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Threshold effect in the relationship between external debt and energy access in sub-Saharan African countries: A dynamic panel threshold specification

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ABSTRACT

This paper investigates the relationship between external debt and energy access in the Sub-Saharan African countries over the period 1999–2021. Results from the dynamic panel threshold method indicates that the link between external debt and energy access is nonlinear. Moreover, the findings reveal a statistically negative relationship between external debt and energy access above the threshold of 5.04 %, beyond which external debt reduces energy access in SSA countries. Besides, results indicate that economic growth and trade openness enhance access to electricity. However, renewable energy consumption decreases energy access. This paper upholds the view that external debt should be kept to a reasonable level in order to avert the opposite effect on energy access.

1. Introduction

In sub-Saharan Africa (SSA), access to modern, high-productivity forms of energy is limited both quantitatively and qualitatively. Electricity, an important indicator of social well-being and economic activity, is a commodity for which universal access in this part of the world remains a distant prospect, and for which the quality of service is inadequate, penalizing both populations and businesses. SSA is the sub-continent with the lowest access to electricity and other forms of modern energy. Moreover, access is marked by major disparities between urban and rural areas. A large part of rural and peri-urban Africa remains unelectrified, and current production capacity is unable to meet demand in the face of rapid population growth and the multiplication of micro, small and medium-sized enterprises.In addition, sub-Saharan Africa suffers from a significant shortage of electricity supply and reliability, resulting in high production and transaction costs, and a lack of competitiveness for companies on the sub-continent.According to the World Bank (Blimpo and Cosgrove-Davies, 2019), 53.2 % of companies in sub-Saharan Africa own or share a diesel generator, compared with 38.2 % in the Middle East and North Africa, and just 17.2 % in Europe and Central Asia.

However, investment in energy infrastructure and new, more efficient and cleaner production capacity must also be able to address the continent's energy production deficit. To overcome the development gap, most low-income countries in sub-Saharan Africa took on debt rapidly after independence.This indebtedness was facilitated by the fact that, in the 1970 s, the development of international financial markets and increased competition among banks led many of them to turn to developing, middle-income or even low-income countries in an attempt to increase the profitability of their investments (Hoogvelt, 1990). The risk of such investments was not obvious at the time, because of the strong growth in these countries and the high inflation that made real interest rates negative. This rapid indebtedness became problematic as the international environment changed dramatically in the early 1980 s. The shift in monetary policy in the United States led to a sharp increase in interest rates, which, combined with the second oil shock, lowered the growth rate of the world economy (Friedman, 1988; Gilbert, 1994).

In the mid-2000s, the Heavily Indebted Poor Countries (HIPC) and Multilateral Debt Relief Initiatives (MDRI) had a very clear effect on the debt stock of African countries (Mustapha and Prizzon, 2018). The stock of official multilateral debt fell by 43 percent between 2004 and 2006, and the stock of official bilateral debt fell by 46 percent over the same period. Unfortunately, the countries that benefited from these cancellations have been indebted without interruption for 15 years. In 2014, the debt stock returned to its pre-HIPC maximum (in 2004). This ceiling was then largely exceeded: at the end of 2019, the overall debt stock of SSA countries reached $395 billion, almost double the 2004

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level and three times the post-cancellation low point reached in 2006. As GDP in Sub-Saharan Africa (SSA) has grown at a slower pace, post-cancellation debt ratios have increased significantly. The average debt ratio in the region has risen from an average of 33.5 percent between 2010 and 2017–50.4 percent in 2019 and 57.3 percent at the end of 2020 (World Bank, 2020).

However, most of studies focused on debt-energy have investigated this relation indirectly (Brew-Hammond, 2010; Gill and Karakulah, 2019; Smith-Nonini, 2020; Farooq et al., 2022; Onuoha et al., 2023; Okere et al., 2023). Firstly, by acting on economic growth, and subsequently on the level of development. This by improving the state of infrastructure, particularly in terms of energy. In particular by enhancing electricity production and transmission, minimizing the difficulties and obstacles to accessing energy, especially in rural areas.

Nevertheless, external debt has often been linked positively to economic growth for some authors (Silva, 2020; Didia and Ayokunle, 2020; Mohsin et al., 2021; Sharaf, 2022), and negatively for others (Dey and Tareque, 2020; Ohiomu, 2020; Yasar, 2021; Wang et al., 2021; Olamide and Maredza, 2021; Ale et al., 2023) which is explained by the debt overhang theory. This theory holds that further domestic and foreign investment is discouraged when future debt outstrips the country's ability to repay (Krugman, 1988; Calvo and Diaz-Alejandro, 1989).

