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Abdulqadir, Idris and Asongu, Simplice

January 2021

A G D I   Working Paper

WP/21/075

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Forthcoming: Economic Analysis and Policy

Idris A. Abdulqadir
Department of Economics and Development Studies,
Federal University Dutse, PMB 5176 Dutse, Jigawa State Nigeria.
E-mail: abdulqadir.idris@fud.edu.ng

Simplice A. Asongu
African Governance Development Institute,
P.O Box 8413, Yaoundé, Cameroun
E-mail: asongusimplice@yahoo.com

2021 African Governance and Development Institute WP/21/075

Research Department

The asymmetric effect of internet access on economic growth in sub-Saharan Africa

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Abstract

This article investigates the asymmetric effect of internet access *(index of the internet)* on economic growth in 42 sub-Saharan African (SSA) countries over the period 2008-2018. The estimation procedure is obtained following a dynamic panel threshold regression technique via *1000* bootstrap replications and the *400* grids search developed by Hansen (1996, 1999, 2000). The investigation first explores the presence of inflection points in the relationship between internet access and economic growth through the application of Hansen's threshold models. The finding from the nonlinearity threshold model revealed a significant internet threshold-effect of 3.55 percent for growth. The article also examines the linear short-run effect of internet access on economic growth while controlling for the effects of private sector credit, trade openness, government regulation, and tariff regimes. The marginal effect of internet access is evaluated at the minimum, and the maximum levels of government regulation and tariffs regime are positive. On the other hand, the minimum and maximum levels of private sector credit and trade openness are negative via the interaction terms. The article advances the literature by its nonlinear transformation of the relevance of internet access on economic growth by exploring interactive mechanisms of: internet access versus financial resource, internet access versus trade, internet access versus government regulation, and internet access versus the tariff regimes from end-user subscriptions. In policy terms, the statistical significance of the joint impact of government regulations and tariff regimes is relevant in the operation of the telecommunication industry in SSA countries.

Keywords: *Internet access; economic growth; government regulations; trade openness; tariff regimes; sub-Saharan Africa.*

1.0 Introduction

Some debates in the global community and sub-Saharan Africa in particular focus on the relevance of economic growth, internet access, government regulations, and tariff regime in economic development (Albiman and Sulong, 2017; Tchamyou, 2017; Asongu and Odhiambo, 2020b, 2020a; David, 2019; Donou-Adonsou, 2019; Forenbacher *et al.*, 2019; Haftu, 2019; Hasbi and Dubus, 2020; Mwakatumbula *et al.*, 2019; Myovella *et al.*, 2020; N'dri and Kakinaka, 2020; Robb and Hawthorne, 2019). The fundamental role that internet connections play has influenced every sector of the global economy through jobs creation (Gómez-Barroso & Marbán-Flores, 2020a). However, the relationship between internet access and economic growth in the period between optimal use and downtime has not been given much attention in most developing and sub-Saharan African countries. This effect is characterized by a lack of infrastructural development and power supply.

The recent contribution from the underlying area of research shows that the relationship between internet access and growth is nonlinear, as documented in the literature (Ghosh, 2016; Qureshi & Najjar, 2017). While the nonlinear transformation of internet access on economic growth has been documented to occur from blurred and old technologies (Gómez-Barroso & Marbán-Flores, 2020b), the topic is still open to debate especially as it pertains to exploring other factors that interact with the internet to influence economic growth. Building on the underlying insight, this article attempts to investigate the nonlinearity of the relationship between internet access and economic growth by exploring the interactions between internet access vs. investment financing, internet access vs. trade, internet access vs. government regulation, and internet access versus the tariff regimes from end-user subscriptions. The primary objective of the article is to investigate an asymmetric effect of internet access on economic growth in SSA countries. Despite the recent contributions in the literature, the nonlinearity/asymmetric effect of internet access on economic growth has not been given the exhaustive scholarly attention it deserves.

Internet access is essential for public institutions, households, and businesses to flourish in SSA countries. In the public sector and private enterprises, internet access can enhance productivity gains and more efficiently in-service delivery. For households, internet access can connect households to the other parts of the world through increased opportunities and human capital building (Mahler et al., 2019; The Economist, 2013; Valkenburg & Peter, 2011). According to the World Bank Reports, internet access in SSA has grown rapidly in recent years, but yet an optimum utilization in the sub-region remains lower compared to the rest of the world (see Mahler et al., 2019). Furthermore, in global internet usage and across countries, only 1 in 5 SSA subscribers utilized the internet in 2017. This predicament was an offshoot of the following pattern of internet access in SSA:

i. Most of the households' internet access subscriptions in SSA are low and tend to be overestimated by the International Telecommunications Union (ITU) figures[1].
ii. In most urban areas in SSA, internet access subscriptions (which are combinations of mobile/fixed-line/fixed-wireless) are higher as compared to the rural areas.
iii. The majority of the subscriptions to access the internet for youths in SSA is through a mobile phone than through a computer[2].
iv. In the public sector and private enterprises, most subscriptions are broadband(Mahler et al., 2019).

