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Is there a life expectancy Preston Hypothesis for Africa?

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Abstract

Background: The inconclusive evidence surrounding the Preston hypothesis and scarcity of findings in Africa motivated the focus of this study. This paper examined the Preston hypothesis for all countries in Africa, over the period 1960-2018. Findings are shown for the effect of per capita income and income-proxy variables on life expectancy.

Methods: Using a two-way fixed effect model, bivariate and multivariate regression were used to determine the strength of income and its proxy variables in explaining health. The direction of causality between income and health was also examined using the Dumitrescu & Hurlin (DH) panel granger causality test. The data used were sourced from the World Development Indicators (WDI) provided by the World Bank.

Findings: The study revealed the existence of the Preston hypothesis but only in the bivariate model. Findings showed stronger effect of the proportion of Investment to GDP ratio than per capita income and other income proxy variables in explaining life expectancy. The multivariate result also showed stronger effect of investment to GDP ratio, immunization rate and fertility rate on life expectancy than per capita income and proxy variables for income. The DH test revealed reverse causality between per capita income and life expectancy.

Conclusion: There is weak evidence of the existence of the Preston Hypothesis in Africa. The gains in life expectancy are largely attributed to investment, immunization and fertility rate than per capita income. Efforts to improve health in Africa should give top priority to raising investment, increase in immunization rate and reduction in fertility rate. This focus should rank high in policy maker's agenda.

Keywords: Preston Hypothesis, Life expectancy, Per capita income, Fixed Effect, Panel Granger causality

Introduction

The Preston Hypothesis (PH), examines the relationship between health and economic wellbeing Preston(1). It supports an increasing concave relationship between life expectancy at birth and economic growth measured by Gross Domestic Product (GDP) per capita. This hypothesis mirrors reality because wealthy countries generally experience higher life expectancy and lower mortality rate than poor countries. In spite of the popularity surrounding the PH, there is still a great deal of dispute about the mechanisms that lie behind the relationship (2–4). Findings in the literature particularly in developed countries show mixed conclusions (2–4). Whether such occurrence is same for Africa remains unclear. This is particularly important given that the African region is characterized with relatively low health status and high income inequality (5,6). The possibility of a positive association between income and health in the region may be dampened by the large majority of those in low-income brackets and hence invalidate the existence of the hypothesis. The debate surrounding the PH motivates further examination of its application in Africa where not much work has been done in this regard. The few existing findings for Africa, covered only a small number of countries in the region (7). This study examines the PH in Africa using data from all 54 countries in the region. The paper contributes to the literature on the PH first, by providing findings for African countries and over a wide data spectrum (1960-2018). Second, the study improves on findings in the literature by controlling for endogeneity from reverse causality and potential omitted variable bias by use of income proxies in a two way fixed effect model. Third, unlike the few existing findings for Africa, this study sheds light on the causality between income and health and hence provides evidence for endogeneity concerns from bidirectional effect. Findings for direction of causality also sheds light on arguments that the direction of causality is commonly from income to health for low and middle-income countries and from health to income for rich countries (8).

Several studies have examined the PH with varying conclusions. Some studies attribute the gains in life expectancy largely to factors that are highly correlated with income such as nutrition, medical and public health services, literacy rate and health technology than on GDP (9,10). There are also arguments that the hypothesis holds for a sample of countries taken at a particular point in time (9,11,12). The indication is that time series and longitudinal data may not display the existence of the PC (9,11,12). This is possible because over time, unpredictable occurrences such as the outbreak of an epidemic for instance, the recent COVID-19 pandemic, can interrupt the trend in health status measures. More so, per capita income levels for a country or between countries is not stable, it generally diverges over time. Hence, the overall effect of income on health may be negative or insignificant (9,11,12).

Other arguments related to the PH is that the relationship between health and economic growth change over the process of economic development (13). That is, more developed societies often show a positive effect of income on health based on the high level of health technology attainment (9,14). The effect of increase in income may not be observed on health status for low income countries as they are generally characterized with low health technology (9). The omission of the health technology frontier in developing countries often overestimates the effect of income on health (9). That is, income matters for health improvement only for developed countries that are typically close to the world health technology frontier. Health technology, comprise of the application of organized knowledge and skills, medicines,

vaccines, procedures and systems developed to solve health problems (15). Focus on providing affordable and effective health technologies is hence fundamental in meeting the health needs of the developing world (16).

In examiming the PH, Husain, (7) took a reverse approach by focusing on the impact that improvements in health can have on economic well-being. Findings are presented using the Demographic Health Survey (DHS) data for the states of India, and four African countries: Ghana, Uganda, Kenya, and Zimbabwe. Findings for India showed positive and elastic impact of life expectancy on economic outcome. The results for Africa showed positive but inelastic impact of increase in life expectancy on wealth index. Further examination of the PH for selected African countries, showed a flat curve indicating minimal influence of income on health. Estimates provided by Dalgaard & Strulik, (17) also found modest direct effect of income on longevity, but a much larger indirect impact via health-care improvements. Shkolnikov et al., (4) also attributes less applicability of the PH. Findings for income-health nexus for 61 countries showed a continuous rise in life expectancy even when GDP stagnated.

