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Health expenditure in sub-Saharan Africa: Is it mean reversion? A Fourier unit root test approach

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Abstract. The aim of the paper is to examine the mean reversion in health expenditure of 45 sub-Saharan African countries. The series on current health expenditure (percent of GDP in total), obtained from the World Development Indicators, each spanned the years 2000–2017. We employed the Fourier unit root test, which allows modelling structural breaks, to deal with any such breaks that could arise as a result of a small sample size (18 years) of data available on health expenditure of the selected countries. The results showed evidence of mean reversion in the health spending pattern of 27 sub-Saharan African countries. There is evidence of non-mean reversion in the health expenditure pattern of the remaining 18 countries considered. We further investigate the link between health expenditure and health outcome, using infant mortality rate and under-five mortality rate as health outcome variables. An inverse association could be observed between the infant mortality rate and health expenditure and between the under-five mortality rate and health expenditure in 24 sub-Saharan African countries. On the other hand, in 13 other sub-Saharan African countries we observed a positive association between the variables. The findings of this study could be of great importance to healthcare delivery programmes in the studied countries.

Keywords: mean reversion, health expenditure, healthcare, Fourier unit root test, sub-Saharan Africa
JEL: C22, H39, H51, I15

Wydatki na zdrowie w Afryce Subsaharyjskiej a zdolność powrotu do wartości średniej. Zastosowanie testu pierwiastka jednostkowego Fouriera

Streszczenie. Celem pracy jest zbadanie zdolności powrotu do wartości średniej (ang. *mean reversion*) w wydatkach na zdrowie w 45 krajach Afryki Subsaharyjskiej. Analizowany jest szereg czasowy odnoszący się do bieżących wydatków na zdrowie (w procentach nominalnego PKB) w okresie 2000–2017. Dane pozyskano z bazy światowych wskaźników rozwoju prowadzonej przez Bank Światowy. Ze względu na prawdopodobieństwo wystąpienia skoków strukturalnych spowodowane stosunkowo krótkim szeregiem czasowym (18 lat) oraz potencjalnymi lukami w dostępnych danych zastosowano test pierwiastka jednostkowego Fouriera, pozwalający na modelowanie skoków w danych. Wyniki analizy pozwoliły stwierdzić zdolność powrotu do wartości średniej wydatków na zdrowie w 27 spośród badanych krajów. W przypadku pozostałych 18 krajów nie stwierdzono takiej zdolności. Za pomocą dwóch wskaźników: umieralności niemowląt oraz śmiertelności dzieci poniżej piątego roku życia przeanalizowano również związek między wydatkami na zdrowie a skutecznością ochrony zdrowia. Negatywną zależność

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zaobserwowano w 24 krajach, a pozytywną – w 13. Wyniki niniejszego badania mogą mieć duże znaczenie dla programów opieki zdrowotnej w badanych krajach.
Słowa kluczowe: zdolność powrotu do wartości średniej, wydatki na zdrowie, służba zdrowia, test pierwiastka jednostkowego Fouriera, Afryka Subsaharyjska

1. Introduction

One of the major indicators used in measuring the economic development of a country is the quality standard of healthcare service delivery. One of the Millennium Development Goals (MDGs) is to foster health improvement in countries. In developed countries, a great percent of the nominal gross domestic product (GDP) is being consumed by households and health expenditure, through household consumption services and healthcare deliveries. In developing countries, health expenditure has posed a major concern, which has become part of a day-by-day discussion (Lu et al., 2010). In brief, health expenditure is a measure of the final consumption of healthcare deliveries (products and services) which includes individual healthcare services and the government's collective healthcare services (Organization for Economic Cooperation and Development [OECD], n.d.). Presently, a considerable amount of funds worldwide has been allocated to the health sector to fight the Covid-19 pandemic. These funds are used to acquire healthcare delivery equipment and medical materials to provide better health services to fight the virus. It is expected that this trend will continue to foster better healthcare delivery both during and after the pandemic. This will ensure adequate planning and policy decisions on healthcare systems and the readiness to effectively fight outbreaks of other diseases which are likely to occur in the future.

All countries have a common objective of developing adequate financing for their healthcare systems, but even the relatively rich ones are struggling to cope with the rising costs of healthcare services, especially currently, when the Covid-related downturn puts more pressure on healthcare spending. The scarcity of health funds is more pronounced in middle-income and low-income countries, where sub-Saharan African countries are mostly classified. The key reasons for limited progress towards the achievement of health MDGs in Africa were the flaws in the healthcare expenditure systems. The health status of Africans has over the years been a major global concern. Sub-Saharan Africans have been faced with many health issues like HIV, tuberculosis or malaria. Sub-Saharan Africa was granted a relatively large percentage of the western aid between 2008 and 2009 which targeted healthcare delivery. The utilisation of this aid resulted in a remarkable reduction in mortality rates in Africa. However, there is a threat that the recent survival gains and decreases in mortality rates for malaria, measles and among people living with HIV will not be continued if key health funding issues are not addressed. Before the outbreak of the Covid-19 pandemic, the continent of Africa had the highest mortality rate in the world. According to Deaton and Tortora (2015), this continent was rated the lowest both for wellbeing and satisfaction with the delivery of healthcare services. Inadequate governmental health funding in Africa contributed largely to the global mortality rates (World Health Organization [WHO], 2013).

Expenditure on health in sub-Saharan Africa is relatively low, and almost half of it goes to the private health sector. Investigation of the mean reversion of the health spending in the countries of that region is very important as it would help address some of the problems associated with health funding. It could also encourage policy-making designed to enhance healthcare delivery schemes, because mean reversion in healthcare expenditure reduces risk predictability (Darmouni & Zeltzer, 2017), and the evidence of short-term mean reversion in a given country suggests that it is time to pay more attention to healthcare delivery in this country.

This study aims to examine mean reversion in the health expenditure of 45 sub-Saharan African countries. The study employed the Fourier unit root test due to its ability to cater for a structural break and its best performance with a small sample size of data. The study further investigates the link between health expenditure and health outcomes in these countries, using the infant mortality and under-five mortality rates as the variables of the health outcome. The study of a mean reversion in health spending patterns and its relationship with the health outcomes in sub-Saharan Africa has important policy implications for the healthcare delivery schemes in these countries.