Through this study, the article aggregates these patterns of internet subscriptions in SSA as a measure of *internet access* in the region following principal component analysis (see David, 2019; Frankfurter et al., 2020; Mahler et al., 2019; Pradhan et al., 2016).

The justifications of this article stalk on the question; what is the internet-threshold for economic growth in SSA countries? Although, in terms of response the perspective that internet access has an impact on economic growth in advanced countries may be a settled matter, for developing countries and sub-Saharan Africa, in particular, it is still a *direction for further research* (Gómez-Barroso & Marbán-Flores, 2020b) not least because of the yet high potential for its penetration in the sub-region (Tchamyou et al., 2019). As for advanced and emerging market economies, future study considerations would have been a focus on smart technologies such as fintech, Internet of a Thing (IoT), and 5G network (see Vu et al., 2020; Vu & Asongu, 2020). However, but for the developing economies such as Sub-Saharan African countries, growth demands effective Broadband, Fixed line and Mobile networks as the required *internet-threshold* is not yet gone beyond 3G, at most 4G networks due to the poor infrastructural equipment and maintenance(see Asongu & Odhiambo, 2020b; David, 2019; Hasbi & Dubus, 2020; Myovella et al., 2020). Furthermore, the nexus between

[1]For a comprehensive detailed and insightful survey on household internet access disparities across subscriptions (see Frankfurter et al., 2020).
[2]For further details on the exponential expansion of mobile phone see (De Bruijn et al., 2009; Porter et al., 2012, 2016)

economic growth and the internet within the framework of emerging and advanced market economies might be symmetric as envisaged in some recent studies highlighted above. However, it is also worthwhile to assess whether the underlying symmetry postulation withstands empirical scrutiny by investigating how internet-access affect economic growth asymmetrically.

The asymmetric effect of internet-access on economic growth in SSA countries appears when the deployed technologies are performing below expectations due to the poor infrastructural equipment. Nevertheless, during optimal utilization, subscribers enjoy the value for their internet subscriptions, while during downtime periods they experience diminished value for the subscription due to less stringent laws and consumer protection issues (Mwakatumbula *et al.*, 2019). In this study, we consider two regimes *lower-bound* $(internet\, access > \gamma)$ indicating downtime and *upper-bound* $(internet\, access \leq \gamma)$ optimal utilization as defined by the threshold approach, as symmetric and asymmetric effects of internet-access on economic growth, respectively. This approach has been utilized in the distinctive split-sample approach in the extant literature (Hansen, 1999). However, none of the prior studies has examined the asymmetric effect of internet-access on economic growth. In this study, we discovered a statistically significant asymmetric threshold effect of internet-access on economic growth and a response to the reality check of the link between internet-growth in SSA countries.

This article contributes to the extant literature on internet-growth nexus in two ways: First, this study emphasizes on the threshold level of internet access rather than the relationship between economic growth and internet access, and vice versa (Aker and Mbiti, 2010; Asongu and Odhiambo, 2020; Datta and Agarwal, 2004; David, 2019; Donou-Adonsou, 2019; Elgin, 2013; Gómez-Barroso and Marbán-Flores, 2020a; Haftu, 2019; Kpodar and Andrianaivo, 2011; Myovella *et al.*, 2020; Njoh, 2018; Vu *et al.*, 2020). Second, despite the recent contributions to the literature, yet, the asymmetric response in a way to explore the nonlinear effect of internet access on economic growth is not well-exposed. This study addresses this gap in the literature by using a dynamic threshold regression. This attempt provides a rationale to investigate the asymmetric effect of internet access on economic growth in sub-Saharan Africa.

The novelty of this article stems from the introduction of an appropriate methodology associated with dynamic panel threshold regression, recommended by Hansen (1996, 1999, 2000). This method has appealing characteristics, as it has a split-sample approach. This feature is overwhelmingly in decomposing the effects of internet access when economic growth is below the threshold as *symmetry* and above the threshold as a*symmetry*. It also features end-user feedback between good-times and bad-times, and between optimal-use and down-times, appropriate for consumer protection issues (see Mwakatumbula et al., 2019). Moreover, the panel application improves the statistical efficiency of the power of our empirical results. Further, the approach is also significant in damping the parameter estimates bias associated with sample approximation and the homogeneity of the cross-sectional units.

The rest of the article is structured as follows: Section 2 presents the empirical literature review. Section 3 dwells on the data and methodology of the study. Section 4 reports the estimated results and interpretations of the significant findings. Section 5 concludes the study.