Earlier findings by Pritchett & Summers, (14) supported the PH showing a substantial impact of GDP per capita on life expectancy. The causal direction was however underpinned by an instrumental variable regression model with use of the terms of trade as instrument among other explanatory variables. Lindahl, (18) also provides micro evidence from analyzing lottery prize winners and finds a robust and sizeable effect of income on life expectancy. Using data from developed countries such as those in Europe, Mackenbach & Looman, (2) showed that improvements in life expectancy in European countries was dependent on their economic growth. Evidence provided by Angel, (3) also supports the PH with result showing negative effect of low income and over indebtedness on health for 25 European countries. Similar inference was drawn by Jetter et al., (19) revealing a sizeable effect of income on life expectancy in a panel study of 197 countries. In this case, income was not directly observed but proxied using trade openness and investment.

The evidence provided in the literature gives some consideration to the use of income proxy variables in explaining the PH and findings examining the direct effect of income on health are still inconclusive. The arguments surrounding the use of the PH stimulates further investigation of its applicability especially in Africa where there are scarcity of findings in the extant literature.

Methods

Slope homogeneity, and Unit root test

To establish the appropriate methodology in the study, we first examined the nature of the slope to check for homogeneity/ heterogeneity (20). The data was further examined for the existence of unit root. The existence of homogenous slope requires the use of models such as the fixed and random effects model or the Generalized Method of Moment estimator; whereas, models with heterogeneous effects can be examined using the SURE, Mean Group Estimator and the Panel Autoregressive Distributed Lag (PARDL) model (20,21). Some of the tests used for examining slope homogeneity include the F-Test (requires T > N), the Hausman style test (valid only if N >T and require strongly exogenous regressors) and the xthst test based on Pesaran & Yamagata,(22) and Blomquist & Westerlund,(23). The xthst test is used to check for slope homogeneity in panels with large number of cross-section (N) and time (T) dimension. This test can be used for both balanced and unbalanced panels

(20,24). In this study, the xthst test is used to check for slope homogeneity/ heterogeneity based on its wide applicability.

Given the nature of panel data to display non-stationary series especially where T>N, the data is checked for the existence of unit root. For stationary series, the traditional panel data analysis (fixed, random, pooled OLS) is used. For non-stationary series, methods often considered include the Dynamic OLS (DOS), Fully Modified OLS (FMOLS), the Pooled Mean Group (PMG) among others. To check for stationarity in the case of panel data, the first- or second-generation tests can be applied. First generation of panel unit root tests are generally based on the cross-sectional independency hypothesis and hence are only appropriate in cases of no cross-sectional dependence and homogenous panel data (25)[i]. Cases of the existence of cross-sectional dependence and heterogeneous panel require the use of second-generation panel unit root test. These tests are well documented in the literature[ii]. In this study, the homogeneity/heterogeneity of the slope parameter informs the choice of panel unit root test conducted.

Empirical Model Specification

In line with the supposition of the PH, we examined the health-income nexus using per capita income as a measure of income and life expectancy as the health outcome variable. Per capita income is often considered as a potentially endogenous regressor in the health-income model. This is mainly due to chances of its bi-directional relationship with health. In this light, the analysis is carried out using per capita income as well as with the use of proxy variables for income. Proxy variables used include initial GDP, trade as a percentage of GDP and the investment-to-GDP ratio. These variables are well documented in the literature as instrument/proxy for per capita income (19,26,27). More than one proxy variable is used in order to establish the variable with stronger effect on life expectancy. Previous income levels can influence current health condition but the reverse cannot hold. Studies have used the initial value of the potentially endogenous regressor as instruments to circumvent the problem of endogeneity due to reverse causality (19,26,27). The use of trade (measured in percentage of GDP) follows from the argument that a country's extent of international trade often relates to income levels but is not directly related to life expectancy. Similar argument is extended to use of the investment-to-GDP ratio as instrument for macroeconomic income (14,19,28).

