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Natural resource dependence and economic growth in SSA: are there threshold effects?

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ABSTRACT

The debate on the natural resource curse hypothesis has attracted the attention of policy makers and policy analysts for the past few decades. However, the empirical findings on such a hypothesis have proven inconclusive. Our study investigates the threshold effects of natural resource dependence on economic growth in sub-Sahara Africa (SSA) using both aggregate and disaggregate data from 1990 to 2019 by employing a threshold effect model. The results indicate a double threshold effect of natural resource rent on economic growth. In particular, below 6% of GDP, aggregate natural resource rent exerts a significant negative effect on economic growth. However, as the rents increase above 6% to about 15% of GDP its negative effect on economic growth significantly reduces. In addition, beyond 15% of GDP natural resource rent exhibit a substantial significant positive impact on economic growth. Further, the disaggregated data reveal that forest rents exhibit a strong weighty adverse effect on economic growth at all levels of thresholds. The study recommends that governments within the sub-region need to put in policies to ensure that natural resources generate at least 15% of GDP annually to promote growth.

1. Introduction

After the post-World-War II, there has been an extensive discussion in the literature on the effect of natural resource dependence on economic growth of resource-rich countries. Findings from some studies suggest that natural resource-rich countries have the tendency to perform poorly and this became known as natural resource curse hypothesis (see Auty 1997; Gelb 1988; Sachs and Warner 1999; Gylfason, Tryggvi, and Gylfi 1999; Brunnschweiler and Bultey 2009). These studies attribute the abysmal performance of the natural resource-rich economies to a predicted fall in export prices due to declining global demand for these resources as well as poor management of revenue obtained from resource exports (Sachs and Warner 2001). By recognizing the volatility trends in prices of global commodities, those studies demonstrate that the natural resource curse is an empirical fact and argue that growth in resource-rich countries turn to be volatile compared with non-resource rich-countries. For instance, countries such as Angola, Sierra Leone, Chad, Ghana, Nigeria and DR Congo depend largely on natural resource export but over the years these countries have recorded unsustainable and very abysmal growth performance (Adika 2020). The poor economic performance leads to some of these countries being classified among the world's poorest in terms of Human Development Index (HDI) rankings.

However, global historical developments have also shown that natural resource dependence determines prosperity. For instance, Britain, Germany and the US depended profoundly on coal and iron ore to attain industrial development (Sachs and Warner 2001), Also other industrialized countries including Canada, Australia and Norway are natural resource-intensive economies that have achieved robust and sustained economic performance over many years (Pendergast, Clarke, and Van Kooten 2011). In addition, Botswana, Namibia, Ethiopia, Rwanda, Singapore, South Korea, and Taiwan have recorded very impressive growth performances and are classified among the fastest growing world economies and have seen a significant improvement in the HDI rankings. Botswana, have attained sustained economic growth backed by a long-term investment of about a

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quarter of their GDP. During independence in 1966, Botswana was cited as one of the poorest countries in sub-Sahara Africa, but thanks to its large reserves of diamonds, it has enjoyed GDP per capita in term of constant Purchasing Power Parity of about 14.8% in the past four decades (Clootens and Kirat 2020). Although, Botswana has escaped most of the fundamental economic problems associated with poor and volatile economic growth, it is believed that its level of growth is still lower than countries such as Singapore, South Korean and Twain who possess and depend on fewer natural resources (van der Ploeg and Poelhekke 2011).

Insight from the above studies suggests that while there exist some countries that grew rapidly backed by natural resources, there are other countries that have experienced deterioration in economic performance by depending greatly on natural resources. In addition, the evidence suggests that the effect of natural resources on economic growth is inconclusive. Based on this, some studies have attributed the effect of natural resources on economic performance to physical capital accumulation (Sachs and Warner 1997; Gylfason, Tryggvi, and Gylfi 1999). They argue that natural resources can affect growth through physical capital in the following ways. First, natural resource wealth could induce policy makers to consume heavily now and invest less in physical capital leading to low capital accumulation in the future which does not promote for economic growth. Second, resource dependence can cause a Dutch Disease where the real exchange rate may appreciate due to the export of natural resources and which could make the manufacturing sector less profitable. In instances where the manufacturing sector is capital intensive compared to the commodity sector, the exchange rate appreciation would cause a reduction in the total amount of capital in the economy. Gylfason, Tryggvi, and Gylfi (1999) and Blancoa and Grier (2012) also argue that natural resource dependence could crowd-out financial capital especially when a substantial amount of the proceeds are kept in foreign banks relative to domestic ones. This would cause the domestic banks to be undercapitalized and would consequently become weak in providing financial support for entrepreneurial activity, leading to poor manufacturing sector performance. In addition, Blancoa and Grier (2012) have assigned natural resource curse to low-skilled requirements by the commodity sector and its relatively low linkage with other sectors of the economy. The authors argue that governments of countries with huge natural resources turn to place less premium on investment in education and as result their workers are unable to reallocate into industry due to low skill level. Finally, other studies argue that resource curse is attributed to poor

institutions in affected countries. For instance, Sala-i-Marin and Subramanian (2003) and Boschini, Pettersson, and Roine (2007) contend that poor quality institutions which generate corruption turn out to be a deleterious channel through which resource dependence can impact economic growth.

Although the reasons assigned for the poor economic growth performance of resource-rich countries have been well investigated, the threshold effects have been given little attention. For instance, if natural resources can promote economic growth, it follows that policy makers should aim at a high rate of resource proceeds. But how high should the rent generated from natural resource exports be to engender economic growth? Also, at what level of natural resources rent does the association between resource dependence and economic growth become positive? These questions have not been fully answered in the literature and that motivates the current study. Our thesis is that at a lower level of resource rent, the association between natural resource rent and economic growth could be negative or non-existent. However, at a higher level of resources rent, the association could be positive. If such a non-linear relationship exists, then it is possible to estimate the threshold at which the sign of the relationship between natural resources proceeds and economic growth could change.

To determine the linkage between natural resource dependence and economic growth, Liu et al. (2022) apply threshold models to find the presence of the natural resource curse hypothesis for some provinces in China. Their findings show the presence of the natural resource curse effect on a greater percentage of the provinces. Furthermore, Hayat and Tahir (2020) specifically test for the link between natural resources, foreign direct investment and economic growth for 83 countries using a fixed effect threshold model and find evidence of natural resource rent of 9.9% of GDP to be the threshold for stimulating economic growth. Also, Clootens and Kirat (2017) divide their sample into two different regions; advanced and developing countries and also between OECD and non-OECD countries to examine the relationship between natural resource rent and economic growth. Their findings reveal that the economic performance of the distinct groups respond differently to natural resource dependence.