The main contributions of this paper to the literature are listed as follows. First, most of studies investigated the indirect impact of external debt on energy access by reducing the growth through investment. However, the direct impact of high indebtedness on energy access has been lacking in most of empirical literature. Second, many empirical studies have shown that linear models do not always make it possible to characterize the dynamics of a particular economic process. The causes of this failure can be varied, mainly, the presence of asymmetry in the data. Also,the previous studies on this subject gives mixed results in terms of the positive and negative effects of external debt. This suggests the existence of an optimal debt threshold above which an inverse effect may exist. Therefore, in this paper we set out to exploit this divergence by studying the potential threshold effects in the relationship between external debt and energy access. Different from previous studies, we use the Dynamic Threshold Panel regression (DTP) recently developed by (Kremer et al., 2013).

The remainder of this study is structured as follows. Section 2 presents the data and methodology while Section 3 shows the model estimation and results and Section 4 concludes.

2. Data and methodology

In this study we use a balanced data of 727 observations for selected 33 Sub-Saharan African countries based on data availability. The period of the study spans from 1999 to 2021. All variables are collected from the World Bank Development Indicators (WDI) database. The 33 Sub-Saharan African countries used in the sample include Burkina Faso, Burundi, Central African Republic, Chad, Congo, Dem. Rep., Gambia, The Guinea-Bissau, Madagascar, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Sudan, Togo, Uganda, Angola, Benin, Cabo Verde, Cameroon, Comoros, Congo, Rep., Cote d'Ivoire, Eswatini, Ghana, Guinea, Kenya, Mauritania, Nigeria, Senegal, Tanzania, Zambia, Zimbabwe.

In this study, three macroeconomic variables are used. They include the access to electricity (lena) which is the percentage of population with access to electricity, external debt (lxd) which is represented by external debt stocks in percentage of GNI, real GDP per capita (ly) measured in millions of constant 2015 U.S dollars, trade openness (lop) which is the sum of exports and imports of goods and services measured as a share of gross domestic product, renewable energy consumption (lre) given by the share of renewable energy in total final energy consumption and the foreign direct investment (lfdi). The natural logarithm is used to express each variable. All variables meet the international standard definition.

We apply the dynamic panel threshold regression approach suggested by Kremer et al. (2013) to identify the potential nonlinear relationship among external debt and energy access in SSA countries. Kremer et al. (2013) extended the Hansen (1999) original static panel threshold estimation and the Caner and Hansen (2004) cross-sectional instrumental variable (IV) threshold model, where generalized methods of moments (GMM) type estimators are used to deal with endogeneity problem. The model, which is based on threshold regression, has the following form:

$$y_{it} = \mu_{it} + \beta_1^{'} z_{it} I(q_{it} \leq \gamma) + \beta_2^{'} z_{it} I(q_{it} > \gamma) + \varepsilon_{it} \quad (1)$$

where i denotes the country index and t denotes the time. The country-specific fixed effect is μ_{it}, while the error term is ε_{it}. I(.) is the indicator function indicating the regime defined by the threshold variable q_{it} and the threshold level γ. z_{it} is a m-dimensional vector of explanatory regressors that may contain lags in y and other endogenous variables. The vector of explanatory variables is partitioned into a subset z_{1it}, of exogenous variables uncorrelated with ε_{it}, a subset of endogenous variables z_{2it},correlated with ε_{it}. Furthermore, the model needs an appropriate set of $k \geq m$ instrumental variables x_{1it} including z_{1it}.

Individual effects (μ_{it}) must be eliminated using a fixed-effects transformation in the first step of model estimation in Eq. (1). As a result, we employ Arellano and Bover (1995) forward orthogonal deviation approach, which is given by:

$$\varepsilon_{it}{}^{*} = \sqrt{\frac{T-t}{T-t+1}} \left[\varepsilon_{it} - \frac{1}{T-1} (\varepsilon_{i(t-1)} + \cdots + \varepsilon_{iT}) \right] \quad (2)$$

This technique has the advantage of avoiding serial correlation of the modified error terms. This feature enables the estimating process developed for a cross-sectional model to be applied to dynamic panel data models.