In this paper, we adopted the fixed and random effect model in the analysis of the data. This model accommodates slope homogeneity and stationary series in panel data studies. The two-way fixed effect model is considered in the analysis to control for country and time-fixed effects and to account for unobserved heterogeneity. Focus on country specific fixed effect gives room to absorb time-invariant country-specific characteristics such as institutional structures, illness prevalence, cultural practices and colonial history. These variables are often used as determinants of the level of income and the use of the fixed effect model ensures that omission of these variables in the model yields zero covariance between income and the error term in the linear equation (29,30). We also controlled for time fixed effects to accommodate developments that can influence life expectancy and income levels simultaneously such as civil war and ethnic crisis as well as the outbreak of an epidemic. We further considered the direction of causality between income and health to establish whether reverse causality exists. This is mainly because the direction of causality is sometimes argued to be from income to health for low-and

middle-income countries, and from health to income for rich countries (8). The causal effect could also be in either or both directions. It is also possible to have no interdependency especially in developing economies that are far from the health technology frontier (9).

The general specification of the model for a two-way linear fixed effects (2FE) model, is stated as:

$$Y_{it} = \alpha_i + \gamma_t + \delta_{yxt} X_{it} + \mu_{it} \quad (1)$$

for i = 1, 2, . . . , N and t = 1, 2, . . . , T. Where Y_{it} is the value of the dependent variable for the $i\ th$ case in the sample at the $t\ th$ time period, α_i and γ_t are unit and time fixed effects respectively. The inclusion of unit and time fixed effects account for both unit-specific (but time-invariant) and time-specific (but unit-invariant) unobserved variables. X_{it} is the vector of time-varying covariates for the $i\ th$ case and at the $t\ th$ time period, δ_{yxt} is the row vector of coefficients that give the impact of X_{it} on Y_{it} at time t and μ_{it} is the random disturbance for the $i\ th$ case at the $t\ th$ time period with $E(\mu_{it}) = 0\ and\ E(\mu_{it}^2) = \mu_t^2$.

Assuming that the time invariant unit specific effect is correlated with the time variant explanatory variables X_{it} the estimates of the predictors in the model will be misleading. Similarly, misleading results will be obtained if the time specific unit invariant effect is correlated with X_{it} . To get unbiased estimates, the time and unit specific variables are captured in a fixed effects approach. Even in the presence of controlling for specific country and time characteristics, the presence of potential simultaneous relationship between health and income distorts the true effect of income on life expectancy. This endogeneity problem is addressed using proxies for income that do not have bidirectional relationship with health. The methodology adopted enables us to account for endogeneity issues from potential omitted variable bias and reverse causality problem.

We estimate how much of the variation in life expectancy can be explained by income levels alone and then with the variables used as proxies for income. We then incorporate other explanatory variables such as health technology measure using the number of children immunized with DPT vaccine, literacy rate captured using adult literacy, government expenditure on health and education, labour force participation and fertility rate. These variables have been commonly considered as predictors of health in the literature (19,31–33). This is to help in illuminating how the coefficient of income and proxies used, change by inclusion of additional controls in the model.

In examining the PH, we use the simplest logarithmic panel data form;

$$Lexp_{it} = \pi + \sigma\ LnGDPpercap_{it} + \varepsilon_{it} \quad (2)$$

Where i = 1, 2 . . ., N denotes a cross-section index of countries, and t = 1, 2 . . , T denotes the time-series index. The dependent variable in Equation (2) $Lexp,$ is life expectancy at birth and $LnGDPpercap$ is the natural log of per capita GDP in constant 2010 USD.

Equation 2 is adjusted with use of each specific proxy ($Prox$) for income so that we have

$$Lexp_{it} = \propto_1 + \propto_2 Prox_{it} + \varepsilon_{it} \quad (3)$$

The proxies used are initial value of per capita GDP ($LnGDP_{it-1}$), Trade in percentage of GDP ($TradeGDP_{it}$) and Investment to GDP ratio ($INVGDP_{it}$).

With inclusion of additional controls, equation (2) and (3) becomes

$$Lexp_{it} = \propto_1 + \propto_2 Inc/Prox_{it} + \propto_3 ImmDPT_{it} + \propto_4 Lit_{it} + \propto_5 Gexph_{it} + \propto_6 Gexped_{it} \propto_7 Lfp_{it} + \propto_8 Flr_{it} + \varepsilon_{it} \quad (4)$$

Where Inc/Prox is income or a specific income proxy, $ImmDPT$ is the number of children between ages 12 to 23 months that received DPT[1], Lit is adult literacy rate as a percentage of individuals age 15 years and above, $Gexph$ is domestic general government health expenditure as a percentage of general government expenditure, $Gexped$ is total government expenditure on education as a percentage of general government expenditure, lfp, is labour force participation as a percentage of total population ages 15 and above while Flr represents total fertility rate (births per woman).

To examine the causality between income and health, we rely on the approach provided by Dumitrescu & Hurlin, (34). This approach is commonly applied to test for granger causality in panel data studies (35–38) and is a buildup on the method developed by Granger, (39) for analyzing the causal relationships between time series variables.