The objective of this study is two-fold. First, we show the presence of a threshold outcome in the natural resources-growth relationship in a panel of 33 countries in sub-Saharan Africa (SSA) from 1990 to 2019. The SSA is noted for its natural resource abundance and dependence even after adopting the World Bank Structural Adjustment Program in the early 1980s to diversify the

economy of the region. For instance, between 1960 and 2008 the percentage of natural resources exports to total merchandise exports in SSA deteriorated marginally from 77% to 65.1% (Carmignani and Chowdhury 2010). Nonetheless, SSA and other developing countries continue to remain major exporters in the global markets for primary products and natural resources. About three-quarters of global trade in natural resources are attributed to SSA and other developing countries (UNCTAD 2014). Second, the study applies disaggregated data of natural resources (oil, gas, coal, minerals, and forest resources) to determine which of them possess a strong threshold effect to stimulate growth. Natural resources are distributed randomly in SSA countries with different intensities and the effects of the value chain differ across countries. For instance, while countries such as Nigeria, Ghana, Sudan, Angola, Gabon, Eritrea, Kenya, South Sudan, Mozambique and Republic of Congo, are greatly endowed in oil and gas, others such as Botswana, Democratic Republic of Congo, Benin, Burkina Faso, Djibouti, Mali, South Africa, Tanzania, Uganda, Zambia and Gambia possess commercial deposits of metallic minerals. Thus, aggregated data on natural resource dependence and economic growth may be misleading since different natural resources drive economic growth differently.

It is worthy to note our study differs from most of the empirical works in the following ways. First, we evaluate the threshold impact of natural resource dependence on economic growth which appears to be a substantive omission from the literature in SSA. Previous studies concentrated on natural resource curse hypothesis (Clootens and Kirat 2020; Auty 1997; Gelb 1988; Sachs and Warner 1995; 1999; Gylfason, Tryggvi, and Gylfi 1999; Brunnschweiler and Bultey 2009) and natural resource dependence and the investment in human capital and non-residential assets (Bravo-Ortega and de Gregorio 2005; Blancoa and Grier 2012). Others focused on natural resource curse and institutional quality (De Rosa and Iootty 2012; Wiens 2013; Itchoko and Pierre 2016) to the neglect of a threshold effect. Following Hansen (1999, 2000), we take into account the possibility that the relationship between natural resource dependence and economic growth could have a threshold effect. Second, we disaggregate the data of natural resources to determine whether different resource types could have a threshold effect on economic growth. Though Boschini, Pettersson, and Roine (2007) investigated the association between natural resources and institutions as well as the effect of institutions across various resource types, the authors failed to conduct a threshold effect of these different resource types.

The rest of the paper is organized as follows: We review literature in section 2. In section 3, we choose assessment methods that examine the existence of a threshold effect in the relationship between natural resource dependence and economic growth. Section 4 discusses the results while section 5 concludes it.

2. Literature review

The influential work of Sachs and Warner (1995), investigates the effect of natural resources on growth, leading to the term 'Resource Curse Hypothesis'. This hypothesis argues that countries with rich natural resources achieve a lower rate of economic growth compared to those countries with a lower natural resources economy. Among the theories that demonstrate and explain the 'Resource Curse' is the popular 'Dutch Disease' effect. Theoretically, the 'Dutch Disease' suggests a boom in the natural resources sector, a decline in the manufacturing sector and a subsequent slowdown in economic growth. It is essentially linked to the exploitation of valuable natural resources and the unexpected negative consequences on the overall economy. This is because abundant natural resources could crowd-out other productive sectors of the economy leading to the overall under performance of the nation. However, the classical economic theory before the 1950s proposed a positive effect (Habakkuk 1962).

According to Norman (2009), numerous studies have used resource abundance and resource dependence interchangeably, ignoring the differences between the two terminologies. Based on this, Ouoba (2016) indicates that ignoring the differences brings lack of clarity in choosing the indicators of the 'resource curse' hypothesis. Badeeb, Lean, and Clark (2017) define resources abundance as the amount of natural resources available in a country and indicate resource dependence as a relative measure as it captures the degree of dependence of a country on natural resources. Stijns (2005) describes resource abundance as an exogenous variable while resource dependence is an endogenous indicator influenced by economic, social and political indicators.

The Resource Curse Hypothesis' has been tested in many empirical studies. These empirical studies can be grouped differently. The first strand of the literature focuses on natural resource abundance and economic growth which indicates inconclusive outcomes. Some studies mainly suggest a negative effect of the former on the latter. Studies that are in support of this assertion of negative effects of natural resource abundance on economic growth include Atkinson and Hamilton (2003), Gylfason and Zoega (2006), Mehlum, Moene, and Torvik (2006), Shao and Yang (2010, 2014), Williams

et al. (2011), James and Aadland (2011), Zuo and Jack (2014), Sarmidi, Hook Law, and Jafari (2014), Ahmed, Mahalik, and Shahbaz (2016), Taguchi and Lar (2016), Cheng, Lianshui, and Liu (2020) and many others. Thus, these studies find evidence in support of the 'Resource Curse' proposition. On the contrary, other studies support the existence of a positive effect of natural resources abundance on economic growth. This can be described as 'natural resource blessings'. Some of these studies include Papyrakis and Gerlagh (2004), Brunnschweiler (2008), Alexeev and Conrad (2009), Sarmidi, Hook Law, and Jafari (2014), Ji, Magnus, and Wang (2014), Oyinlola, Adeniyi, and Raheem (2015), Smith (2015), Ndjokou and Tsopmo (2017), Muhammad et al. (2019), Adika (2020), Katoka and Jörg Dostal (2022).

The second plethora of studies focuses on natural resource dependence on growth based on economics and political economy. The economic literature supports the 'resource curse' hypothesis include Sachs and Warner (1995, 1997, 2001); Pendergast, Clarke, and Van Kooten (2011); Shao and Yang (2014). In addition, Bravo-Ortega and de Gregorio (2005) provide evidence which suggests that a large human capital development has the potential to compensate and counterbalance the adverse consequences of natural resource dependence on economic growth. The political economy studies on the other hand, trace the origins of the natural resource curse to socially sub-optimal activities. These studies argue that natural resource dependence stimulates financial motive for violent conflicts and serves as a fertile ground for the creation of wars due to weak institutions (Collier and Hoeffler 2005: Rose 2004: Humphreys 2005; Fearon 2005: Basedau and Lay 2009). Political economy studies further argue that the absence of democratic institutions to ensure checks and balances breed corruption and looting for the elites rather than producing welfare-enhancing opportunities to the ordinary people. This could reduce the opportunity cost for rebellion leading to a high probability of civil war. The political economy literature believes that the silver bullet to resolving the natural resource curse is to build strong institutions to strengthen political checks and balances. For instance, Boschini et al. (2007) examine the relationship between natural resources and institutions as well as the effect of institutions on different resource types. The authors find that countries with weak institutions experience resource curse and that improvements in these institutions can reverse the curse. Finally, the authors reveal that due to technical and economic grounds some natural resources are more likely to cause problems of rent-seeking than others.

The third strand of studies consider the application of non-linear models in the natural resources-growth literature, definition and measurement issues. Among them is the work of Majda and Oliver (2013). The authors apply regime switching techniques to investigate the natural resource curse hypothesis. The findings reveal that below a threshold value of 51% oil revenue as a percentage of GDP promotes growth but above it, it becomes a curse to growth of the countries sampled. Also, Clootens and Kirat (2020) employ Hansen (2000) sample-splitting approach and reveal that given the initial level of growth, countries display variant responses to natural resource dependence. Similarly, Ampofo et al. (2020) apply Nonlinear Autoregressive Distributed Lag (NARDL) to investigate the natural resources-economic growth nexus for ten top-rich mineral economies. The authors reveal that natural resource rent is a curse in Australia, DRC, and India but enhances growth in Brazil and Canada. However, the study of Sun and Kai (2020) relates natural resource dependence and financial development to economic growth by applying a threshold approach. The results suggest that the ability to moderate the resource curse hypothesis is contingent on the extent of the advancement of the financial sector.

