Threshold effects of public debt on economic growth in Africa: a new evidence

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Abstract

Purpose – The purpose of this study is to seek to re-examine the threshold effects of public debt on economic growth in Africa.

Design/methodology/approach – This study applies panel smooth transition regression approach advanced by González *et al.* (2017). The method allows for both heterogeneity as well as a smooth change of regression coefficients from one regime to another.

Findings – A debt threshold in the range of 62–66% is estimated for the whole sample. Low debt is found to be growth neutral but higher public debt is growth detrimental. For middle-income and resource-intensive countries, a debt threshold in the range of 58–63% is estimated. As part of robustness checks, a dynamic panel threshold model was also applied to deal with the endogeneity of debt, and a much higher debt threshold was estimated, at 74.3%. While low public debt is found to be either growth neutral or growth enhancing, high public debt is consistently detrimental to growth.

Research limitations/implications – The findings of this study show that there is no single debt threshold applicable to all African countries, and confirm that the debt threshold level is sensitive to modeling choices. While further analysis is still needed to suggest a policy, the findings of this study show that high debt is detrimental to growth.

Originality/value – The novelty of this study is twofold. Contrary to previous studies on Africa, this study applies a different estimation technique which allows for heterogeneity and a smooth change of regression coefficients from one regime to another. Another novelty distinct from the previous studies is that, for robustness checks, this study divides the sample into low- and middle-income countries, and into resource- and nonresource intensive countries, as debt experience can differ among country groups. Further, as part of robustness checks, another estimation method is also applied in which the threshold variable (debt) is allowed to be endogenous.

Keywords Africa, Economic growth, Public debt, Debt threshold, Panel smooth transition regression

Paper type Research paper

1. Introduction

Due to internal and external shocks, large amounts of debt were accumulated by several African countries since 1980s. The increasing debt accumulation became unsustainable, causing repayment difficulties and a debt crisis in the 1990s, as well as a drag on growth and other development goals. Since 1996, a number of African countries benefited from debt relief under the Highly Indebted Poor Countries (HIPC) program initiated by the World Bank and the International Monetary Fund (IMF), with a condition of sound economic management and poverty reduction strategies. As a result, average general government debt as a percent of gross

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domestic product (GDP), fell substantially from 110% in 2001 to 35% in 2012 (Coulibaly *et al.*, 2019). However, there have been concerns recently of a looming debt crisis in Africa again. The World Bank (2018a) notes that the pace of debt accumulation in sub-Saharan Africa has been too fast since the HIPC debt relief. Indeed, average public debt-to-GDP ratio in sub-Saharan Africa rose from 37% in 2012 to 57% by 2017 (World Bank, 2018a). In addition, in less than a decade, the number of sub-Saharan African countries at high risk of debt distress has more than doubled, from eight countries in 2013 to 18 countries in 2018 (IMF, 2018). According to Coulibaly *et al.* (2019), a number of causes are behind the resurgence of public debt problem in sub-Saharan Africa recently; these include the 2008 global financial crisis shocks, adverse commodity price shocks, countries' imprudent fiscal policies, drop in official development assistance, an increasingly diverse group of lenders, as well as large financing gaps for infrastructure. Indeed, AFDB (2018) estimates financing gaps for infrastructures at $68 *bn* to $108 *bn*. As debt levels escalate again in Africa, governments should be reminded of the detrimental effects of high levels of debt on long-term growth. While, IMF (2018) [1] acknowledges that a moderate level of public debt is essential for low-income countries to raise living standards if used appropriately of course, they warn of the harmful effects of high levels of debt on growth and other development goals. Indeed, high levels of debt harm long-run growth via higher long-term interest rates, higher future distortionary taxation, inflation and greater uncertainty about prospects and policies, all of which discourage investments (Ndoricimpa, 2017).

With the debt problems in developing countries since the 1980s, a number of studies examined the issue of threshold effects of debt on growth (see for example, Kaminsky and Pereira, 1996; Deshpande, 1997; Elbadawi *et al.*, 1997). Following the 2008 global financial crisis, the interest in the question also shifted to developed industrial countries (see, for example, Reinhart and Rogoff, 2010; Cecchetti *et al.*, 2011; Pescatori *et al.*, 2014). The existing empirical literature gives mixed evidence on the debt threshold effect on growth in developing countries. For example, Elbadawi *et al.* (1997) find a debt threshold at around 97% of GDP, Cordella *et al.* (2005) estimate a debt threshold between 10 and 35% of GDP, Pattillo *et al.* (2011) find a debt threshold in the range of 35–40% of GDP, while Chudik *et al.* (2017) find the debt threshold to be in the range of 30–60% of GDP. Different estimation techniques account for the difference in debt threshold estimates found. Indeed, as Égert (2015b) points out, examining nonlinearities in the debt-growth nexus can be sensitive to modeling choices. Elbadawi *et al.* (1997) employ a quadratic equation to identify the possible *U*-shaped relationship between debt and growth, Pattillo *et al.* (2011) use quadratic and spline model estimated using fixed effects and system Generalized Method of Moments (GMM), while Chudik *et al.* (2017) apply panel threshold-Autoregressive Distributed Lag (ARDL) model. In addition, Égert (2015a) points out that a country's coverage matters substantially for the threshold effect. Sample of countries considered is also another explanation for the difference in debt threshold estimates found in empirical literature.

Despite having suffered recurrent debt problems since the 1980s, studies on the debt threshold effects for Africa remain scarce. To my knowledge, only two studies exist in the empirical literature, that is, Ndoricimpa (2017) and Mensah *et al.* (2019). However, they give contradicting results on the level of debt threshold. Ndoricimpa (2017) finds a debt threshold between 92.8% and 102.6%, while Mensah *et al.* (2019) finds a debt threshold between 20% and 50%. Ndoricimpa (2017) uses nondynamic and dynamic panel threshold regressions, while Mensah *et al.* (2019) use panel threshold-ARDL regression model.

The debt threshold effects on growth in Africa is re-examined in this study for the following reasons. Firstly, because of the recent concerns of a looming debt crisis in Africa again after the debt relief benefited by a number of African countries under the HIPC initiative, it seems important to suggest policymakers, a debt level beyond which growth can be compromised. Secondly, this study applies a different estimation technique, panel smooth transition regression (PSTR) proposed by González *et al.* (2017). The methodology applied is different from that employed by previous studies on Africa by both Ndoricimpa (2017) and

Mensah *et al.* (2019) in the sense that it allows for heterogeneity. It also allows a smooth change of regression coefficients from one regime to another. Indeed, Sokbae *et al.* (2017) notes that the effect of public debt on growth can be heterogeneous in terms of both magnitude and nonlinearity. Thirdly, another difference from the previous studies on Africa is the distinction in country profiles with comparisons between low- and middle-income countries, and between resource and nonresource intensive countries, as debt experiences can differ among country groups. Fourthly, as part of robustness checks, another estimation approach, dynamic panel threshold model of Seo and Shin (2016), is applied, in which the threshold variable (public debt) is allowed to be endogenous.

