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Causal Analyses of Health Outcome Indicators and Health Development Assistance: Evidence from Sub-Saharan African Countries

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ABSTRACT

Since no researcher has so far discussed the causal analysis that exists between each of the health outcome indicators used in this study (Life Expectancy at Birth (LEB), Child Mortality Rates (CMR)) and Health Development Assistance (HDA), this study therefore examines the causal analysis between LEB, CMR and HDA in 20 sub-Saharan African countries (SSACs) using the panel dataset spanning from 1990-2021. The study applies Panel Granger Causality test estimation technique to identify relationship between LEB, CMR and HDA. Findings reveal that bidirectional causality relationships exist between LEB and HDA while a unidirectional causality relationship exists between CMR and HDA. Some of the suggestions of this study are: sustainability of bidirectional causal analysis between LEB and HDA, uncovering reasons for unidirectional causal analysis between CMR and HDA, correct management of HDA in SSACs, efficiency of health-related investments and others. However, the study concludes that SSACs should work towards the promotions of those domestic explanatory variables within the two employed models that can result into bidirectional relationships between LEB, CMR and HDA as SSACs cannot carry on depending on foreign donors or foreign resources for the development of its health sector.

Keywords: Health outcome indicator, Health development assistance, Life expectancy at birth, Child mortality rates.

1. Introduction

Human capital formation, according to Sudeshna (2018), is considered to be the greatest critical investment in human beings. Significant studies embarked upon in this area to examine the factors that ascertain investment in human welfare found that health, education are among the crucial factors. Heavy investment in country's health sector by external donors through their health development assistance (HDA) increases health inputs in terms of available drugs and infrastructure in a country, which in turn results into higher life expectancy at birth, reduced mortality rates in the country or region and other positive growth and development in the health sector of the country. Due to paucity of resources experienced by the governments of sub-Saharan African Countries (SSACs) over the years which has negative effects on the regional health sector, external donors over the years have been complementing these paucity of resources in SSACs to make sure that health related diseases, mortality rates and other health challenges in the region are reduced to the bearest minimum. This, the donors do by deploying health development assistance (HDA) to the region.

However, to assess economic progress and population's general health status in the region, two of the commonly employed indicators are life expectancy at birth (LEB) and Child mortality rates (CMR). According to Ministry of Health, Social Policy and Equality (2016), life expectancy at birth is considered as a total variable which shows the impact of a broad diversity of indicators on the functioning of present-time public healthcare while Ryoko, Sarah, Solomon, Kenneth, Jan and Stephane (2023) point out that beyond the health sector factors (like immunization coverage and growth of primary health care), which are responsible for reductions in CMR in SSACs, social determinants which include education, women empowerment and economic development also contributed immensely in these reductions. The present compounded health condition, identified by the sustained linkage of a large number of variables of various kinds, influences the causal examination of these variables which can show, among other aspects, the extent to which the available resources to the public healthcare authorities (of which HDA is included) add to the effective achievement of healthcare strategies. Also, the rapidly growing volume of HDA from external donors and agencies to SSACs, reductions in the SSAC people's quality of life and also 78 child deaths per 1000 live births in SSACs as at 2019 (WHO, 2020 & UN, 2022) have escalated questions about LEB, CMR and health development assistance (HDA) association.

Behiye and Obadiah (2021) states that the desire of the countries of the world is to have higher life expectancy, the reason is that the gains associated with it are enormous. Higher life expectancy at birth provides individuals an opportunity to contribute more to economic prosperities of their nations i.e stimulating economic growth and on a contrary angle, a low life expectancy can result into reduction in total labour supply in a country. Advancement in life expectancy at birth in SSACs has been experienced over some years in SSACs and this cheering news still slumps below the remaining countries of the world. It is found that SSACs people are the unluckiest and may likely to pass away premature than people from economically developed countries. Universal analogy reveals that sub-Saharan African countries have uppermost mortality rates and base-bottom life expectancy at birth. According to Okpala (2019) SSACs remain to be wreaked by regular ill-health condition despite the deployment of huge HDA to the region. Statista (2023) states clearly that the average life expectancy at birth across Africa was 61 years for males and that of females was 64 years. It also states that at the global front, the average LEB for males was 70years while that of females was 75years at mid-2021.

