mortality rates. The error correction term has the correct negative sign showing that the dependent variable GDP converges to steady state equilibrium at speed of 32% which is significant at 1% level. The reliability of the estimated VECM is tested through the conventional diagnostic tests and the results are reported in table (7). Stability of the VECM is confirmed by the figure of roots characteristic as shown by figure (1).

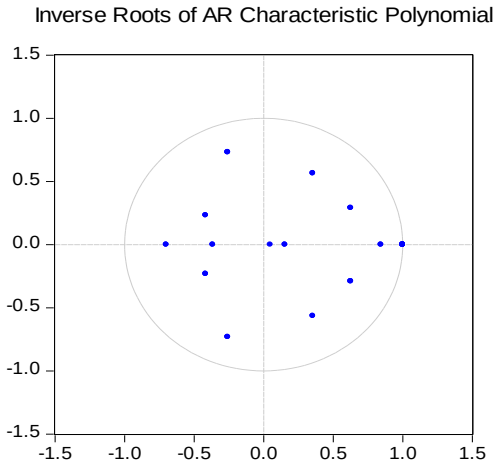

Figure 1. VECM stability test

In accord with the estimated VECM, the study performs the response of the GDP to variations in the explanatory variables using the impulse response function IRF. Results of the IRF show that UMR, IMZ, TIV, and THE have the highest influence on GDP, while the least influencing factors are CO_2 emissions and GDP itself to any external shock as presented in table (8). Consistent with VECM findings, the results IRF indicate that GDP is more responsive to health than to external shocks associated with investment.

Table 8. Response of GDP

Period	L(GDP)	L(TIV)	L(THE)	L(UMR)	L(CO2P)	L(IMZ)
1	0.10439	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.10555	0.00970	-0.04684	-0.04044	-0.02490	0.01585
3	0.10154	-0.06709	-0.05369	-0.01419	-0.07480	0.02978
4	0.09186	-0.07822	-0.09285	-0.05142	-0.03850	0.00533
5	0.07652	-0.00020	-0.10540	-0.05108	-0.00724	0.00260
6	0.03744	0.03289	-0.09516	-0.07874	0.00209	-0.01986
7	0.01782	0.03184	-0.08484	-0.07014	0.02793	-0.03382
8	0.00576	0.05751	-0.07988	-0.07674	0.04334	-0.05079
9	-0.00940	0.07042	-0.06782	-0.07473	0.04145	-0.05791
10	-0.02060	0.06943	-0.06046	-0.07608	0.044866	-0.07004

Notes: Cholesky Ordering: L(GDP) L(TIV) L(THE) L(UMR) L(CO2P) L(IMZ)

Furthermore, the variance decomposition analysis shows that much of GDP variations are explained by total health expenditure, followed by GDP itself and under-five mortality rates. Total investment contributes about 13 percent in

explaining variations in GDP while CO_2 emissions and immunization contributes equally about 7 percent as presented in table (9).

Table 9. Variance decomposition of GDP

Period	S.E.	L(GDP)	L(TIV)	L(THE)	L(UMR)	L(CO2P)	L(IMZ)
1	0.10439	100.0000	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.16381	82.13189	0.35057	8.17675	6.09479	2.31010	0.93589
3	0.22630	63.16726	8.97372	9.91394	3.58693	12.1365	2.22167
4	0.28026	51.92902	13.6405	17.4405	5.70536	9.79989	1.48472
5	0.31333	47.50821	10.9129	25.2687	7.22198	7.89355	1.19471
6	0.34105	41.30509	10.1410	29.1144	11.4257	6.66645	1.34734
7	0.36288	36.72436	9.72684	31.1816	13.8281	6.48076	2.05836
8	0.38955	31.89002	10.6197	31.2628	15.8798	6.86181	3.48583
9	0.41480	28.17812	12.2490	30.2473	17.2518	7.05041	5.02351
10	0.44007	25.25354	13.3712	28.7603	18.3158	7.30323	6.99596

Notes: Cholesky Ordering: L(GDP) L(TIV) L(THE) L(UMR) L(CO2P) L(IMZ)

5.5. Granger Causality Analysis

Direction of causality amongst the model's variables is tested using the standard Granger (1969) causality test. Based on equation (2) a Granger causality model is specified as follows:

$$LGDP = \beta_0 + \beta_1 DLGDP + \beta_2 LTHE + \beta_3 LTIV + \beta_4 LUMR + \beta_5 LCO_2 + \beta_6 LIMZ + \varepsilon_1 \quad (6)$$

$$LTHE = \alpha_0 + \alpha_1 DLTHE + \alpha_2 LGDP + \alpha_3 LTIV + \alpha_4 LUMR + \alpha_5 LCO_2 + \alpha_6 LIMZ + \varepsilon_2 \quad (7)$$

$$LTIV = \gamma_0 + \gamma_1 DLTIV + \gamma_2 LGDP + \gamma_3 THE + \gamma_4 LUMR + \gamma_5 LCO_2 + \gamma_6 LIMZ + \varepsilon_3 \quad (8)$$