2. Literature review

Good health significantly influences the effective use of skills and knowledge acquired by an individual through education (Schultz, 1999). Barro (1996) argues that the depreciation of education capital can be reduced if people maintain good health, which, in turn, can increase the positive influence of education on economic growth. A study conducted by Gyimah-Brempong and Mark (2004) finds a positive association between health investment and economic growth in sub-Saharan African countries. Bloom and Canning (2000, 2003) assert that a healthier individual is likely to influence the economy in four different ways: firstly, they are likely to remain in employment or their profession relatively long; secondly, they are inclined to invest a considerable amount of money and resources in education and self-development;

thirdly, they are likely to be more creative and productive in the workplace, and thereby earn a higher income, and finally, they are likely to acquire assets and save resources with the expectation of living longer than a less healthy individual.

The basic understanding of the health spending patterns of developing countries would help manage their expenditure and prepare for any future changes, e.g. in times of shocks (disease outbreak) which might occur in the future (Nik Mustapha et al., 2011). According to Mahdavi-Damghani (2013), mean reversion is based on the assumption that historical values of a phenomenon will always tend to revert to their average value over time. Etheridge (2015) stated that the investigation of mean reversion is germane to understanding the structure of household expenditure. The general strategies of mean reversion in health expenditures is based on the primary belief that the expenditure on health has a basic stationary trend. Nevertheless, there is no guarantee that it will revert to its normal pattern over time, as it can be influenced by both an individual's income and government revenue. Mean reversion of health expenditure may take two forms, i.e. the expected health expenditure may divert from the direction of the actual expenditure, or the expected health expenditure can return to its average (mean) value. When we say 'revert to mean value', we mean that the series is stationary and having an unchanged mean value. On the other hand, non-mean reversion means that the series is not stationary, i.e. diverting from its mean value.

Micah et al. (2019) used annual series on domestic health expenditure of 46 sub-Saharan African countries to investigate the trends and drivers of governmental health expenditure in the countries of that region. The authors used a regression model and the Shapley decomposition to examine the factors and variations associated with governmental spending on health. The findings of the study indicated a positive association between governmental spending on health and good governance. The study also found that governmental spending on health varies significantly across sub-Saharan Africa. Anyanwu and Erhijakpor (2007), on the other hand, used annual series data on GDP per capita, government expenditure on health, health outcomes, urban population, number of physicians and the accessibility of education for females in 47 African countries, to study the effect of health spending on health outcome – under-five and infant mortality rates. The authors adopted a panel data regressions method. The study found a significant influence of the total health expenditure on health outcomes with a particular association to sub-Saharan African countries. In another study, conducted by Crémieux et al. (1999), the authors examined the association between the total health expenditure and health outcomes – infant mortality rates and life expectancy. The authors used time-series cross-section data that spanned 1978–1992. The findings of the study indicated a strong relationship between health spending and health outcomes. By the same token, Simplicio and Amba (2016) used annual series of health expenditure per capita and GDP per capita that covered the period of 1995 to 2014 in their work, to investigate any long-run association between the economic income and healthcare spending of the Economic Community of Central African States (ECCAS). The authors adopted a spatial panel framework and employed cointegration test methodology. The study found a significant association between healthcare spending and economic development. Similarly, Lv and Zhu (2014) studied the association between health expenditure per capita and GDP per capita. The study encompassed 42 African countries and spanned the period of 1995 to 2009. The authors used a semi-parametric panel-data method of analysis. The findings established the importance of spending on healthcare delivery in African countries. Several other works related to healthcare expenditure in that region could be mentioned in this context as well (e.g. see Burnside & Dollar, 1998; Filmer & Pritchett, 1999; Gbesemete & Gerdtham, 1992; Gerdtham et al., 1992; Jaunky & Khadaroo, 2008; Okunade, 2005; Olaniyan et al., 2013; Wagstaff & Cleason, 2004; Zaman et al., 2017).

The above compilation demonstrates that there is a considerable amount of literature about health expenditure. To the authors' best knowledge, however, the study described in this paper is the first piece of research that uses the Fourier unit root approach to examine mean reversion in the health expenditure of sub-Saharan African countries. It aims to fill this gap, allow a better understanding of the nature of health expenditure in sub-Saharan Africa, and thus foster Africans' wellbeing. This, in turn, is likely to enhance economic growth.

This present study adopted a method of statistical analysis, which is different from the methods of analysis used in the above-mentioned works. More specifically, the study employs a unit root test analysis method developed on the basis of the Augmented Dickey-Fuller (ADF) test, thus taking the form of Fourier nonlinearity with structural breaks (FADF-SB), which was proposed in Furuoka (2017). It is justifiable to use this approach (see Yaya et al., 2019), especially because of the small sample size of the series available, having fixed the unit root lag to 1. We also adopted two more tests, ADF and FADF, which are the restricted versions of the FADF-SB test, to further justify the superiority of the test primarily adopted in the study.