The rest of the paper is organized as follows. Section 2 gives stylized facts on public debt and growth in Africa. Section 3 highlights the literature review. Section 4 presents the methodology. Section 5 presents and discusses the empirical results. Section 6 concludes the study.

2. Stylized facts on public debt and growth in Africa

This section presents stylized facts on public debt and growth in Africa. Public debt is categorized into four arbitrary debt regimes following Reinhart and Rogoff (2010); low public debt (below 30% in ratio of GDP), medium-low public debt (between 30% and 60%), medium-high public debt (between 60% and 90%) and high public debt (above 90%). Table 1 highlights the number of country-years in each debt category, the average public debt and associated average economic growth by country samples. Debt experiences seem to be similar across country groups, with some few differences however. For example, the average public debt is comparable for resource- and nonresource intensive countries for the first three debt categories, but for the high debt category (beyond 90%), resource-intensive countries have a higher average debt (147.6%) compared to nonresource intensive- countries (115.2%). Resource-intensive countries also seem to have been in the high debt category (debt-to-GDP of over 90%) more frequently than nonresource-intensive countries; 237 country-years against 171. The same observation can be made for low- and middle-income country groups. A more detailed analysis [2], country by country indicates for instance that for the period 1980–2017, some countries for a greater part of the period have been in the high debt regime (29 years for Congo, 27 years for Gambia, 24 years for Zambia, 22 years for RDC, 21 years for Madagascar and Togo, 18 years for Mali, Malawi and Seychelles and 17 years for Burundi and Equatorial Guinea).

A look at the recent years (2012–2017) (see Table A1 in Appendix) shows that debt ratio remains low in most African countries after the HIPC debt relief except for countries like Cape Verde (114.3%) and The Gambia (103.3%) which still have high debt levels, while some other countries such as Congo Republic (73.1%), Seychelles (70.6%), Togo (65.1%) and Ghana (65.8%) have medium debt levels. Over the recent period (2012–2017), countries with the fastest rise in public debt include Equatorial Guinea (46.1%), Congo Republic (30.4%), Gabon (24.8%), Ethiopia (18.6%), Zambia (18.1%) and Cameroon (16.8%). According to the World Bank (2018b), countries with the fastest rise in debt are often fragile and affected by a number of things such as conflict, weak governance or commodity-dependence.

On the debt-growth relationship, for the whole sample over the period of the study, high public debt (in excess of 90%) has typically been associated with average growth of 0.2% vs 2.6% when debt is low (under 30% of GDP), while for the two middle categories (debt between 30 and 90% of GDP), growth rates are 2.1% and 1.5%, respectively. In addition, from one debt category to another, average growth rate seems to decline by the same percentage points except for the last debt category (beyond 90%). The highest decline in average growth is observed when public debt is beyond 90%, for all samples of countries. By simple descriptive statistics analysis, we are not able to detect the existence on nonlinearities in the debt–growth relationship. Even if we were, the debt threshold suggested would be exogenous.

Table 1.
Real per capita GDP growth as the level of public debt varies in Africa, 1980–2012

	Samples of countries														
	Whole sample			Low-income			Middle-income			Resource-intensive			Nonresource-intensive		
Public debt categories	Obs.	Av. D.	Av.gr	Obs.	Av. D.	Av.gr	Obs.	Av. D.	Av.gr	Obs.	Av. D.	Av.gr	Obs.	Av. D.	Av.gr
Below 30%	230	20.8	2.6	86	24.3	2.3	144	18.7	2.8	153	20.3	2.9	77	21.9	1.9
30–60%	333	44.9	2.1	130	43.8	1.1	203	45.7	2.7	188	44.3	2.1	145	45.8	2.0
60–90%	314	74.6	1.5	131	75.2	0.5	183	74.1	2.2	147	74.1	1.2	167	75.0	1.7
Beyond 90	408	134	0.2	213	124	−0.5	195	144.8	0.9	237	147.6	0.4	171	115.2	−0.2

Note(s): Author’s calculations using data from IMF (Historical Public Debt database) and WDI (2018). Obs. stands for the number of observations, Av. D. stands for average public debt and Av.gr for average economic growth

3. Literature review

A vast empirical literature exists on the debt threshold effects on economic growth. Some few studies have focused on samples of developing countries (see Elbadawi *et al.*, 1997; Imbs and Ranciere, 2005; Pattillo *et al.*, 2011). Elbadawi *et al.* (1997) applies quadratic model using fixed and random effects estimations on a sample of 99 developing countries and find that the effect of debt on growth becomes negative when the level of debt is beyond the threshold of 97%. Imbs and Ranciere (2005) use Kernel estimations on 87 developing economies, and finds that debt overhang occurs when the debt reaches 55–60% of GDP. Pattillo *et al.* (2011), on 93 developing countries, employ quadratic and spline models, and find that the average impact of debt on growth becomes negative at about 160–170% of exports or 35–40% of GDP.

In the aftermath of the 2008 global financial crisis, most studies focused on developed Organisation for Economic Cooperation and Development (OECD) countries (see, Checherita-Westphal and Rother, 2012; Baum *et al.*, 2013; Égert, 2015a, 2015b; Sokbae *et al.*, 2017). Checherita-Westphal and Rother (2012) uses a quadratic model on 12 euro area countries and finds a non-linear impact of debt on growth with a turning point found at about 90–100% of GDP. On the same sample of countries, Baum *et al.* (2013) employ nondynamic panel threshold regression model of Hansen (1999), and dynamic panel threshold regression model suggested by Kremer *et al.* (2013). This study suggests that the effect of debt on GDP growth is positive and highly statistically significant, but decreases to around zero and loses significance when public debt-to-GDP ratio rises beyond 67%. For debt-to-GDP above 95%, additional debt has a negative impact on economic activity. Égert (2015a), on a sample of 20 advanced economies uses nonlinear threshold models to examine debt threshold effects on growth. This study indicates that finding a negative nonlinear relationship between the public debt and economic growth is extremely difficult and sensitive to modeling choices and data coverage. In cases where nonlinearity is detected, the negative effects are detected at very low levels of public debt (between 20 and 60% of GDP). On the same sample of countries, Égert (2015b) applies nondynamic panel threshold regression of Hansen (1999) and finds that the nonlinear relation between debt and growth is not robust. This study suggests that a negative association between central government debt and growth may set in at debt levels as low as 20% of GDP, while for general government debt, the threshold is considerably higher at about 50%. Sokbae *et al.* (2017) tests for threshold effects in the relationship between public debt and median real GDP growth in advanced countries using the methodology in Lee *et al.* (2011), and find a debt-threshold effect at around 30%.

