Journal of Economics and Development Studies
December 2018, Vol. 6, No. 4, pp. 19-37
ISSN: 2334-2382 (Print), 2334-2390 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/jeds.v6n4a3
URL: https://doi.org/10.15640/jeds.v6n4a3

Threshold Effects of Health on Economic Growth in Sub-Saharan African Countries: Evidence from a Dynamic Panel Threshold Model

Jeffrey Kouton[1], Coffie Francis José N'guessan[2] & Firmin Ayivodji[3]

Abstract

This paper investigates the presence of threshold effects in the health-economic growth nexus for 24 Sub-Saharan Africa countries. We apply a dynamic panel threshold model and find that health human capital stock, measured by life expectancy at birth, has a positive and significant impact on economic growth. This impact becomes more important as health investments, captured by public health expenditures, increase. We estimate a threshold of 3.5% of the ratio public health expenditures/GDP above which life expectancy at birth has a higher impact on economic growth. This may be due to the fact that even if life expectancy is increased, individuals will not be productive unless they are able to maintain and improve their health status. We recommend investments in health in order to make drugs purchase much easier. More investments should be devoted to fight malaria, HIV/AIDS and diseases with a high morbidity that reduce the productivity of individuals.

Keywords: Dynamic panel threshold model, Economic growth, Health investments, Drugs purchase.

JEL: I10, J17, F43, C33, O40, O55.

1. Introduction

The analysis of the link between human capital and economic growth went through two major movements over the years. The different researches first considered education as the main measure of human capital (Becker, 1964), and then, health has been incorporated into growth models (Sachs and Warner, 1997; Barro, 2001). According to Weil (2014), health plays an important role in the measure of a country's development.

Health is, by nature, a multidimensional concept. One of the most common measures of health is the probability of death, measured by life expectancy or the infant mortality rate. However, the variations in the probabilities of death are not sufficient to provide sufficient information on health status (Weil, 2014). Let's take an example to illustrate this. Life expectancy is used as a measure of the impact of diseases on health. This is because early death is the most observable impact of the disease on the individual. In other words, an individual who is not sick could benefit from a higher life expectancy. However, the occurrence of death is not the only way to understand the consequences of disease. There are also other indicators such as the number of years lost to disability. This indicator measures the condition of a person in poor health or with a disability.

[1]Ecole Nationale Supérieure de Statistique et d'Economie (ENSEA), Abidjan, Côte d'Ivoire, Email: jeffrey.kouton@gmail.com
[2]Centre Ivoirien de Recherches Economiques et Sociales (CIRES), Abidjan, Côte d'Ivoire
[3]Université de Montréal, Québec, Canada

According to the World Health Organization, "health is a state of complete physical, mental and social well-being and not just the absence of disease or infirmity". Health can also be measured by the Body Mass Index, the height, the proportion of women not suffering from anemia, or intelligence (Weil, 2014).

Generally, studies which analyze the relationship between health and economic growth show a positive and significant relationship between them (Weil, 2007; Aghion et al., 2010; Sghari and Hammami, 2013; Vijesandran and Vinayag athasan, 2014; Atilgan et al., 2016; Wang and Liu, 2016 among others). However, the conclusions vary from one research to another. In fact, some studies stand out from the general trend, leading to a negative or insignificant effect of health on economic growth (Acemoglu and Johnson, 2007). In addition, most of the studies that have focused on the relationshipbetween the two variables assumes a linear relationship between them. This may be inconvenient because some studies show that macroeconomic relations are not always linear. More theoretical and empirical works have therefore started to examine the existence of non-linearity between economic growth and health. On the one hand, thisapproach aims to conciliate the divergent results obtained by the empirical studies. On the other hand, the hypothesis on which most of these works are based is that health is a variable that can contribute to enter (or leave) in a "poverty trap". Aisa and Pueyo (2006) showed that the impact of public health spending on economic growth is positive in poor countries and negative in developed countries. This implies that the impact of public health expenditure on economic growth depends on the level of development.

Reinhart (1999) found that a high life expectancy has a positive effect on economic growth, but that effect is non-linear: the impact of improving life expectancy on economic growth is greater when the level of life expectancy is low. Blackburn and Cipriani (2002) derived a threshold effect between human capital and economic growth. They demonstrated that there is a level of human capital below which economies are underdeveloped and above which economies are developed. In the same way, Cooray (2013) analyzed the differential effects of health on economic growth and showed that the impact of life expectancy at birth on economic growth is significant only when life expectancy is associated with health and education expenditures. In other words, the increase in health and education spending lead to a positive and significant impact of health capital on economic growth. Gyimah-Brempong and Wilson (2004) studied the effects of health human capital on the per capita growth rate of Sub-Saharan African and the OECD countries.

Using a Solow growth model augmented with human capital that they estimated with a dynamic panel, they found that growth rate per capita is positively and significantly influenced by the stock and the investment in human capital. These authors also highlighted a quadratic relationship between the health human capital stock and the growth rate of GDP per capita. In other words, the impact of health human capital on economic growth decreases for high health stock values. Their results are similar to those of Sachs and Warner (1997). Indeed, Sachs and Warner (1997) showed that there is a non-linear (quadratic) relationship between economic growth and the accumulation of human capital. The variable they used to approach human capital is life expectancy at birth.

Using a smooth transition model applied to panel data on the period 1975-2003 and for seventeen (17) OECD countries, Chakroun (2009) found that the relationship between health expenditure (health care) and the income is non-linear, varying in time and space. Desbordes (2011) studied the non-linear effects of life expectancy on economic growth over the period 1940-1980 for fourty-seven (47) countries. He showed a negative and significant impact of life expectancy on per capita income in countries with an initial life expectancy less than 43 years. By contrast, countries with an initial life expectancy of more than 53 years register a positive impact of life expectancy on per capita income.

Chakroun (2012) used the threshold detection method suggested by Hansen (1999) to prove the existence of nonlinear effects between economic growth and health. The health capital stock is approximated by life expectancy. Investment in health is measured by the share of public spending in health. He showed the existence of threshold effects in the relationship and leads to the conclusion that health has heterogeneous effects on the long-run growth dynamics of countries. More specifically, he concluded, at first, a positive but decreasing marginal effect of life expectancy on economic growth. In a second step, the author's estimations revealed that the impact of health human capital is lower in countries whose share of public health expenditure in GDP exceeds 1.77%. The author explains this result by the fact that the economic gains of health are evicted by the macroeconomic costs of public resources devoted to the health sector. Thus, the researches on non-linearity seem to raise an important fact. Should economies have a given level of health human capital to raise economic growth and to achieve development goals?

According to the Africa Data Report 2016, health is an essential component of development investments and one of the most critical factors in achieving the Sustainable Development Goals (SDGs), including the eradication of the HIV / AIDS epidemic, malaria and other communicable diseases by 2030.