3. Data and methodology

We utilised annual time series data, i.e. the current health expenditure series, computed as a percentage of GDP (percent of GDP in total) in 45 sub-Saharan African countries. The data were collected from the World Development Indicators (World Bank, n.d.). The current health expenditure of the 45 sub-Saharan countries spanned 2000 and 2017. The World Bank Development Indicators classified 48 African countries as sub-Saharan African countries. We limited our study to 45 of them, leaving out Somalia, South Sudan and Zimbabwe, as the data on them for the period covered in this study are not available. Although more extensive data is available for a few of the sub-Saharan African countries, the choice of the period from 2000 to 2017 was based on the general data availability for all the countries considered. The time plot of the original series of each country considered in the study is presented in the Figure. As shown in this set of graphs, there are some variations in the health spending pattern across the sub-Saharan African countries, namely health spending in the majority of the countries follows a nonlinear pattern, except for Chad, Comoros, Mauritius, Malawi, Sudan, Togo, and Zambia (7 out of 45 considered), whose health spending pattern appears to be linear within the studied period. Table 1 presents the descriptive statistics of the datasets illustrating the health expenditure series for 2000 and 2017 (% of GDP in US dollars), as well as the minimum, maximum, and the average values across the considered countries. The rank of each country is also presented in ascending order based on the average expenditure on health in the considered period – where the country with the highest average is ranked as 1 and so on. Table 1 shows that by comparing the series of 2000 and 2017, there was an increment in the health expenditure of Angola, Botswana, Burkina Faso, Burundi, Cabo Verde, the Central African Republic, the Congo Republic, the Democratic Republic of the Congo, Equatorial Guinea, Eswatini, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, the Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, and Togo (68.9% of the considered cases), while there were reductions in health expenditure of the remaining countries (31.1%). The increment in the changes in health expenditure ranges from about 0.16% to 6.30%, while the reduction in the changes in health expenditure ranges from about 0.13% to 4.86%. Sierra Leone, Namibia and Comoros, in that order, are the three countries with the highest average expenditure on health, while Equatorial Guinea, the Congo Republic and Gabon, in that order, are the three countries with the lowest average expenditure on health.

Figure. Time plot of health expenditure (% of GDP in USD) series of sub-Saharan African countries in 2000–2017

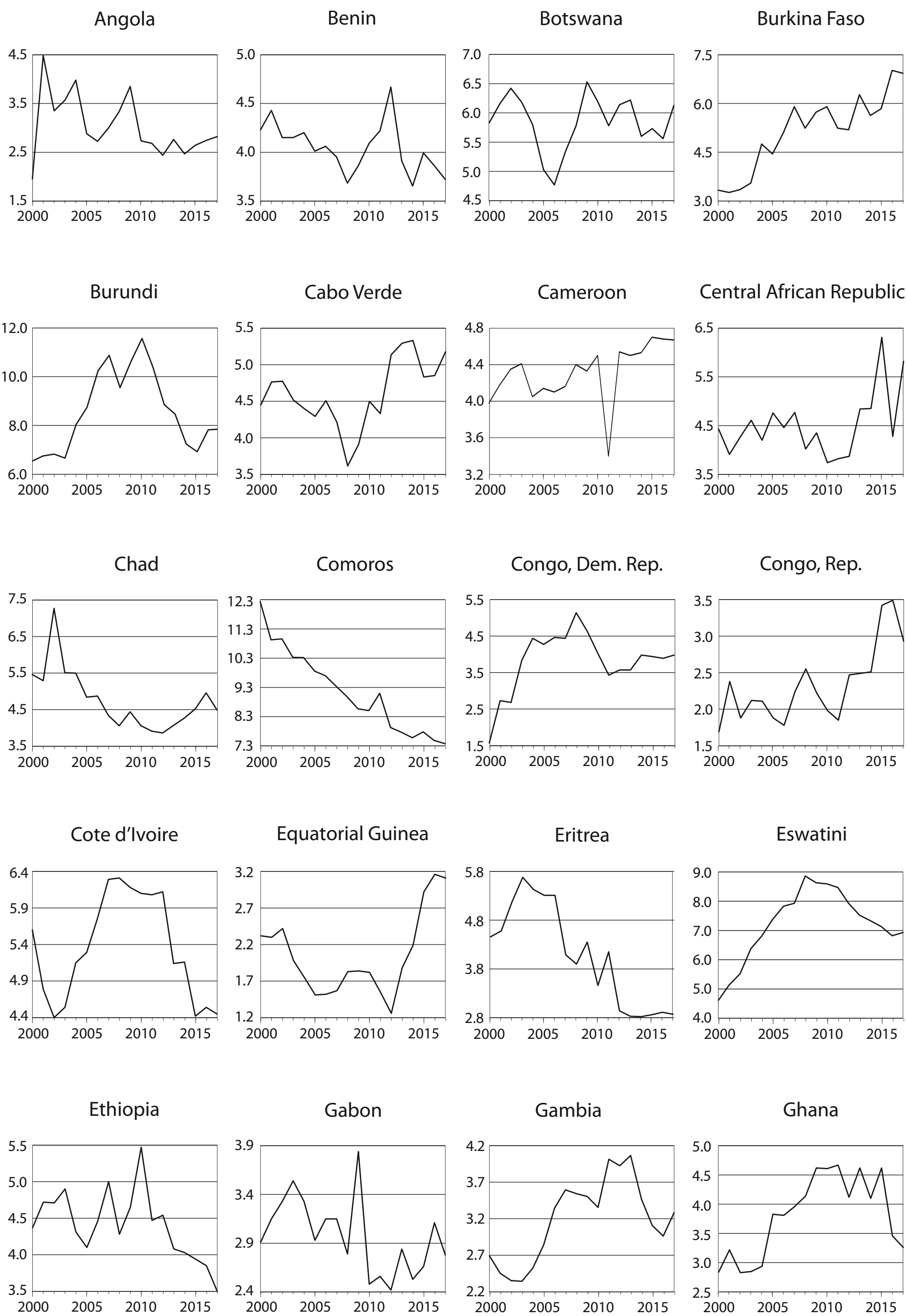


Figure. Time plot of health expenditure (% of GDP in USD) series of sub-Saharan African countries in 2000–2017 (cont.)