Some studies examined the debt threshold effects by comparing advanced and developing countries (see for example Caner *et al.*, 2010; Kumar and Woo, 2010; Chudik *et al.*, 2017; Eberhardt and Presbitero, 2015). On a sample of 101 emerging and developed economies, Caner *et al.* (2010) uses different threshold models and finds a debt threshold of 77% (% GDP) for developed countries and 64% for emerging economies. This study shows further that when debt is beyond the threshold, each additional percentage point of debt reduces annual growth by 0.017% points for developed countries, and by 0.02% points for emerging economies. Kumar and Woo (2010) consider randomly 3 ranges of debt level, i.e. below 30% (low debt), between 30 and 90% (medium debt) and above 90% (high debt), and then applies different static and dynamic panel data estimation approaches. This study finds that while the effect of low and medium debt on growth is mixed, the effect of high debt is robustly negative. Eberhardt and Presbitero (2015) apply panel econometric techniques allowing for the presence of nonlinearities and asymmetric effects, on a sample of 118 developed and developing countries. This study finds some support for a negative relationship between public debt and long-run growth across countries, but no evidence for a similar debt threshold within countries. Chudik *et al.* (2017) uses panel threshold-ARDL model on 19 advanced and 21 developing countries. This study finds the debt threshold to be in the range of 60–80% for the full sample, 80% for the advanced economies, and between 30 and 60% for the developing countries.

It is to be noted that even with the resurgence of debt problems in Africa, studies focusing specifically on Africa are still scarce. To our knowledge, only two studies have focused on African countries; Ndoricimpa (2017) and Mensah *et al.* (2019). Ndoricimpa (2017) employs nondynamic panel threshold regression model of Hansen (1999), and dynamic panel threshold regression model suggested by Kremer *et al.* (2013) and shows that the estimated debt threshold is sensitive to the estimation technique used and to growth control variables included in the estimation. For some cases, debt threshold is estimated at 92% while for other cases, it is found to be at 102%. This study finds however that while low debt is neutral or growth-enhancing, high debt is consistently detrimental to growth for all the cases considered. Mensah *et al.* (2019) applies panel threshold-ARDL model and finds that public debt hampers economic growth when it is in the range of 20–80% of GDP. Based on debt trajectory, this study shows that increasing public debt beyond 50–80% of GDP adversely affects economic growth in Africa.

From the existing empirical literature, we note that different estimation methods are applied, including quadratic and spline models, panel threshold regression (nondynamic and dynamic), panel smooth transition regression, panel threshold-ARDL model, etc. The existing empirical literature gives also mixed evidence on the debt threshold effect on economic growth, which can be explained by the difference in threshold estimation approaches used, as well as samples of countries considered. The estimated debt threshold for developed countries is found to be much higher than that for developing countries. Against this backdrop, this study revisits the issue of the debt threshold effects, by applying a different estimation technique which allows for heterogeneity and a smooth change of regression coefficients from one regime to another. In addition, this study divides the sample into low- and middle-income countries, and into resource- and nonresource intensive countries, as debt experience can differ among country groups.

4. Methodology

This study applies the PSTR model advanced by González *et al.* (2017) to examine the debt threshold effects on growth in Africa. PSTR model is a nonlinear panel model, a generalization of the panel threshold regression of Hansen (1999) that allows regression coefficients to vary across individuals and over time, as well as to change smoothly from one regime to another.

A PSTR model with two extreme regimes is written as follows:

$$y_{it} = \mu_i + \beta_0^{'} x_{it} + \beta_1^{'} x_{it} g(q_{it}; \gamma, c) + u_{it}, \text{ for } i = 1, \ldots, N, \text{ and } t = 1, \ldots. T \qquad (1)$$

where y_{it} is the dependent variable, x_{it} is a vector of time-varying exogenous variables, μ_i represent the fixed individual effects, and u_{it} are the errors. $g(q_{\text{it}}; \gamma, c)$ is called the transition function normalized to be bounded between zero and one. It is a function of the threshold variable q_{it}, the slope parameter γ and the threshold parameter c. β_0 are the regression coefficients in the first extreme regime (when debt is below the threshold), while $(\beta_0 + \beta_1)$ captures the marginal effect of the threshold variable in the second extreme regime (when debt is beyond the threshold).

For a logistic function, the transition function is written as follows:

$$g(q_{it}; \gamma, c) = \left\{ 1 + \exp\left[-\gamma \prod_{j=1}^{m} (q_{it} - c_j) \right] \right\}^{-1} \qquad (2)$$

According to González *et al.* (2017), it is sufficient in practice to consider $m = 1$ or $m = 2$. If $m = 1$, the model implies that the two extreme regimes are associated with low and high values of q_{it} with a monotonic transition of the coefficients from β_0 to $\beta_0 + \beta_1$.

As González *et al.* (2017) points out, the PSTR model building procedure consists of specification, estimation and evaluation. The specification phase consists of testing for linearity, while evaluation consists of testing for no remaining nonlinearity after estimation.

González *et al.* (2017) show that estimation of coefficients $(\beta_0, \beta_1, \gamma, c)$ in Model (1) is done by first eliminating individual effects μ_i using the fixed effects estimator, then applying nonlinear least squares to the transformed data. To eliminate individual effects, González *et al.* (2017) rewrite the Model (1) as follows:

$$y_{it} = \mu_i + \beta' x_{it}(\gamma, c) + u_{it} \tag{3}$$

where $x_{it}(\gamma, c) = (x_{it}', x_{it}' g(q_{it}; \gamma, c))'$ and $\beta = (\beta_0', \beta_1')'$ Individual effects are then eliminated by taking the deviation from the individual means from Eqn. (3), which gives: $\bar{y}_{it} = y_{it} - \bar{y}_i$, $\bar{x}_{it}(\gamma; c) = (x_{it}' - \bar{x}_i, x_{it}' g(q_{it}; \gamma, c) - \bar{w}_i(\gamma, c))'$, $\bar{u}_{it} = u_{it} - \bar{u}_i$, and $\bar{y}_i, \bar{x}_i, \bar{w}_i, \bar{u}_i$ are individual means, with $\bar{w}_i(\gamma, c) \equiv T^{-1}\sum_{t=1}^{T} x_{it} g(q_{it}; \gamma, c)$.

4.1 Linearity test

From Model (1), testing for linearity is done by either testing the null hypothesis of $H_0 : \beta_0 = 0$ or $H_0 : \gamma = 0$

According to González *et al.* (2017), the associated tests are nonstandard because under either null hypothesis, the PSTR model contains unidentified nuisance parameters. González *et al.* (2017) however circumvents the identification problem by replacing $g(q_{\text{it}}; \gamma, c)$ in (1) with its first-order Taylor expansion around $\gamma = 0$. After reparameterisation, this leads to the following auxiliary regression:

$$y_{\text{it}} = \mu_i + \beta_0'^{*} x_{\text{it}} + \beta_1'^{*} x_{\text{it}} q_{\text{it}} + \ldots + \beta_m'^{*} x_{\text{it}} q_{it}^{m} + u_{it}^{*} \tag{4}$$

Testing $H_0 : \gamma = 0$ is equivalent to testing $H_0 : \beta_1^* = \ldots = \beta_m^* = 0$ in (4), since $\beta_1^*, \ldots \beta_m^*$ are multiple of γ.