Moreover, the objective behind the implementation of large-scale health programs is not only the reduction or the elimination of diseases, but also the achievement of probable economic gains thanks to a health human capital of quality. These health programs are based on investments in health. However, the amounts allocated to health expenditure vary from one country to another. For example, in Sub-Saharan Africa, the overall trend in health investments is as follows: during the period 1996-2000, public health expenditures were about 2.05% of GDP and 2.24% over the period 2001-2005, 1.16% and 1.68% respectively over the periods 2006-2010 and 2011-2014. At the same time, the health capital stock of the region, measured by life expectancy at birth, had an upward trend, from an average of 50 years in 1996-2000 to an average of 58 years in 2011-2014. Yet most of Sub-Saharan African countries remain less developed and must repeatedly face epidemics and diseases that could penalize economic growth. So, what is the threshold of investment in health likely to improve productive capacities andimprove economic growth? To answer that question, it is appropriate to define the notion of health threshold. Boidin (2009) apprehended the notion of health threshold in two ways.

A first approach is to define the health threshold at the individual level. Thus, health threshold is the minimum level of health below which the health of the individual deteriorates as well as his capacity to be autonomous. The second approach is the macroeconomic approach where the health threshold is defined as the point separating situations of weakness of the health human capital of the economy and situations where the level of health capital allows "to maintain the resilience of the population in a context of strong socio-economic constraints".According to the latter approach, it is situations of blocking countries in a trap of human underdevelopment. These definitions lead to the concept of optimal level of health expenditure which is a certain level of health expenditure that can guarantee good health for individuals while ensuring the preservation of the major macroeconomic equilibrium and promoting growth.

Based on the previous observations, this study aims to examine the existence of threshold effects between health and economic growth in Sub-Saharan African countries. We focus on Sub-Saharan Africa because it is the region of the world with the worst health outcomes. We also aim to highlight the effect of the health human capital stock on economic growth through its interactions with the public health expenditure.This study contributes to the existing literature by providing a review of the link between economic growth and health in Sub-Saharan Africa through a recent methodology using a dynamic panel threshold model. The choice of that method is justified with two main arguments. Firstly, growth equations are frequently used to analyze the link between health and economic growth. To estimate such equation, one must take into account the initial level of GDP, otherwise, a bias of specifications may rise (Eggoh, 2009). Caselli et al. (1996) also showed that the endogeneity can be a problem (unbiased estimators, false conclusions) in the estimation of economic growth model based on linear regressions on panel data since the initial income in these models is endogenous by construction. The estimation of a dynamic equation using GMM helps to solve this problem. Thus, using a dynamic model is appropriate to address the relation between health and economic growth.

Secondly, non-linearity is an important feature of the dynamics of macroeconomic aggregates. Empirical studies mentioned in the literature review show that an interesting way to model non - linearity is to use regime switching models. These models give an economic explanation of the non-linearity. A way to analyze threshold effects is to use the panel threshold model introduced by Hansen (1999). In Hansen's model, all explanatory variables are assumed exogenous. Thus, using this model to analyze the threshold effects between health and economic growth presents a problem because of the endogeneity. To overcome this problem, Kremer et al. (2013) introduce an estimation technique on panel data that takes into account the endogeneity bias. Their model is an extension of Hansen's (1999) non-dynamic panel threshold model and Caner and Hansen's(2004)instrumental variable estimation in a threshold effects model. To the best of our knowledge, the health-economic growth nexus has not been analyzed using the dynamic panel threshold model, specifically for the case of Sub-Saharan African countries.The remainder of this article is organized as follows. Section 2 discusses the methodology and describes the data, while Section 3 presents and discusses the results. Section 4 concludes.

2. Methodology and data

2.1. The dynamic panel threshold model and the data

This study aims to examine the existence of threshold effects between health and economic growth in Sub-Saharan Africa by using the dynamic panel threshold model initiated by Kremer et al. (2013).

The principle of threshold regressions is comparable to the principle of change point or structural break models with the threshold variable equivalent to time. This allows for a flexible functional form by splitting the sample used, according to a given value of the threshold variable. In fact, contrary to the existing methods to capture non-linearity (squared values, spline regressions, etc.), it is not necessary with the dynamic panel threshold to rely on a specific functional form of non-linearity aspect of the model.

The panel threshold model is specified as follows:

$$y_{it} = \mu_i + \beta'_1 z_{it} I(q_{it} \leq \gamma) + \beta'_2 z_{it} I(q_{it} > \gamma) + \varepsilon_{it}, \quad (1)$$

Where $1 \leq i \leq N$ represent the country and $1 \leq t \leq T$ indexes time. y_{it} is the dependent variable, q_{it} the threshold variable divides the observations into two regimes distinguished by differing regression slopes β_1 and β_2, γ is the threshold value, z_{it} is a m-vector of explanatory regressors which may include lagged values of y_{it} and other endogenous variables. The vector of explanatory variables is partitioned into a subset z_{1it} of exogenous variables uncorrelated with ε_{it}, and a subset of endogenous variables z_{2it}, correlated with ε_{it}. Moreover, the estimation of the model requires a suitable set of $k \geq m$ instrumental variables x_{it} which may include z_{1it}. $I(.)$ is the indicator function, ε_{it} is the error term and is identically and independently distributed ($\varepsilon_{it} \sim (0,\sigma^2)$), μ_i refers to the country-specific fixed effect. The term μ_i captures cross-sectional unobserved heterogeneity due to differences in technology between countries and also all other determinants of the variability inthe dependent variable y_{it}, which are not already controlled in the model.

Before the estimation of the model **(1)**, country-specific fixed effects must be eliminated. Nickell (1981) has shown that the estimation of a dynamic model on panel data by using OLS (Ordinary Least Squares), LSDV (Least Squares Dummy Variable) or corrected LSDV (Bruno, 2005) estimates is biased when N is large and T is fixed because the endogenous variable is correlated with the error term. Applying a first differencing technique to eliminate the country-specific effect implies negative serial correlation of the error-term and it is not possible to apply the distributional theory for panel data developed by Hansen (1999). Thus, in the dynamic model, the transformation used is the forward orthogonaldeviation transformation suggested by Arellano and Bover (1995). This technique subtracts the average of all future available values for the variable concerned and ensures that transformed errors are no longer auto-correlated. For the error term, the forward orthogonal deviation transformation is written in the following form:

$$\varepsilon^*_{it} = \sqrt{\frac{T-t}{T-t+1}}\left[\varepsilon_{it} - \frac{1}{T-t}(\varepsilon_{i(t+1)} + \cdots + \varepsilon_{iT})\right].$$

After the fixed-effects are eliminated, the estimation procedure of model (1) involves three steps. Firstly, following Caner and Hansen (2004), we estimate a reduced form regression for the potential endogenous variable, as a function of the instruments, using the least squares method. The predicted values of the variable are then substituted into equation (1) and the threshold point is estimated using least squares. Secondly, this step is repeated for a strict subset of the support of the threshold variable. Finally, the estimator of the threshold value is selected as the one associated with the smallest sum of squared residuals. In accordance with Hansen (1999) and Caner and Hansen (2004), the critical values for determining the 95% confidence interval of the threshold value are given by:

$$\Gamma = \{\gamma : LR_n(\gamma) \leq C(\alpha)\}.$$

Where $LR_n(\gamma) = n\frac{S_n(\gamma) - S_n(\hat{\gamma})}{S_n(\hat{\gamma})}$ **and** $C(\alpha)$ is the 95% percentile of the asymptotic distribution of the likelihood ratio $LR_n(\gamma)$.

$$C(\alpha) = -2\log(1 - \sqrt{1-\alpha})$$

The asymptotic confidence interval for γ is then easy to find by plotting $LR(\gamma)$ against γ and drawing an horizontal line at $C(\alpha)$.