2.0 Empirical literature review

There has been a growing debate on the contribution of internet access to economic growth as well as allowing information flow to the economy in all respects (Aguilar et al., 2020). A review of comprehensive literature on the most recent studies on internet access and economic growth is presented in this strand of literature (see Gómez-Barroso and Marbán-Flores, 2020b; Vu et al., 2020).

Furthermore, focusing on the studies for developed countries, Madden and Savage (2000) found a significant positive relationship of telecommunication using multi-country analysis. Roller and Waverman (2001) uncovered a significant definite nexus between economic growth and telecommunication in the Organisation for Economic Co-operation and Development (OECD) nations. Datta and Agarwal (2004) unveiled a robust positive relationship between telecommunication and economic growth in OECD countries. Similarly, other studies have established a significant effect of telecommunication on growth in the OECD (Czernich et al., 2011; Kongaut & Bohlin, 2017; Koutroumpis, 2009; Rohman & Bohlin, 2012; Sezer & Abasiz, 2016; Castaldo et al., 2018). Studies on the United States reported a positive impact of telecommunication (Correa, 2006; Crandall *et al.*, 2007; Haynes *et al*., 2006; Nadiri *etal.*, 2018; Whitacre *et al.*, 2014; Yilmaz and Dinc, 2002) among others. For the studies on China, Shiu and Lam (2008) and Ward and Zheng (2016) revealed the positive impact of telecommunication. Katz et al. (2010) focused on Germany to broadly confirm the findings in developed countries. Such evidence is also apparent in studies involving many countries (Chakraborty and Nandi, 2011; Farhadi *et al.*, 2012; Gruber and Koutroumpis, 2011; Lam & Shiu, 2010; Noh and Yoo, 2008; Qiang et al., 2009; Thompson and Garbacz, 2007; Torero *et al.*, 2006; Ward and Zheng, 2016; Waverman *et al.*, 2005; Yang and Olfman, 2006; Zahra *et al.*, 2008), among others.

In the studies on developing countries, Chakraborty and Nandi (2003) found bidirectional causality between telecommunication and economic growth in 12 Asian countries. Cieslik and Kaniewska (2004) discovered a definite link between telecommunication and regional income in Poland. In the case of multi-country analysis, Freund and Weinhold (2004) revealed the impact of telecommunication on trade using a panel framework. Similarly, Choi and Yi (2009) found the effect of telecommunication on economic growth in a cross-section study. In another study, Choi (2010) unveiled the effect of telecommunication on trade services in the multi-country analysis. Badran (2012) uncovered the impact of internet access on economic growth in 22 emerging and Arab countries.

In studies focusing on Africa economies, Aker and Mbiti (2010) uncovered the effect of the mobile phone in sub-Sahara Africa. Njoh (2018) discovered that there is a low level of ICT access in Africa. Forenbacher *et al.* (2019) revealed the linear growth of mobile penetration in Nigeria. Albiman and Sulong (2017) found a positive impact of telecommunication on growth in sub-Saharan Africa. Myovella *et al.* (2020) revealed the significant effect of mobile technologies in sub-Sahara African countries. Hasbi and Dubus (2020) uncovered the determinants of internet access using household surveys from Nigeria, Tanzania, Kenya, and Uganda. David (2019) found bidirectional long-run causality between telecommunication and economic growth in the selected African countries. Robb and Hawthorne (2019) uncovered a competitive framework for internet access in South Africa. Albiman and Sulong (2016) revealed a threshold effect of 4.5% and 5% for mobile phones and internet on economic growth in sub-Saharan Africa. Haftu (2019) uncovered mobile phone penetration to have a significant effect on GDP per capita in sub-Saharan Africa. The next section presents the data and methodology applied in this article.

3.0 Data and methodology

Following the development in the empirical studies on telecommunication and economic growth, this article advances from the literature to investigate the nonlinearity effect of internet access on economic growth in sub-Saharan African countries. Data for 42 sub-Saharan African countries from 2008 to 2018 come from World Development Indicators (WDI) of the World Bank (2020).