Three steps are required to estimate the threshold value; First, a reduced form regression is estimated for the endogenous variables $y_{i,t-1}$ as a function of the instruments and substitutes the endogenous variable with the predicted value $\hat{y_{i,t-1}}$. Second, we estimate equation (1) by least squares for a fixed threshold γ where, $y_{i,t-1}$, replaced by its predicted values from first step. Finally, the least sum of square residuals S (γ) is used to determine the optimal threshold value which is the one with the smallest S(γ). The slope coefficient can be computed using the GMM estimator once the threshold value has been determined. Following Caner and Hansen (2004), the confidence interval for γ is estimated by $\Gamma\{\gamma: LR(\gamma) \geq C(\alpha)\}$, where $C(\alpha)$ is the asymptotic distribution of the likelihood ratio indicator of LR (γ) at 95 % level.

We specify the following threshold model using the dynamic panel threshold model to analyze the effect of external debt on energy access in SSA countries:

$$lena_{it} = \mu_{it} + \beta_1^{'} lxdt_{it} I(lxd_{it} \leq \gamma) + \delta_1 I(lxd_{it} \leq \gamma) + \beta_2^{'} lxd_{it} I(lxd_{it} > \gamma) + \theta z_{it} + \varepsilon_{it} \quad (3)$$

where $xdebt_{it}$ is both the threshold variable and the regime-dependent regressors in our application. z_{it}donates the vector of partly endogenous control variables, where slope coefficients are assumed to be regime independent. Following Kremer et al. (2013), we allow for differences in the regime intercept δ_1. Initial energy access is considered as endogenous variable, z_{2ti} = Initial = $lena_{it-1}$while z_{1it}contains the remaining control variable which for our application include the economic growth (ly), the foreign direct investment (lfdi), the trade openness and renewable energy consumption (lre).

Following Arellano and Bover (1995) and Kremer et al. (2013), we employ dependent variable lags ($lena_{it-1}$, …$lena_{it-p}$) as instruments. There is a bias/efficiency trade-off in finite samples when selecting the number (p) of instruments. Using all available lags of the instrumental variable (p = t) can increase efficiency, while reducing the number of instruments to 1 (p = 1) can avoid over-fitting the instrumented variables, which could lead to biased coefficient estimates.

Table 1
Pesaran's test of cross sectional independence.

Variables	CD-test	corr	abs(corr)
lena	85.58***	0.870	0.870
ly	43.37***	0.441	0.647
lxd	45.79***	0.470	0.577
lfdi	5.15***	0.044	0.296
lop	7.08***	0.065	0.4
lre	36.73***	0.373	0.588

Note: ***,**, and * indicate statistical significance at 1 %, 5 %, and 10 % levels, respectively

3. Results and discussion

The Pesaran's cross-sectional dependence test (CD) (Pesaran, 2004) outlined in Table 1 rejects the null hypothesis of no cross-sectional dependence. Consequently, the second generation of panel unit root tests can be employed.

Second-generation panel unit root test results proposed by Pesaran (2007) are presented in Table 2. Findings indicate that the null hypothesis of the unit root cannot be rejected at 1 % of significance for all series except the economic growth, trade openness and the renewable energy consumption. However, by testing for the unit root in the first difference, all panel unit root tests reject the null hypothesis at the 1 % level of significance. Hence, the cointegration can be examined using the Westerlund cointegration test (Westerlund and Edgerton, 2007).

Findings are summarized in Table 3 and show that there is no cointegration among the variables.

Given evidence of no panel cointegration among variables, we perform the dynamic threshold panel model.

Therefore, the linearity tests are investigated. The purpose is to prove that the relation between energy access and external debt is nonlinear. To achieve this, we perform a test of linearity against the dynamic threshold panel model. We utilize the Wald test, which is expressed as follows:

$$LM_w = \frac{NT(SSR_0 - SSR_1)}{SSR_0}$$

where SSR_1 and SSR_0 are the panel sum of square residuals under H_0 (linear dynamic panel model) and the panel sum of square residual under H_1 (dynamic threshold panel model) respectively. For small sample, Gonzalez et al. (2017) suggest to use the Fisher test defined as:

$$LM_F = \frac{NT(SSR_0 - SSR_1)/k}{SSR_0/(TN - N - K)}$$

with k the number of explanatory variables. LM_F follows a Fisher distribution with k and (TN-N-k) degrees of freedom (F(mk,TN-N-k)). All these linearity tests are distributed $\chi^2(k)$ under the null hypothesis.

Findings are reported in Table 4. This table shows that the model's linearity hypothesis is rejected at the 1 % significance level Table 5.

Table 4 displays the estimated coefficients. The upper part of the table displays the estimated external debt (lxd) threshold and the corresponding 95 % confidence interval. The middle part shows the regime-dependent coefficients of external debt on energy access. Specifically, $\hat{\beta}_1$ and $\hat{\beta}_2$ donates the marginal effect of external debt on energy access in the low and high regime.