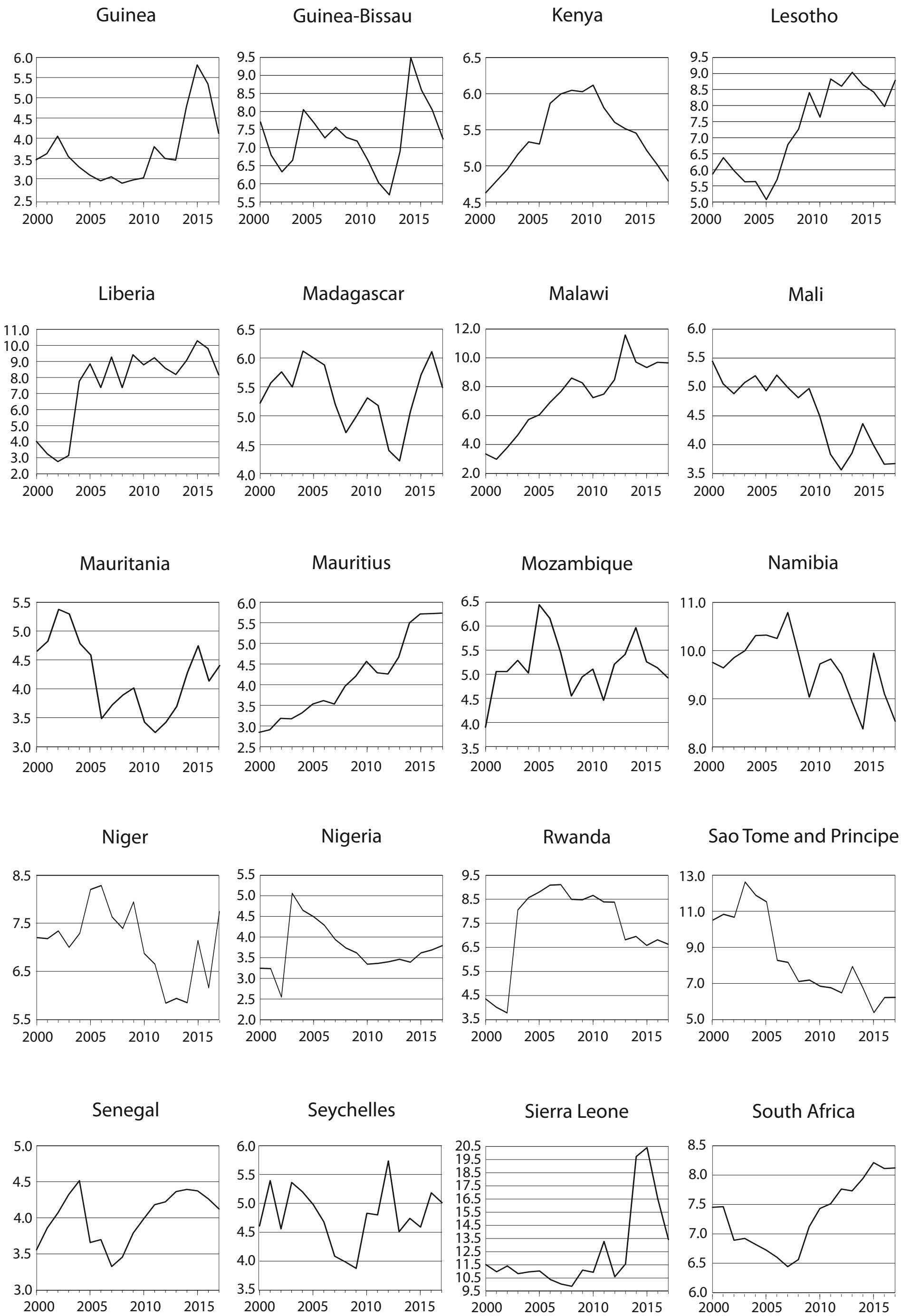
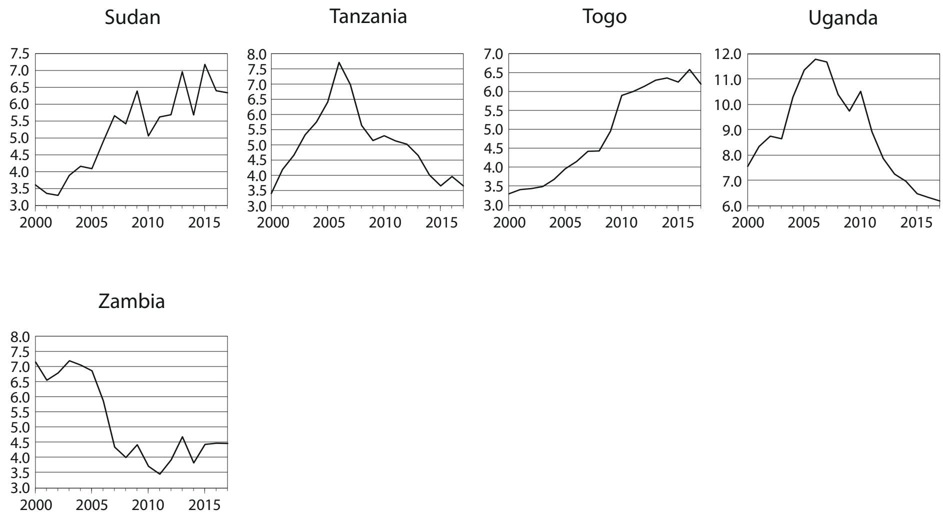


Figure. Time plot of health expenditure (% of GDP in USD) series of sub-Saharan African countries in 2000–2017 (cont.)



Source: authors' estimations based on the World Bank data on health expenditure (World Bank, n.d.).

Table 1. Descriptive statistics of health expenditure in total series of sub-Saharan African countries

Country (code)	2000	2017	Min.	Max.	Overall average	Rank based on overall average
	in % of GDP in USD					
Angola (AGO)	1.91	2.79	1.91	4.48	3.00	42
Benin (BEN)	4.23	3.72	3.65	4.67	4.05	35
Botswana (BWA)	5.83	6.13	4.77	6.53	5.84	15
Burkina Faso (BFA)	3.32	6.92	3.25	7.01	5.14	22
Burundi (BDI)	6.18	7.52	6.18	11.28	8.23	6
Cabo Verde (CPV)	4.43	5.17	3.58	5.33	4.59	28
Cameroon (CMR)	3.98	4.67	3.40	4.70	4.31	31
Central African Republic (CAF)	4.43	5.82	3.74	6.31	4.52	29
Chad (TCD)	5.46	4.49	3.86	7.27	4.76	26
Comoros (COM)	12.24	7.38	7.38	12.24	**9.15**	**3**
Congo, Dem. Rep. (COD)	1.57	3.98	1.57	5.14	3.81	37
Congo, Rep. (COG)	1.69	2.93	1.69	3.49	**2.33**	**44**
Cote d'Ivoire (CIV)	5.60	4.45	4.40	6.31	5.35	18
Equatorial Guinea (GNQ)	2.32	3.11	1.26	3.16	**2.05**	**45**
Eritrea (ERI)	4.46	2.87	2.82	5.68	4.06	34
Eswatini (SWZ)	4.61	6.93	4.61	8.86	7.21	13
Ethiopia (ETH)	4.37	3.50	3.50	5.47	4.41	30
Gabon (GAB)	2.91	2.78	2.42	3.84	**2.97**	**43**
Gambia (GMB)	2.69	3.28	2.34	4.06	3.18	41

Table 1. Descriptive statistics of health expenditure in total series of sub-Saharan African countries (cont.)