3.1 Data

Table 1. Data definitions and measurements

Variables	*Indicators*	*Unit of measurement*	*Source*
(1) Economic Growth	The annual percentage *growth rate of GDP per capita* (gross domestic product divided by midyear total population) is based on a constant local currency	Percent	World Bank
(2) Internet access	Internet subscription is derived from the principal component analysis (PCA) to calculate the principal *index of the internet* for internet access, i.e., the broadband subscription (per 100 people), fixed-wireless subscription(per 100 people),and mobile subscription(per 100 people),(David, 2019; Pradhan et al., 2016; Tchamyou, 2017).	Index	World Bank
(3) Income per capita	GDP per capita (constant 2010 US$) is gross domestic product divided by midyear population	Dollar	World Bank
(4) Credits	Domestic credit to the private sector (% of GDP) is derived from financial resources provided to the private sector by financial corporations	Percent	World Bank
(5) Trade	Trade openness is derived via the sum of exports and imports as % GDP	Percent	World Bank
(6) Government	government final consumption expenditure (% of GDP) as a proxy to national security/regulation	Percent	World Bank
(7) Deflator	Inflation, GDP *deflator* (annual %) as a proxy for the changes in tariff regimes	Percent	World Bank

3.1.1 Estimation procedure and threshold regression method

Our models are built based on the theoretical support from the endogenous growth theory that explains balance-growth as a product of information spillover (Romer, 1986, 1990). This paper hypothesizes the assumption that the internet plays a significant role in connecting the globe (Choi and Hoon Yi, 2009). Therefore, economic growth is positively related to the use of the internet. To explore the growth threshold effect of the internet on economic growth, we follow Barro (1997) growth equation and augment the model using

Hansen (1996, 1999, 2000) threshold regression. The model is a nonlinear method specified as follows:

$$growth_{it} = \alpha_0 x_{it} + \alpha_1 Internet_{it} I(Internet_{it} \leq \gamma) + \alpha_2 Internet_{it} I(Internet_{it} > \gamma) + u_{it} \quad (1)$$
$$u_{it} = \mu_i + \phi_t + \varepsilon_{it}$$

Where x_{it} represents the vector of control variables, i.e., initial GDP per capita [*income*], domestic credit to private sector [*credit*], trade openness [*trade*], government final consumption expenditure [*government*], and inflation-deflator. μ_i is a country-specific fixed effect, ϕ_t is the time fixed effect, and ε_{it} is an error term. $I(\bullet)$ is an indicator function while γ it is the threshold value.

The coefficient of *internet access* is expected to be positive in the growth model as an injection in the global economy. The coefficient of *credit* is expected to have a positive sign as a booster to private sector investment (see Mankiw et al., 1992). The coefficient of trade is expected to have a positive sign, as it affects economic growth through rising income per capita, considering its effect on telecommunication (see Myovella et al., 2020). The coefficient of *government* is expected to be negative as withdrawal to the private sector influences private decisions (Barro, 1997). The coefficient of *deflator* is expected to be negative as a high tariff regime is associated with low economic growth (Attari & Javed, 2013; Fernandez, 2003).

To determine the threshold, we defined the residual sum of the square for the estimated threshold as $S(\gamma) = \hat{u}(\gamma)'\hat{u}(\gamma)$ while the optimal γ is thus:

$$\gamma = \underset{\gamma}{\arg\min}\ S(\gamma) \quad (2)$$

Next, we test for the threshold effect using equation (1)[3]. α_1 and α_2 are the regression slope under each regime and the error term $u_{it} \sim iid(0, \sigma_{it}^2)$. The likelihood ratio (LR) test of no threshold as against the null hypothesis $H_0 : \alpha_1 = \alpha_2$ based on:

$$LR_0 = (S_0 - S_1(\hat{\gamma})) / \hat{\sigma}^2 \quad (3)$$

Where S_0 is the residual sum of squares while $\hat{\sigma}^2$ is the estimated error variance.

[3]Hansen (1999) proposes a bootstrap technique to simulate the asymptotic distribution of the likelihood ratio (LR) test.

3.1.2 Testing for a single threshold

The estimation process involves the two-step least squares approach: first, the sum of square error is calculated exclusively for any specific threshold $\hat{\gamma}$. Conversely, the certainty of this process is justified by testing the existence of a threshold $H_0 : \alpha_1 = \alpha_2$. The asymptotic distribution F-statistic $F_1(\gamma) = (S_0 - S_1(\hat{\gamma})) / \hat{\sigma}^2$ of the likelihood is derived under the null hypothesis via several bootstrapping processes to compute the p-value and the F-statistic employing the likelihood ratio statistics test[4].

$$LR_1 = (S_1(\gamma) - S_1(\hat{\gamma})) / \hat{\sigma}^2 \tag{4}$$

Hence, Hansen (1999) theorem $LR_1(\gamma) \rightarrow d\omega$, as $n \rightarrow \infty$ where ω reflects a random variable within the remit of the distribution function:

$$P(\omega \leq Internet) = (1 - \exp(-\frac{Internet}{2}))^2 \tag{5}$$

The asymptotic distribution corresponding to LR_1, though non-standard, is not affected by nuisance parameters. The attendant asymptotic distribution can be employed to draw confidence intervals of asymptotic nature via an inverse distribution function in equation (6) thus:

$$c(\alpha) = -2\log(1 - \sqrt{1-\alpha}) \tag{6}$$

We calculate the full sample critical values at the asymptotic level. For 1%, 5%, and 10%, critical values are 21.19%, 16.05%, and 13.51%, respectively.