To test that null hypothesis, González *et al.* (2017) suggest five types of tests; a χ^2 - version LM test (LM_χ), a Fischer-version LM test (LM_F), their robust versions (Heteroscedasticity-Autocorrelation Consistent ((HAC_χ) and (HAC_F)], as well as the Wild Bootstrap (WB) and Wild Cluster Bootstrap (WCB) LM tests. However, González *et al.* (2017) warn that the standard and the HAC versions of the tests suffer serious size distortions. They therefore recommend to use the bootstrapped tests especially the WCB test as it outperforms the others.

4.2 Testing for no remaining nonlinearity

According to González *et al.* (2017), the testing procedure for no remaining nonlinearity is sequential. In the first step, the null hypothesis of a PSTR model with one transition function $(H_0 : r = 1)$, i.e. two regimes, is tested against the alternative of a PSTR model with two transition functions $(H_0 : r = 2)$, i.e. three regimes. If the null hypothesis fails to be rejected, the procedure ends there, otherwise the procedure continues by testing the null hypothesis of a PSTR model with two transition functions $(H_0 : r = 2)$ against the alternative of a PSTR model with three transition functions $(H_0 : r = 3)$. The continues until the null hypothesis fails to be rejected.

A PSTR model with two transitions ($r = 2$) is written as:

$$y_{it} = \mu_i + \beta_0' x_{it} + \beta_1' x_{it} g_1\left(q_{it}^{(1)}; \gamma_1, c_1\right) + \beta_2' x_{it} g_2\left(q_{it}^{(2)}; \gamma_2, c_2\right) + u_{it} \tag{5}$$

The null hypothesis of no remaining nonlinearity is set as $H_0 : \gamma_2 = 0$ in (5). Again, because of identification problem under the null hypothesis, $g_2(q_{it}^{(2)}; \gamma_2, c_2]$ is replaced by Taylor expansion around $\gamma_2 = 0$, leading to the following auxiliary regression:

$$y_{it} = \mu_i + \beta_0^{*'} x_{it} + \beta_1^{'} x_{it} g_1\left(q_{it}^{(1)}; \gamma_1, c_1\right) + \beta_{21}^{*'} x_{it} q_{it}^{(2)} + \ldots + \beta_{2m}^{*'} x_{it} q_{it}^{(2)m} + u_{it}^{*} \qquad (6)$$

The hypothesis of no remaining nonlinearity is restated as $H_0 : \beta_{21}^{*} = \ldots = \beta_{2m}^{*} = 0$ since $\beta_{21}^{*}, \ldots, \beta_{2m}^{*}$ are multiples of γ_2. The same tests suggested to test for linearity, i.e LM_{χ}, LM_F, HAC_{χ}, HAC_F, WB and WCB, are also employed to test the null hypothesis of no remaining nonlinearity.

5. Data, results [3] and discussion

In examining the debt threshold effects on growth in Africa, this study considers "growth rate of real GDP per capita" as the dependent variable and "public debt-to-GDP ratio" as the threshold variable. According to the growth literature (see, Barro and Sala-i-Martin, 2003; Rodrik, 1999; Easterly *et al.*, 2006; Anyanwu, 2014; Akobeng, 2016), factors affecting a country's economic growth include, among others, the rate of investment, foreign direct investment, official development assistance, human capital, innovation and research and development (R&D) activities, economic policies and macroeconomic conditions, openness to trade, institutions, demography, etc. The control variables are therefore chosen following this growth literature and previous studies on threshold effects modeling (see for example, Kremer *et al.*, 2013; Seleteng *et al.*, 2013). This study considers as control variables, population growth rate, investment ratio (percent of GDP), openness to trade (percent of GDP), growth rate of terms of trade, the ratio of foreign direct investment (percent of GDP) and the ratio of government spending (percent of GDP). It should be noted that all these variables passed the robustness tests of Levine and Renelt (1992) and Sala-i-Martin (1997). The effect of investment, openness to trade, growth rate of terms of trade and foreign direct investment is expected to be positive, while population growth and government spending are expected to negatively affect economic growth. According to Edwards (1997), trade openness enhances growth by raising productivity and competitiveness, and by allowing technological imitation. On the effect of foreign direct investment, Ndoricimpa (2014) points out that Foreign Direct Investment (FDI) promotes economic growth through its impact on host countries' financial resources and investment, by enhancing their technological capabilities, by boosting their export competitiveness and by generating employment and strengthening their skills base. On the effect of government spending, Barro and Sala-i-Martin (1997) point out that high level of public expenditures drains out the most efficient private investment and inhibits growth.

The list, definition, description, sources of data as well as descriptive statistics for the variables used, are in Table 2. This study is based on a balanced panel of 39 African countries for the period 1980–2012 due to debt data availability. As Table 2 shows, the panel mean value is 1.43% for growth of per capita GDP, 76.1% for public debt, 2.5% for population growth, 21.4% for investment ratio, 2.7% for foreign direct investment ratio, 4.1% for openness to trade ratio and 18.8% for government spending ratio. For robustness checks, we redo the exercise on four country groups, low- and middle-income countries, as well as resource- and nonresource-intensive countries (see Table A2).

5.1 Baseline results

The baseline results are based on the whole sample of all 39 African countries in the estimation (see Table A1). The first step in the PSTR estimation consists of testing for linearity. The results of the linearity test presented in Table 3 indicate that all the versions of

Variables	Definition, description and source	Obs.	Mean	Std. Dev.	Min	Max
Growth	Growth rate of real GDP per capita [Source: World Development Indicators, WDI (2019) and UNCTAD Statistics]	1287	1.43	7.023	−47.3	142.0
Public debt	Public debt-to-GDP ratio (Source: Historical Public Debt database created by IMF)	1287	76.14	50.16	0.8	325.6
Pop. growth	Growth rate of population [Source: WDI (2019)]	1287	2.51	1.10	−7.59	10.25
Investment	Investment ratio (% of GDP) proxied by the GDP ratio of gross fixed capital formation [Source: WDI (2019)]	1287	21.37	17.99	−5.26	219.0
TOT growth	Growth rate of terms of trade (TOT) [Source of data for TOT is WDI (2019)]	1287	0.66	13.66	−80.2	182.1
Foreign Dir. Inv.	Foreign Direct Investment (FDI) ratio (% GDP) [Source: WDI (2019)]	1287	2.66	5.55	−14.5	90.45
Openness to trade	Openness to trade, measured by the GDP ratio of the sum of exports and imports [Source: WDI (2019)]	1287	4.11	0.56	1.61	6.27
Government spend.	The ratio of government spending (% GDP) [Source: WDI (2019)]	1287	18.79	13.45	2.06	98.27

Source(s): Author

Table 2. Definition, description and descriptive statistics of the variables

Tests	Statistic	p-value
χ^2- version Lagrange Multiplier test (LM_χ)	62.37	0.000
F - version Lagrange Multiplier test (LM_F)	8.544	0.000
χ^2- version HAC test (HAC_χ)	14.46	0.043
F - version HAC test (HAC_F)	1.981	0.054
Wild Bootstrap LM test (WB)		0.081
Wild Cluster Bootstrap LM test (WCB)		0.030

Note(s): H0: linear model; H1: PSTR model with at least one threshold. HAC stands for Heteroskedasticity and Autocorrelation Consistent. 4,000 bootstraps (repetitions) and 25 cores are used for WB and WCB tests

Table 3. Linearity (homogeneity) tests

the tests (χ^2 – version LM test, Fischer-version LM test, their robust versions (HAC), as well as the WB and WCB LM tests] used reject the null hypothesis of linearity. González *et al.* (2017) recommend the WCB approach when testing linearity as it outperforms the others, which suffer serious size distortions, although WB test is better than the standard and the HAC versions of the tests. The WCB LM test rejects the linearity hypothesis at 5% significance level. This indicates that the relationship between public debt and economic growth in Africa is nonlinear.