Country (code)	2000	2017	Min.	Max.	Overall average	Rank based on overall average
	in % of GDP in USD					
Ghana (GHA)	2.84	3.26	2.83	4.67	3.80	38
Guinea (GIN)	3.47	4.12	2.89	5.81	3.71	39
Guinea-Bissau (GNB)	7.71	7.24	5.69	9.49	7.28	11
Kenya (KEN)	4.64	4.80	4.64	6.12	5.43	16
Lesotho (LSO)	5.86	8.76	5.07	9.01	7.24	12
Liberia (LBR)	4.02	8.16	2.76	10.29	7.52	7
Madagascar (MDG)	5.23	5.50	4.23	6.13	5.37	17
Malawi (MWI)	3.35	9.65	2.98	11.58	7.29	9
Mali (MLI)	5.56	3.79	3.68	5.56	4.67	27
Mauritania (MRT)	4.65	4.40	3.24	5.37	4.22	32
Mauritius (MUS)	2.90	5.72	2.90	5.72	4.18	33
Mozambique (MOZ)	3.93	4.94	3.93	6.44	5.20	20
Namibia (NAM)	9.75	8.55	8.39	10.77	**9.65**	**2**
Niger (NER)	7.20	7.74	5.84	8.28	7.09	14
Nigeria (NGA)	3.20	3.76	2.49	5.05	3.68	40
Rwanda (RWA)	4.26	6.57	3.67	9.09	7.29	10
Sao Tome and Principe (STP)	10.51	6.23	5.39	12.62	8.41	5
Senegal (SEN)	3.57	4.13	3.34	4.52	4.02	36
Seychelles (SYC)	4.61	5.01	3.88	5.73	4.78	25
Sierra Leone (SLE)	11.52	13.42	9.87	20.41	**12.48**	**1**
South Africa (ZAF)	7.44	8.11	6.43	8.20	7.31	8
Sudan (SDN)	3.61	6.34	3.30	7.18	5.21	19
Tanzania (TZA)	3.40	3.65	3.40	7.71	5.03	23
Togo (TGO)	3.31	6.20	3.31	6.58	4.95	24
Uganda (UGA)	7.56	6.19	6.19	11.79	8.84	4
Zambia (ZMB)	7.15	4.47	3.46	7.19	5.18	21

Note. Data for the three highest-ranking countries and the three lowest-ranking countries are in bold.
Source: authors' estimations, using current health expenditure data from the World Bank (n.d.).

We begin by considering the conventional Augmented Dickey-Fuller (ADF) test equation defined as:

$$\Delta Hexp_t = \alpha + \beta t + (\theta - 1)Hexp_{t-1} + \sum_{i=1}^{q} d_i \, \Delta Hexp_{t-i} + \varepsilon_t, \quad (1)$$

where $Hexp_t$ represents the current health expenditure of a given country at time t; ε_t is the error term; θ denotes the slope parameter on the first lagged independent variable; $\theta = 1$ when a characteristic of a unit root is present in the health expenditure series; d and q each represent the lag length and the slope of the augmentation's component, respectively. However, the traditional ADF test lacks the power of accounting for a structural break in a series, and since health expenditure is likely to experience a smooth or instantaneous break (see Perron, 1989), we consider the Fourier function as presented in Enders and Lee (2012a, 2012b), which caters for a structural break.

Enders and Lee (2012a, 2012b) expanded the classical ADF test by accounting for the shortcoming of the ADF test. The authors employed a Fourier function, using a battery of frequencies in a nonlinear framework. The Fourier function by Enders and Lee is defined as:

$$G(t) = \alpha + \beta t + \sum_{l=1}^{m} \lambda_l \sin\left(\frac{2\pi lt}{N}\right) + \sum_{l=1}^{m} \gamma_l \cos\left(\frac{2\pi lt}{N}\right); \quad m \leq \frac{N}{2}; \quad t = 1, 2, \ldots, \quad (2)$$

where α and β are the estimator of the model's intercept and the trend's coefficient, respectively; λ_l and γ_l estimate the amplitude and displacement, respectively, as determined by the Fourier component; π traditionally takes the value of 3.1416; l is a particular frequency which assumes a value from 1 to m; m represents the optimal number of frequencies, specifically determined using information criteria, and N represents the number of data points (18 in this study). λ_l and γ_l represent the nonlinear parameters in the setup Fourier function, whose values upon estimation are assumed to take on real numbers. However, if λ_l and γ_l are 0, then the function in (2) becomes entirely linear. By putting together the equations (1) and (2) we have the Fourier ADF (FADF) test equation, which was developed by Enders and Lee:

$$\Delta Hexp_t = \alpha + \beta t + (\theta - 1) Hexp_{t-1} + \sum_{l=1}^{m} \lambda_l \sin\left(\frac{2\pi lt}{N}\right) + \\ + \sum_{l=1}^{m} \gamma_l \cos\left(\frac{2\pi lt}{N}\right) + \sum_{i=1}^{q} d_i \, \Delta Hexp_{t-i} + \varepsilon_t. \quad (3)$$

In the modelling of time series, testing for unit root is inevitable. The FADF unit root test caters for a smooth break in the series (Becker et al., 2006). However, Furuoka (2017) widened the test with one structural break, which was derived in the process simultaneously. Hence, in this study, we employ the FADF-SB unit root test as in Furuoka (2017), given as:

$$\Delta Hexp_t = \alpha + \beta t + \delta DU_t + \partial D(T_B)_t + (\theta - 1)Hexp_{t-1} + \\ + \sum_{l=1}^{m} \lambda_l \sin\left(\frac{2\pi lt}{N}\right) + \sum_{l=1}^{m} \gamma_l \cos\left(\frac{2\pi lt}{N}\right) + \sum_{i=1}^{p} c_i \, \Delta Hexp_{t-i} + \varepsilon_t, \tag{4}$$

where δ is the break dummy variable's coefficient, DU_t. $DU_t = 1$, when $t > T_B$, otherwise $DU_t = 0$; T_B represents the structural break date; ∂ is the one-time break date dummy's coefficient, whereby $D(T_B) = 1$ when $t = T_B$, otherwise $D(N_B) = 0$. Following the ADF test framework, we tested the hypothesis of unit root, $\theta - 1 = 0$, adopting a t-test, in the models, equations (3) and (4). These equations correspond to the FADF and the FADF-SB unit root tests, respectively.