In the same vein, child mortality rates for the past seven decades have steadily plummeted, 311 child deaths per 1000 live births between 1950-1955 and as at 2020, it had reduced to 71 child deaths per 1000 live births (Statista, 2022). Ryoko, Sarah, Solomon, Kenneth, Jan and Stephane (2023) claimed that while global CMR was 38 per 1000 in 2019, that of SSACs was 78 per 1000 in the same year and it shows that SSACs is confronting higher CMR than any other region in the world.

Assessments into the current literature about life expectancy at birth, child mortality rates and HDA clearly show that many researchers have investigated into the effect or impact of HDA on various health outcome indicators like LEB and CMR in SSACs but there is no single researcher that has opted to examine the causal analysis between HDA and any health outcome indicator in SSACs. So, the research question is to address the causal links between life expectancy at birth (LEB), CMR and HDA. The present work targets to link the vacuum in the body of knowledge by investigating the causal link between health aid (HDA) and health outcome indicator i.e life expectancy at birth and CMR in 20 selected SSACs. This study seeks to identify whether the parameter of HDA in the midst of other explanatory variables is a granger causal for the variable “life expectancy at birth” and “child mortality rates” according to the Granger causality test for panel data. The results of this study are of great significance for the donors and the recipient countries health policies makers in SSACs because they will highlight what to do to HDA so as to increase the level of life expectancy at birth the more and reduce CMR the more in SSACs.

2. Theoretical and Empirical Review of Literature

The Big Push theory propounded by Rosenstein Rodan (1943) discusses the importance of investing huge foreign aid by external donors and agencies in form of HDA, because of the scarce resources setting of developing countries, to propel growth and development in the dormant or idle health sector of developing countries. If HDA (one of the sources of health financing in SSACs) is considered an essential investment in building human capital in SSACs, then it means there is need to further discuss it. United Nations Development Programmes (2015), having described life expectancy as living a long and healthy life. Meanwhile, child mortality rate is defined as the probability that a newborn would breathe his/her final breath (die) before the attainment of 5 years of age. This is always expressed in 1000 per live births. So, LEB and CMR are essential gauges for the measurement of Human Development Index (HDI) and hence the need for the verification of human development-health development assistance (HDA) association.

Existing works from the earlier researchers on HDA and health outcome indicators tried to invest much of their efforts concentrating on the effect of HDA on a particular health outcome indicator in developing countries without considering the causal link that exists between HDA and any of the health outcome indicator in SSACs.

Some works of earlier researchers which centre on the effect of HDA on health outcome indicators include Global Burden of Disease Health Financing Collaborator Network (2020), Li, Richter and Lu (2019), Kotsadam, Ostby, Rustad, Tollefsen, and Urdal (2018), Lu, Li, and Patel (2018), and many others. The implication of this is that no work on causal analysis between HDA and any health outcome indicator (human welfare) has so far been carried-out in any developing country. For this reason, researching into this kind of topic becomes an essential matter especially in SSACs. Also, some works carried-out on causal link between LEB and other explanatory variables (exclusion of HDA) include Pedro, Nuria and Salvador (2019) and Suna and Ibrahim (2016) and no causal analysis on CMR and any explanatory variable has so far been carried-out.

3. Model Specification

Trailing behind the theoretical model propounded by Rosenstein Rodan (1943) which illustrates that the determinants of health outcome indicator (HOI) are HDA and other explanatory variables, thus the implicit functional model of this work is clearly stated as follows:

$$\ln HOI_{(i,t)} = \beta_0 + \beta_1 lnHDA_{(i,t)} + \beta_2 lnGDPPC_{(i,t)} + \beta_3 DPHE_{(i,t)} + \beta_4 DGHE_{(i,t)} + \beta_5 INF_{(i,t)} + \beta_6 lnEXR_{(i,t)} + \beta_7 lnFDI_{(i,t)} + \beta_8 lnPREDFEM_{(i,t)} + \beta_9 POP_{(i,t)} + + \beta_{10} GOEF)_{(i,t)} + \varepsilon_{(i,t)} + \mu_{1(i)} + \mu_{2(t)} \ldots\ldots..(1)$$

Equation (1) stands to be the long-run determinants of log of health outcome indicator (*ln*HOI).