Next, we estimate a two-regime PSTR model [4]. The estimation results are presented in Table 4 for both optimization algorithms used (L-BFGS-B and CG). Prior to discussing the results, we assess the adequacy of the estimated PSTR model by testing for parameter constancy and no remaining nonlinearity. Following González *et al.* (2017), we rely on the HAC versions of the tests, and WB and WCB tests, which perform better than the standard tests. Results in Table 5 indicate that those tests fail to reject the null hypotheses of parameter constancy and of no remaining nonlinearity. The estimated PSTR model with one transition is therefore adequate. Since the estimated model is found to be adequate, we continue to the next step of interpreting the results from the estimated PSTR model presented in Table 4.

Variables	Parameter estimates			
	L-BFGS-B[a] method		CG[b] method	
Dependent variable: growth	First extreme regime β_0	Second extreme regime $\beta_0+\beta_1$	First extreme regime β_0	Second extreme regime $\beta_0+\beta_1$
Public debt	0.039 (0.033)	−0.026*** (0.008)	0.040 (0.059)	−0.026*** (0.007)
Population growth	−0.182 (0.223)	0.169 (0.399)	−0.142 (0.282)	0.129 (0.467)
Investment	0.308** (0.157)	0.098*** (0.021)	0.319* (0.184)	0.098*** (0.024)
Terms of trade gr.	0.011 (0.024)	0.001 (0.016)	0.008 (0.021)	0.005 (0.015)
Openness to trade	0.866 (0.973)	2.929** (1.061)	0.677 (1.635)	2.915***(0.941)
Government spend.	−0.003 (0.079)	−0.079** (0.042)	0.0024 (0.1002)	−0.074* (0.043)
Foreign Dir. Inv.	0.120 (0.207)	0.128* (0.072)	0.127 (0.158)	0.133** (0.073)
Transition parameters				
Threshold (c)	65.9*** (7.085)		61.9*** (12.14)	
Slope (γ)	0.65 (0.762)		1.70 (2.252)	

Note(s): Between parentheses (.) are standard errors. *, **, *** denote significance at 10%, 5 and 1%, respectively
[a]L-BFGS-B is an optimization algorithm in the family of quasi-Newton methods that approximates the Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm using a limited amount of computer memory
[b]CG stands for conjugate gradient method

Table 4.
PSTR model estimation: baseline results for the whole sample

	Parameter constancy test				No remaining nonlinearity test			
	L-BFGS-B method		CG method		L-BFGS-B method		CG method	
Tests	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value
LM_χ	78.11	0.000	81.09	0.000	189.8	0	206.5	0
LM_F	5.289	0.000	5.49	0.000	12.85	0	13.98	0
HAC_χ	19.98	0.130	19.44	0.149	22.86	0.063	20.05	0.128
HAC_F	1.353	0.169	1.316	0.190	1.548	0.087	1.358	0.167
WB		1		0.998		1		1
WCB		0.945		0.941		1		1

Note(s): LM_χ and LM_F are the χ^2- and F- versions Lagrange Multiplier test; HAC_χ and HAC_F are χ^2- and F- versions HAC test; WB and WCB stand for Wild Bootstrap and Wild Cluster Bootstrap LM test, respectively. HAC stands for Heteroskedasticity and Autocorrelation Consistent. 1,000 bootstraps (repetitions) and 10 cores are used for WB and WCB tests

Table 5.
Misspecification tests

The table presents estimation results from two optimization algorithms used, L-BFGS-B and CG, for the two extreme debt regimes. The estimations from both algorithms give threshold values which are robustly significant. The first one giving a public debt-to-GDP threshold of 65.9% and the other, a debt threshold of 61.9%.

Furthermore, Table 4 presents the estimation coefficients by two extreme regimes. The coefficients in the first extreme regime indicate the direct marginal effect of the threshold variable (public debt) and of other control variables, when the level of public debt is less or equal to the estimated threshold (c); this is captured by the coefficient β_0. In the second extreme regime, coefficients show the marginal effect of the explanatory variables (threshold variable and other control variables) when public debt exceeds the threshold; as discussed in the methodological section, this is captured by $\beta_0+\beta_1$. On the effect of public debt, results indicate that for both optimization algorithms used, low debt (when public debt is below the threshold) does not have a significant effect on growth although its coefficient is positive, but high public debt (when public debt is beyond the threshold) has a robust significant negative effect on growth, at 1% level. This implies that while low debt is growth neutral, high debt is detrimental to growth. The results indicate that each additional percentage point of debt-to-GDP beyond the threshold reduces annual growth by 0.024% points.

With regard to the effect of the control variables included in the estimation, results indicate that the estimated coefficients in both debt regimes have expected signs from the literature. In the low debt regime, only investment has a significant effect on growth, while in the high debt regime, investment, openness to trade, foreign direct investment and government spending have a statistically significant effect on growth. Government spending exerts a negative effect on growth, while the other variables, investment, openness to trade and foreign direct investment, have a positive effect. This is in accordance with other growth empirical literature; Kremer *et al.* (2013), Mijiyawa (2013) and Thanh (2015) also find that investment has a significant positive effect on growth, Vinayagathasan (2013) finds that openness to trade enhances economic growth; and Seleteng *et al.* (2013) also find a negative impact of government spending on economic growth. Figure 1 presents the estimated transition function, which shows the transition from the lower debt regime to the upper debt regime. Figure 2 shows the response of growth to public debt. It gives further evidence of the nonlinear effect of public debt on economic growth. It confirms our findings that growth is positively associated with public debt so long as the level of debt is less than the estimated threshold (vertical red line), and negatively associated with public debt if it goes beyond the threshold. From Figure 2, it should be noted that beyond the threshold, the detrimental effect of debt on growth increases with the level of debt.