The underlying regression for the DH test can be written as

$$Y_{i,t} = \propto_1 + \sum_{k=1}^{k} \gamma_{i,k} Y_{i,t-k} + \sum_{k=1}^{k} \beta_{i,k} X_{i,t-k} + \varepsilon_{it} \quad \text{with } i = 1, \dots, N \; t = 1, \dots, T \quad (5)$$

where $X_{i,t}$and $Y_{i,t}$are the observations of two stationary variables for individual i in period t. Coefficients are allowed to vary across individuals but are assumed time-invariant. The lag order K is assumed to be identical for all individuals and the panel must be balanced. The DH test assumes there can be causality for some individuals but not necessarily all individuals or units in the panel. The null hypothesis is therefore stated as:

$$H_0 = \beta_{i1} = \cdots = \beta_{1K} = 0 \quad \forall\, i = 1 \dots, N \quad (6)$$

This implies absence of causality for all individuals in the panel,

The alternative hypothesis is stated as the absence of causality for some individuals. That is

$$H_1 = \beta_{i1} = \cdots = \beta_{1K} = 0 \quad \forall\, i = 1 \dots, N_1 \quad (7)$$

$$\beta_{i1} \neq 0 \; or \dots or \; \beta_{1K} \neq 0 \quad \forall\, i = N_1 + 1, \dots, N$$

where $N_1 \in [0, N-1]$ is unknown. If $N_1 = 0$ =, there is causality for all individuals in the panel. N_1 must be strictly smaller than N, otherwise there is no causality for all individuals and H_1 reduces to H_0.

The underlying regression using life expectancy and per capita income for the DH test can be stated as

$$Lexp_{it} = \propto_1 + \sum_{k=1}^{k} \beta_{ik} Lexp_{it-k} + \sum_{k=1}^{k} \gamma_{ik} GDPpercap_{it-k} + \varepsilon_{it} \quad (8)$$

Here, $Lexp_{it}$ and $GDPpercap_{it}$ are the observations of the stationary values of the variables for individual i in period t. The coefficients are allowed to vary across individuals but time invariant.

The study pooled cross-section and annual time series data from 1960 to 2018 for 54 countries in Africa. The data used were sourced from the World Development Indicators (WDI) provided by the WorldBank, (40). The analysis is carried out using Stata 16.

Results and Discussion

We present the findings of the study beginning with the descriptive statistics of variables as shown in Table 1.

In table 1, the average length of life for the period considered in the study, is approximately 53 years. This is relatively low compared to global figures of 72 years in 2016 and 72.6 as at 2019 (41,42). Average GDP per capita is about 1,904.42 United States Dollars (USD). The deviation of income values from the mean is somewhat high at about 2,571.21 USD and is expected given the heterogeneous

[1] DPT is a class of combination vaccines against three infectious diseases in humans: diphtheria, pertussis (whooping cough), and tetanus

Table 1: Descriptive statistics of the variables used in the study

Variable	Mean	SD	Min.	Max.	Variable definition and measurement
$Lexp$	52.59	9.33	26.17	76.69	Life expectancy at birth, total (years)
$GDPpercap$	1,904.42	2,571.21	164.19	20,512.94	GDP per capita (constant 2010 US$)
$Trade/GDP$	65.94	35.56	6.32	376.22	Trade (% of GDP)
INV/GDP	0.20	0.10	-0.03	0.84	Gross fixed capital formation (% of GDP)
$ImmDPT$	67.29	25.85	1.00	99.00	Immunization, DPT (% of children ages 12-23 months)
Lit	59.42	22.47	5.40	95.87	Literacy rate, adult total (% of people ages 15 and above)
$Gexph$	7.09	3.57	0.65	31.91	Domestic general government health expenditure (% of general government expenditure
$Gexped$	16.85	5.71	0.88	37.52	Government expenditure on education, total (% of government expenditure
Lfp	65.87	12.87	41.15	91.10	Labor force participation rate, total (% of total population
Flr	5.81	1.41	1.36	8.46	Fertility rate, total (births per woman)

Source: Authors' Computation from WDI (2019)

nature of country cross sections. Trade as a percentage of GDP is fairly high at 65% on average. This suggests higher trade volume relative to macroeconomic income in the region. Investment to GDP ratio is quite low at approximately 20 percent. Low investment spending in Africa is however expected given that most countries in the region are in the low income grouping and hence spending on consumables are given top priority before considerations for investment expenditure (43). The result also shows that on average, 67 percent of children between ages 12-23 months received the DPT vaccine. This suggests that about 33% of children between the ages of 12-23 months in the African region did not receive the DPT vaccine for the period used in this study. Immunization generally provides individuals with better chance of a healthy life right from childhood. The DPT vaccine in particular protect individuals against infectious diseases that can cause serious illness and disability. The statistics for children that received the DPT immunization is low when compared with global average rates of 85 percent of children immunized with the vaccine in 2019 (44).