3.2 Estimation procedure and two-step difference model

To explore the short-run estimates of our endogenous growth model, we apply the Roodman (2009a, 2009b) being an extension of Arellano and Bover (1995). The following equations in level (7) and first difference (8) summarize the standard estimation procedure[5]. The model which is a linear method *two-step* procedure rather than the *one-step* approach is applied to control for heteroscedasticity and specified as follows:

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[4]Hansen (2000) suggests the grid search to be restricted to the threshold value that minimizes the percent of the elements within regime.

[5]This approach followed closely with Blundell & Bond (1998), and Arellano & Bover (1995) generalized method of moments (GMM).

$$growth_{i,t} = \alpha_0 + \alpha_1 growth_{i,t-\tau} + \sum_{h=1}^{6} \beta_h X_{h,i,t-\tau} + \eta_i + \psi_t + \varepsilon_{i,t} \quad (7)$$

$$growth_{i,t} - growth_{i,t-\tau} = \alpha_1 (growth_{i,t} - growth_{i,t-2\tau}) + \sum_{h=1}^{6} \beta_h (X_{h,i,t-\tau} - X_{h,i,t-2\tau}) + (\psi_t - \psi_{t-\tau}) + \varepsilon_{i,t-\tau} \quad (8)$$

Where $growth_{i,t-1}$ is the growth indicator of the country i at a period t, while α_0 is a constant, and X is the vector of control variables (*internet access*; *credit*; *trade*; *government*; *inflation-deflator*), τ denotes the coefficient of autoregression which is one for the specification, ψ_t is the time-specific constant, η_i is the country-specific effect and $\varepsilon_{i,t}$ is the error term and all variable presented in logarithm. In terms of exclusion restrictions, economic growth as the dependent variable is influenced by the strictly exogenous variables exclusively through the endogenous explaining variables. This identification procedure is consistent with Roodman (2009b) and contemporary GMM-centric literature (Tchamyou, 2019; 2020) as it would not be feasible for the time-invariant indicators to be endogenous after a first difference[6]. For the simultaneity, the study used lagged explanatory variables as instruments. Moreover, for the exclusion restrictions, the study adopted strictly exogenous variables (time-invariant indicators) that have an impact on economic growth exclusively through the suspected endogenous variables (i.e. internet access and attendant control variables). The validity of this exclusion restrictions approach is justified via the Hansen test statistic for the relevance of instruments[7]. As a rule of thumb, the null hypothesis should not be rejected for the variables exhibiting strict exogeneity to explain economic growth only through the endogenous explaining variables. It is worthy to note that the instrumental variable approach is justified with the rejection of the alternative hypothesis of the Sargan Overidentification Restrictions test which implies that the dependent variable is exclusively explained by the instruments via the predetermined variables (Asongu and Nwachukwu, 2016a; Beck et al., 2003; Tchamyou et al., 2018). The transformation of equation (8) leads to equation (9): thus

[6]The technique for treating *ivstyle* (year) is "iv (year, eq(diff))" whereas the *gmmstyle* is employed for predetermined variables.
[7]The model followed meticulously with the identification, simultaneity and exclusion restriction as in (Asongu & Nwachukwu, 2016b; Asongu et al., 2017; Asongu & Acha-anyi, 2018; Boateng et al., 2018; Tchamyou et al., 2019; Tchamyou & Asongu, 2017).

$$growth_{i,t} - growth_{i,t-\tau} = \alpha_1(growth_{i,t} - growth_{i,t-2\tau}) + \alpha_2(Internet_{i,t} - Internet_{i,t-\tau}) + \alpha_3(credit_{i,t} - credit_{i,t-\tau})$$
$$+\alpha_4(trade_{i,t} - trade_{i,t-\tau}) + \alpha_5(government_{i,t} - government_{i,t-\tau})$$
$$+\alpha_6(deflator_{i,t} - deflator_{i,t-\tau}) \qquad (9)$$
$$+\sum_{h=1}^{6}\beta_h(X_{h,i,t-\tau} - X_{h,i,t-2\tau}) + (\psi_t - \psi_{t-\tau}) + \varepsilon_{i,t-\tau}$$

However, long-run effects are calculated given the significant short-run estimates by dividing each significant short-run coefficient $1-\alpha$. The stability of the empirical model is justified using various simulation options. As a case in point, using two-step robust options to provide a heteroscedastic and autocorrelation consistent (HAC) variance-covariance matrix. The long-run effects for the β^{th} parameter is computed as follows:

$$\ell_\beta \div [1-\alpha] \qquad (10)$$

Where ℓ applies only to the significant short-run GMM estimates, whereas the long-run panel coefficients from the two-step GMM approach are compared with the corresponding short-run significant coefficients from panel two-step GMM for policy recommendation.