5.2 Robustness checks

Four robustness checks are carried out in this study. Firstly, as we know, a number of African countries that reached the completion period [5] received debt relief from the World Bank and IMF under the HIPC initiative that started in 1996. In addition, as Chudik *et al.* (2013) points out, in some countries with no or less active government bond markets, fiscal deficit is often financed through money creation with high inflation. As a first robustness check therefore, we consider two more control variables, namely, a HIPC completion point dummy to capture the effect of debt relief and inflation. The results of the first robustness check presented in Table 6 indicate that adding those two more control variables does not change the

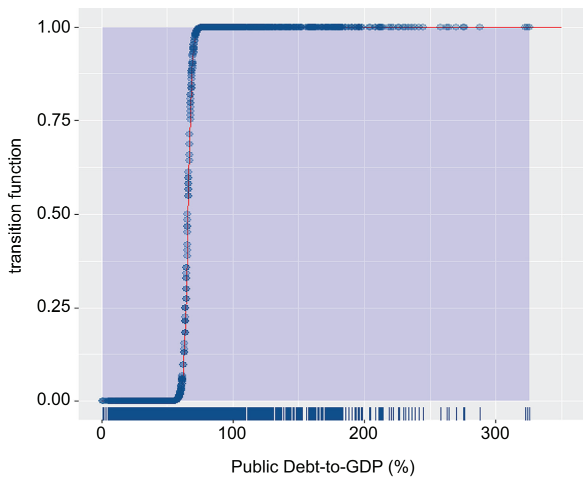

Figure 1.
Estimated transition function

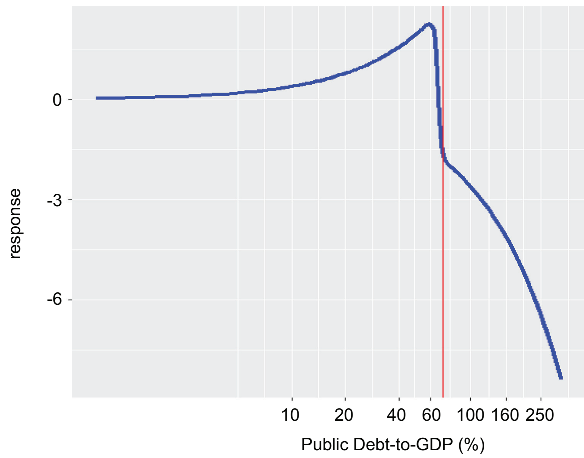

Figure 2.
Response of growth to public debt

Table 6.
PSTR model estimation with two more regressors

Variables	Parameter estimates			
	L-BFGS-B method		CG method	
Dependent variable: growth	First extreme regime β_0	Second extreme regime $\beta_0 + \beta_1$	First extreme regime β_0	Second extreme regime $\beta_0 + \beta_1$
Public debt	0.045 (0.037)	−0.024** (0.010)	0.048 (0.064)	−0.024*** (0.008)
Population growth	−0.158 (0.237)	0.218 (0.391)	−0.134 (0.245)	0.183 (0.428)
Investment	0.322* (0.176)	0.094*** (0.023)	0.336* (0.192)	0.094*** (0.024)
Terms of trade gr.	0.017 (0.028)	−0.004 (0.013)	0.016 (0.025)	−0.001 (0.022)
Openness to trade	0.303 (1.358)	2.533** (1.090)	0.083 (1.845)	2.502** (1.001)
Government spend.	0.006 (0.089)	−0.082* (0.049)	0.013 (0.106)	−0.078* (0.048)
Foreign Dir. Inv.	0.075 (0.206)	0.150* (0.085)	0.075 (0.176)	0.155** (0.084)
Inflation	−0.013 (0.012)	−0.00004 (0.000)	1.574 (1.204)	−0.0003 (0.00003)
HIPC completion point	1.442 (1.160)	0.461 (1.205)	−0.012 (0.012)	0.571 (1.003)
Transition parameters				
Threshold (c)	65.6*** (4.317)		61.4*** (8.04)	
Slope (γ)	0.65 (0.53)		1.804 (2.060)	

Note(s): Between parentheses (.) are standard errors. *, ** and *** denote significance at 10%, 5% and 1%, respectively

baseline results. The linearity hypothesis in the debt-growth relationship is still rejected by all the tests [6] used at conventional significant rate. The estimated debt threshold is also similar to that of the baseline results; 65.6% and 61.4%, respectively with L-BFGS-B and CG optimization algorithms. The debt threshold effects on growth are also similar to those in the baseline results; low public debt has a positive but insignificant effect on growth, while high debt has a significant negative effect on growth.

5.2.1 Debt threshold effects on economic growth in Africa by some country samples. The empirical literature shows that the level of debt threshold depends on the level of development of countries under study; it is usually found to be higher for developed compared to emerging and developing countries (See Chudik *et al.*, 2017). In addition, the

World Bank (2019) raises a concern that a number of low-income countries are again in debt distress or at a high risk, after the HIPC program. We therefore re-analyze the issue of debt threshold by dividing the sample study into two: low-income and middle-income countries (see Table A2). That is our second robustness check. Furthermore, debt experience might differ depending on whether a country is resource-rich or resource-poor. A number of resource-rich African countries have used their resources as collateral when contracting and negotiating the terms of their debts (Manzano and Rigobon, 2001). A third robustness check consists therefore in dividing the sample into two, resource-intensive countries and nonresource intensive countries (see Table A2), and re-estimating the debt threshold. The results of the second and third robustness checks are presented in Tables 7–10.

Linearity tests results [7] indicate that for middle-income countries, the null hypothesis of linearity is rejected at least at 10% level, by all tests used except WB, while for low-income countries, all the tests fail to reject the linearity hypothesis. This indicates that the relationship between public debt and growth is linear in low-income countries, but nonlinear for the sample of middle-income countries. Similarly for nonresource intensive countries, all the tests also fail to reject the linearity hypothesis, while for resource-intensive countries, two tests, LM_{χ} and LM_F reject the linearity hypothesis at 1% level. It should however be pointed out that González *et al.* (2017) caution that χ^2- and F - versions of LM test might suffer serious size distortions when testing linearity hypothesis. Non-linearity in the relationship between debt and growth for resource-intensive countries should therefore be taken with caution. We estimate a PSTR model with two regimes for middle-income countries and resource-intensive countries.

The estimation results of the PSTR model for both groups of countries are reported in Tables 7 and 8 while the results of the misspecification tests are in Tables 9 and 10. Again, following González *et al.* (2017), we rely on HAC versions of the tests, WB and WCB that are more robust, and suffer less size distortions. These tests do not reject the null hypotheses of parameter constancy and of no remaining nonlinearity. The estimated PSTR model for middle-income countries, and resource intensive countries is therefore valid. The debt

Table 7. PSTR model estimation for the sample of middle-income countries

Variables	Parameter estimates			
	L-BFGS-B method		CG method	
Dependent variable: growth	First extreme regime β_0	Second extreme regime $\beta_0+\beta_1$	First extreme regime β_0	Second extreme regime $\beta_0+\beta_1$
Public debt	0.093 (0.063)	−0.042*** (0.009)	0.134* (0.073)	−0.042*** (0.009)
Population growth rate	−0.229 (0.505)	−0.691** (0.328)	−0.287 (0.481)	−0.890** (0.332)
Investment	0.368** (0.170)	0.111*** (0.028)	0.378** (0.162)	0.113*** (0.026)
Terms of trade growth	0.055* (0.029)	0.003 (0.015)	0.059** (0.028)	0.002 (0.012)
Openness to trade	1.299 (1.769)	4.663*** (1.268)	0.699 (1.882)	4.429*** (1.183)
Government spending	−0.049 (0.186)	−0.061 (0.047)	−0.047 (0.175)	−0.062 (0.043)
Foreign direct invest	0.063 (0.242)	0.092 (0.082)	0.066 (0.244)	0.086 (0.080)
Transition parameters				
Threshold (c)	62.36*** (1.127)		58.06*** (0.054)	
Slope (γ)	0.959** (0.464)		42.59*** (7.084)	