We obtain the best frequency, $\hat{l}$, in (3) and (4), by minimising their associated sum of squares residuals (SSR) to its least value using:

$$SSR_{FADF}(\hat{l}) = \inf_{l} SSR_{FADF}(l);\ SSR_{FADF\text{-}SB}(\hat{l}) = \inf_{l} SSR_{FADF\text{-}SB}(l). \tag{5}$$

While considering the FADF-SB cases, as in Zivot and Andrews (1992), we determined endogenously the one structural break. The number of observations to the break date ($\widehat{N}_B$) is then derived. Also, we estimate the break fraction ($\hat{\lambda}$) using:

$$\hat{\lambda} = \frac{N_B}{N}. \tag{6}$$

As shown in Furuoka (2017), the optimal break date ($\hat{T}_B$) proved that the FADF-SB test model responds to frequency ($\hat{l}$) as well as the break-position ($\widehat{N}_B$); therefore, we jointly obtained the location of the optimal break date and the frequency using:

$$\varphi_{FADF\text{-}SB}(\hat{\omega}, \hat{j}) = \inf_{\omega, j} \omega_{FADF\text{-}SB}(\hat{\omega}, \hat{j}), \tag{7}$$

which reduces the FADF-SB statistic value in equation (4) to its minimum.

We conducted a Pearson moment correlation analysis to ascertain the link between governmental health expenditure and the health outcome – taking the infant mortality rate (number of children dying before reaching one year of age per 1,000 live births) and under-five mortality rate (number of children dying before reaching the age of 5) as the health outcome variables. The Pearson moment correlation coefficient is given as:

$$R_{xy} = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n \sum x_i{}^2 - (\sum x_i)^2} \sqrt{n \sum y_i{}^2 - (\sum y_i)^2}}, \tag{8}$$

where n is the number of observations; x_i represents health expenditure and y_i represents each of the health outcomes, i.e. infant mortality rate and under-five mortality rate, respectively.

4. Empirical findings

As we mentioned in the methodology section, the classical ADF test is not capable of catering for a structural break in time series, therefore, in order to justify the results of the three unit root tests considered (ADF, FADF, and FADF-SB) we fixed the augmentation lag to 1, and conducted the tests. Table 2 presents the results of the three tests. The result of the ADF test indicates no evidence of mean reversion in the health expenditure of the 45 countries considered. The result of the Fourier form of the test (FADF) on the other hand, shows the presence of mean reversion in health expenditure of Benin, Burkina Faso, Chad, Guinea, Madagascar, Mali, Mozambique, Namibia, and Sierra Leone, so in 20% of the 45 countries considered. As we can see, there is a slight difference between the results of the ADF and FADF tests. The result of the FADF-SB test, however, shows a greater rejection of the unit root hypothesis. It indicates evidence of mean reversion in Angola, Benin, Burkina Faso, Cabo Verde, Cameroon, the Central African Republic, Chad, the Congo Republic, Eswatini, Gabon, Guinea, Guinea-Bissau, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, and Uganda (60% of the total cases). The rejection of more unit roots in the countries examined by FADF-SB results from the fact that the test makes allowances for a structural break. As we can see then, the FADF and FADF-SB jointly provide evidence of mean reversion in health expenditure of Benin, Burkina Faso, Chad, Guinea, Madagascar, Mali, Mozambique, Namibia, and Sierra Leone (9 out of 45). On the other hand, the three tests could not find evidence of mean reversion in the health expenditure of Botswana, Burundi, Comoros, Cote d'Ivoire, the Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Ghana, Kenya, Lesotho, Liberia, Niger, Rwanda, Sao Tome and Principe, the Seychelles and Zambia (40% of cases) – this shows non-mean reversion in these 18 countries. As to determine the appropriate test that will give the most accurate decision on mean reversion, following Furuoka (2017) and Yaya et al. (2019), we based our mean reversion decision on the result of the FADF-SB test result due to its superiority proven in literature cited earlier in the paper.

Table 2. Results of ADF, FADF, and FADF-SB unit root tests on health expenditure in sub-Saharan African countries