The above literature review indicates that even though non-linear estimation techniques such as NADRL and threshold analysis have been applied to evaluate whether natural resource dependence drives or drags growth of resource rich-countries, empirical evidence is limited on SSA countries. Again, a greater percentage of the extant literature used only aggregate resources revenue or rent to analyse the effect of natural resource dependence and economic growth. Based on this, we contribute to the literature in the following ways. First, we apply the dynamic sample-splitting threshold technique suggested by Hansen (1999) to evaluate the natural resource hypothesis for 33 SSA countries. Second, we disaggregate the data into various natural resources rents such as forest, oil, coal, mineral and gas and estimate their threshold effects on growth. Disaggregated data permits a comprehensive understanding of the role each resource plays in either promoting growth or stifling growth. More so, it unearths patterns that are likely to be disguised with the large pool of resource rent or revenue. Thus, our study provides a better understanding of the behavior of each resource in influencing growth in the sub-region.

3. Methodology

To accomplish our objective, we adopt the augmented Solow growth model by Mankiw, Romer, and Weil (1992) as extended by Polimerni, Polimerni, and Trees

(2007) to include natural resources. Using a production function, we specify the model as follows:

$$Y(t) = K(t)^a H(t)^\beta N(t) A(t) L(t)^{1-a-\beta} \quad \alpha + \beta < 1 \quad (1)$$

here $Y(t)$ denotes output, $K(t)$ represents capital stock, $L(t)$ captures labor force, $H(t)$ represents the stock of human capital and $N(t)$ denotes the stock of natural resources. From this model, the dynamics of capital per unit of effective labour is written as:

$$k(t) = s_k y(t) - (n + g + \delta)k(t)$$
$$= s_k N(t)^{1-a-\beta} k(t)^a - (n + g + \delta)k(t) \quad (2)$$

and the dynamics of human capital per unit of effective labour is derived as:

$$\dot{h}(t) = s_h y(t) - (n + g + \delta)h(t)$$
$$= s_h N(t)^{1-a-\beta} h(t)^\beta - (n + g + \delta)h(t) \quad (3)$$

where α is the proportion of physical capital in output, β is the proportion of human capital stock in output, n is population growth rate, g is the rate of growth in technology and δ is the rate of depreciation.

The economy converges to a steady-state when.

$$k^* = N(t)\left[\frac{s_k^{1-\beta} s_k^\beta}{(n + g + \delta)}\right]^{\frac{1}{1-a-\beta}} \quad (4)$$

$$h^* = N(t)\left[\frac{s_h^a s_h^{1-a}}{(n + g + \delta)}\right]^{\frac{1}{1-a-\beta}} \quad (5)$$

Combining equations (4), (5) and (1) and applying natural logarithm we derive the equation for output per unit of effective labour as follows:

$$\ln\left[\frac{Y(t)}{L(t)}\right] = \ln A(0) + gt + \ln N(0)$$
$$- \frac{a + \beta}{1 - a - \beta}\ln(n + g + \delta)$$
$$+ \frac{a}{1 - a - \beta}\ln(s_k) + \frac{\beta}{1 - a - \beta}\ln(s_h) \quad (6)$$

where $\ln(n + g + \delta)$ denotes break-even investment (due to depreciation and population growth), s_k denotes the portion of output invested in physical capital stock and s_h represents the portion of output invested in the stock of human capital. Here, $\frac{a + \beta}{1 - a - \beta}$ is the elasticity of output with respect the break-even investment, $(n + g + \delta)$. Also, $\frac{a}{1 - a - \beta}$ captures the elasticity of output with respect to the fraction of investment in physical capital stock, s_k and $\frac{\beta}{1 - a - \beta}$ denote

the elasticity of output with respect to the fraction of the stock of human capital that is invested in an economy. Equation (6) states that growth in output per unit of effective labour is dependent on population growth, physical capital, accumulation of human capital and the stock of exogenous variables called technical progress and natural resources.

Note that Equation (6) is the steady state version of the model. In order to account for the time varying version, the model should start away from the steady state level. Mankiw, Romer, and Weil (1992) started from the speed of convergence to the steady state given by:

$$\frac{d\ln(y(t))}{dt} = \gamma[\ln(y^*) - \ln(y(t)], \text{ where } \gamma$$
$$= (n + g + \delta)(1 - \alpha - \beta) \quad (7)$$

$$\ln(y(t)) = (1 - e^{-\gamma t})\ln(y^*) + e^{-\gamma t}\ln(y(0)) \quad (8)$$

where, $y(0)$ is income per effective worker at some initial date. We assumed income level for 1989 as the initial level. Thus, $y(0) =$ GDP per capita for 1989. Subtracting $\ln(y(0))$ from both sides of equation (8) yields:

$$\ln(y(t) - \ln(y(0)) = (1 - e^{-\gamma t})\ln(y^*) - (1 - e^{-\gamma t})\ln(y(0)) \quad (9)$$

Finally, substituting for y^* by putting equation (6) into equation (9) gives us:

$$\ln(y(t)) - \ln(y(0)) = (1 - e^{-\gamma t})[\ln A(0)$$
$$+ \tau t] + (1 - e^{-\gamma t})[\ln Z(0)]$$
$$+ (1 - e^{-\gamma t})\frac{\alpha}{1 - \alpha - \beta}\ln(s_k)$$
$$+ (1 - e^{-\gamma t})\frac{\beta}{1 - \alpha - \beta}\ln(s_h) \quad (10)$$
$$- (1 - e^{-\gamma t})\frac{\alpha + \beta}{1 - \alpha - \beta}\ln(n + g + \delta)$$
$$- (1 - e^{-\gamma t})\ln(y(0)$$

Re-defining terms, equation (10) can be re-stated as:

$$\ln g_{y,it} = a_{0i} + b_{1i}\ln z_t + b_{2i}\ln s_{kt} + b_{3i}\ln s_{ht} - b_{4i}\ln l_t$$
$$+ b_{5i}\ln y_{t-1} + u_t \quad (11)$$

where $\ln g_{y,it} = \ln(y(t)) - \ln(y(0))$ is the growth rate of GDP per capita, $a_{0i} = (1 - e^{-\gamma t})[\ln A(0) + \tau t]$ captures all relevant growth variables that are not explicitly captured, $b_{1i} = (1 - e^{-\gamma t})$ is the parameter on natural resources, $b_{2i} = (1 - e^{-\gamma t})\frac{\alpha}{1 - \alpha - \beta}$ is the parameter on physical stock of capital, $b_{3i} = (1 - e^{-\gamma t})\frac{\beta}{1 - \alpha - \beta}$ is the parameter on human capital,

$b_{4i} = (1 - e^{-\gamma t}) \frac{\alpha + \beta}{1 - \alpha - \beta}$ is the parameter on break-even investment (this is the rate of investment that is required in each period to offset the rate of depreciations in both physical and human capital stocks and to maintain a constant technological progress), and $b_{5i} = (1 - e^{-\gamma t})$ is the parameter on the initial level of GDP per capita (1989).