$$LUMR = \phi_0 + \phi_1 DLUMR + \phi_2 LGDP + \phi_3 THE + \phi_4 LTIV + \phi_5 LCO_2 + \phi_6 LIMZ + \varepsilon_4 \quad (9)$$

$$LCO_2 = \omega_0 + \omega_1 DLCO_2 + \omega_2 LGDP + \omega_3 THE + \omega_4 LTIV + \omega_5 UMR + \omega_6 LIMZ + \varepsilon_5 \quad (10)$$

$$LIMZ = \eta_0 + \eta_1 DLIMZ + \eta_2 LGDP + \eta_3 THE + \eta_4 LTIV + \eta_5 LUMR + \eta_6 LCO_2 + \varepsilon_6 \quad (11)$$

The above specified Granger causality model (equation 6-11) is estimated at a lag length of 2 and the results summarized and reported in table (10). The results indicate that no Granger causality between total investment and GDP, since the p-value for both direction of causality is found to be greater than 0.05%. There exists a unidirectional causal relationship running from total health expenditure to GDP, while the vice versa does not hold. Under-five mortality rate is found to be Granger causing GDP with no sign of feedback confirming the effect of health on economic growth established from the findings of the VECM. There is also a unidirectional causal relationship running from GDP to CO_2 emissions, which could give explanation that GDP growth have not been resulting in reduction in under-five mortality rates.

Table 10. *Summary of pair wise Granger causality results*

Null Hypothesis:	Obs.	F-Statistic	Prob.	Decision	Direction of Causality
H_0: L(TIV) does not Granger Cause L(GDP)	45	0.982	0.3834	Accept	None
H_0: L(GDP) does not Granger Cause L(TIV)		2.002	0.1483	Accept	None
H_0: L(THE) does not Granger Cause L(GDP)	45	0.909	0.4111	Accept	None
H_0: L(GDP) does not Granger Cause L(THE)		3.867	0.0292	Reject	GDP to THE
H_0: L(UMR) does not Granger Cause L(GDP)	45	2.872	0.0683	Reject	UMR to GDP
H_0: L(GDP) does not Granger Cause L(UMR)		0.015	0.9847	Accept	None
H_0: L(CO2P) does not Granger Cause L(GDP)	45	1.044	0.3613	Accept	None
H_0: L(GDP) does not Granger Cause L(CO2P)		3.978	0.0266	Reject	GDP to Co2P
H_0: L(IMZ) does not Granger Cause L(GDP)	45	0.426	0.6563	Accept	None
H_0: L(GDP) does not Granger Cause L(IMZ)		0.713	0.4962	Accept	None
H_0: L(TIV) does not Granger Cause L(THE)		2.836	0.0705	Reject	TIV to THE
H_0: L(UMR) does not Granger Cause L(TIV)	45	5.221	0.0097	Reject	UMR to TIV
H_0: L(TIV) does not Granger Cause L(CO2P)		7.129	0.0022	Reject	TIV to CO2P
H_0: L(UMR) does not Granger Cause L(THE)	45	2.629	0.0846	Reject	UMR to THE
H_0: L(UMR) does not Granger Cause L(CO2P)		2.545	0.0911	Reject	UMR to CO2P

6. Conclusions

The relationship between human health and economic growth is a complex one. This in part is complicated by the definition of health and its measurement as a latent variable and as a result the indicators used to proxy health status as well as the availability and reliability of data. Factors affecting health and economic growth are diverse and dynamic including the supply of and demand for health care services driven by both economic and non-economic factors chief among them being GDP, GDPP, inflation, population, fertility rates, morbidity and mortality rates, life expectancy at birth, environmental state as well as education. On the other hand, achievements in health improvements measured for example by reductions in child mortality rates, declines in fertility rates, and increases in overall life expectancy have proven positive effects on economic growth. The study find such relationship by means of empirical investigation employing dynamic econometric techniques including the Johansen cointegration test, the vector error correction modeling and Granger causality analysis. The stationarity of variables is established at I(1) and the cointegration test shows that a long-run equilibrium relationship exists among the variables of the health and economic growth in Sudan. The findings from the VECM show that total health expenditure, under-five morality rates and immunization have sizable and statistically significant effect on GDP growth in the long run. Granger causality test reveals that GDP growth is affected by health factors in terms of under-five morality rates and health expenditure with no sign of feedback effect from economic growth to these health factors. The study recommends that government should ensure macroeconomic stability in terms of stable growth and prices, increase the resources allocated to the health sector in order to achieve the under-five MDG and effective coordination with donors in order to ensure full coverage of children immunization.

References

African Development Bank, (2013). *African Economic Outlook*. [Retrieved from].