Health outcome indicator is proxied by life expectancy at birth (LEB) and child mortality rates (CMR), the reason for choosing LEB and CMR is not far-fetched, the two health outcome indicators stand to be the commonest measures always employed in the literature.

$$LEB_{(i,t)} = \beta_0 + \beta_1 lnHDA_{(i,t)} + \beta_2 lnGDPPC_{(i,t)} + \beta_3 DPHE_{(i,t)} + \beta_4 DGHE_{(i,t)} + \beta_5 INF_{(i,t)} + \beta_6 lnEXR_{(i,t)} + \beta_7 lnFDI_{(i,t)} + \beta_8 PREDFEM_{(i,t)} + \beta_9 POP_{(i,t)} + \beta_{10} GOEF)_{(i,t)} + \varepsilon_{1(i,t)} + \mu_{1(i)} + \mu_{2(t)} \ldots\ldots(2)$$

$CMR1_{(i,t)} = U5MR1_{(i,t)} = \alpha_0 + \alpha_1 lnHDA_{(i,t)} + \alpha_2 lnGDPPC_{(i,t)} + \alpha_3 DPHE_{(i,t)} + \alpha_4 DGHE_{(i,t)} \quad \alpha_5 INF_{(i,t)} + \alpha_6 lnEXR_{(i,t)} + \alpha_7 lnFDI_{(i,t)} + \alpha_8 IMMS_{(i,t)} + \alpha_9 PCRF_{(i,t)}$

$+ \alpha_{10} GOEF_{(i,t)} + \varepsilon_{2(i,t)} + \mu_{3(i)} + \mu_{4(t)}$ ……………………..................(3)

where i = 1, 2, . . . , 20, t = 1, 2, . . . , 32 and where $\varepsilon_{1\&2(i,t)}$ represent the random perturbation of the model, $\mu_1(i)$, $\mu_2(t)$, $\mu_3(i)$ and $\mu_4(t)$ are country- and time-specific effects, appropriately.

Where *LEB* and *CMR* are employed as proxies for health outcome indicator, *LEB and CMR* are not logged because LEB is in years and CMR is in rates), *lnHDA* is the log of health development assistance channeled to SSACs, its inclusion is done to determine the total amount of health aid from donors and agencies, *lnGDPPC* measures the Gross Domestic Product Per Capita, *DGHE* is the Domestic Government Health Expenditure, *DPHE* is the Domestic Private Health Expenditure, INF is the inflation rate, *lnEXR* is measured by the exchange rate, *lnFDI* is measured by the foreign Direct Investment, *PREDFEM* is the Primary Education of female, POP is the Population ages between 15-64, IMMS is used to measure the vaccination rate, PCRF is used to measure primary completion rate of female, GOEF is a measure for Government Effectiveness.

4. Estimation Method

In this study, Panel Granger Causality test established by Dumitrescu and Hurlin (2012) was employed. Its choice is hinged on the fact that it provides room for the employment of the duo of cross-sectional and time series information to test relationships among variables of interest. It tests for the heterogeneous panel data models with fixed coefficients and reduces the collinearity among explanatory variables.

The estimated cross-section units i and time period t is stated as follows:

$$y_{it} = \alpha_{it} + \sum_{k=1}^{k} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{k} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

The two stationary variables for i individuals and in t periods in equation (3) are x and y. $\beta_i = (\beta_i^{(k)}, \ldots\ldots. \beta_i^{(k)})$ and the individual effects α_i are considered to be unchangeable in the time dimension. There was an assumption of lag-order k cross-section units of the panel to be common. Similarly, there was an assumption that the autoregressive parameters $\gamma_i^{(k)}$ and the regression coefficients slopes $\beta_i^{(k)}$ varied across countries.

The causal links or directions of causality between Life Expectancy at Birth and HDA together with other endogenous variables are as follows:

$$\Delta LEB_{it} = \sum_{k=1}^{p} \beta_k \Delta LEB_{i,t-k} + \sum_{k=0}^{p} \theta_k \Delta HDA_{i,t} + \sum_{k=0}^{p} \alpha_k \Delta GDPPC_{i,t} + \sum_{k=0}^{p} \varphi_k \Delta DPHE_{i,t} + \sum_{k=0}^{p} \gamma_k \Delta DGHE_{i,t} + \sum_{k=0}^{p} \sigma_k \Delta INF_{i,t} + \sum_{k=0}^{p} \tau_k \Delta EXR_{i,t}$$
$$+ \sum_{k=0}^{p} ϗ_k \Delta FDI_{i,t} + \sum_{k=0}^{p} \Psi_k \Delta PREDFEM_{i,t} + \sum_{k=0}^{p} \pi_k \Delta POP_{i,t}\, \varepsilon_{it}$$
$$+ \sum_{k=0}^{p} \phi_k \Delta GOEF_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\Delta HDA_{it} = \sum_{k=1}^{p} \beta_k \Delta HDA_{i,t-k} + \sum_{k=0}^{p} \theta_k \Delta LEB_{i,t} + \sum_{k=0}^{p} \alpha_k \Delta GDPPC_{i,t} + \sum_{k=0}^{p} \varphi_k \Delta DPHE_{i,t} + \sum_{k=0}^{p} \gamma_k \Delta DGHE_{i,t} + \sum_{k=0}^{p} \sigma_k \Delta INF_{i,t} + \sum_{k=0}^{p} \tau_k \Delta EXR_{i,t}$$
$$+ \sum_{k=0}^{p} ϗ_k \Delta FDI_{i,t} + \sum_{k=0}^{p} \Psi_k \Delta PREDFEM_{i,t} + \sum_{k=0}^{p} \pi_k \Delta POP_{i,t}\, \varepsilon_{it}$$
$$+ \sum_{k=0}^{p} \phi_k \Delta GOEF_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. ($$

The causal links or directions of causality between CMR and HDA together with other endogenous variables are also as follows:

$$\Delta CMR_{it} = \sum_{k=1}^{p} \beta_k \Delta CMR_{i,t-k} + \sum_{k=0}^{p} \theta_k \Delta HDA_{i,t} + \sum_{k=0}^{p} \alpha_k \Delta GDPPC_{i,t} + \sum_{k=0}^{p} \gamma_k \Delta DPHE_{i,t} + \sum_{k=0}^{p} \varphi_k \Delta DGHE_{i,t} + \sum_{k=0}^{p} \Psi_k \Delta INF_{i,t}$$
$$+ \sum_{k=0}^{p} \pi_k \Delta EXR_{i,t} + \sum_{k=0}^{p} \rho_k \Delta FDI_{i,t} + + \sum_{k=0}^{p} þ_k \Delta IMMS_{i,t} + \sum_{k=0}^{p} ɥ_k \Delta PCRF_{i,t} + \sum_{k=0}^{p} \phi_k \Delta GOEF_{i,t}$$

…………………………………………………………………………………………………(7)

$$\Delta HDA_{it} = \sum_{k=1}^{p} \beta_k \Delta HDA_{i,t-k} + \sum_{k=0}^{p} \theta_k \Delta CMR_{i,t} + \sum_{k=0}^{p} \alpha_k \Delta GDPPC_{i,t} + \sum_{k=0}^{p} \gamma_k \Delta DPHE_{i,t} + \sum_{k=0}^{p} \varphi_k \Delta DGHE_{i,t} + \sum_{k=0}^{p} \Psi_k \Delta INF_{i,t}$$
$$+ \sum_{k=0}^{p} \pi_k \Delta EXR_{i,t} + \sum_{k=0}^{p} \rho_k \Delta FDI_{i,t} + \sum_{k=0}^{p} þ_k \Delta IMMS_{i,t} + \sum_{k=0}^{p} ɥ_k \Delta PCRF_{i,t} + \sum_{k=0}^{p} \phi_k \Delta GOEF_{i,t}$$

………………………………………………………………………………………………(8)

In this study, causal links or directions are only considered between LEB and HDA, HDA and LEB, CMR and HDA, and HDA and CMR.

In time series studies, panel unit root test is essential for getting significant results from econometric examinations. In this work, the stationarity of the variables is determined by employing the unit root tests developed by Levin, Lin and Chu (LLC), Im, Pesaran and Shin (IPS) as well as Fisher test. This is followed by carrying-out panel co-integration test. The panel co-integration test is carried-out in this study to test for the existence of long-run relationship between the investigated variables using Kao and Fisher tests.

5. Data

To examine this work, panel data ranging between 1990-2021 which refer to life expectancy at birth, CMR, HDA and other explanatory variables jointly associated with LEB and CMR, the description of which is presented in Table 1. A configured database of 640 observations were composed, that is 32 annual observations of the dependent and independent variables for each of 20 SSACs. These countries are equally chosen from each region of SSACs. Central African region: Central African Republic, Chad, Equatorial Guinea, Gabon and DR Congo, East African region: Ethiopia, Kenya, Madagascar, Mauritius and Tanzania, South African region: Angola, Botswana, Lesotho, South Africa and Zambia while West African region are: Benin Republic, Cote D'ivoire, Ghana, Nigeria and Senegal.