Table 2
Second-generation panel unit-root test.

Variables	Levels CIPS	First differences CIPS
lena	−5.980***	−17.917***
lxd	−3.792***	−11.975***
lfdi	−5.987***	−16.557***
ly	2.789	−8.024***
lop	0.829	−12.276***
lre	−0.091	−8.606***

Note: ***,**, and * indicate statistical significance at 1 %, 5 %, and 10 % levels, respectively.

Table 3
Westerlund panel cointegration test.

Westerlund test	Test statistic	P-value
Some panels	−0.5707	0.2841
All panels	0.3254	0.3724

Table 4
Linearity tests.

	Statistics
Lagrange multiplier (LM_w)	89.02791***
Fisher Test (LM_F)	8739.574***
Likelihood-ratio test (LR)	96.00637***

Note: ***,**, and * indicate statistical significance at 1 %, 5 %, and 10 % levels, respectively.

Table 5
Dynamic panel threshold estimation.

$\hat{\lambda}$	5.042961	
95 % Confidence interval	[4.432915, 5.451835]	
	Coefficients	Prob.
$\hat{\beta}_1$	0.199402	0.000***
$\hat{\beta}_2$	−0.149178	0.01**
Initial	0.4033	0.0055**
ly	1.0981054	0.000***
lfdi	0.0027573	0.8260550
lop	0.1019814	0.0857719*
lre	−0.5013045	0.000***
$\hat{\gamma}_1$	−0.503390	0.000***
Observations	727	
Number of countries	33	

Note: ***,**, and * indicate statistical significance at 1 %, 5 %, and 10 % levels, respectively.

The estimated external debt threshold for sub-Saharan countries is (5.04 %) as ($e^{5.04}$ = 154.47 % of GNI), and lies within the confidence interval. Thus, the low regime corresponds to the values of the transition variable, lxd, that is below the threshold parameter (5.04 %) and the high regime corresponds to the value of the transition variable that is above the threshold parameter.Below the threshold, ($\hat{\beta}_1$ = 0.199402) external debt is positively linked with the energy access. This involves that when lxd is below 154.47 % of GNI, it will improve access to energy. Specifically, an increase of 1 % of external debt increases energy access in the low regime by 0,19 %. Indeed, improving energy infrastructure and rolling out electricity networks in rural areas, and meeting the growing demand for energy consumption, requires a considerable financial effort. Public aid for development in SSA countries is still insufficient to finance large-scale infrastructure projects such as rural electrification and the construction of electricity grids. Still, foreign finance remains one of the most sought-after solutions for financing large-scale projects such as energy transportation and access.

The region's development and economic recovery are severely hampered by stunted and inefficient power sectors, which limit electricity consumption and therefore economic activity. However, economic development remains a major challenge for the African continent in order to lift its population out of the endemic poverty that is so prevalent in the region. Nevertheless, despite the huge need, investment in transmission lines is lacking. In 2018, for the whole of Africa, only $10 billion was invested in network infrastructure, whereas the needs were estimated at $60 billion Senyagwa (2022).The IEA now estimates that investment needs in network infrastructure will average $40 billion a year over the period 2026–2030 Senyagwa (2022). Substantial financial commitments are required to absorb this deficit, in particular the external borrowing. Indeed, a better allocation of external debt, mainly in the improvement and reinforcement of the central electricity network, can increase the rate of electrification.

However, above the threshold, ($\hat{\beta}_2 = -0.149178$) external debt is negatively correlated with energy access and an increase of 1 % of external debt decreases energy access in high regime by 14 %. This means that, at a certain point, debt becomes unbearable and its positive effect fades, leading to a reverse effect. The optimal threshold of external debt for the SSA countries is still very high (154.7 % of GNI), which suggests that these countries are highly dependent on external financing and increasing the debt would curb access to energy. Furthermore, all borrowing has a cost, usually interest and amortization, which can become a considerable financial burden for the government, reducing the resources available for essential public spending, such as investment in education, health and energy infrastructure. Moreover, this change signals a risky environment and could create a barrier to capital inflows. As a result, investment in the social sector and in improving infrastructure, production and access to energy is declining. Furthermore, additional borrowing may lead to a shift in access to modern or clean energy sources towards fossil fuel-based electricity.