Note(s): Between parentheses (.) are standard errors. *, ** and *** denote significance at 10%, 5% and 1%, respectively

Variables	Parameter estimates			
	L-BFGS-B method		CG method	
Dependent variable: growth	First extreme regime β_0	Second extreme regime $\beta_0+\beta_1$	First extreme regime β_0	Second extreme regime $\beta_0+\beta_1$
Public debt	0.052 (0.062)	−0.029** (0.015)	0.084 (0.065)	−0.028*** (0.008)
Population growth	−0.318 (0.738)	−0.033 (0.833)	−0.105 (0.686)	−0.119 (0.685)
Investment	0.422** (0.186)	0.116*** (0.026)	0.428** (0.169)	0.113*** (0.027)
Terms of trade growth	0.017 (0.034)	0.013 (0.075)	0.019 (0.032)	0.010 (0.013)
Openness to trade	0.992 (2.178)	3.729** (1.150)	0.380 (1.312)	3.709*** (1.072)
Government spending	0.058 (0.108)	−0.043 (0.062)	0.094 (0.102)	−0.046 (0.055)
Foreign direct invest.	−0.007 (0.245)	0.134 (0.093)	0.024 (0.256)	0.144 (0.093)
Transition parameters				
Threshold (c)	63.16 (40.88)		58.81*** (0.056)	
Slope (γ)	0.942 (5.890)		20.62*** (4.957)	

Note(s): Between parentheses (.) are standard errors. *, ** and *** denote significance at 10%, 5% and 1%, respectively

Table 8.
PSTR model estimation for resource-intensive countries

Tests	Middle-income countries				Resource-intensive countries			
	L-BFGS-B method		CG method		L-BFGS-B method		CG method	
	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value
LM_χ	86	0.000	82.35	0.000	71.66	0.000	67.93	0.000
LM_F	5.720	0.000	5.477	0.000	4.766	0.000	4.518	0.000
HAC_χ	16.99	0.256	17.90	0.2113	15.92	0.318	17.59	0.226
HAC_F	1.130	0.327	1.191	0.277	1.059	0.392	1.17	0.294
WB		1		1		1		1
WCB		1		1		1		1

Note(s): HAC stands for Heteroskedasticity and Autocorrelation Consistent. 1,000 bootstraps (repetitions) and 25 cores are used for WB and WCB tests

Table 9.
Parameter constancy test

Tests	Middle-income countries				Resource-intensive countries			
	L-BFGS-B method		CG method		L-BFGS-B method		CG method	
	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value
LM_χ	184.2	0	193.8	0	200.1	0	205.7	0
LM_F	12.25	0	12.89	0	13.31	0	13.68	0
HAC_χ	19.68	0.140	19.85	0.134	12.85	0.538	10.62	0.715
HAC_F	1.309	0.196	1.32	0.189	0.854	0.608	0.706	0.769
WB		1		1		1		1
WCB		1		1		1		1

Note(s): HAC stands for Heteroskedasticity and Autocorrelation Consistent. 1,000 bootstraps (repetitions) and 25 cores are used for WB and WCB tests

Table 10.
No remaining nonlinearity test

threshold estimated for middle-income countries is 58% with CG and 62.3% with L-BFGS-B optimization algorithm (see Table 7). For both methods, the estimated debt threshold is statistically significant at 1% level. The estimated slope parameter (γ) is also statistically significant although it is much higher for the estimation with CG method. While public debt in the lower regime is either growth neutral (with L-BFGS-B method) or growth enhancing (with CG method), public debt in the upper regime is detrimental to growth for both methods. For middle-income countries, each additional percentage point of debt-to-GDP beyond the threshold reduces annual growth by 0.042% points. On the effects of control variables, investment affects growth in both regimes, growth in the terms of trade affects economic growth only in the lower debt regime, while population growth and openness to trade affect growth only in upper debt regime. As expected, investment, openness to trade and growth in terms of trade affect growth positively, but population growth affects growth negatively.

Similar results are obtained for resource-intensive countries. The estimated debt threshold is 58.8% and 63.1%, respectively, with CG and L-BFGS-B optimization methods (see Table 8). This is in the range of what is estimated for the whole sample and the sample of middle-income countries. The effect of public debt is similar to that in the baseline results; public debt is growth neutral when it is low, but becomes detrimental to growth when it rises beyond the threshold. Each additional percentage point of debt-to-GDP beyond the threshold reduces annual growth by 0.028% points. As in previous estimations, investment has a positive effect on growth in both debt regimes, while openness to trade positively affects growth but only in the upper regime. The other control variables do not affect growth in resource-intensive countries.

5.2.2 Debt threshold effects using a dynamic panel threshold model. As a fourth robustness check, to deal with the potential endogeneity of debt, this study applies a dynamic panel threshold model of Seo and Shin (2016) in which the threshold variable and regressors are allowed to be endogenous. The estimation results reported in Table 11 indicate that linearity hypothesis is strongly rejected at 1% level, confirming the presence of debt threshold effects on growth. The estimated debt threshold is 74.3%, and is found to be significant at 1% level. Below the threshold, the effect of public debt is positive, although not strongly significant (at 10%); but beyond the threshold, debt is harmful to growth. On the effect of control variables, the results show that the convergence hypothesis is supported only in the upper regime (when public debt is beyond the threshold) where the coefficient of the lagged growth is significant; the effect of growth of terms of trade is positive as expected but only significant in the lower regime (when public debt is below the threshold); the effect of government spending is negative but only significant in the upper regime. For FDI, the effect is significant in both

Variables Dependent variable: growth	Parameter estimates Lower regime	 Upper regime
Lagged growth	−0.102 (0.065)	−0.323*** (0.114)
Public debt	0.112* (0.062)	−0.237*** (0.077)
Terms of trade growth	0.061*** (0.011)	0.022 (0.032)
Openness to trade	2.062 (2.982)	3.187 (3.159)
Government spending	−0.160 (0.164)	−0.391** (0.162)
Foreign Direct Investment	−0.241* (0.142)	0.719*** (0.112)
Threshold	74.3*** (24.573)	
Linearity test	p-value = 0.000	

Note(s): Results are obtained using the STATA command "xthenreg" written by Seo *et al.* (2019). Between parentheses (.) are standard errors. *, ** and *** denote significance at 10%, 5% and 1%, respectively

Table 11. Estimation results using a dynamic panel threshold model of Seo and Shin (2016)

regimes but with opposite signs, negative in the lower regime and positive in the upper regime. Openness to trade does not have a significant effect on growth in either regime.