Table 1. Description of variables and their sources

Variable	Short Definition	Measurement	Source
LEB	Life expectancy at birth	Years	WDI
HDA	Health Development Assistance	Million US Dollars	Financing Global Health
GDPPC	Gross Domestic Product Capita	Thousand US Dollars	WDI
DPHE	Domestic Private Health Expenditure	Percentage of GDP	WDI
DGHE	Domestic Government Health Expenditure	Percentage of GDP	Global Health Expenditure
INF	Inflation Rate	Consumer Price Index	WDI
EXR	Exchange rate	A country currency Interchanged with another country	WDI
FDI	Foreign Direct Investment	Million US Dollar	WDI
PREDFEM	Primary Education of Female	Percentage of total Admission	WDI
POP	Population ages 15-64	Percentage of population	WDI
IMMS	Immunization Status	Percentage of children btw 12-23 months	WDI
PCRF	Primary completion rate of Female	Proportion of the enrollment	WDI
GOEF	Government Effectiveness	ranges between -2.5 to 2.5	Worldwide Governance Indicators

WDI: World Development Indicators

Table 2: Health-related indicators across SSACs (1990-2021)

Descriptive statistics of variables

Variables	Obs	Mean	Std. Dev.	Min	Max
LEB	640	56.244	7.191	42.595	74.515
CMR	640	105.526	49.824	14.493	222.280
HDA	640	201.518	320.325	0.000	1972.380
GDPPC	640	2232.542	3214.666	102.598	22942.580
DPHE	640	1.971	0.899	0.034	4.948
DGHE	640	1.427	1.171	0.000	5.800
INF	640	8.638	4.920	0.000	23.773
EXR	640	375.057	534.771	0.000	3618.322
FDI	640	762.146	1411.110	-27.676	10028.210
PREDFEM	640	90.268	27.137	-7.910	236.450
POP	640	54.769	4.993	48.031	70.775
IMMS	640	68.242	21.847	10.000	99.000
PCRF	640	57.624	25.444	4.787	114.694
GOEF	640	-0.559	0.887	-2.400	2.300

Note: *LEB= Life Expectancy at birth (years); CMR= Child mortality rates (deaths per 1000 live births); LEB= Life Expectancy at birth (years); CMR= Child mortality rates (deaths per 1000 live-births); Health Development Assistance(million USD); GDPPC= Gross Domestic Product Per Capita (USD); DGHE = Domestic Government Health Expenditure (% of GDP); DPHE = Domestic Private Health Expenditure (% of GDP); INF =Inflation Rate (%); EXR =Exchange Rate (LCU); FDI =Foreign Direct Investment (million USD); PREDFem = Primary Education Total Female enrollment (% of gross enrolment); POP = Population ages 15 to 64 (% of population); IMMS =Immunization status (%); PCRF = Primary Completion Rate of Female (%); Government Effectiveness (ranges between -2.5 to 2..*

6. Results

Table 3

Optimal lag selection results of information criteria

Lag	Information criterion (LEB)				Information criterion (CMR)			
	LR	AIC	SC	HQ	LR	AIC	SC	HQ
0	NA	86.32	86.40	86.35	NA	74.11	74.20	74.14
1	13975.58	60.30	61.35	60.71	11023.47	53.68	54.73	54.09
2	2316.86	56.26	58.27*	57.05	1334.98	51.55	53.56*	52.33*
3	476.95*	55.77*	58.74	56.93*	363.33*	51.28*	54.25	52.44

Note: * indicates lag order selected by the criterion and LR is the sequentially modified LR test statistic (each test at 5% level), AIC is the Akaike information criterion, SC is the Schwarz information criterion, and HQ is the Hannan-Quinn information criterion.

Table 3 above shows the selection criteria for employed in this work are LR, AIC, SC and HQ. The work utilized optimal lag three (3) for LEB and lag two (2) and three (3) for CMR for the purpose of evaluations in this work.