After the threshold is identified, the generalized method of moments (GMM) is used to estimate the coefficients for the previously used instruments and the estimated threshold.One advantage of the GMM method is that it provides a more efficient weighting matrix.

For this study, we specified the following equation, based on Kremer et al. (2013):

$$\boldsymbol{y_{it}} = \boldsymbol{\mu_i} + \boldsymbol{\theta_1 h_{it} I(q_{it} \leq \gamma)} + \boldsymbol{\delta_1 I(q_{it} \leq \gamma)} + \boldsymbol{\theta_2 h_{it} I(q_{it}} > \gamma) + \emptyset \boldsymbol{z_{it}} + \boldsymbol{\varepsilon_{it}} \quad (2)$$

Where $\boldsymbol{y_{it}}$ is the real GDP per capita growth rate,

$\boldsymbol{h_{it}}$ repesents life expectancy at birth (in natural logarithm),

$\boldsymbol{q_{it}}$ is the threshold variable, public health expenditure as a percentage of GDP.

$\boldsymbol{\delta_1}$ is the regime intercept.According to Bick (2010), allowing for differences in the regime intercepts (δ_1) can play an important role in the threshold panel analysis. In fact, the introduction of $\boldsymbol{\delta_1}$ minimizes the risk of biased estimators in the threshold effects as well as the marginal impacts associated. Estimating the model without including the regime intercept, if it is present in the data generating process, can lead to a bias proportional to $\boldsymbol{\delta_1}$because orthogonality of the regressors are not anymore preserve.

$\boldsymbol{z_{it}}$ is a set of control variables including initial GDP capita. The equation is dynamic in that it includes initial GDP per capita. Initial GDP per capita is measured by the one period lagged value of real GDP per capita. We introduce that variable to account for transitional convergence. In fact, one major implication of the neoclassical growth model is that there exists transitional dynamics in which the growth rate relies on the initial position of the economy. According to the hypothesis of transitional convergence, poor countries may grow faster than rich countries due to decreasing returns to scale in output.The remaining control variables are: openness to trade, inflation rate, domestic credit to private sector by banks (% of GDP) as a measurement of financial development,and a democracy index.The choice of the variables is motivated by the extended theoretical and empirical literature on health-economic growth nexus.The openness to trade is measured by the GDP ratio of the sum of exports and imports. The democracy index is an institutional variable that captures the level of democracy.

All the variables are taken from the World Development Indicators (WDI) database for 24 Sub-Saharan African countries, except the democracy index, Polity2, which is taken from the POLITY IV PROJECT 2016 database. The democracy index construction is based on the evaluation of elections in the country in terms of competition, openness and level of participation. The index takes its values between -10 and 10. 10 corresponds to a fully democratic country while - 10 corresponds to an autocracy.We also employ a political instability index (CIVTOT) which is taken from the Systemic Peace database. The political instability index captures major episodes of political violence and conflicts. The index ranges from 0 to 10; 1 (lowest), 10 (highest) and 0 denotes no episodes of political instability. For all the variables used for this study, the period considered is 1996 to 2014.

The selected countries are: Benin, Burkina-Faso, Burundi, Cameroon, Chad, Gambia, Ghana, Madagascar, Malawi, Mali, Mozambique, Niger, Central African Republic, Congo Democratic Republic,Republic of Congo, Rwanda, Senegal, Sierra Leone, Sudan, Swaziland, Tanzania, Togo, Uganda, and Zambia. It should be noted that the choice of both time-period and countries used in this study is based on data availability. Tables1aand 1b shows some descriptive statistics of the variables used in the study and the correlation matrix. Focusing specifically on economic growth rate, all the variables are positively correlated to the economic growth rate, except inflation rate, the variable of financial development and the Political instability index.

Table 1a: Descriptive statistics of variables (1996-2014)

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
Growth rate of real GDP / per capita	456	0.020	0.043	-0.368	0.287
Initial GDP per capita	456	802.609	721.195	170.582	3994.957
Domestic credit to private sector by banks (% GDP)	456	0.161	0.111	-0.161	0.639
Life expectancy at birth	456	53.581	5.647	35.974	66.372
Inflation rate	456	0.121	0.411	-0.358	5.139
Openness to trade	456	0.627	0.294	0.179	1.704
Public Health expenditure (% of GDP)	456	3.288	1.969	0.045	11.283
Democracy Index*Polity2*	456	0.864	4.984	-9.000	9.000
Political instability index*Civtot*	456	0.763	1.635	0.000	7.000

Source: WDI, POLITY IV PROJECT 2016, Systemic Peace database and authors'calculations

Able 1b: Correlations

	GROWTH	INFL	LEB	DEMO	PHE	FC	INITIAL	OUV	INST*
GROWTH	1.000								
INFL	-0.175	1.000							
LEB	0.033	-0.083	1.000						
DEMO	0.093	-0.008	-0.004	1.000					
PHE	0.012	-0.048	0.134	-0.018	1.000				
FC	-0.133	-0.048	0.213	-0.138	-0.019	1.000			
INITIAL	0.209	-0.161	0.041	-0.032	0.009	0.055	1.000		
OPEN	0.092	-0.085	0.072	0.012	0.043	0.112	-0.033	1.000	
INST*	-0.087	0.231	0.009	-0.150	-0.150	0.039	0.086	0.054	1.000

Note: GROWTH= Growth rate of real GDP per capita; INFL= Inflation rate; LEB= Life expectancy at birth; DEMO= Democracy index Polity2; PHE= Public Health Expenditure (% GDP); FC= Domestic credit to private sector by banks (% GDP); INITIAL= Initial GDP per capita; OPEN= Openness to trade; INST= Political instability index Civtot. (*) The variable INST is only used for robustness analysis.
Source:Authors'calculations

2.2. Panel causality tests

This study also investigated the causal relationship between some variables.The panel causality test used is the test developed by Dumitrescu and Hurlin (2012). This approach is an extension of the standard tests of causality in time series, to which is added the individual dimension. The test takes into account the possible heterogeneity in the data by allowing the coefficients to be different from one individual to another. The test also allows for cross-sectional dependence and is based on the use of stationary variables. The null hypothesis is that there is no causality from a variable X to a variable Y for all the cross-units of the panel.

3. Results, discussion and policies implications

3.1. Unit root tests results

We determine the unit root properties of the series using the Levin, Lin, Chu (LLC) and the Im, Pesaran, Shin (IPS) unit root tests. The results are presented in Table 2. The Growth rate of real GDP per capita, Life expectancy at birth and Inflation rate are stationary at level while the other variables are I(1). The LLC and IPS unit root test assume independence between cross-sections. Yet, this assumption can sometimes be unreal in many empirical frameworks and if cross-sectional dependence is neglected, the estimators may be biased and not precise. In econometric terms, cross-sectional dependence means that individuals on the panel are correlated over time. In economic terms, it means that, as some individuals in the panel are affected by a shock; other individuals are affected as well. Pesaran (2007) proposed a unit root test that takes into account cross-sectional dependence. This is the CIPS test based on the null hypothesis of unit root. When the statistic of the test is less than the critical value, the null hypothesis is rejected. Before doing this test, a cross-sectional dependence test is implemented, the CD-test of Pesaran (2004). The test is based on the null hypothesis of cross-sectional independence. The results are presented in Table 3 and show that except the Growth rate of real GDP per capita, all the variables exhibit a cross-sectional dependence.