Equation (11) states that growth in output is a function of the rate of natural resource dependence, lnz_{it}, the level of investment in physical capital, $lns_k it$, the level of investment in human capital, $lns_h it$, the level of break-even investment, lnl_{it}, and a host of other variables which may have some impact on growth and a country-specific factor, a_{0i}. Errors in measurement and other variables are captured in e_{it}.

From the above model specification, the stock of natural resources affects the growth of output per unit of effective labour. However, extant literature on the effect of natural resources on economic growth generate mixed outcomes. In the very short run, the stock of natural resources is said to have a negative effect on economic growth. This is counter-intuitive. In this study we argue that the stock of natural resources has a threshold effect such that at the initial low level of their exploitations, natural resource may not have weighty positive influence on economic growth. But beyond the threshold, natural resource could have a positive relationship with economic growth.

3.1. Threshold model specification

Following Hansen (1999), we modify our model to capture the threshold effect. Consider the following double threshold model

$$y_{it} = a_{0i} + a_{1i}Z_{it} + x_{it}(q_{it} < \gamma_1)\beta_1 + a_{2i}Z'_{it}$$
$$+ x_{it}(q_{it} \geq \gamma_1)\beta_2 + \mu_{it} + e_{it} \quad (12)$$

where y_{it} is the growth of output per capita, a_{0i} is the constant term representing exogenous technical progress, μ_{it} is the individual country fixed effect and e_{it} is the disturbance. Here, Z_{it} is the covariate matrix capturing the control variables, x_{it} is the regime-dependent variable and the variable q_{it} is the threshold variable. Also, γ_i are the threshold parameters that divide the equation into multiple regimes with coefficients β_1 and β_2 as regime-dependent coefficients.

3.2. Data and empirical model specification

To estimate the model, we retrieved time series data from the World Development Indicators (WDI) spanning 1990–2019 on 33 countries. The Data on GDP per capita is used as the growth variable. The independent variables include gross capital formation as a percentage of GDP, Human capital is measured by total current expenditure on education as a percentage of total expenditure in public institutions. The rest of the variables include the share of the population between the ages of 19 and 59 who have at least secondary education and expenditure on health, population growth rate as annual percentage changes, and total natural resource rent as a percentage of GDP. The data also includes bribery index as a percentage of firms that have experienced at least one bribe payment request, trade as a percentage of GDP, inflation as year-on-year changes in consumer price index, current account balance, trade with the rest of the world, official exchange rates and fertility rate. Table 1 lists the number of countries considered in the study.

We use total resource rent as a percentage of GDP to measure natural resource dependence. We also obtained data on five different natural resource types to capture the disaggregated natural resource rent. They include coal rents as a percentage of GDP, forest rents as percentage of GDP, mineral rent as percentage of GDP, oil rent as percentage of GDP, and natural gas rent as percentage of GDP for all the 33 countries. It is to be noted that selection of these countries was primarily driven by availability of data.

To estimate the model, we specify the double threshold effect model as:

$$lng_{y,it} = a_0 + a_1 lngdp_{it-1} + a_2 lncapt_{it} + a_3 expdt\_edu_{it}$$
$$+ a_4 lnschool_{it} + a_5 lnpop_{it} + \beta_1 resrent_{it} I(resrent_{it-1}$$
$$\leq \gamma_1) + \beta_2 resrent_{it} I(\gamma_1 < resrent_{it-1})$$
$$+ a_6 lnbrib_{it} + a_7 lnexch_{it} + a_8 infl_{it} + a_9 lnfert_{it}$$
$$+ a_{10} cab_{it} + a_{11} lntrade_{it} + a_{12} lnhealth_{it} + e_{it}$$
$$(13)$$

where $lng_{y,it}$ is growth rate of real GDP per capita, $lngdp_{it-1}$ is log of real GDP per capita for the previous period, $lncapt_{it}$ is log of gross capital investment, $expdt\_edu_{it}$ is log of share current expenditure on education, $lnschool_{it}$ is secondary school education attained, $lnhealth_{it}$ is public expenditure on health, and $lnpop_{it}$ is population growth rates annual percentages. Following Mankiw, Romer, and Weil (1992), we assume the sum of depreciation rate and growth rate in technology to be 0.05 and used $ln(pop_{it} + 0.05)$ for the break-even investment. The control variables are $lnbribe_{it}$, log of bribery index, as a proxy for institution and $lntrade_{it}$ is log of trade as a percentage of GDP. $lnexch_{it}$ is official exchange rate, $infl_{it}$ is CPI inflation, and cab_{it} is current account

Table 1. Countries and their share of natural resource rent as a percentages of GDP.

No.	Country	%	No.	Country	%	No.	Country	%
1.	Angola	35.5	12.	Cote d'Iviore	5.06	23.	Mozambique	11.5
2.	Benin	4.80	13.	Gabon	28.8	24.	Niger	7.92
3.	Botswana	2.01	14.	Gambia	3.53	25.	Nigeria	16.0
4.	Burkina Faso	9.11	15.	Ghana	11.1	26.	Rwanda	7.19
5.	Burundi	21.2	16.	Guinea	15.1	27.	Senegal	2.74
6.	Cape Verde	0.56	17.	Guinea-Bissau	17.1	28.	Sierra Leone	12.6
7.	Cameroon	7.55	18.	Kenya	3.91	29.	South Africa	4.75
8.	Central A. rep.	10.3	19.	Lesotho	4.27	30.	Togo	10.2
9.	Chad	18.9	20.	Madagascar	5.76	31.	Uganda	14.2
10.	Congo, DR	23.4	21.	Mali	6.34	32.	Zambia	11.4
11.	Congo Rep.	40.7	22.	Mauritius	0.01	33.	Zimbabwe	7.24

Source: computed from WDI database.

balance and $Infert_{it}$ is log of fertility rate used as control for demography.

The main variable of interest is $Inresrent_{it}$, which is total natural resource rent as a percentage of GDP. We focus on the effects of this variable on economic growth and assess whether it exhibits a threshold effect. For estimation procedure, we first run the model using panel GLS fixed effects estimator and analyse the impact of natural resource rent on economic growth. Based on the findings, we further assess whether there exist any threshold effects using structural threshold estimators. Separate models are further estimated on the disaggregated natural resource types.

4. Results and analysis

Table 2 reports the descriptive statistics of the variables used. The results indicate that among the 33 SSA countries growth rate of GDP per capita averaged at 1.83% over the sample period with standard deviation of 5.2. Average GDP per capita is about $1641, with a minimum of $204 and a maximum of $10,643. Average gross capital formation as a percent of GDP for the period is 21.8% with a minimum of 0.293% and a maximum of 79.4%. Total natural resources rent is averaged at 11.5% of GDP

with a minimum of 0.001% and a maximum of 58.7% of GDP. The results indicate that natural resource rent is low and this explains why they are not growth-enhancing.