Panel Unit Root Test Result

Variables	level			first difference			Remark
	LLC	IPS	FISHER	LLC	IPS	FISHER	
LEB	-8.36104*	-3.58567*	91.9705*	---	---	---	I(0)
CMR	-6.42588*	-3.92829*	94.8496*	---	---	---	I(0)
HDA	-3.40953*	-1.28548	49.8369	-29.7005*	-31.9191*	579.259*	I(1)
GDPPC	-1.58365	2.48156	21.9235	-17.4829*	-16.3378*	297.747*	I(1)
DPHE	-3.95503*	-3.33607*	69.3006*	---	---	---	I(0)
DGHE	-3.07711*	-3.11350*	71.0858*	---	---	---	I(0)
INF	-6.43150*	-9.14803*	186.743*	---	---	---	I(0)
EXR	-7.37885*	-4.98317*	93.5621*	---	---	---	I(0)
FDI	-1.72546	-1.13444	10.085	-14.6343*	-25.4874*	444.836*	I(1)
PREDFEM	-3.79732*	-2.24636*	82.1832*	---	---	---	I(0)
POP	-9.29053*	-4.64545*	105.289*	---	---	---	I(0)
IMMS	-5.13787*	-4.64075*	88.6313*	---	---	---	I(0)
PCRF	-2.78613*	-3.42979*	86.7168*	---	---	---	I(0)
GOEF	-0.09938	-12.8669	28.108	-21.7937*	-28.1583*	456.178*	I(1)

NOTE: *HDA**,** GDPPC**,** EXR and FDI are in natural logarithms while others are not*

(*) connote rejection of unit root hypothesis at (5%) level of significance level

Source: Author's Computation, (2023)

Employment of Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS) and Fisher test (FT) were made used to test for stationarity in this work. The table above reveals that LEB, CMR, DPHE, DGHE, INF, EXR, PREDFEM, POP, IMMS and PCRF are stationary at level meaning that they are integrated of order zero I(0) while HDA, GDPPC, FDI and GOEF came to stationary level after first difference I(1). This points out that the panel unit root results of the employed variables in this work are mixture of integrated orders I(0) and I(1) and this is trailed by the employment of Kao and Fisher tests to examine the existence of long-run relationships between Life Expectancy at Birth (LEB), child mortality rates (CMR) and Health Development Assistance (HDA).

Table 5: ***Panel co-integration test results for LEB***

Model	**Test**	**Stats.**	**Stat. Value**	**Prob.**
LEB	Kao test	(ADF-stat)	-1.665149*	0.0479
	Fisher test	(Trace stat)	197.6*	0.0000
		(Max-eigen stat)	76.48*	0.0002

Note**: *** *connote significance at 5% level of significance; (Fisher test reports test concerning the rejection of 'at most' 1 and 2 co-integrating equation for LEB, hence indicating the existence of at least 1 and 2 co-integration equation for LEB model.*

Source: Author's Computation (2023).

In Table 5, the results reveal an affirmation in its entirety for the dismissal of null hypothesis of 'no co-integration' between LEB and its analogous variables. It shows -1.665149 ($p < 0.05$) for Kao ADF stat and Fisher results indicate 197.6 ($p< 0.05$) and 76.48 ($p< 0.05$) for trace and max eigen stats accordingly, thus a strong proof manifests in support of co-integration between LEB and the employed determinants in this study.

Table 6: ***Panel co-integration tests results for CMR***

Model	**Test**	**Stats.**	**Stat. Value**	**Prob.**
CMR	Kao test	(ADF-stat)	-5.416045*	0.0000
	Fisher test	(trace stat)	594.0*	0.0000
		(Max-eigen stat)	2079.*	0.0000

***Note*: *** *connote significance at 5% level of significance; (Fisher test reports test concerning the rejection of 'at most' 1 and 2 co-integrating equation for CMR, hence indicating the existence of at least 1 and 2 co-integration equation for CMR model.*

Source: Author's Computation (2023).

Similarly, in table 6, the results show an affirmation in its entirety for the dismissal of null hypothesis of no co-integration between CMR and its analogous variables. It reveals -5.416045 ($p< 0.05$) for Kao ADF stat, and that of Fisher stood at 594 ($p< 0.05$) and 2097 ($p< 0.05$) for trace and max eigen stats appropriately, so an indication of a strong proof in agreement of co-integration between CMR and the utilized determining variables in this work.