Country (code)	ADF	FADF		FADF-SB			
			L		T_B	λ	L
Angola (AGO)	–2.686	–2.651	2	–6.840***	2008	0.50	1
Benin (BEN)	–2.934	–4.930***	2	–7.929***	2012	0.72	2
Botswana (BWA)	–2.935	–3.246	2	–4.546*	2008	0.50	1
Burkina Faso (BFA)	–2.167	–4.729**	1	–7.567***	2003	0.22	1
Burundi (BDI)	–1.524	–3.187	1	–4.418*	2016	0.94	1
Cabo Verde (CPV)	–2.047	–2.937	1	–5.480***	2011	0.67	1
Cameroon (CMR)	–2.567	–3.253	1	–9.069***	2010	0.61	1
Central African Republic (CAF)	–1.375	–1.403	2	–5.966***	2014	0.83	2
Chad (TCD)	–1.324	–6.762***	1	–9.218***	2011	0.67	1
Comoros (COM)	–2.161	–2.964	1	–3.908	2011	0.67	1
Congo, Dem. Rep. (COD)	–2.049	–2.884	1	–4.124*	2010	0.61	2
Congo, Rep. (COG)	–2.778	–3.789	1	–5.363***	2005	0.33	2
Cote d'Ivoire (CIV)	–1.105	–3.533	1	–3.917	2012	0.72	1
Equatorial Guinea (GNQ)	–3.215	–2.706	1	–4.335*	2006	0.39	1
Eritrea (ERI)	–1.295	–3.101	1	–4.004	2007	0.44	1
Eswatini (SWZ)	–1.903	–3.853	1	–5.181**	2012	0.72	1
Ethiopia (ETH)	–1.528	–2.700	1	–4.485*	2011	0.67	1
Gabon (GAB)	–2.852	–3.241	1	–5.928***	2008	0.50	1
Gambia (GMB)	–1.778	–2.977	1	–3.919	2005	0.33	2
Ghana (GHA)	0.496	–2.932	1	–4.237	2014	0.83	1
Guinea (GIN)	–2.709	–5.933***	1	–6.982***	2013	0.78	2
Guinea-Bissau (GNB)	–3.210	–3.507	2	–7.256***	2013	0.78	1
Kenya (KEN)	–0.345	–3.329	1	–4.028	2014	0.83	1
Lesotho (LSO)	–1.823	–1.858	1	–3.657	2008	0.50	1
Liberia (LBR)	–1.708	–3.762	1	–4.644*	2007	0.44	1
Madagascar (MDG)	–3.267	–5.249***	1	–5.505***	2004	0.28	2
Malawi (MWI)	–2.526	–3.071	1	–8.477***	2012	0.72	1
Mali (MLI)	–3.184	–4.561**	2	–5.999***	2011	0.67	2
Mauritania (MRT)	–1.489	–3.745	1	–5.976***	2005	0.33	2
Mauritius (MUS)	–3.045	–4.253*	1	–5.587***	2013	0.78	2
Mozambique (MOZ)	–2.411	–4.332**	2	–5.791***	2004	0.28	2
Namibia (NAM)	–3.157	–5.180***	1	–7.911***	2013	0.78	2
Niger (NER)	–1.415	–2.586	1	–4.034	2003	0.22	1
Nigeria (NGA)	–2.315	–2.984	1	–5.097**	2004	0.28	1
Rwanda (RWA)	–2.199	–3.014	1	–4.572*	2007	0.44	1
Sao Tome and Principe (STP)	–1.960	–2.300	1	–3.502	2003	0.22	1
Senegal (SEN)	–1.965	–2.516	1	–4.913**	2003	0.22	1
Seychelles (SYC)	–1.685	–1.358	2	–4.175*	2016	0.94	2
Sierra Leone (SLE)	–3.024	–4.781**	1	–8.548***	2013	0.78	2
South Africa (ZAF)	–3.163	–3.078	1	–7.500***	2014	0.83	2
Sudan (SDN)	–1.752	–2.843	1	–5.438***	2010	0.61	1
Tanzania (TZA)	–2.307	–3.198	1	–5.087**	2008	0.50	1
Togo (TGO)	–1.208	–3.213	1	–5.084**	2007	0.44	1
Uganda (UGA)	–1.874	–4.366*	1	–4.967**	2008	0.50	1
Zambia (ZMB)	–1.401	–2.821	1	–4.081	2006	0.39	1

Note. ***, **, * – significant at a 1%, 5%, and 10% level, respectively. See Furuoka (2017) for critical values. L – Fourier frequency, T_B – structural break date, λ – break fraction.

Source: authors' estimations, using current health expenditure data from the World Bank (n.d.).

We further conducted a correlation analysis to establish a link between health expenditure and infant mortality, and between health expenditure and the under-five mortality rates in sub-Saharan African countries. As presented in Table 3, there is an inverse association between health expenditure and infant mortality rates, and the under-five mortality rates in Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, the Congo Republic, Equatorial Guinea, Eswatini, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Malawi, Mauritius, Mozambique, Rwanda, Senegal, Sierra Leone, South Africa, Sudan and Togo (altogether 24 countries), with correlation coefficients ranging from –0.09 to –0.96. The result implies that an increase in governmental expenditure on health reduces infant and under-five mortality rates. Also, we found a direct relationship between the health expenditure and infant mortality rates, and between health expenditure and the under-five mortality rates in Angola, Botswana, Comoros, Cote d'Ivoire, Eritrea, Ethiopia, Madagascar, Mali, Namibia, Niger, Sao Tome and Principe, Tanzania, Uganda and Zambia (altogether 14 countries), with correlation coefficients ranging from 0.01 to 0.92. The result indicates that there is no positive effect of health expenditure on the mortality rates in these countries, as an increase in the mortality rate signifies an increase in health expenditure, although not a significant one. For the remaining 7 countries health expenditure had a direct association with infant mortality rates, while an inverse association with under-five mortality rates was observed in Benin, Chad, Gabon, Mauritania, Nigeria and the Seychelles (altogether 6 countries). In the remaining country, the Democratic Republic of the Congo, health expenditure had an inverse association with the infant mortality rate but a direct association with the under-five mortality rate.

This result cannot justify any significant link between health expenditure and mortality rates in sub-Saharan African countries. As an implication, in the majority of the countries, i.e. Burkina Faso, Cabo Verde, Cameroon, the Central African Republic, the Congo Republic, Guinea, Guinea-Bissau, Liberia, Malawi, Mauritius, Mozambique, Senegal, Sierra Leone, South Africa, Sudan and Togo (16 altogether), where evidence of mean reversion was found in their health expenditure pattern, we also observed an inverse association between their health expenditure and the infant mortality rates, and health expenditure and the under-five mortality rates. We found that in Angola, Madagascar, Mali, Namibia, Tanzania, and Uganda (6 countries alto-gether), where evidence of mean reversion was justified in their health expendit-ure pattern, there was a direct association between their health expenditure and the infant mortality rates and health expenditure and under-five mortality rates. We could not find a significant association between health expenditure and the child mortality rates in the remaining 5 countries, i.e. Benin, Chad, Gabon, Mauritania, and Nigeria, where the evidence of mean reversion was observed in their health spending pattern.