6. Concluding remarks

Following recent concerns about the looming debt crisis in Africa after the HIPC debt relief, this study sought to re-examine the debt threshold effects on growth for Africa using PSTR approach advanced by González *et al.* (2017). For the whole sample, this study estimates a public debt threshold in the range of 62% and 66%. Low debt is found to be growth neutral but higher public debt is growth detrimental. Four robustness checks were used, (1) by adding more control variables; (2) by dividing the countries' sample according to their level of development, into low-income countries and middle-income countries; (3) by dividing the sample into two, resource-intensive countries and nonresource-intensive countries and (4) by applying another methodology that deals with the potential endogeneity of debt.

The results indicated that adding more control variables does not change the baseline results. For samples of low-income countries and nonresource-intensive countries, linearity in the relationship between public debt and growth was not rejected. For middle-income and resource-intensive countries, this study estimates a debt threshold in the range of 58% and 63%. For those two country samples, low public debt is found to be either growth neutral or growth enhancing, but high public debt is found to be detrimental to growth. On the effect of control variables, investment, population growth, openness to trade and growth in terms of trade are found to affect growth. Investment, openness to trade and growth in terms of trade affect growth positively, but population growth affects growth negatively. However, the effects of those control variables on growth differ across debt regimes. For instance, investment affects growth in both regimes, growth in the terms of trade affects economic growth only in the lower debt regime, while population growth and openness to trade affect growth only in the upper debt regime.

However, when a dynamic panel threshold model of Seo and Shin (2016) was applied to deal with the potential endogeneity of debt, a much higher debt threshold is estimated, at 74.3%; with debt exerting a positive effect on growth in the lower regime and a negative effect in the upper regime.

While the estimated debt threshold for Africa in this study is comparable to that found by Imbs and Ranciere (2005) who found a debt threshold of 60% for developing countries, it is different from that estimated by most of previous studies. For developing countries, Pattillo *et al.* (2011) estimated a debt threshold between 35% and 40%, Chudik *et al.* (2017) found a debt threshold in the range of 30–60% for developing countries, Mensah *et al.* (2019) found a debt threshold in the range of 20–50% for a sample of African countries, while Ndoricimpa (2017) estimated a much higher debt threshold for Africa, between 92% and 102%.

The findings of this study show that there is no single debt threshold applicable to all African countries; for some groups of countries, nonlinearity in the debt-growth relationship was even rejected. The findings confirm also that the level of debt threshold varies depending on the estimation technique used, on whether the endogeneity of debt is dealt with or not. However, this study provides some debt management policy insights; for all cases considered, the study does point to the detrimental effects of high debt on economic growth, which occur when public debt-to-GDP rises beyond around 60% (when debt is assumed to be exogenous), and around 74% (when debt is allowed to be endogenous). The debt threshold suggested in this study is close to the convergence criterion for public debt for Southern African Development Community, which is set at 60%, but differ from that of other regional economic communities such as East African Community (EAC), West Africa Economic and Monetary Union (WAEMU) and Economic and Monetary Community of Central Africa

(CEMAC). For EAC, the convergence criterion for public debt is fixed at 50%, while for WAEMU and CEMAC, the limit is 70%. It should also be noted that the debt threshold estimated in this study is close to the convergence criterion on public debt set by the African Monetary Cooperation Programme.

The fact that there is no single debt threshold applicable to all African countries shows that there is need for assessing possible country-specific nonlinearities which would entail estimating threshold models for individual countries. This gives us an area for further research.

Notes

(1) https://www.imf.org/en/News/Articles/2018/09/13/managing-debt-vulnerabilities-in-lics

(2) The table analysis is not reported in this study for space considerations but is available upon request.

(3) All estimations in this study are done using the "PSTR" package available in R Software.

(4) We consider a logistic transition function with one threshold parameter ($m = 1$). According to González *et al.* (2017), it is sufficient in practice to consider $m = 1$.

(5) To qualify for debt relief, countries had to comply with certain conditions, including carrying out strong programs of macroeconomic adjustment and structural reforms designed to promote growth and reduce poverty. Only countries that reached the completion period qualified.

(6) The Table results of linearity test are not presented for space consideration, but is available upon request.

(7) Tables' results of linearity test are not presented for space consideration, but are available upon request.

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Further Reading

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Appendix

Table A1.
Mean public debt-to-GDP ratio and mean debt growth in Africa (2012–2017)

Country	Mean d	Mean debt growth	Country	Mean d	Mean debt growth
Algeria	–	–	Mauritania	–	–
Benin	38.6	10.8	Mauritius	57.0	2.8
Botswana	16.8	−3.7	Morocco	–	–
Burkina Faso	33.1	4.6	Niger	36.6	9.7
Burundi	42.8	7.9	Nigeria	17.2	7.1
Cape Verde	114.3	8.6	Rwanda	31.8	9.3
Cameroon	25.3	16.8	Senegal	53.6	7.5
Central African Rep.	51.9	12.5	Seychelles	70.6	−2.1
Chad	41.4	10	Sierra Leone	43.3	6.3
Congo, Dem. Rep.	20.2	−11.1	South Africa	47.8	4.9
Congo Republic	73.1	30.4	Sudan	–	–
Cote d'Ivoire	45.7	−5.7	Eswatini	20.2	9.6
Egypt	–	–	Tanzania	36.5	−0.3
Equatorial Guinea	25.6	46.1	Togo	65.1	10.4
Ethiopia	46.0	18.6	Tunisia	–	–
Gabon	42.7	24.8	Uganda	33.0	5.3
Gambia	103.3	8.4	Zambia	46.8	18.1
Ghana	65.8	8.9			
Kenya	50.3	2.6			
Lesotho	37.4	−1.1			
Madagascar	36.3	0.1			
Malawi	57.6	7.2			
Mali	30.9	3.8			

Source(s): Author's computations using data from IMF (2018), "Regional Economic Outlook: Sub-Saharan Africa", April, 2018

Table A2. Sub-samples of African low-income, middle-income, resource-intensive and nonresource-intensive countries

Low-income	Middle-income	Resource-intensive	Nonresource-intensive
Benin	Algeria	Algeria	Benin
Burkina Faso	Botswana	Burkina Faso	Burundi
Burundi	Cape Verde	Central African Rep.	Cape Verde
Central African Rep.	Cameroon	Congo, Dem. Rep.	Cote d'Ivoire
Chad	Congo Republic	Cameroon	Ethiopia
Congo, Dem. Rep.	Cote d'Ivoire	Chad	Gambia, The
Ethiopia	Egypt	Congo Republic	Kenya
Gambia, The	Eq. Guinea	Egypt	Lesotho
Madagascar	Gabon	Eq. Guinea	Madagascar
Malawi	Ghana	Gabon	Malawi
Mali	Kenya	Ghana	Mauritius
Niger	Lesotho	Mali	Rwanda
Rwanda	Mauritania	Mauritania	Senegal
Sierra Leone	Mauritius	Morocco	Seychelles
Tanzania	Morocco	Niger	Eswatini
Togo	Nigeria	Nigeria	Togo
Uganda	Senegal	South Africa	Uganda
	Seychelles	Sierra Leone	
	South Africa	Tanzania	
	Eswatini	Tunisia	
	Tunisia	Zambia	
	Zambia		

Source(s): IMF (2018), "Regional Economic Outlook: Sub-Saharan Africa", April, 2018

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