Further, economic growth impacts positively the access to energy. Thus, a 1 % increase in economic growth increases access to electricity by 109 %. This suggest that the fundamental way to solve energy problems in the SSA countries would be to strengthen their capacity for autonomous development and achieve sustainable development. Moreover, this outcome is plausible given that economic growth can encourage individuals to migrate from less environmentally and health-damaging traditional energy sources to more environmentally and health-friendly modern energy consumption habits.

Likewise empirical findings show that renewable energy consumption contributes to the decline in electricity access. Results indicate that a 1 % increase of renewable energy consumption decreases the access to electricity by 50 %.In general, electricity is produced from non-renewable sources, mainly gas and coal. Renewable energies, on the other hand, are generated by photovoltaic panels, particularly in rural areas lacking infrastructure. An expansion in the consumption of renewable energies could therefore have a negative impact on access to electricity from non-renewable sources. In particular, the decentralized solar systems market has grown rapidly over the past decade in SSA countries, especially among residential consumers, due to the emergence of new business models such as Pay-As-You-Go. This system gives access to a solar kit as part of a leasing contract that allows SSA people to use a solar system while gradually paying it back with mobile money.

Apart from the advantages in terms of reliability of electricity supply, there are many economic benefits to be gained from using these systems. A household equipped with a decentralized solar system can protect itself from fluctuating fossil fuel prices, such as those associated with the use of a diesel generator, as well as rising electricity tariffs.

Moreover, findings indicate that a 1 % increase in trade openness increases electricity access by 10 %. Indeed, trade openness leads to increased economic growth, particularly in developing countries. As economies grow and industrialize, electricity demand often increases to power manufacturing and service sectors. This can lead to increased electricity consumption.Besides, this results indicate that the SSA economy is aligned with the technology transfer theory, according to which trade openness grants greater accessibility to unique technologies as well as expertise and information on modern energy sources, which favors the country's development (Lin et al., 2016; Hashemizadeh et al., 2021). However, findings show that foreign direct investment (lfdi) is positive and non significant. This indicates that energy-related investments remain fairly negligible.

4. Conclusion

This study explores the external debt- energy access nexus for the SSA countries over the period 1999–2021. Results from dynamic panel threshold estimates suggest that external debt has a negative and significant effect on energy access above the threshold level of 154.47 % of GNI in the SSA countries. However, below the estimated threshold external debt improves energy access in the SSA countries. Moreover, findings indicate that economic growth and trade openness enhances access to energy. Otherwise, results indicate that renewable energy consumption decreases access to electricity.

The findings of this paper suggest that external debt leads to a reduction in energy access at high regime, and an improvement at low regime. High indebtedness reduces capital inflows, cuts investment - particularly in the social sectors - and curbs access to energy. In particular, financial markets and donors perceive countries with high levels of external debt as risky for investment.

This paper have some relevant policy implications. SSA countries need to contract external debt at a reasonable level and channel it into energy investment.This is to avoid reaching the critical threshold above which foreign debt can become a burden and induce a reverse effect. Moreover, to mitigate the SSA countries energy shortfall, production capacity and investment should be doubled over the next decade, with the emphasis on renewable energy. It's a logical step in the context of climate change and for a continent with abundant natural resources, particularly in solar and geothermal energy.This can be achieved by boosting the endogenous development capacities of SSA countries.

Indeed, SSA countries can lighten their external debt burden and improve their development by increasing domestic savings, which can be channeled into financing infrastructure projects. This can be achieved in two ways; First, by encouraging private savings and, second, by increasing public savings through a reduction in budget spending. Encouraging private savings would require measures to make savings an attractive substitute for consumption. As many SSA countries have high inflation rates and very low nominal interest rates, substantial increases in interest rates may be needed to encourage private savings, so that real interest rates become positive. This policy can prove difficult to implement, and may be met with strong opposition to rate hikes. For this reason, it must be implemented gradually, and accompanied by social measures to benefit the population. This policy also calls for energetic measures to lower the inflation rate, through vigorous fiscal and monetary adjustment.As for public savings, this will require measures to reduce the budget deficit through increased budget revenues and appropriate cuts in operating expenses. To achieve revenue growth, countries will need to implement far-reaching reforms of tax legislation and revenue administration and collection, while spending cuts will require rigorous monitoring systems.

However, given the scale of the investment required for electrification in SSA countries, and its long-term profitability, the use of mixed instruments such as public-private partnerships and blending seems unavoidable.The latter, for instance, involves bringing together public and private actors on a single project and mobilizing financing in the form of both grants and loans, the relative importance of which may vary according to the level of development of the concerned countries.The goal of blending is to increase the potential of official development assistance, and to use it as a lever to attract much higher levels of investment.

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