4.1. Fixed effects panel estimation results

We estimate a fixed effects model as a start to have a general sense of the impact of natural resources on growth without a threshold effect. We use the Hausman specification test for the model selection which rejects the null at 10% significance level [chi2 20.12 (0.0923)]. We however report the results of the random effects in Appendix A for comparison. The results from the fixed effects estimation are presented in Table 3. It consists of six different estimation results where the second column gives results for total natural resource rent. The third to sixth columns present the results for the disaggregated resource rent. The results from these estimations suggest that natural resource rent have a negative impact on economic growth. In particular, a one percentage increase in natural resource rent leads to about 0.423% fall in the growth rate of GDP per capita, albeit not significant. This finding is consistent with empirical studies which confirmed the resource curse hypothesis (e.g. Sachs and Warner 1995;

Table 2. Summary statistics.

Variable	Obs.	Mean	Std. Dev.	Min	Max
GDP per capita growth	990	1.183	5.207	−47.503	37.535
Real GDP per capita	990	1641.466	1942.189	204.024	10643.771
Gross capital formt.	990	21.835	10.084	0.293	79.401
Expdt on edu.	990	3.847	2.055	0.622	13.22
Population growth	990	2.554	.888	0.01	8.118
Bribery incidence	990	23.678	15.493	2	70.4
School attainment	990	35.081	22.089	5.221	109.444
Total natural res	990	11.479	10.483	0.001	58.65
Fertility rate	990	5.254	1.343	1.36	7.772
Inflation	990	19.073	66.012	−88.6	550
Current acc. Bal.	990	−5.059	8.767	−95	24.035
Trade	990	66.165	31.428	19.684	165.059
Official exch. Rates	990	81492151	7.361e+08	0	6.723e+09
Health_expdt.	990	5.265344	2.269471	1.453098	20.41341

Note: Computed by the authors.

1997; 2001; Stijns 2005; Bruckner 2010; Pendergast, Clarke, and Van Kooten 2011; Papyrakis and Gerlagh 2004; Shao and Yang 2014). However, the finding contradicts that of Philippot (2010) who finds a positive impact of natural resources on economic growth.

It can also be seen that income reversion has a dampening impact on economic growth as indicated by coefficients of first lags of GDP per capita (−7.947). According to the prediction of the growth model, break-even investment as captured by coefficient of $ln(pop_{it} + 0.05)$ is expected to be negative. However, this is not the case from the results as it shows a positive and statistically significant impact on growth in GDP per capita.

In addition, capital accumulation shows a positive impact on growth in GDP per capita. Specifically, a one percent increase in gross investment per GDP results in about 2.8% increase in growth of GDP per capita,

ceteris paribus, at 1% significance level. External influences shown by exchange rates and current account balance exert stabilizing effects. In particular, depreciation of exchange rates has a positive impact on growth in GDP per capita and improvement in the current account exhibits a positive impact. The dynamics of inflation suggests a negative relationship between inflation and growth in per capita GDP. High fertility rate also has negative effects on economic growth in SSA.

The results for the disaggregated resource rent suggest that forest and coal rents have significant negative impacts on economic growth. The results show that a one percent increase in forest rents leads to 2.8% fall in GDP growth rate at 1% level of significance. Minerals and natural gas rents show positive but insignificant impact on economic growth while oil rent has a positive and statistically significant effect on economic growth.

Table 3. Results fixed effects estimation.

VARIABLES	Total rents gdpgr	Forest rents gdpgr	Min rents gdpgr	Coal rents gdpgr	Oil rents gdpgr	Gas rents gdpgr
$lngdp_{it-1}$	−7.947***	−9.954***	−7.158***	−3.576	−4.454***	−2.605
	(1.082)	(1.118)	(1.200)	(2.987)	(1.561)	(2.158)
$lnpop_{it}$	0.982**	0.799*	1.801***	2.547	3.490	0.107
	(0.477)	(0.469)	(0.598)	(1.714)	(2.308)	(2.361)
$lncapt_{it}$	2.800***	2.723***	2.555***	3.128***	0.0958	0.311
	(0.470)	(0.460)	(0.539)	(1.052)	(0.832)	(1.163)
$lnexpdt\_edu_{it}$	−0.530	−0.513	−0.864	−1.154	−0.927	1.402
	(0.594)	(0.584)	(0.700)	(1.374)	(1.014)	(1.424)
$lnschool_{it}$	0.0147	0.00833	0.0111	0.0124	0.0335	−0.0705
	(0.0151)	(0.0146)	(0.0167)	(0.0233)	(0.0298)	(0.0482)
$lnhealth_{it}$	0.430	0.530	0.566	1.573	−2.927*	−3.437
	(1.003)	(0.980)	(1.112)	(2.944)	(1.602)	(2.399)
$lnresrent_{it}$	−0.423					
	(0.469)					
$lnbribe_{it}$	−0.0629	−0.451	−0.616	−0.597	−0.892	−2.425
	(0.426)	(0.425)	(0.549)	(1.317)	(1.031)	(1.470)
$lnfert_{it}$	−8.402***	−7.020***	−9.098***	−6.769	−3.183	−10.91**
	(2.199)	(2.146)	(2.402)	(7.012)	(4.269)	(5.270)
$lntrade_{it}$	0.848	1.889**	0.00681	2.048	3.790***	2.129
	(0.896)	(0.839)	(0.947)	(2.017)	(1.143)	(1.552)
$infl_{it}$	−0.00852**	−0.00512	−0.00995**	−0.0321***	−0.00920*	−0.0117
	(0.00368)	(0.00366)	(0.00400)	(0.0114)	(0.00495)	(0.0119)
cab_{it}	0.0639***	0.0540**	0.0445*	0.0855	0.00845	0.0356
	(0.0232)	(0.0217)	(0.0249)	(0.0641)	(0.0281)	(0.0435)
$lnexch_{it}$	0.208***	0.215***	0.162**	0.180*	0.528***	0.613***
	(0.0666)	(0.0655)	(0.0732)	(0.107)	(0.128)	(0.166)
$forestrents_{it}$		−2.806***				
		(0.490)				
$mineralrent_{it}$			0.0481			
			(0.100)			
$coalrents_{it}$				−0.511		
				(0.311)		
$oilrents_{it}$					0.847***	
					(0.300)	
$gasrents_{it}$						0.0991
						(0.141)
Constant	57.13***	68.76***	57.23***	16.48	23.13	39.86**
	(10.39)	(10.40)	(11.33)	(31.36)	(15.20)	(19.77)
Observations	957	957	783	203	348	232
R-squared	0.159	0.188	0.165	0.220	0.274	0.207
Number of count	33	33	27	7	12	8

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

These findings suggest that the negative effects of total resource rent on economic growth could be influenced by shares of forest and coal rent in the total resource rent. It could as well be attributed to scale effect which could mean that there is a threshold effect such that there is a threshold below which resource rent exhibit negative impact but beyond that threshold, the resource rent would reverse the negative impact on economic growth. Weak institutions exert negative and insignificant effect of natural resource rent on growth and this is in line with Boschini, Pettersson, and Roine (2007) who indicates that high-quality institution can lead to a reduction in rent-seeking behaviour associated with natural resources exports.