Literacy rate in the region is about 59 percent and is also relatively low when compared to global estimates of approximately 86 percent in 2018 (45). The low statistics for literacy rate has unfavorable implication for enhancing human capabilities, poverty eradication and broadening participation in society (46). Over the study period, average domestic general government health expenditure as a percentage of general government expenditure is approximately 7%. These statistics suggest that African economies are characterized with high out of pocket health spending and this expenditure type is generally catastrophic particularly for low-income earners. Average government expenditure on education as a percentage of total government spending is approximately 17 percent. The indication is that public spending on education is more than twice the percentage value of spending on health care in Africa. Labour force participation is approximately 66% and is suggestive that more than half of the

working population are gainfully employed. However, labour employment is generally in the informal sector where income earnings are often low (47). The statistics for fertility rate show approximately 6 children per woman and is thrice that of global average value of approximately 2 children in 2018 (48). In Africa as the case of most developing countries preference is given to having more children as they are needed for income support in terms of labor supply in self-employed ventures and to provide parents with care in their old age. High fertility rates can also be related with low contraceptive use and generally low female literacy rates(49,50).

To enable the determination of the type of panel unit root test to be conducted, the result for slope homogeneity is first presented. This is shown in table 2.

Table 2: Xthst test for slope homogeneity across cross-sectional units

Variable	$LnGDPpercap$	$LnGDPpercap\_1$	$Trade/GDP$	INV/GDP
H_0: slope coefficients are homogenous	-0.80	-0.48	-1.56	-0.45

*Note: Delta coefficient reported. *** p<0.01, ** p<0.05, * p<0.*

The result for slope homogeneity suggests that all slope coefficients are identical across cross-sectional units. This is expected as all countries involved in the analysis are from Africa and they share similar features and characteristics. Hence economic and socio economic variables would have achieved some level of convergence over time (51,52).

Based on the result for homogenous slope, first generation panel unit root tests specifically the Fisher-type augmented Dickey-Fuller and Phillips-perron test statistic are applied. This is due to missing data for some of the series in the data set.

Table 3: Results for Unit root test

LEVEL

SERIES	Fisher-type unit-root test based on augmented Dickey-Fuller tests		Fisher-type unit-root test based on Phillips-Perron tests	
	No Trend	Trend	No Trend	Trend
$Lexp$	16.03***	-6.10	-5.52	-6.10
$GDPpercap$	2.02**	-0.98	2.02**	-0.98
$Trade/GDP$	-3.15***	7.93 ***	6.12 ***	7.93 ***
INV/GDP	-2.04**	4.87 ***	2.82 ***	4.87 ***
$ImmDPT$	27.34***	14.18***	23.37 ***	14.18 ***
Lit	158.51***	164.23***	171.09***	164.23***
$Gexph$	19.11***	9.59***	9.28**	9.59***
$Gexped$	66.60***	58.90***	66.60***	58.90***
Lfp	6.45***	-4.02	-1.19	-4.02***
Flr	15.66***	22.59 ***	-4.77	22.59***

*Note: Modified inv. chi-squared values reported with *** p<0.01, ** p<0.05, * p<0.1 denote rejection of the null hypothesis of non-stationary series at 1%, 5% and 10% respectively.*

The ADF and Phillips Perron test statistic reveal stationary series for all the variables at level except for life expectancy that show existence of unit root with the Phillips perron statistic. The ADF statistic however showed stationarity for life expectancy at level. Given the stationarity of the series at level, the fixed and random effect model can therefore be estimated.

We present findings for the bivariate regression in table 4.

Table 4: Bivariate regression results for per capita GDP, initial per capita GDP, trade to GDP ratio and investment to GDP ratio controlling for time and country fixed effect

Variables	$LnGDPpercap$		$LnGDPpercap\_1$		$Trade/GDP$		INV/GDP	
Dependent variable: Life Expectancy	4.08*** (-0.14)	6.46*** (-0.36)	-1.38*** (-0.15)	7.89*** (-0.31)	0.06***- (0.00)	0.08***- (0.01)	19.23*** (-2.14)	23.32*** (-2.07)
Constant	25.16*** (-0.95)	8.53*** (-2.53)	62.51*** (-1.05)	-2.49 (-2.18)	50.03*** (-0.34)	48.38*** (-0.51)	52.76*** (-0.45)	51.94*** (-0.43)
Observations	2,562	2,562	2,503	2,503	2,425	2,425	1,473	1,473
R-squared	0.55	0.60	0.40	0.66	0.42	0.58	0.22	0.59
Time effect	Yes		Yes		Yes		Yes	
Country effect		Yes		Yes		Yes		Yes
Hausman test	33.82 ***		33.24***		42.38***		2063.40***	
F-Test Time effect	61.57***		62.58***		4.88***		23.08***	

*Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

The results show a positive significant relationship between life expectancy and per capita income. Similar result is shown for the proxies of per capita income. We noticed stronger link between life expectancy and predictor variables when country specific heterogeneity is accounted for than when time specific effects are accounted. This is in terms of the magnitude of significant coefficients. This result suggests that country specific characteristics such as institutional structure, cultural practices, and colonial history among other country specific factors, have strong effect in predicting the length of life in Africa than time specific occurrences say for instance the outbreak of an ethnic crisis. Cultural norms and belief systems influences the willingness of individuals to adapt to new technological advancement in medicine and the use of modern medical health care services that invariably promotes better health and reduces the risk of mortality. Similar argument is documented in an earlier study by Caldwell (53).