To explore the relationship between internet use and trade, the joint test *internet access*, and *credit* is required. Conversely, following the interactive regression in Brambor et al. (2006), all constructive terms are included in the specifications with the effect of the modifying variables, the interaction between either $\alpha_{7a}(Internet_{i,t} \times credit_{i,t})$, $\alpha_{7b}(Internet_{i,t} \times trade_{i,t})$, $\alpha_{7c}(Internet_{i,t} \times government_{i,t})$, and $\alpha_{7d}(Internet_{i,t} \times deflator_{i,t})$. If α_2 and α_3 are jointly significant, it implies that *internet access* and domestic *credit* to the private sector exert an impact on economic growth. Hence, a loose version of the test of significance. On the other hand, for the more strict version of the test, the assumption holds when the interaction between internet access and credit jointly validate the hypothesis on economic growth, in which the interaction term is imputed separately in the equation(11) as follows:

$$growth_{i,t} - growth_{i,t-\tau} = \alpha_1(growth_{i,t} - growth_{i,t-2\tau}) + \alpha_2(Internet_{i,t} - Internet_{i,t-\tau}) + \alpha_3(credit_{i,t} - credit_{i,t-\tau})$$
$$+\alpha_4(trade_{i,t} - trade_{i,t-\tau}) + \alpha_5(government_{i,t} - government_{i,t-\tau})$$
$$+\alpha_6(deflator_{i,t} - deflator_{i,t-\tau}) + \alpha_{7a}(interaction_{i,t} - interaction_{i,t-\tau}) \qquad (11)$$
$$+\sum_{h=1}^{7}\beta_h(X_{h,i,t-\tau} - X_{h,i,t-2\tau}) + (\psi_t - \psi_{t-\tau}) + \varepsilon_{i,t-\tau}$$

Hence, if the estimated coefficient α_{7a} is statistically significant, this means that economic growth is enhanced when the internet access couples with domestic credit to the private sector through internet enterprises.

If the coefficients α_2 and α_4 are jointly significant, it implies that *internet access* and *trade openness* exert an impact on economic growth. Hence, the assumption holds when the interaction between internet access and trade jointly validate the hypothesis on growth, where the interaction term is imputed separately in the equation (12) as follows:

$$\begin{aligned} growth_{i,t} - growth_{i,t-\tau} = {} & \alpha_1(growth_{i,t} - growth_{i,t-2\tau}) + \alpha_2(Internet_{i,t} - Internet_{i,t-\tau}) + \alpha_3(credit_{i,t} - credit_{i,t-\tau}) \\ & + \alpha_4(trade_{i,t} - trade_{i,t-\tau}) + \alpha_5(government_{i,t} - government_{i,t-\tau}) \\ & + \alpha_6(deflator_{i,t} - deflator_{i,t-\tau}) + \alpha_{7b}(interaction_{i,t} - interaction_{i,t-\tau}) \\ & + \sum_{h=1}^{7}\beta_h(X_{h,i,t-\tau} - X_{h,i,t-2\tau}) + (\psi_t - \psi_{t-\tau}) + \varepsilon_{i,t-\tau} \end{aligned} \tag{12}$$

Hence, if the estimate α_{7b} is statistically significant, this means that economic growth is enhanced when *internet access* promotions trade as it enhances growth via rising income per capita[8].

To examine the relationship between internet use and trade, the joint test *internet access* and *government* is required. If the coefficients α_2 and α_5 are jointly significant, it implies that internet access and government expenditure or regulation exert a negative impact on economic growth through distortion of private decisions. If the estimate α_{7c} is statistically significant; therefore, the assumption holds when the interaction between internet access and government regulation jointly validate the hypothesis on the growth model. The interaction term is imputed separately in the equation (13) as follows:

$$\begin{aligned} growth_{i,t} - growth_{i,t-\tau} = {} & \alpha_1(growth_{i,t} - growth_{i,t-2\tau}) + \alpha_2(Internet_{i,t} - Internet_{i,t-\tau}) + \alpha_3(credit_{i,t} - credit_{i,t-\tau}) \\ & + \alpha_4(trade_{i,t} - trade_{i,t-\tau}) + \alpha_5(government_{i,t} - government_{i,t-\tau}) \\ & + \alpha_6(deflator_{i,t} - deflator_{i,t-\tau}) + \alpha_{7c}(interaction_{i,t} - interaction_{i,t-\tau}) \\ & + \sum_{h=1}^{7}\beta_h(X_{h,i,t-\tau} - X_{h,i,t-2\tau}) + (\psi_t - \psi_{t-\tau}) + \varepsilon_{i,t-\tau} \end{aligned} \tag{13}$$

[8] This model approach followed is consistent with recent literature (see Myovella et al., 2020).