Indeed, the p-value is less than 5%, except for theGrowth rate of real GDP per capita. We can then now conduct the CIPS unit root test on the variables that show a cross-sectional dependence. The CIPS test is obtained with 3 different lags (p=1,2,3). The result of the CIPS test are presented in Table 4 and suggest that life expectancy at birth and inflation rate are stationary in level, while the other variables are stationary in first difference.

Table 2: LLC and IPS unit roots tests

Variables	Level				First Difference			
	Test LLC		Test IPS		Test LLC		Test IPS	
	Stat.	*p-value*	*Stat.*	*p-value*	*Stat.*	*p-value*	*Stat.*	*p-value*
GROWTH	-5.543	0.000	-6.937	0.000	-	-	-	-
INITIAL	0.082	0.533	3.419	0.999	-4.839	0.000	-6.225	0.000
LEB	-33.592	0.000	-27.433	0.000	-	-	-	-
INFL	-12.946	0.000	-13.097	0.000	-	-	-	-
OPEN	0.405	0.657	0.736	0.769	-9.523	0.000	-9.723	0.000
FC	3.123	0.999	3.854	0.999	-5.633	0.000	-5.999	0.000
DEMO	-0.241	0.405	3.812	0.999	-20.179	0.000	-13.504	0.000
PHE	-1.395	0.082	0.839	0.799	-10.672	0.000	-10.122	0.000

Note: GROWTH= Growth rate of real GDP per capita; INFL= Inflation rate; LEB= Life expectancy at birth; DEMO= Democracy index Polity2; PHE= Public Health Expenditure (% GDP); FC= Domestic credit to private sector by banks (% GDP); INITIAL= Initial GDP per capita; OPEN= Openness to trade.
Source: Authors' calculations

Table 3: Pesaran's (2004) CD-test

Variables	CD-Test	p-value
GROWTH	1.12	0.262
INITIAL	34.03	0.000
LEB	60.47	0.000
INFL	25.55	0.000
OPEN	16.61	0.000
CREDIT	17.54	0.000
PHE	23.18	0.000
DEMO	7.83	0.000

Note: GROWTH= Growth rate of real GDP per capita; INFL= Inflation rate; LEB= Life expectancy at birth; DEMO= Democracy index Polity2; PHE= Public Health Expenditure (% GDP); FC= Domestic credit to private sector by banks (% GDP); INITIAL= Initial GDP per capita; OPEN= Openness to trade.
Source: Authors' calculations

Table 4: Pesaran's (2007) CIPS unit root test

Variables	Level				First Difference			
	$CIPS_1$	$CIPS_2$	$CIPS_3$	Critical Value	$CIPS_1$	$CIPS_2$	$CIPS_3$	Critical Value
INITIAL	-2.006	-2.094	-1.882	-2.2	-3.575	-3.583	-3.767	-2.2
LEB	-2.456	-3.321	-3.685	-2.2	-	-	-	-2.2
INFL	-3.729	-3.729	-3.777	-2.2	-	-	-	-2.2
OPEN	-2.362	-2.378	-2.245	-2.38	-4.407	-4.143	-4.151	-2.2
FC	-1.544	-1.416	-1.399	-2.2	-4.484	-4.484	-4.323	-2.2
DEMO	-1.936	-2.082	-2.162	-2.2	-2.897	-2.799	-2.897	-2.2
PHE	-2.153	-2.171	-2.161	-2.2	-4.514	-4.514	-4.804	-2.2

Note: -2.2 and -2.38 are the critical values respectively at the 5% and 1% levels.
Source: Authors' calculations

3.2. Results of the dynamic panel threshold model

We first empirically address the validity of one threshold model by following Hansen (1999) procedure. The results of the Hansen's (1999) likelihood ratio test are presented in Table 5. We find that the test for a single threshold F1 is significant with a bootstrap p-value of 0.02. But the test for a double threshold F2is not significant, with a bootstrap p-value of 0.35. We conclude that there is strong evidence that there is one threshold in the regression relationship. For the remainder of the analysis, we can therefore work with the one threshold as specified by Kremer et al. (2013).

Table 5: Testing for threshold effect

	Test Statistic	Bootstrap p-value
Single threshold F1	11.66***	0.03
Double threshold F2	4.85	0.35

Note: Test of null of no threshold against alternative of threshold. *** represents significant at 5% level. Threshold test and asymptotic *p*-values are obtained through 500 bootstrap replications.
Source: Authors' calculations

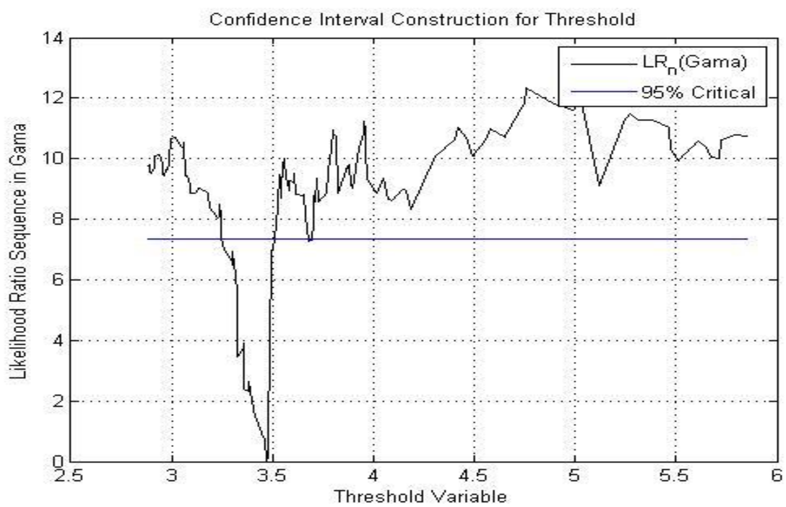
Fig. 1 shows the likelihood ratio (LR) sequence for the threshold variable. The non-linearity in the health-economic growthnexus is established forthe Sub-Saharan African countries considered. Indeed, as shown in the Fig. 1, the ratio of maximum likelihood is minimal for a value of public health expenditure as a percentage of GDP of 3.467% and is less than the 95% critical value of the asymptotic distribution. In Fig. 1, the horizontal line denotes the critical value (7.35) at the 95% confidence level. Moreover, since the LR sequence has a sharp V shape, it means that the sample used for this study has strong information about γ (Carner and Hansen, 2004). This shows the presence of two regimes characterized by the existence of a threshold at this point (Hansen, 2000). The estimated threshold is 3.467%with a 95% confidence interval ranging from [3.259%; 3.697%]. The confidence interval is very tight which implies that the threshold estimate has been precisely estimated (Hansen, 2000).According to these results, the threshold relationship between health and economic growth is valid.It is important to note that the analysis was conducted based on the stationary series to avoid spurious regression. The use of stationary variables is consistent with Hansen (1999) and Kremer et al. (2013) where all the variables used in the panel threshold model are stationary.Table 6 presents the results of the dynamic panel threshold regression. The lagged endogenous variables are used as instruments (Arellano and Bover, 1995; Kremer et al., 2013).The results of the dynamic panel threshold model shows the impact of life expectancy at birth on economic growth through its interactions with public health expenditure. The estimated threshold is 3.467%. The stock ofhealth human capital, measured by the life expectancy at birth, significantly and positively impact economic growth in the countries of our sample. However, that impact is different according to the level of public health expenditure. When the share of public health expenditure in GDP is above3.467%, the impact of life expectancy on economic growth is higher than when the share of public health expenditure in GDP is below at 3.467%. Thus, any increase of investments in health leads to a greater positive impact of life expectancy on economic growth. The following countriesare located below the threshold: Benin, Burkina Faso, Burundi, Democratic Republic of Congo, Gambia, Central African Republic, Chad, Ghana, Madagascar, Malawi, Senegal, Sierra Leone, Swaziland, Tanzania, Togo, Uganda and Zambia. The countries located above the threshold are: Cameroon, Mali, Mozambique, Niger, Republic of Congo, Rwanda and Sudan.