We also estimate the model using the different natural resource types as independent variables. This is done with the view to finding out the key resource types which may be the main drivers of the effect of the aggregate resource rent on economic growth. The results are shown in Table 4. However, this was possible for only three countries giving a total sample size of 69 observations. The results suggest that forest rent is the key driver of the negative impact of aggregate resource rent on economic growth.

For robustness of the results, we split the sample in two equal parts and run the model separately. The results reported in Appendix B, indicate the outcome is not affected by different sample sizes. In particular, the negative effect of natural resource rent is maintained albeit of different magnitude.

4.2. Threshold estimation

The first thing to consider in threshold modeling is the choice of the threshold variable. We select two candidate variables for the threshold which include the first lag of real GDP per capita and first lag of natural resource rent. Using a regression-based threshold test we compute the F-statistics and compare their levels of significance for these two selected variables, at single, double and triple thresholds. At a 5% level of significance, we reject the null hypothesis on both variables that the first lag of natural resources does not show the existence of threshold effect. Based on this, we use the first lag of natural resource rent as the threshold variable. The test results for double threshold effects at 10% level of significance are shown in Table 5.

It can be seen that for the single threshold, the F_1 statistic of 159.08 is statistically significant at 1% level of significance. Thus, we reject the null hypothesis of no threshold effect. Based on the results of the single threshold test, we proceed to determine the presence of double thresholds. The null hypothesis of the presence of a single threshold is stated as a unit threshold against the alternative of double threshold. The test reveal F_2 statistic value of 82.42 with a p-value of 0.0600, indicating the null hypothesis of single threshold is rejected at 10% significance level against the alternative. Thus, we conduct a triple threshold test with the null hypothesis of double threshold compared to the alternative of triple threshold. With the F_3 value being 45.04 and a p-value of 0.74, we fail to reject the null hypothesis of double thresholds. This implies a double threshold effect. The point estimates for the two threshold points together with the asymptotic 95% and 99% confidence intervals are presented in Table 6.

The point estimates for the two threshold cut-offs are 6.1010 and 15.6298 which divide the sample into three periods. The first period is the sample with observations below 6.1010. The second period is the sample period with observations between 6.1010 and 15.6298 and the third sample period is with observations above 15.6298. Thus, the three categories of natural resource

Table 4. Fixed effects estimates for all resource types.

VARIABLES	(Fixed effect) gdpgr
$lngdp_{it-1}$	−22.36***
	(4.085)
$lnpop_{it}$	−4.244*
	(2.199)
$lncapt_{it}$	−2.019
	(1.483)
$lnexpdt\_edu_{it}$	−0.970
	(2.463)
$lnschool_{it}$	0.114***
	(0.0403)
$lnhealth_{it}$	−0.777
	(2.104)
$lnresrent_{it}$	−0.420
	(0.883)
$coalrents_{it}$	0.995***
	(0.321)
$mineralrent_{it}$	0.0244
	(0.300)
$forestrents_{it}$	−4.221***
	(1.172)
$oilrents_{it}$	0.181
	(0.371)
$gasrents_{it}$	1.608**
	(0.623)
Constant	189.0***
	(33.46)
Observations	69
R-squared	0.641
Number of c_id	3

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Test for threshold effects.

Number of thresholds	F_i	p-value	Critical values at 10%, 5%, 1%
Single	159.08	0.0000	74.4845, 86.3169, 118.3793
Double	82.42	0.0600	71.1900, 85.9621, 100.9034
Triple	45.04	0.7400	134.656, 158.022, 199.9234

Source: computed by the authors.

Table 6. Threshold cut-off Estimates.

	99% confidence interval	
Threshold Coefficients	Lower	Upper
$\widehat{\gamma}_1 = 6.1010$	5.4998	6.1117
$\widehat{\gamma}_2 = 15.6298$	57.844	15.1117

Source: computed by the authors.

exploitation are those with natural resource rent below 6% of GDP, between 6% and 15% of GDP and those with resource rent above 15% of GDP. The asymptotic confidence intervals for the thresholds are identical close-fitting signifying that there is diminutive doubt about the manner of this sample-splitting.

Moreover, Table 7 reports results from the threshold model. As expected, gross capital formation has a weighty and favorable effect on economic growth. Quantitatively, a 1% rise in gross capital formation would lead to 2.895% increase in GDP per capita growth albeit at 1% significance level. Break-even investment is contrary to the prediction of the theory; instead, it has a significant positive influence on economic growth. This is not surprising since in most SSA countries the population growth rates play an important role in economic growth rates. Proxies for human capital have no important positive impact on economic growth. This result is not consistent with empirical studies which suggest a statistically weighty and positive impact of human capital on economic growth (Zuven 2014). Fertility rate has a dampening effect on economic growth as it shows a negative and highly significant coefficient. Similarly, there is a negative relationship between inflation and economic growth. Also, both current accounts and exchange rate have positive and statistically significant impacts on economic growth.

Turning to the effect of aggregate natural resource rent (Totalresrents) on economic growth, zero bootstrap suggests no threshold effect. Also, natural resource rent exerts unfavorable and statistically weighty impact (−1.155) on economic growth. However, at the first bootstrapping, the negative impact reduces in magnitude and becomes statistically insignificant (−0.382). At the second bootstrap, the impact turns positive and statistically significant (1.431) albeit 5% level of significance. This result suggests that at lower levels of natural resource rent (i.e. below 6% of GDP), it has a significant negative influence on economic growth. Specifically, a unit increase in natural resource rent exerts about 1.155% reduction in the growth rate of real GDP per capita. However, as natural resource rent increases above 6% to about 15%, the harmful influence on economic growth significantly reduces. At that threshold level, a unit increase in rent accumulation leads to about 0.382% reduction in the growth rate of real per

capita GDP. However, beyond 15% natural resource rent exhibits a substantially weighty and favourable effect on economic growth. Thus, at the very low level of exploitation, natural resources have undesirable influence on economic growth. Nevertheless, as resource rent increases, its impact gradually becomes positive on growth to a certain level. This confirms that natural resource exhibits threshold effects on economic growth in SSA.

The above finding suggests that, contrary to the earlier studies which confirmed the natural resource curse hypothesis by using linear estimation techniques (see for example Sachs and Warner 1995; 1997; 2001; Stijns 2005; Bruckner 2010; Pendergast, Clarke, and Van Kooten 2011; Mavrotas et al. 2011; Shao and Yang 2014), our findings indicate the presence of a threshold effect of natural resource rent on economic growth. At a scale below the threshold value, the negative relationship between natural resource dependence and economic growth is maintained. However, beyond a given threshold, the relationship becomes positive.

Furthermore, the results for the disaggregated natural resource rent shows that forest rent has a strong negative threshold effect on growth at all levels of the threshold values. The results indicate that these disaggregated natural resources have a significant negative impact on real GDP growth rates at all levels of threshold bootstrap. Specifically, at zero bootstrapping forest rent impact value of −2.635 is statistically significant at 1% level. At the first threshold level its adverse impact increased to −3.495 but later fell to −1.869 at the second threshold level. These findings are not surprising because removing forest cover usually leads to land degradation. Since agriculture is the largest contributor to GDP in most of the sub-Saharan African countries, anything that affects its production would impact negatively on GDP.