To explore the relationship between internet use and trade, the joint test *internet access* and *inflation-deflator* is also required. If the coefficients α_2 and α_6 are jointly significant, it implies that internet access and inflation-deflator exerts a negative impact on economic growth given a high tariff regime. If the estimate α_{7d} is statistically significant, the assumption holds when the interaction between internet access and inflation-deflator jointly validate the hypothesis on the growth model. The interaction term is imputed separately in equation(14) as follows:

$$\begin{aligned} growth_{i,t} - growth_{i,t-\tau} = {} & \alpha_1(growth_{i,t} - growth_{i,t-2\tau}) + \alpha_2(Internet_{i,t} - Internet_{i,t-\tau}) + \alpha_3(credit_{i,t} - credit_{i,t-\tau}) \\ & + \alpha_4(trade_{i,t} - trade_{i,t-\tau}) + \alpha_5(government_{i,t} - government_{i,t-\tau}) \\ & + \alpha_6(deflator_{i,t} - deflator_{i,t-\tau}) + \alpha_{7d}(interaction_{i,t} - interaction_{i,t-\tau}) \\ & + \sum_{h=1}^{7} \beta_h (X_{h,i,t-\tau} - X_{h,i,t-2\tau}) + (\psi_t - \psi_{t-\tau}) + \varepsilon_{i,t-\tau} \end{aligned} \quad (14)$$

The interaction terms are between *internet access* and private sector *credit*; *internet access* and *trade openness*; *internet access*, and *government* consumption expenditure; and as well as *internetaccess* and *inflation-deflator*. The marginal effects of equations (11), (12), (13), and (14), respectively, are projected to shed light on the relative significance of those channels in promoting *interne taccess*. If α_{7a} in equation (11) is to be higher than α_{7b} in equation (12), α_{7c} in equation (13), and α_{7d} equation (14), this implies that private sector credit encourages more significant internet access than trade, government, and inflation-deflator, respectively. Similarly, we also compare each of the remaining coefficients of the subsequent interaction terms and vice-versa. At this end, the total effect of changes in internet access due to domestic credit to the private sector, trade openness, government expenditure, and inflation-deflator can be calculated through examining the partial derivative of economic growth with respect to internet access variables:

$$\frac{\partial growth_{i,t}}{\partial Internet_{i,t}} \approx \alpha_{7a} credit_{i,t} + \alpha_2 \quad (15)$$

$$\frac{\partial growth_{i,t}}{\partial Internet_{i,t}} \approx \alpha_{7b} trade_{i,t} + \alpha_2 \quad (16)$$

$$\frac{\partial growth_{i,t}}{\partial Internet_{i,t}} \approx \alpha_{7c} governement_{i,t} + \alpha_2 \quad (17)$$

$$\frac{\partial growth_{i,t}}{\partial Internet_{i,t}} \approx \alpha_{7d} deflator_{i,t} + \alpha_2 \qquad (18)$$

The prior expectations from the derivatives given in equations (15) and (16) are expected to be positive while negative for equations (17) and (18), respectively.

4.0 Empirical results and analysis

Table 2(a), (b), and (c) report the matrix of correlation among the variables, each of which corresponds to the distinct sample (Full sample, oil producing and West African countries). As shown in the tables, the correlations between economic growth indicators with internet access and tariff are positive. For instance, the full sample reports that internet subscription and tariff regime have positive correlations of 0.018 and 0.109, respectively, with the economic growth indicator. The oil-producing region reports that internet subscription and tariff regime have positive correlations of 0.001 and 0.172, respectively, with the economic growth indicator[9]. The West African region presents internet access, trade openness, and tariff regime to have a positive correlation of 0.046, 0.022, and 0.093, respectively, with the economic growth indicator.

INSERT TABLES IN 2 HERE

Also, income per capita, private sector credit, and government expenditure have positive correlations of 0.257, 0.536, and 0.262, respectively, with the index of the internet in the oil-producing region. Similarly, income per capita, private sector credit, trade openness, and government expenditure have positive correlations, of 0.257, 0.536, and 0.262, respectively, with the index of the internet in the West African region. Table 3 presents the descriptive statistics.