Table 7: Panel-based pairwise granger causality test results for LEB, CMR and HDA

Null hypothesis	Lag	Stacked test (common coefficients)	Dumitrescu Hurlin test (individual coefficients)	
		F-Stat.	W-Stat	Zbar-Stat
LEB -> HDA	1	0.038	6.090***	13.7072***
	2	3.843**	10.116***	14.7060***
	3	4.160***	8.955***	8.06276 ***
HDA -> LEB	1	57.508***	13.031***	32.7168***
	2	2.366*	7.746***	10.3093***
	3	5.923***	11.288***	11.4093***
CMR -> HDA	1	0.615	10.813***	26.6426***
	2	3.978**	11.602***	17.4645***
	3	3.351**	10.156***	9.7856***
HDA -> CMR	1	20.353***	9.248***	22.3564***
	2	1.414	1.893	-0.55286
	3	0.808	3.145	-0.27065

*Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$*

Table 7 above portrays the panel-based pairwise granger causality results (F Stat) and the Pairwise Dumitrescu Hurlin Panel Causality Tests results (W. Stat. and Zbar-Stat). The first type of test is the staked test which assumed that the cross-sections possessed a common coefficient whereas the other one assumed that the cross-sections have different coefficients. These tests are carried-out at various lags to vigorously examine the outcome. F Stat. and pairwise Dumistrescue-Hurlin panel granger causality test results reveal that a bi-directional causal relationship exists between life expectancy at birth and health development assistance consistently at lag two and three under the common and the individual coefficients assumption, given significance of F Stat., the reported W-statistics (the global panel statistics) and Zbar statistics (the standardized statistics) in table 7. However, CMR results reveal that CMR granger causes HDA consistently at lag two and three; and that HDA only granger causes CMR at lag one, henceforth, there is no strong evidence that HDA granger causes CMR (unidirectional). The implication of bi-directional causal analysis between LEB and HDA is that LEB has promoted the expansion of HDA to SSACs and equally HDA has also expedited the expansion of LEB in sub-Saharan African countries. The implication of unidirectional causal analysis between CMR and HDA is that CMR has promoted the expansion of HDA to SSACs but HDA has not expedited the reduction of CMR in the region.

7. Discussion

This research examined the causal analysis between health development assistance (HDA) and each of the employed health outcome indicators (LEB and CMR) in SSACs. The findings reveal that LEB causes the only examined explanatory (HDA). In the same vein, HDA causes LEB (health outcome indicator) (bidirectional). Considering the second health outcome indicator, CMR causes HDA but HDA does not cause CMR (unidirectional). These results are very essential for the design of health policies in SSACs as it identifies where the required attention is needed in HDA so as to increase LEB and reduce CMR in the region.

8. Conclusion

This study examined annual time series data from 20 countries of SSACs spanning from 1990-2021. Panel granger causality test was employed to examine the relations between each of the health outcome indicators employed (LEB and CMR) and HDA. Findings show bidirectional causality from LEB and HDA and unidirectional causality from CMR and HDA. HDA investment raises LEB of SSACs while there is no enough proof to show that HDA causes CMR. Particularly, HDA expenditure results into an increase in residents of SSACs quality of life but there is a lack of substantial evidence to support that HDA expenditure results into reduction in CMR in the region. The lack of enough proof to back the existence of causal relation between HDA and CMR may have resulted as a result of many political and corruptive factors. This study is contributing to researches in three different ways: this is the first time that the work on causal analysis between LEB, CMR and HDA will be carried-out and the Panel Granger Causality test employed. Second, the work considered the causal analysis between health outcome indicators and HDA on regional perspective. Third, the study made use of panel data, which is important when dealing with information that is based on various countries of SSACs. Based on the findings in this study, the following suggestions are offered: the positive effect of causal analysis between HDA and LEB should be sustainable while reasons for unidirectional causal analysis between CMR and HDA be investigated in the region. However, increases in HDA are not only essential as a single indicator by itself, but correct management of HDA spending is also vital. In the area of making HDA investments, efficiency of the investments in different health related-focal areas should be increased by keeping it away from politically concerned matters. On account of efficiency of the health related investments, regional solutions should be fashioned-out for the form and the standard of the investments by taking into account population, geographical position and regional disturbances that may pose themselves as barriers to the efficiency of health related investments. In conclusion, it is recommended that SSACs should take time to promote and develop those explanatory variables within the two models that can result into bidirectional causal analyses for LEB, CMR and HDA. Reason for this recommendation is that SSACs cannot continue to heavily depend on HDA in order to promote growth and development in its health sector; also fluctuations in HDA may negatively affect the growth of SSACs health sector.

Declaration

Not applicable

Competing interest

Not applicable**.**

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