The results in table 4 show that investment to GDP ratio induces larger positive effect on life expectancy than per capita income and other proxies used in the study. The results show that a 1 percent increase in per capita income will induce a rise in life expectancy by approximately 4 and 7 years in the time and country fixed effect model respectively. Findings for investment to GDP ratio show that a 1 percent increase in the volume of investment to GDP will induce approximately 19 and 23 years increase in life expectancy in the time and country fixed effect model respectively. Interestingly, similar finding was observed by Jetter et al., (19) using panel data set of 197 countries over 213 years. This result suggests that the volume of investment in an economy has stronger link with life expectancy than income. This may be due to high income inequality in the region (5,6).The results also showed relatively

smaller magnitude for the coefficient of trade to GDP ratio in explaining life expectancy than other income proxy, suggesting that trade to GDP ratio may not be the best measure to capture the relationship between economic wellbeing and health. Jetter et al., (19) found similar result. The result for the effect of the initial value of per capita income is inconclusive.

The time specific effect showed negative effects on life expectancy while that for the country specific effect is positive.

Findings for the multivariate model are shown in tables 5, 6, 7 and 8. We present findings for the multivariate regression results controlling for per capita income and additional regressors in table 5.

Table 5: Multivariate regression results for the effect of GDP and other predictors on life expectancy

Variables	Time-fixed effect model	Country-fixed effect model
$LnGDPpercap$	-1.21 (-1.24)	2.85 (-3.07)
$ImmDPT$	0.122*** (-0.04)	0.03 (-0.04)
Lit	-0.09** (-0.04)	0.07 (-0.05)
$Gexph$	-0.07 (-0.21)	-0.08 (-0.17)
$Gexped$	0.02 (-0.10)	0.00 (-0.07)
Lfp	-0.04 (-0.06)	0.09 (-0.14)
Flr	-4.13*** (-0.84)	-7.61*** (-0.91)
Constant	85.86*** (-15.31)	62.51** -27.36
Observations	105	105
R-squared	0.70	0.98
Time effect	Yes	-
Country effect	-	Yes
Hausman Test	87.41***	

*Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

The results in table 5 show that per capita income loses its relevance in explaining life expectancy when additional controls are included in the model. The variables that influence the length of life in table 5 are the number of children with DPT immunization, literacy and fertility rates. Fertility rate had larger effect on life expectancy than other predictors in the model. With 1 percent increase in fertility rate, the length of life will fall by about 4 years in the time effect model and approximately 8 years in the model with control for country effect. Generally, a fall in fertility rate frees up resources that can be invested in promoting human and physical capital consequently translating to improvements in welfare and health (54). Significant effect of immunization on life expectancy is observed only in the time-effect model. Evidence shows that with 1 percent increase in the number of children ages 12-23 months immunized with the DPT vaccine, life expectancy will rise by about 0.12 years. The result for literacy rate is significant only in the time effect model and the evidence reveal that a 1 percent increase in basic literacy rate, induces a fall in life expectancy by about 0.09 years. In line with Grossman, (55), increase in literacy rate should ordinarily improve health through improvement in the efficiency of the use of health care goods and services. But in most African economies, what is observed is low infrastructure provision for health care so that with higher literacy, quality health care goods are not available to induce any positive effect when they are efficiently used. Grossman, (55) also argue that improved literacy should raise the productivity of labour so that higher wage rates will provide better financial access to health care. The small size of the formal

sector in most African economies creates underemployment for most literate persons so that there is a case of more labour supply of literate persons than there are for demand. In line with this position, there is the possibility to observe negative effects of improved literacy on life expectancy.

Similar results were obtained by Osakede and Ajayi (33) for sub-Saharan African economies.

Multivariate regression results controlling for initial per capita GDP and additional explanatory variables are shown in table 6.