Again, coal rent also has a negative and statistically significant impact on economic growth at all levels of real per capita GDP, with increasing adverse impact at higher thresholds. For example, at zero bootstrap, it has a negative impact value of −0.638 on economic growth. At the second threshold, its adverse impact on economic growth becomes substantially negative (−1.311) with the negative impact worsening (−4.0320) at a higher level of per capita GDP.

It can be seen that mineral rent also exhibits a threshold effect. As shown in column 4, at a small level of resource rent, mineral exploitations have negative and significant impact on real GDP growth, with a coefficient of value of −1.167. However, as rent increases, its effects on real GDP growth tend to reduce at the second threshold level (−0.313) and statistically

Table 7. Regression results of total resources rents.

VARIABLES	Total rents gdpgr	Forest rent gdpgr	Min. rents gdpgr	Coal rents gdpgr	Oil rents gdpgr	Gas rents gdpgr
$lngdp_{it-1}$	−10.04***	−9.016***	−4.754***	−6.715**	−3.934**	−4.010*
	(1.207)	(1.187)	(1.291)	(3.113)	(1.637)	(2.158)
$lnpopn_{it}$	1.156**	0.698	1.468**	2.485	3.378	−0.0645
	(0.502)	(0.477)	(0.599)	(1.683)	(2.297)	(2.312)
$lncapt_{it}$	2.895***	2.840***	2.866***	3.613***	0.340	0.174
	(0.465)	(0.460)	(0.545)	(1.046)	(0.835)	(1.139)
$lnexpdt\_edu_{it}$	−0.345	−0.545	−0.960	−0.392	−0.753	0.430
	(0.589)	(0.582)	(0.698)	(1.378)	(1.029)	(1.427)
$lnschool_{it}$	0.00457	0.00978	0.0160	0.0272	0.0214	−0.0635
	(0.0150)	(0.0146)	(0.0165)	(0.0280)	(0.0307)	(0.0472)
$lnhealth_{it}$	0.411	0.623	1.388	0.914	−2.969*	−6.393**
	(0.997)	(0.977)	(1.126)	(2.911)	(1.595)	(2.526)
$lnbribe_{it}$	−0.267	−0.286	−0.216	0.510	−0.733	−0.869
	(0.424)	(0.426)	(0.549)	(1.345)	(1.036)	(1.520)
$lnfert_{it}$	−10.11***	−7.351***	−7.623***	−9.541	−2.671	−10.68**
	(2.222)	(2.145)	(2.399)	(6.946)	(4.254)	(5.160)
$lntrade_{it}$	0.617	2.199**	0.667	3.198	3.588***	2.321
	(0.894)	(0.852)	(0.945)	(2.052)	(1.158)	(1.521)
$infl_{it}$	−0.0104***	−0.00442	−0.00917**	−0.0316***	−0.00941*	−0.0144
	(0.00369)	(0.00367)	(0.00395)	(0.0112)	(0.00494)	(0.0116)
cab_{it}	0.0621***	0.0583***	0.0437*	0.0556	0.00454	0.0405
	(0.0230)	(0.0217)	(0.0246)	(0.0638)	(0.0281)	(0.0426)
$lnexch_{it}$	0.185***	0.222***	0.193***	0.111	0.548***	0.609***
	(0.0660)	(0.0653)	(0.0726)	(0.108)	(0.129)	(0.162)
0. $lnresrents_{it}$	−1.155**					
	(0.551)					
1. $lnresrents_{it}$	−0.382					
	(0.485)					
2. $lnresrents_{it}$	1.431**					
	(0.616)					
0. $forestrent_{it}$		−2.635***				
		(0.570)				
1. $forestrent_{it}$		−3.495***				
		(0.541)				
2. $forestrent_{it}$		−1.869***				
		(0.679)				
0. $mineralrent_{it}$			−1.167***			
			(0.342)			
1. $mineralrent_{it}$			−0.313**			
			(0.136)			
2. $mineralrent_{it}$			0.207*			
			(0.108)			
0. $coalrent_{it}$				−0.638**		
				(0.309)		
1. $coalrent_{it}$				−1.311***		
				(0.426)		
2. $coalrent_{it}$				−4.032**		
				(1.680)		
0. $oilrent_{it}$					0.512	
					(0.355)	
1. $oilrent_{it}$					1.510***	
					(0.419)	
2. $oilrent_{it}$					0.986**	
					(0.449)	
0. $gasrent_{it}$						0.503***
						(0.187)
1. $gasrent_{it}$						−0.118
						(0.154)
Constant	75.46***	61.07***	32.17***	33.45	18.17	50.82**
	(11.56)	(11.12)	(12.41)	(31.30)	(15.36)	(19.66)
Observations	957	957	783	203	348	232
R-squared	0.183	0.197	0.189	0.257	0.286	0.244
No. of countries	33	33	27	7	12	8

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

significant at 5% level of significance. A unit increase in mineral rent, beyond a given threshold, leads to about −0.313 decrease in real GDP per capita growth rate. This impact becomes significantly positive at the third bootstrap (0.207). This result may be attributed to negative tendencies associated with mining practices which may have adverse impact on other aspects of this sector of the economy. For example, illegal mining in

Ghana is causing destruction to forest cover and water bodies. Even though the overall effect of increased mining may be positive on the growth rate of real GDP in the country, the negative effects on forest cover and water resources may tend to reduce the positive impact. This may be explained by the Kuznets (Apergis and Ozturk, 2015) curve hypothesis.

Natural gas rent shows a direct positive impact at initial level without any threshold effect. Specifically, at the zero bootstrap without threshold, a unit increase in natural gas rent is associated with a 0.503% increase in the growth rate of real GDP per capita. Finally, oil rent reveals a threshold effect. At the initial levels of exploitation oil rent exhibit positive but statistically insignificant impact on economic growth. However, at higher resource rent, oil rent exhibit significant positive impact on economic growth. Specifically, at the first threshold, a unit increase in oil rent is associated with 1.510% increase in economic growth. This positive impact is realized at the second threshold level. The initial insignificant result may be attributed to high sunk cost at the exploration stage which may not have any positive impact on growth. However, as oil is discovered at commercial quantities, its impact on economic growth may begin to manifest.

5. Conclusion and policy implications

The role of natural resources in economic growth largely depends on the amount of rent it generates. At the very low level of the natural resource rent, its impact may be seen as a curse rather than a blessing. However, at a higher level or beyond a certain level of rent accumulation, natural resource rent could have a positive impact on economic growth and this is known as the threshold effect. In this paper we investigate the threshold effect of natural resource dependence on economic growth in sub-Sahara Africa (SSA) using both aggregate and disaggregate data from 1990 to 2019 by employing a threshold effect model.

Our results show that, at the aggregate level, natural resource rent exerts a negative effect on economic growth. Further, at the disaggregated level, our study reveals that forest rent exhibits a strong significant negative. The study therefore concludes that, at the very low level, aggregate natural resource rent has a negative impact on economic growth and this turns positive as the rent increases. However, the disaggregated data reveals dissimilar threshold effects on growth, stressing the importance of distinguishing between the types of natural resource rent a country depends on and rent-seeking behaviour.