Alkema, L., Chou, D., Hogan, D., Zhang, S., Moller, A.B., Gemmill, A., Ma Fat, D.,. Boerma, D., Temmerman, M., Mathers, C., & Say., L. (2015). Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: A systematic analysis by the UN maternal mortality estimation inter-agency group, *The Lancet*, doi. 10.1016/S0140-6736(15)00838-7

Bhalotra, S. (2007). Spending to save? State health expenditure and infant mortality in India, *Health Economics*, 16, 911-928. doi. 10.1002/hec.1260

Black, R.E., Laxminarayan, R., Temmerman, M., & Walker, N. (2016). Reproductive, maternal, newborn, and child health. Disease Control Priorities, third edition, volume 2. Washington, DC: World Bank. doi. 10.1596/978-1-4648-0348-2

Barro, R.J. (1996). *Health, Human Capital and Economic Growth, Paper for the Program on Public Policy and Health, Pan American Health Organization and World Health Organization*, Washington: Pan American Health Organization.

Barro, R.J. (2013). Health and Economic Growth, *Annals of Economics and Finance*, 14(1), 305-342.
Baumol, W.J. (1993). Health care, education and the cost disease: a looming crisis for public choice. *Public Choice*, 77(1), 17-28. doi. 10.1007/978-94-017-3402-8_3
Baumol, W.J. (1967). Macroeconomics of unbalanced growth: the anatomy of urban crisis. *The American Economic Review*, 57(3), 415-426.
Bloom, D.E., Canning, D., & Sevilla, J. (2004). The effect of health on economic growth: A production function approach, *World Development*, 32(1), 1-12. doi. 10.1016/j.worlddev.2003.07.002
Bourne, P.A. (2012) Under-five mortality, health and selected macroeconomic variables: The children behind the digits. *Epidemiol*, 2, 115. doi. 10.4172/2161-1165.1000115
Central Bureau of Statistics, (2009). *National Baseline Household Survey*, Republic of the Sudan. [Retrieved from].
Eltis, W. (1983). The interconnection between public expenditure and inflation in Britain, *The American Economic Review,* 73(2), 291-296.
Filmer, D., & Pritchett, L. (1997). Child mortality and public spending on health: How much does money matter? World Bank, *Policy Research Working Paper*, No.1864. [Retrieved from].
Filmer, D., & Pritchett, L. (1999). The impact of public spending on health: Does money matter?, *Social Science &Medicine*, 49(10), 1309-1323. doi. 10.1016/S0277-9536(99)00150-1
Getzen, T.E. (2014). Macroeconomic dynamics of health: Lags and variability in mortality, employment and spending, *in* A. Culyer, (ed), *Encyclopedia of Health Economics*, Oxford: Elsevier.
Granger, C.W.J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, 37(3), 424-438. doi. 10.2307/1912791
Farahani, M., Subramanian, S.V., & Canning, D. (2009). Effects of state-level public spending on health on the mortality probability in India, *Program Health Economics*, 19(11), 1361-1376. doi. 10.1002/hec.1557
Federal Ministry of Health, (2002). *25 Years Strategic Plan for Health Sector*, Federal Ministry of Health, Khartoum, Republic of the Sudan. [Retrieved from].
Novignon, J., Olakojo, S.A., & Novignon, J. (2012). The effects of public and private health expenditure on health status in Sub-Saharan Africa: New evidence from panel data analysis, *Health Economics Review*, 2(1), 1-8. doi. 10.1186/2191-1991-2-22
Pablo, D.M., Marti,n G., & Carlos, D. (2017). New evidence of the health status and economic growth relationship, *Panoeconomicus*, 64(4), 439-459. doi. 10.2298/PAN150505020M
Preston, S.H. (1975). The changing relation between mortality and level of economic development. *Population Studies*, 29(2), 231–248.
Plümper, T., & Neumayer, E. (2013). Health spending, out-of-pocket contributions and mortality rates, Public Administration, 91(2), 403-418. doi. 10.1111/j.1467-9299.2012.02039.x
Sachs, J.D., & Warner, A.M. (1997). Fundamental sources of long-run growth, *The American Economic Review*, 87(2), 184-188.
Toda, H.Y., & Philips, P.C.B. (1993). Vector autoregrassions and causality. *Econometrica,* 61(6), 1367-1393. doi. 10.2307/2951647
Virts, J.R., & Wilson, G.W. (1984) Inflation and health care prices, *Health Affairs*, 3(1), 88-100. doi. 10.1377/hlthaff.3.1.88
Weil, D.N. (2005). Accounting for the effect of health on economic growth, NBER Working Paper, No.11455. doi. 10.3386/w11455
Weil, D.N. (2013). Health and Economic Growth, Handbook of Economic Growth, Volume 2.June 24, [Retrieved from].
World Health Organization. (2015). Sudan health profile 2015/ World Health Organization. *Regional Office for the Eastern Mediterranean*. No.WHO-EM/HST/231/E. [Retrieved from].
World Bank, (2017). World Development Indicators. [Retrieved from].
Zakir, M., & Phanindra, V.W. (1999). Factors affecting infant mortality rates: evidence from cross-sectional data. *Applied Economics Letters*, 6(5), 271-273. doi. 10.1080/135048599353203