Table 6: Multivariate regression results for the effect of initial per capita GDP and other predictors on life expectancy

Variables	Time-fixed effect	Country-fixed effect
$LnGDPpercap\_1$	-0.04 (-0.57)	6.06* (-3.05)
$ImmDPT$	0.08* (-0.04)	0.02 (-0.04)
Lit	-0.06 (-0.06)	0.03 (-0.04)
$Gexph$	0.07 (-0.24)	-0.10 (-0.18)
$Gexped$	0.08 (-0.10)	-0.06 (-0.09)
Lfp	-0.01 (-0.06)	0.13 (-0.14)
Flr	-3.55*** (-0.68)	-6.74*** (-1.07)
Constant	72.96*** (-7.49)	37.14 (-27.5)
Observations	93	93
R-squared	0.75	0.988
Time effect	Yes	
Country effect		Yes
Hausman test	10.96**	

*Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

The evidence suggests that initial per capita GDP maintains its relevance in explaining life expectancy with use of additional controls in the analysis but only in the country fixed effect model. The results show that a 1 percent increase in initial per capita GDP induces a rise in life expectancy by approximately 6 years. Other variables shown to influence life expectancy in table 6 are the level of DPT immunization (time fixed effect model) and fertility rate (time and country fixed effect model). These findings are similar to those obtained in table 5 and hence will not be explained to avoid repetition.

Multivariate regression results controlling for trade to GDP ratio and additional explanatory variables are presented in table 7. The result reveals that the ratio of trade to GDP becomes insignificant when more predictors are included in the model. This result is the same in the time and country fixed effect model. The result buttresses findings in the bivariate model (table 4) that the trade volume to GDP may not be a good predictor for life expectancy. Findings for the other variables in table 7 that influence life expectancy are similar to those of previous tables.

Multivariate regression results controlling for investment to GDP ratio and additional explanatory variables are shown in table 8. The result show that the investment to GDP ratio remained relevant in explaining life expectancy even with the inclusion of additional control variables. However, this is only in the model accounting for time specific heterogeneity. Findings show that a 1 percent rise in the investment to GDP ratio, increases life expectancy by as much as 26 years. Other variables that influence life expectancy in table 8, have similar impact as observed in previous multivariate regression and hence their effects are not also explained here.

Table 7: Multivariate regression results for the effect of trade to GDP ratio and other predictors on life expectancy

Variables	Time-fixed effect	Country-fixed effect
$Trade/GDP$	-0.01 (-0.04)	0.03 (-0.02)
$ImmDPT$	0.16*** (-0.05)	0.03 (-0.04)
Lit	-0.13*** (-0.05)	0.09* (-0.05)
$Gexph$	-0.02 (-0.23)	-0.05 (-0.19)
$Gexped$	0.01 (-0.10)	-0.01 (-0.09)
Lfp	0.01 (-0.05)	0.14 (-0.15)
Flr	-4.03*** (-0.95)	-8.05*** (-1.01)
Constant	73.15*** (-8.90)	77.51*** (-12.09)
Observations	101	101
R-squared	0.72	0.98
Time effect	Yes	-
Country effect	-	Yes
Hausman	37.07***	

*Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Table 8: Multivariate regression results for the effect of investment to GDP ratio and other predictors on life expectancy

Variables	Time-fixed effect	Country-fixed effect
INV/GDP	26.13*** (-9.12)	5.45 (-9.29)
$ImmDPT$	0.18*** (-0.05)	0.00 (-0.0532)
Lit	-0.11** (-0.05)	0.04 (-0.07)
$Gexph$	-0.018 (-0.28)	0.03 (-0.21)
$Gexped$	0.07 (-0.12)	-0.02 (-0.10)
Lfp	0.01 (-0.06)	-0.01 (-0.17)
Flr	-3.73*** (-0.58)	-8.21*** (-1.20)
Constant	62.14*** (-5.73)	93.85*** (-17.04)
Observations	93	93
R-squared	0.715	0.976
Time effect	Yes	-
Country effect	-	Yes
Hausman	12.65**	

*Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Overall, only the initial per capita income and the investment to GDP ratio remained relevant in explaining life expectancy in the multivariate regression models. These findings give credence to evidence shown in the bivariate analysis suggesting strong effect of increase in investment on life expectancy. Findings for the multivariate regression show larger magnitude for the coefficient of investment to GDP ratio on life expectancy than initial per capita income indicating key role of investment on health.

To carry out the DH heterogeneous panel Granger-causality test requires that the variables used are stationary. The results for panel unit root test statistics for life expectancy and per capita income are earlier presented in table 3. The unit root test statistics shown using the Fisher-type augmented Dickey-Fuller and Phillips-perron test statistic reveal that life expectancy and per capita GDP are stationary series and hence the DH granger causality test can be applied. The result for

the DH heterogeneous panel Granger-causality test is shown in table 9.