Our results have several policy implications. First, they imply that aggregate natural resource rent propels economic growth but only after a threshold value of 15% of GDP is obtained. This means SSA policy designs and implementation should ensure that natural resources generate rent beyond 15% of GDP per annum to promote economic growth. In addition, SSA should continue to extract forest resources judiciously to promote economic growth. However, afforestation as well as restoration of the forest cover must take the center stage in policy circles to ensure sustainable extraction of these natural resources. Such resources attract substantial rents because of the absence or little rent-seeking in their production. The initial adverse impact of natural resources on economic growth may be attributed to the specific impact of forest and coal rents in the total resource rent.

It is worthy to note that this study could not differentiate between pristine and plantation forest since the former is more capable of bringing in higher rent due to little rent-seeking associated with its production. In addition, natural resources generate shocks which may induce a significant effect on economic growth but our study fails to capture them. We therefore suggest that future studies should take into account these issues to unearth other important findings of the resource curse hypothesis.

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Appendix A

Table A1. Results random effects estimation.

VARIABLES	Total rents gdpgr	Forest rents gdpgr	Min. rents gdpgr	Coal rents gdpgr	Oil rents gdpgr	Gas rents gdpgr
$lngdp_{it-1}$	−2.015***	−3.004***	−2.263***	−2.138**	−2.331***	−2.685***
	(0.381)	(0.434)	(0.510)	(0.860)	(0.475)	(0.610)
$lnpop_{it}$	1.191***	1.239***	1.652***	2.084	−1.147	−0.932
	(0.433)	(0.429)	(0.563)	(1.417)	(2.131)	(2.130)
$lncapt_{it}$	2.896***	2.771***	2.682***	3.110***	1.208	1.259
	(0.419)	(0.418)	(0.491)	(0.982)	(0.754)	(0.988)
$lnexpdt\_edu_{it}$	−0.147	−0.0682	−0.417	−1.368	−0.137	0.918
	(0.425)	(0.428)	(0.546)	(0.956)	(0.801)	(1.098)
$lnschool_{it}$	0.0146	0.0139	0.0186	0.0258	0.0404	0.0195
	(0.0131)	(0.0130)	(0.0151)	(0.0178)	(0.0247)	(0.0421)
$lnhealth_{it}$	0.229	0.334	−0.0437	−0.831	0.650	−0.525
	(0.549)	(0.556)	(0.673)	(1.343)	(0.800)	(1.229)
$lnresrent_{it}$	−0.397**					
	(0.196)					
$lnbribe_{it}$	−0.160	−0.142	−0.441	−0.116	−2.230***	0.205
	(0.322)	(0.322)	(0.403)	(0.741)	(0.648)	(0.847)
$lnfert_{it}$	−2.892*	−2.305	−4.909***	−7.538**	3.425	−3.262
	(1.585)	(1.494)	(1.803)	(3.335)	(3.007)	(4.378)
$lntrade_{it}$	0.684	0.717	−0.456	1.560	1.338*	1.697*
	(0.595)	(0.588)	(0.751)	(1.219)	(0.788)	(0.951)
$infl_{it}$	−0.00859***	−0.00758**	−0.0123***	−0.0324***	−0.0119***	0.00530
	(0.00319)	(0.00319)	(0.00355)	(0.0106)	(0.00413)	(0.0102)
cab_{it}	0.0732***	0.0672***	0.0535**	0.0846*	0.0615**	0.0961**
	(0.0216)	(0.0212)	(0.0241)	(0.0505)	(0.0278)	(0.0421)
$lnexch_{it}$	0.166***	0.175***	0.147**	0.209***	0.125	0.279**
	(0.0567)	(0.0565)	(0.0632)	(0.0698)	(0.101)	(0.132)
$forestrents_{it}$		−1.144***				
		(0.240)				
$mineralrent_{it}$			0.0209			
			(0.0814)			
$coalrents_{it}$				−0.331		
				(0.219)		
$oilrents_{it}$					0.299	
					(0.186)	
$gasrents_{it}$						−0.00681
						(0.119)
Constant	7.678	14.12***	18.15***	12.82	9.078	14.04
	(5.021)	(4.824)	(6.345)	(10.89)	(7.812)	(9.681)
Observations	957	957	783	203	348	232
Number of coun.	33	33	27	7	12	8

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix B

Table A2. Robustness test – fixed effect model.

VARIABLES	(1990–2004) gdpgr	(2005–2019) gdpgr
$lngdp_{it-1}$	−17.15***	−11.92***
	(2.805)	(2.301)
$lnpop_{it}$	1.581\ast	2.161**
	(0.816)	(0.856)
$lncapt_{it}$	3.555***	5.567***
	(0.771)	(0.914)
$lnexpdt\_edu_{it}$	0.603	0.493
	(1.336)	(0.780)
$lnschool_{it}$	0.0549	0.0384**
	(0.0544)	(0.0184)
$lnhealth_{it}$	0.665	−3.243**
	(3.103)	(1.380)
$lnresrent_{it}$	−0.244	−2.223***
	(0.929)	(0.614)
$lnfert_{it}$	−19.89***	2.290
	(5.836)	(4.107)
$lntrade_{it}$	−1.179	2.290*
	(1.757)	(1.239)
$infl_{it}$	−0.000196	−0.0394***
	(0.00780)	(0.0146)
cab_{it}	0.00641	0.145***
	(0.0403)	(0.0308)
$lnexch_{it}$	0.237	−0.0882
	(0.173)	(0.203)
Constant	140.8***	62.82***
	(24.44)	(20.76)
Observations	462	462
R-squared	0.187	0.239
Number of c_id	33	33

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix C

Table A3. Threshold model.

VARIABLES	(1990–2004) gdpgr	(2005–2019) gdpgr
$lngdp_{it-1}$	−21.39***	−10.78***
	(3.032)	(2.336)
$lnpop_{it}$	1.826**	2.955***
	(0.809)	(0.912)
$lncapt_{it}$	3.596***	5.430***
	(0.761)	(0.910)
$lnexpdt\_edu_{it}$	0.960	1.072
	(1.323)	(0.812)
$lnschool_{it}$	0.0610	0.0380**
	(0.0537)	(0.0183)
$lnhealth_{it}$	2.041	−3.629***
	(3.090)	(1.381)
$lnfert_{it}$	−23.41***	2.061
	(5.852)	(4.085)
$lntrade_{it}$	−1.858	2.554**
	(1.746)	(1.237)
$infl_{it}$	−0.00314	−0.0407***
	(0.00775)	(0.0145)
cab_{it}	0.00748	0.151***
	(0.0398)	(0.0307)
$lnexch_{it}$	0.179	−0.200
	(0.171)	(0.207)
$0.lnresrent_{it}$	−1.341	−1.296*
	(0.971)	(0.721)
$1.lnresrent_{it}$	0.377	−2.735***
	(0.935)	(0.646)
Constant	175.3***	53.62**
	(26.13)	(20.99)
Observations	462	462
R-squared	0.209	0.250
Number of countries	33	33

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.