These results could be justified by the fact that even if life expectancy increases, individuals will not be productive unless they are able to maintain and improve their health status.The results suggest the importance of investments in health, on the one hand, and the necessity for the countries of the sample to devote a minimum of public expenditures to health (health investments) on the other hand, in order to have higher health returns on growth.Healthy people are more productive and are therefore likely to earn more, save more, invest more, consume more and work longer. These are all factors that have a positive impact on economic growth. The results of this study are in line with those of Cooray (2013) and Eggoh et al. (2015). Cooray (2013) showed that the impact of life expectancy on economic growth increases as health expenditure increases. In addition, Eggoh et al. (2015) showed that the stock of human capital (life expectancy at birth, enrollment in primary and secondary) have a small positive impact on growth and explained this result by the low level of education and health expenditures and the inefficiency with which these expenditures are converted into human capital stock.

However, our results are different from Chakroun (2012) who showed up for a set of developed and developing countries that the impact of health human capital is low in countries where the share of public health expenditure in GDP exceeds 1.77%. Concerning the impact of control variables on economic growth, the results show a negative and significant impact of inflation, in accordance with the theoretical and empirical literature. The openness to tradehas a positive and significant impact on economic growth because countries take advantage of the international competition and the international specialization. Moreover, financial development, measured by domestic credit to the private sector by banks, has a negative and significant impact on economic growth of countries in the sample. This could be due to many reasons such as the presence ofthreshold effect or non-linearity in the relationship between economic growth and financial development (Allegret and Azzabi, 2012; Eggoh, 2009).

The initial GDP(as transitional convergence control, because less favored countries often grow faster due to a higher capital return) has a positive but not significant impact on economic growth, suggesting the absence of convergence between the countries in the sample. Finally, the impact of democracy on economic growth ispositive, indicating that a higher democracy would increase GDP growth, nevertheless, this variable is not significant. This could be explained by the low level of democracy in most countries in the sample (see Appendix 2 for the data related to the democracy index). Ndoricimpa (2017) found a similar result.

Fig. 1: Confidence interval for Public Health Expenditure threshold



Source: Authors'calculations

3.3. Robustness check

According to Roodman (2009), empirical results may depend on the number of instruments used. Moreover, the application of the GMM in the case of small cross-section dimension, as in this study (24 countries), may lead to biased standards errors and parameters (Windmeijer, 2005) and a weakened over-identification test (Bowsher, 2002). We therefore test for robustness and follow the approach of Kremer et al. (2013) by specifying a second empirical benchmark. In the first specification, all available lags of the instrument variable were used in order to increase efficiency. In the second specification, we estimate the model using only one lag of the instrument variable. This allows us to avoid an overfit of instrumented variables which is likely to lead to the coefficient with bias. This approach is also used by Ndoricimpa (2017). The choice of instruments does not affect the estimated public health expenditure threshold and the nonlinear relationship still valid (see Appendix 1). The confidence interval is now [3.248%; 3.697%], which is very close to [3.259%; 3.697%]. The impact of life expectancy at birth on economic growth is nearly the same as in the first estimation. What changes is the impact of some control variables.

Variables	
Threshold estimate	
$\hat{\gamma}$	3.467%
95% confidence interval	[3.259% ; 3.697%]
Impact of life expectancy on economic growth	
$\hat{\theta}_1$ (Coef. below $\hat{\gamma}$)	0.073***
	(0.027)
$\hat{\theta}_2$ (Coef. above $\hat{\gamma}$)	0.134**
	(0.054)
Impact of covariates	
Initial GDP per capita	0.228
	(0.163)
Inflation rate	-0.017***
	(0.003)
Openness to trade	0.039*
	(0.023)
Domestic credit to private sector by banks	-0.244***
	(0.051)
Democracy index	0.001
	(0.001)
$\hat{\delta}_1$	0.269
	(0.251)
No. Obs. Regime 1	311
No. Obs. Regime 2	145
No. Obs. Total	456

The impact of Initial GDP per capita is now significant but still positive, and the impact of the openness to trade which remain positive but not significant. As another robustness check, we estimated the model with the political instability index (CIVTOT) (see Appendix 4). The findings are near to the initial estimation.

The traditional approach of Hansen (1999) is also used to examine some similarities, although the results may be influenced by the treatment of individuals fixed effects and the endogeneity of initial GDP (Kremer et al., 2013). The results of the estimated coefficients are reported in Appendix 4. The threshold of public health expenditure (% GDP) is 3.466%, like that found with the approach of Kremer et al. (2013). The stock of health human capital influences significantly and positively economic growth for all the countries of the sample. The marginal impact of life expectancy at birth on economic growth is 0.077 below the threshold and 0.082 above the threshold. However, although the health impact on economic growth in the high-health regime is different from the one found with the approach of Kremer et al. (2013), the results in terms of signs of coefficients is the same. First, this may be due to how individuals fixed effects are eliminated using the two methods. Second the fact that the endogeneity is not take into account could explain these results. The signs obtained for the coefficients of the control variables remain similar to those found with the dynamic panel threshold model.

Finally, we envisage the possibility of the existence of a cross-sectional dependence in the error terms of the model (2). As a final robustness check, we use a factor-augmented dynamic panel threshold regression model with estimated common components to deal with cross-sectional dependence (Floro and van Roye, 2017). Indeed, in the dynamic panel threshold regression literature, error cross-sectional dependencies across countries are most of the time neglected. Yet, the presence of cross-sectional dependence can lead to biased estimators, consistency problems or spurious regression (Phillips and Sul, 2003; Bai, 2009).

Moreover, assuming independence could make one believe that there are threshold effects or non-linear effects of health on economic growth while it may not be the case.We usePesaran (2004)'s cross-sectional dependence test on the residuals the dynamic panel threshold (model 2), as in Floro and van Roye (2017). The result of the test is presented in Table 7.