Table 9: DH heterogeneous panel Granger-causality test results

Z-bar/ Z-bar tilde	GDP to Life expectancy		Life Expectancy to GDP	
	Lag order: 1	Lag order: 2	Lag order: 1	Lag order: 2
Z-bar	11.25***	4.77***	7.27***	6.54***
Z-bar tilde	10.37***	4.15***	6.64***	5.79***
	Hypothesis **H0:** GDP per capita does not Granger-cause Life expectancy **H1:** GDP per capita does Granger-cause Life expectancy for at least one panel var (ID).		Hypothesis **H0:** Life expectancy does not Granger-cause GDP per capita. **H1:** Life expectancy does Granger-cause GDP per capita for at least one panel var (ID).	

*Note: *** p<0.01, ** p<0.05, * p<0.1*

The DH panel granger causality test suggests a bidirectional relationship between per capita income and life expectancy establishing the existence of endogeneity from bidirectional effect. The finding is also contrary to arguments that the direction of causality is commonly from income to health for low and middle-income countries and from health to income for rich countries (Erdil & Yetkiner, 2004). The result is however similar to findings by Chen et al., (56) using infant mortality rate as the measure for health for a panel of 58 developing countries[2]. African economies are often categorized in the low and middle-income country grouping and the evidence provided in this study supports the position that the prevailing poor health condition in Africa is instrumental for existing low-income levels in the region. The result also suggests that the prevalence of poor health condition in Africa has implications on the ability of countries in the region to attain reduction in poverty levels.

Conclusion

This study provides evidence for the existence of the PH for a panel of 54 countries in Africa with control for country and time heterogeneity. In line with the argument of endogeneity between wealth and health, the results are shown using per capita income and proxy variables for per capita income. We also examined the relevance of the estimates in a bivariate model and with inclusion of other control variables. The causal relationship between income and health was also tested. Findings showed relevance of the PH in Africa only in the bivariate model. The PH did not hold in the multivariate regression, suggesting stronger effects of other variables in influencing the length of life than the level of income. Findings also suggest strong effect of country specific characteristics on the length of life relative to time specific occurrences. The results in the bivariate and multivariate regression showed the key role of investment to GDP ratio as the main driver of health than income and income proxies such as initial income level and the trade to GDP ratio. That is, in terms of the PH, findings of the study attribute the gains in life expectancy largely to investment than per capita income in the African region. This result can be associated with high income inequality in the region. Other interesting results in the study reveal the importance of immunization particularly for DPT and

[2] Chen et al (2014) however found non causality between health and wealth for some countries in the Sub Saharan Africa region

fertility rate in promoting health outcome. Contrary to classical thought of one-way relationship between income and health for developing countries, the heterogeneous panel test detects a bidirectional link. Policy measures that drive increase in investment is key in promoting health outcome in Africa. Tactic actions in this direction has consequential effect on macroeconomic income levels. Policy focus on increase in immunization rate and reduction in fertility rate will also lead to improvement in the length of life in the region.

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Appendix
Correlation Matrix

	Lexp	*GDPpercap*	*GDPpercap_1*	*Trade/GDP*	*INV/GDP*	*Imm DPT*	*Lit*	*Gexph*	*Gexped*	*Lfp*	*Flr*
Lexp	1.00										
GDPpercap	0.37	1.00									
GDPpercap_1	0.06	-0.31	1.00								
Trade/GDP	0.12	0.44	-0.23	1.00							
INV/GDP	0.36	0.33	0.05	0.24	1.00						
ImmDPT	0.46	0.04	0.16	-0.03	0.10	1.00					
Lit	0.18	0.24	-0.08	0.14	0.08	0.15	1.00				
Gexph	0.03	0.07	0.01	-0.05	-0.10	0.30	0.17	1.00			
Gexped	0.04	0.09	-0.12	-0.02	-0.18	0.13	0.06	0.24	1.00		
Lfp	-0.31	-0.59	0.22	-0.19	-0.19	-0.03	-0.04	0.04	-0.05	1.00	
Flr	-0.60	-0.68	0.13	-0.42	-0.18	-0.49	-0.31	-0.28	-0.18	0.40	1.00

The results in the appendix show the correlation matrix. This is done to ensure that multicollinearity does not exist among the explanatory variables. The linear correlation coefficient ranges from 0.001 to 0.677. This suggests that no multicollinearity problem exists among the explanatory variables, as the values are below the benchmark of 0.80.

[i] Some examples of the first-generation unit root test include the Hadri LM test by Hadri (2000), Harris-Tzavalis unit root test proposed by Harris-Tzavalis unit root test proposed by Harris and Tzavalis (1999). Others include the test proposed by Levin and Lin (1992, 1993), Levin, Lin and Chu (2002), Im, Pesaran and Shin (1997, 2002, 2003), Fisher-type (Choi 2001) and several others well documented in the literature.

[ii] Second generation tests are also well documented in the literature and includes those proposed by Bai and Ng (2001, 2004), Moon and Perron (2004a), Phillips and Sul (2003a) Pesaran (2003), Choi (2002) etcetera.