Table 3. Results of the correlation analysis between health expenditure, infant mortality rate, and under-five mortality rate

Country (code)	R_1	R_2	Country (code)	R_1	R_2
Angola (AGO)	0.428	0.464	Lesotho (LSO)	−0.903	−0.910
Benin (BEN)	0.469	−0.229	Liberia (LBR)	−0.856	−0.853
Botswana (BWA)	0.007	0.107	Madagascar (MDG)	0.282	0.320
Burkina Faso (BFA)	−0.898	−0.832	Malawi (MWI)	−0.943	−0.933
Burundi (BDI)	−0.261	−0.128	Mali (MLI)	0.864	0.827
Cabo Verde (CPV)	−0.358	−0.328	Mauritania (MRT)	0.376	−0.700
Cameroon (CMR)	−0.501	−0.563	Mauritius (MUS)	−0.818	−0.924
Central African Republic (CAF)	−0.484	−0.551	Mozambique (MOZ)	−0.170	−0.163
Chad (TCD)	0.623	−0.761	Namibia (NAM)	0.598	0.346
Comoros (COM)	0.919	0.452	Niger (NER)	0.421	0.463
Congo, Dem. Rep. (COD)	−0.408	0.663	Nigeria (NGA)	0.069	−0.051
Congo, Rep. (COG)	−0.598	−0.600	Rwanda (RWA)	−0.467	−0.427
Cote d'Ivoire (CIV)	0.052	0.006	Sao Tome and Principe (STP)	0.871	0.874
Equatorial Guinea (GNQ)	−0.557	−0.292	Senegal (SEN)	−0.358	−0.377
Eritrea (ERI)	0.712	0.809	Seychelles (SYC)	0.063	−0.277
Eswatini (SWZ)	−0.394	−0.408	Sierra Leone (SLE)	−0.634	−0.727
Ethiopia (ETH)	−0.244	−0.224	South Africa (ZAF)	−0.844	−0.907
Gabon (GAB)	0.499	−0.598	Sudan (SDN)	−0.912	−0.913
Gambia (GMB)	−0.685	−0.094	Tanzania (TZA)	0.120	0.075
Ghana (GHA)	−0.573	−0.473	Togo (TGO)	−0.964	−0.912
Guinea (GIN)	−0.373	−0.244	Uganda (UGA)	0.402	0.467
Guinea-Bissau (GNB)	−0.196	−0.212	Zambia (ZMB)	0.851	0.838
Kenya (KEN)	−0.388	−0.312			

Note. R_1 represents the correlation coefficient between health expenditure (in percent of GDP in US dollars in total) and the infant mortality rate (number of child deaths before the age of one per 1,000 live births); R_2 represents the correlation coefficient between health expenditure (in percent of GDP in US dollars in total) and the under-five mortality rate (number of deaths of children under the age of five).

Source: authors' estimations, using current health expenditure data from the World Bank (n.d.).

5. Conclusions

This study investigated the mean reversion in the health expenditure patterns of 45 sub-Saharan African countries. The data utilised in the study spanned 2000–2017. We adopted the Fourier unit root test with a structural break (FADF-SB) due to its capacity to cater for a structural break in the series. The test performs well when dealing with a small sample size (< 200) of data points. We also considered two restrictive versions of the FADF-SB test, namely ADF and FADF unit root tests. The ADF test could not find evidence of mean reversion in the health expenditure patterns of all the 45 sub-Saharan countries considered. However, the FADF test found evidence of mean reversion in 9 countries, representing 20% of the total cases. The FADF-SB test found evidence of mean reversion in 27 countries, i.e. in 60% of the 45 considered countries. The FADF-SB test demonstrated performance superior to the performance of the FADF test, as 9 cases of the unit root rejections in the FADF test were among the 28 cases of rejection in the FADF-SB test result. According to the result of the FADF-SB test, there is evidence of mean reversion in 27 out of 45 sub-Saharan African countries considered in this study. By using three tests (ADF, FADF and FADF-SB), we were able to detect evidence of non-mean reversion in 18 countries. These were: Botswana, Burundi, Comoros, Cote d'Ivoire, the Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Ghana, Kenya, Lesotho, Niger, Rwanda, Sao Tome and Principe, the Seychelles, and Zambia. The implication herewith is that the governments of the countries where the evidence of mean reversion is justified should devote increased attention to the quality of their healthcare delivery.

Looking closer at the results of the correlation analysis, we can see that there is an inverse association between health expenditure and the infant mortality rates as well as between health expenditure and under-five mortality rates in 24 sub-Saharan countries considered. Also, there is a direct association between health expenditure and the infant mortality rates as well as between health expenditure and under-five mortality rates in 14 countries. Health expenditure had an inverse association with the infant mortality rates but had a direct association with the under-five mortality rates in 6 countries. Health expenditure had a direct association with the infant mortality rate and an inverse association with the under-five mortality rate in one country. The explanation here seems to be the fact that the majority of the examined countries allocate a significant part of the GDP to the health sector, having experienced a high rate of mortality, due to e.g. an outbreak of a serious disease that claimed a lot of lives in the previous or current years. As regards the countries where an inverse relationship between health expenditure and health outcomes was observed, it could be inferred that they were increasing their health expenditure in order to be prepared for any occurrence of a disease or to fight against an existing one. In countries in this situation, health expenditure determines health outcomes. A direct relationship between health expenditure and the performance of the health sector is an indication that countries where this could be observed channel increased amounts to their healthcare systems, having experienced an increase in the mortality or morbidity rates. In these countries, the health outcome determines health expenditure. All in all, the health spending of these sub-Saharan African countries is likely to be influenced by their GDP. The majority of the countries examined in this study are not rich, and for this reason they tend to spend their resources on current necessities rather than on the preparation for any future occurrences. In addition, some of these countries were exposed to diseases, lacking the resources necessary to tackle them adequately. The findings of this study are of great pertinence to the healthcare delivery programmes in sub-Saharan Africa. Governments of that region should review their healthcare policies and allocate a relevant fraction of their budgets to their healthcare delivery systems. This would improve the quality and accessibility of healthcare services and enhance the inhabitants' wellbeing in sub-Saharan African countries.

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