Table 6: Dynamic panel threshold results using all available lags of the instrument variable

Notes: Standard errors in brackets. *, **, *** indicate significance at 10%, 5% and 1% respectively. The dependent variable is the Growth rate of GDP per capita. Life expectancy at birth represents the regime dependent variable and public health expenditure (% of GDP), the threshold variable. Life expectancy and Initial GDP per capita are transformed to the natural logarithm. Following Hansen (1999), each regime contains at least 5% of all observations.
Source: Authors' calculations

Table 7: Pesaran (2004)'s CD-test

	CD-test	**p-value**
Residuals of the dynamic panel threshold model	18.756	0.000

Note:Under the null hypothesis of cross-section independence *CD* ~*N* (0*,* 1).
Source: Authors' calculations

Table 7 shows that the CD-statistic is significant, allowing to reject the null hypothesis of cross-sectional independence in the dynamic panel threshold model. Thus, the choice of the factor-augmented dynamic panel threshold regression model with estimated common components is valid. In the presence of cross-sectional dependence, the error terms can be decomposed in a multifactor error structure (Pesaran, 2006; Bai, 2009). The decomposition gives: $\boldsymbol{\varepsilon_{it} = \delta_j' f_t + e_{it}}$, where $\boldsymbol{f_t}$is a *m* x 1 vector of common unobserved components;$\boldsymbol{\delta_j'}$ represent unobserved country-specific factor loadings and $\boldsymbol{e_{it}}$are the idiosyncratic terms of $\boldsymbol{\varepsilon_{it}}$**.** The common unobserved components measure the effects of unobserved common shocks that simultaneously affects all the individuals of the sample.

In the empirical procedure, one must estimate the common unobserved components. Since $\boldsymbol{f_t}$is unobservable, we follow Bai (2009) by using the principal components of the estimates residuals $\boldsymbol{\varepsilon_{it}}$. The author argued that this method is a quick and effective approach of extracting common factors. In fact, the common correlated coefficients estimator (CCE) approach proposed by Pesaran (2006) requires an *a priori* value of the threshold variable, which would not be suitable in our analysis given that our threshold values are determined endogenously (Floro and van Roye, 2017). The question that arises now is the number of factors than should be incorporated in the regression. We follow a classical approach that is used in the principal components literature and retain the number of factors that corresponds to 45.12% of the total variance of the panel. This number is three. The results of estimation of the factor-augmented dynamic panel threshold model are presented in Table 8. A positive effect of the second and third factors on economic growth is observed. The coefficient of the first factor is negative and non-significant. What is important here is that even in the presence of cross-sectional dependence, the threshold estimate still valid. The coefficients found in the low and high health regimes are similar to those of the dynamic panel threshold.The control variables effect on economic growth holds as well. From Table 8, we can see that the CD test statistic for the new residuals is equal to -1.28 with a pvalue of 0.199. Consequently, there is not enough evidence to reject the null hypothesis of cross-sectional independence. This validate the use of the Factor-augmented dynamic panel threshold (Floro and van Roye, 2017).

3.4. Panel causality tests results

Table 9 shows the result of the Dumitrescu and Hurlin (2012) panel causality test. The null hypothesis that life expectancy at birth does not homogenously cause economic growth is rejected. Moreover, there is no reverse causality from economic growth rate to life expectancy at birth, implying a unidirectional causality between the two variables. Thus, this result allows us to say that life expectancy at birth has a predictive ability for economic growth. In other words, past health stock values predict the trajectory of economic growth.

This result supports the fact that policies to improve economic growth should take into account the health capital stock. For the other variables, the null hypothesis of no causality is not rejected. However, there is a causal link between economic growth and the rate of inflation. This result therefore calls for the achievement of the level of economic growth compatible with the inflation target pursued by central banks.

Table 10 presents the Dumitrescu and Hurlin (2012) test but this time for each country. Here, we only present the causality between life expectancy at birth and economic growth. The null hypothesis of no causality is rejected for 8 of the 24 countries namely: Cameroon, Mozambique, Niger, Uganda, Democratic Republic of Congo, Central African Republic, Swaziland and Togo. Moreover, the null hypothesis that the economic growth does not cause life expectancy at birth is rejected for 4 countries out of 24. These countries are: Burundi, Chad, Gambia and Mali. According to these results, the countries do not show a two-way causal relationship between life expectancy at birth and economic growth.

Table 8: Factor-augmented dynamic panel threshold results

Variables	
Threshold estimate	
$\hat{\gamma}$	3.467%
95% confidence interval	[3.298% ; 3.520%]
Impact of life expectancy on economic growth	
$\hat{\theta}_1$ **(Coef. below** $\hat{\gamma}$ **)**	0.071**
	(0.033)
$\hat{\theta}_2$ **(Coef. above** $\hat{\gamma}$ **)**	0.122**
	(0.053)
Impact of covariates	
Initial GDP per capita	0.235
	(0.167)
Inflation rate	-0.017***
	(0.003)
Openness to trade	0.040*
	(0.023)
Domestic credit to private sector by banks	-0.231***
	(0.053)
Democracy index	0.001
	(0.001)
$\hat{\delta}_1$	0.232
	(0.261)
1	-0.000092
	(0.001050)
F2	0.002401**
	(0.000981)
F3	0.001574*
	(0.000924)
CD Statistic [pvalue]	-1.28 [0.199]

Notes: Standard errors in brackets. *, **, *** indicate significance at 10%, 5% and 1% respectively. The dependent variable is the Growth rate of GDP per capita. Life expectancy at birth represents the regime dependent variable and public health expenditure (% of GDP), the threshold variable. Life expectancy and Initial GDP per capita are transformed to the natural log. Following Hansen (1999), each regime contains at least 5% of all observations. F1, F2 and F3 represent the estimates of the common unobserved factors.

Source: Authors' calculations

Table 9: Panel causality test in heterogeneous panels (Dumitrescu and Hurlin, 2012)

	W-Stat	Z-bar tilde Stat	p-value	Lags*
LEB does not cause GROWTH	19.695	7.907	0.000	4
GROWTH does not cause LEB	9.376	1.949	0.051	4
INFL does not cause GROWTH	1.082	-0.191	0.848	1
GROWTH does not cause INFL	5.117	4.529	0.000	2
CREDIT does not cause GROWTH	1.043	-0.296	0.767	1
GROWTH does not cause GROWTH	0.828	-0.869	0.385	1
OPEN does not cause GROWTH	8.556	1.476	0.140	4
GROWTH does not cause OPEN	0.837	-0.843	0.399	1

Note: * Optimal lag selected based on AIC criterion. The *W* bar test statistic corresponds to the cross sectional average of the *N* standard individual Wald statistics of Granger non causality tests. The *Z* bar statistic corresponds to the standardized statistic (for fixed *T* sample).
Source: Authors' calculations

Table 10: Dumitrescu and Hurlin (2012) individual wald granger causality test

Countries	GROWTH does not cause LEB		LEB does not cause GROWTH	
	W_i	$p\text{-value}_i$	W_i	$p\text{-value}_i$
Benin	3.913	0.484	10.138	0.148
Burkina Faso	11.565	0.119	5.546	0.343
Burundi	20.339	**0.039**	3.925	0.483
Cameroon	4.000	0.475	99.188	**0.001**
Central African Republic	0.589	0.958	20.072	**0.040**
Chad	33.824	**0.012**	12.738	0.100
Democratic Republic of Congo	3.103	0.579	18.159	**0.049**
Gambia	21.243	**0.036**	3.336	0.550
Ghana	5.421	0.351	12.099	0.109
Madagascar	12.200	0.108	3.043	0.587
Malawi	5.766	0.328	13.067	0.095
Mali	30.228	**0.016**	15.193	0.071
Mozambique	5.993	0.313	22.636	**0.031**
Niger	2.094	0.724	27.288	**0.020**
Republic of Congo	11.050	0.128	3.550	0.525
Rwanda	10.151	0.148	14.995	0.073
Senegal	0.792	0.931	4.968	0.386
Sierra Leone	6.603	0.278	7.139	0.250
Soudan	1.308	0.851	13.506	0.090
Swaziland	2.205	0.706	23.896	**0.027**
Tanzania	13.362	0.091	3.370	0.546
Togo	7.724	0.225	87.832	**0.001**
Uganda	8.341	0.201	33.980	**0.012**
Zambia	3.220	0.564	13.018	0.096

Note: Values in bold indicates rejection of the null hypothesis of homogenous non causality.
Source: Authors' calculations

3.5. Policies implications

The results of this study have interesting policies implications. Firstly, the Sub-Saharan African countries should increase the investments in health by devoting more public resources to health. This concerns both the countries in the low-health regime and those in the high-health regime. The first ones will strengthen efforts to achieve at least a minimum level of investment and the others will continue to invest more.

This is important since, according to the Africa Data Report 2016, Sub-Saharan Africa will not reach the target of SDGs by 2030 unless there is a significant increase in health expenditures. Secondly, the investments must be oriented in a way to have a direct impact on individuals. The objective will be to make drugs purchase much easier, in a context where the World Health Organization (WHO) noted the weakness of access to medicines in Sub-Saharan Africa.

Thirdly, the investments should also be used in the fight against endemic diseases and epidemics. This recommendation is justified since, according to the WHO, the fastest increase in the life expectancy in the world between 2000 and 2015 has mainly been observed in the WHO African Region. In that region, life expectancy gained 9.4 years to reach 60 years, because of the progress in child survival, the fight against malaria and the improvement of access to antiretroviral drugs for treating HIV. Thus, for a high impact of health stocks capital on economic growth, more investments should be devoted to fight malaria, HIV/AIDS and other diseases with a high morbidity that reduce the productivity of individuals.

4. Conclusion

This study provided evidence on a non-linear relationship between health and economic growth in 24 Sub-Saharan African countries during the period 1996-2014. Specifically, we search for the existence of a potential endogenous threshold level of public health expenditure that could introduce life expectancy at birth's differential effects on economic growth. One major contribution of the paper is that we use the dynamic panel threshold model proposed by Kremer et al. (2013) to overcome the endogeneity problem and to capture dynamics in the growth equation. The empirical results show that there is a threshold effect in the health–economic growth relationship.We find that there is a minimal level of public health expenditure, 3.5% of GDP, which should be devoted to health in order to have a higher impact of life expectancy at birth on economic growth.The study also performed causality analysis and found that life expectancy at birth and inflation rate have a significant causal relationship with economic growth.

We check for robustness by including an instability index in the growth equation, by using various number of instruments and by taking into account cross-sectional dependence.We find similar results.Based on the results of the study, governments should increase public investment in the health sector in order to further improve the human capital and productivity of the labor force and subsequently the level of economic development. Investments which are individuals-oriented are required. The objective would be to make drugs purchase much easier. We also suggest more investments devoted to fight malaria, HIV/AIDS and other diseases with a high morbidity that reduce the productivity of individuals. Since life expectancy is likely to interact with other variables, future research could apply the dynamic panel threshold method to investigate the differential effects of life expectancy on economic growth through its interactions with educational human capital.

References

Acemoglu, D., and Johnson, S. (2007). Disease and development: the effect of life expectancy on economic growth. *Journal of political Economy*, *115*(6), 925-985.

Aghion, P., Howitt, P., and Murtin, F. (2010). *The relationship between health and growth: when Lucas meets Nelson-Phelps* (No. w15813). National Bureau of Economic Research.

Aisa, R., and Pueyo, F. (2006). Government health spending and growth in a model of endogenous longevity. *Economics letters*, *90*(2), 249-253.

Allegret, J. P., and Azzabi, S. (2012). Finance, growth and threshold effects. *Panoeconomicus*, *59*(5), 553-581.

Arellano, M., and Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of econometrics*, *68*(1), 29-51.

Atilgan, E., Kilic, D., and Ertugrul, H. M. (2017). The dynamic relationship between health expenditure and economic growth: is the health-led growth hypothesis valid for Turkey? *The European Journal of Health Economics*, *18*(5), 567-574.

Bai J. (2009). Panel data models with interactive fixed effects. *Econometrica*, 77(4), 1229–1279.

Barro, R. J., and Lee, J. W. (2001). International data on educational attainment: updates and implications. *Oxford Economic Papers*, *53*(3), 541-563.

Becker, G. S. (1964). Human capital theory. *Columbia, New York*.

Bick, A. (2010). Threshold effects of inflation on economic growth in developing countries. *Economics Letters*, *108*(2), 126-129.
Blackburn, K., and Cipriani, G. P. (2002). A model of longevity, fertility and growth. *Journal of Economic Dynamics and Control*, *26*(2), 187-204.
Boidin, B. (2009). Capabilities and Health Thresholds. *Revue Tiers Monde*, (2), 335-355.
Bowsher, C. G. (2002). On testing overidentifying restrictions in dynamic panel data models. *Economics letters*, *77*(2), 211-220.
Bruno, G. S. F. (2005) Approximating the bias of the LSDV estimator for dynamic unbalanced panel data models. *Economics Letters 87,*361–366.
Caner, M., and Hansen, B. E. (2004). Instrumental variable estimation of a threshold model. *Econometric Theory*, *20*(5), 813-843.
Caselli, F., Esquivel, G., and Lefort, F. (1996). Reopening the convergence debate: a new look at cross-country growth empirics. *Journal of economic growth*, *1*(3), 363-389.
Chakroun M. (2009). Health care expenditure and GDP: An international panel smooth transition approach.*International Journal of Economics, 4(1),* 189-200.
Chakroun, M. (2012). Les Effets Non Linéaires De La Sante Sur La Croissance. *Revue Tunisienne d'Economie et de Gestion*, *31*(1), 121-151.
Cooray, A. (2013). Does health capital have differential effects on economic growth? *Applied Economics Letters*, *20*(3), 244-249.
Desbordes, R. (2011). The non-linear effects of life expectancy on economic growth. *Economics Letters*, *112*(1), 116-118.
Dumitrescu, E. I., and Hurlin, C. (2012). Testing for Granger noncausality in heterogeneous panels. *Economic Modelling, 29*, 1450–1460.
Eggoh, J. C. (2009). *Croissance économique et développement financier : éléments d'analyse théorique et empirique* (Doctoral dissertation, Orléans).
Eggoh, J., Houeninvo, H., and Sossou, G. A. (2015). Education, health and economic growth in African countries. *Journal of Economic Development*, *40*(1), 93.
Floro, D. and van Roye, B. (2017) Threshold effects of financial stress on monetary policy rules: a panel data analysis.*European Central Bank Working paper, No 2042, April 2017.*
Gyimah-Brempong, K., and Wilson, M. (2004). Health human capital and economic growth in Sub-Saharan African and OECD countries. *The Quarterly Review of Economics and Finance*, *44*(2), 296-320.
Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of econometrics*, *93*(2), 345-368.
Kremer, S., Bick, A., and Nautz, D. (2013). Inflation and growth: new evidence from a dynamic panel threshold analysis. *Empirical Economics*, 1-18.
Ndoricimpa, A. (2017). Threshold Effects of Inflation on Economic Growth: Is Africa Different?. *International Economic Journal*, 1-22.
Nickell, S. (1981). Biases in dynamic models with fixed effects. *Econometrica: Journal of the Econometric Society*, 1417-1426.
Pesaran M. Hashem (2004). General diagnostic tests for cross section dependence in panels. *CESifo Working Paper, No. 1229,* 40p.
Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica 74* (4), 967–1012.
Pesaran M. Hashem (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, Vol.22, 2007,* 265-312.
Phillips, P. C. and D. Sul (2003). Dynamic panel estimation and homogeneity testing under cross section dependence. *The Econometrics Journal 6* (1), 217–259.
Reinhart, V. R. (1999). Death and taxes: their implications for endogenous growth. *Economics Letters*, *62*(3), 339-345.
Roodman, D. (2009). A note on the theme of too many instruments. *Oxford Bulletin of Economics and statistics*, *71*(1), 135-158.
Sachs, J. D., and Warner, A. M. (1997). Sources of slow growth in African economies. *Journal of African economies*, *6*(3), 335-376.

Sghari, M. B. A., and Hammami, S. (2013). Relationship between health expenditure and GDP in developed countries. *IOSR Journal of Pharmacy*, *3*(4), 41-45.

Sirag, A., Matemilola, B. T., Law, S. H., and Bany-Ariffin, A. N. (2017). Does environmental Kuznets curve hypothesis exist? Evidence from dynamic panel threshold. Journal of Environmental Economics and Policy, 1-21.

Vijesandiran, S., and Vinayagathasan, T. (2015). Dynamic relationship between human capital and economic growth in Sri Lanka: A co-integration analysis. *Asian Online Journal*, *2*(2), 20-29.

Wang, Y., and Liu, S. (2016). Education, Human Capital and Economic Growth: Empirical Research on 55 Countries and Regions (1960-2009). *Theoretical Economics Letters*, *6*(02), 347.

Weil, D. N. (2007). Accounting for the effect of health on economic growth. *The quarterly journal of economics*, *122*(3), 1265-1306.

Weil D. (2014). Health and Economic Growth. *Handbook of Economic Growth, Vol. 2B*, 623-682.

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient twostep GMM estimators. *Journal of Econometrics, 126(1),* 25-51.

Variables	
Threshold estimate	
$\hat{\gamma}$	3.467%
95% confidence interval	[3.248% ; 3.697%]
Impact of life expectancy on economic growth	
$\hat{\theta}_1$ (Coef. below $\hat{\gamma}$)	0.081***
	(0,027)
$\hat{\theta}_2$ (Coef. above $\hat{\gamma}$)	0.150***
	(0.054)
Impact of covariates	
Initial GDP per capita	0.339*
	(0.196)
Inflation rate	-0.015***
	(0.004)
Openness to trade	0.040
	(0.027)
Domestic credit to private sector by banks	-0.251***
	(0.079)
Democracy index	0.001
	(0.001)
$\hat{\delta}_1$	0.301
	(0.289)
No. Obs. Regime 1	311
No. Obs. Regime 2	145
No. Obs. Total	456

Appendix

Appendix 1: Dynamic panel threshold results using only one instrument lag

Notes: Standard errors in brackets. *, **, *** indicate significance at 10%, 5% and 1% respectively. The dependent variable is the Growth rate of GDP per capita. Life expectancy at birth represents the regime dependent variable and Public health expenditure (% of GDP), the threshold variable. Life expectancy and Initial GDP per capita are transformed to the natural logarithm. Following Hansen (1999), each regime contains at least 5% of all observations.
Source: Authors' calculations

Appendix 2: Democracy index Polity2 (Mean over the period 1996-2014)

Country	1996-2005	2006-2014	1996-2014
Benin	6	7	6
BurkinaFaso	-2	0	-1
Burundi	0	6	3
Cameroon	-4	-4	-4
Central African Republic	3	-1	1
Chad	-2	-2	-2
Congo, Democratic Republic	1	5	3
Gambia	-5	-5	-5
Ghana	4	8	6
Madagascar	7	4	6
Malawi	6	6	6
Mali	7	6	6
Mozambique	5	5	5
Niger	2	5	3
Republic of Congo	-4	-4	-4
Rwanda	-5	-3	-4
Senegal	4	7	6
Sierra Leone	3	7	5
Soudan	-6	-3	-5
Swaziland	-9	-9	-9
Tanzania	-1	-1	-1
Togo	-2	-3	-3
Uganda	-4	-1	-2
Zambia	3	7	5

Note: 10 and -10 respectively correspondsto a fully democratic country and to an autocracy.
Source: Authors'calculations based on POLITY IV PROJECT 2016 database

Appendix 3: Dynamic panel threshold results using all available lags of the instrument variable and the variable "political stability index"

Variables	
Threshold estimate	
$\hat{\gamma}$	3.467%
95% confidence interval	[3.259% ; 3.494%]
Impact of life expectancy on economic growth	
$\hat{\theta}_1$ (Coef. below $\hat{\gamma}$)	0.075***
	(0.027)
$\hat{\theta}_2$ (Coef. above $\hat{\gamma}$)	0.138**
	(0.054)
Impact of covariates	
Initial GDP per capita	0.247
	(0.159)
Inflation rate	-0.016***
	(0.004)
Openness to trade	0.041*
	(0.023)
Domestic credit to private sector by banks	-0.245***
	(0.050)
Democracy index	0.001
	(0.001)
Political instability index	-0.004
	(0.005)
$\hat{\delta}_1$	0.277
	(0.250)
No. Obs. Regime 1	311
No. Obs. Regime 2	145
No. Obs. Total	456

Notes: Standard errors in brackets. *, **, *** indicate significance at 10%, 5% and 1% respectively. The dependent variable is the Growth rate of GDP per capita. Life expectancy at birth represents the regime dependent variable and Public health expenditure (% of GDP), the threshold variable. Life expectancy and Initial GDP per capita are transformed to the natural logarithm. Following Hansen (1999), each regime contains at least 5% of all observations.
Source: Authors' calculations

Appendix 4: The results of the traditional approach of non-dynamic panel threshold (Hansen, 1999)

Variables	
Threshold estimate	
$\hat{\gamma}$	3.466%
95% confidence interval	[3.355% ; 3.478%]
Impact of life expectancy on economic growth	
$\hat{\theta}_1$ (Coef. below $\hat{\gamma}$)	0.077***
	(0.007)
$\hat{\theta}_2$ (Coef. above $\hat{\gamma}$)	0.082***
	(0.004)
Impact of covariates	
Initial GDP per capita	0.098
	(0.317)
Inflation rate	-0.017***
	(0.003)
Openness to trade	0.038*
	(0.023)
Domestic credit to private sector by banks	-0.226***
	(0.051)
Democracy index	0.001
	(0.229)
No. Obs. Regime 1	310
No. Obs. Regime 2	146
No. Obs. Total	456

Notes: Standard errors in brackets. *, **, *** indicate significance at 10%, 5% and 1% respectively. The dependent variable is the Growth rate of GDP per capita. Life expectancy at birth represents the regime dependent variable and public health expenditure (% of GDP), the threshold variable. Life expectancy and Initial GDP per capita are transformed to the natural logarithm. Following Hansen (1999), each regime contains at least 5% of all observations.
Source: Authors' calculations