4.1 Threshold existence

The empirical results of the equations (1–3) are reported in Table 4 which presents the summary results of the estimated threshold and statistically significant levels of the threshold value along with the asymptotic critical values in the various clusters. The asymptotic probability values of the likelihood ratio statistics indicate that the null hypothesis of no-threshold effects is rejected at a 5% significance level for the full sample and oil-producing state cluster. Contrary wise, the asymptotic probability values of the likelihood ratio statistics

[9]See the correlation matrix reported in Abdulqadir et al. (2020), for oil-exporting countries SSA as given by the optimal inflation targets.

indicate that the null hypothesis of no-threshold effects is not rejected at a 10% significance level for the West African region sample.

INSERT TABLE 5 HERE

The inclusive result of the full sample of 42 sub-Saharan African countries revealed a statistically significant internet-threshold value of 3.55% for economic growth and a response to the main objective of the article[10]. The threshold value splits the total observations into the low regime symmetrically and upper regime asymmetrically. Figure 1A *(Panel I)* presents the likelihood ratio function diagram for the full sample countries.

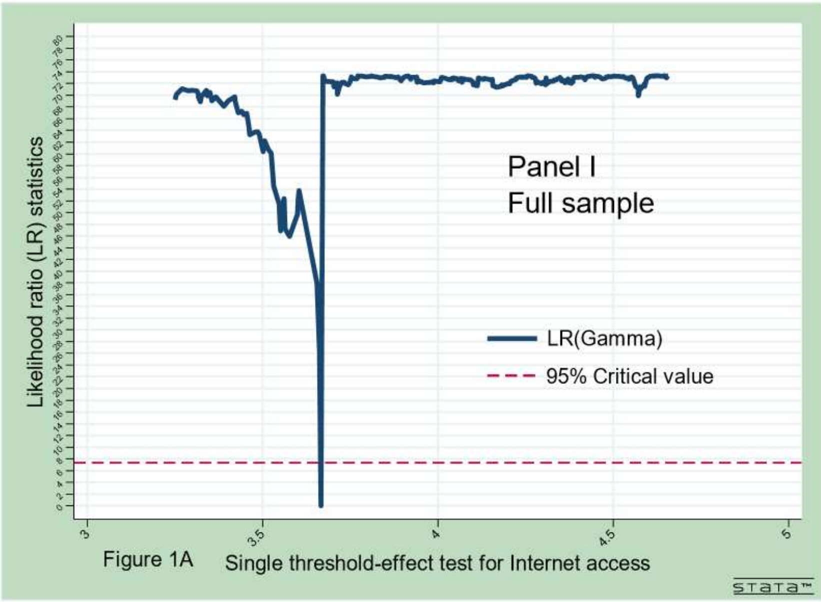

Figure 1A: FULL SAMPLE

The result form oil-producing states revealed a statistically significant internet threshold value of 3.55% for economic growth. This threshold value also splits the total observations into the low regime symmetrically and upper regime asymmetrically. Figure 1B *(Panel II)* presents the likelihood ratio function diagram for the sixteen *(16)* oil-producing states.

[10]See Albiman and Sulong (2017) who have also reported statistically significant mobile and internet penetration in sub-Saharan African countries using a pooled mean group panel framework.

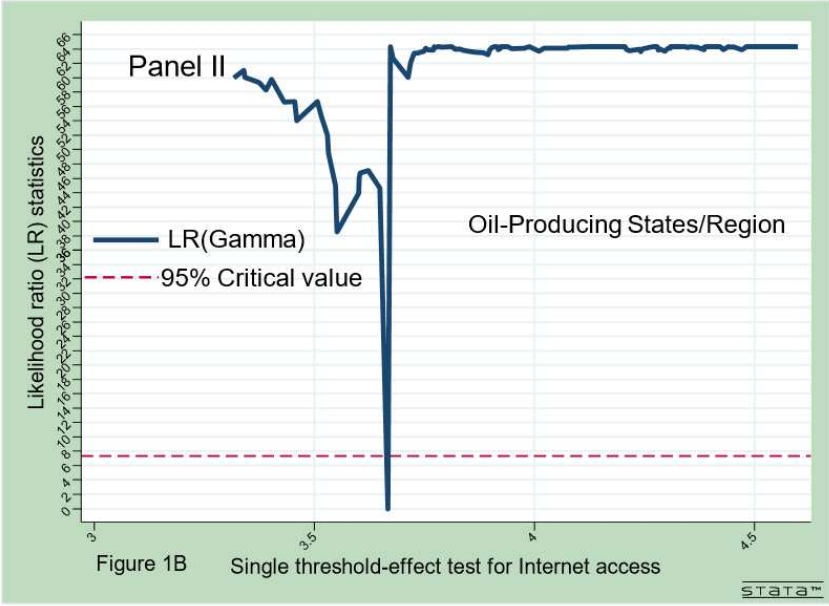

Figure 1B: OIL-PRODUCING STATES/REGION

The result from West African countries revealed that the internet threshold value 3.92% for economic growth is not statistically significant at the 10% level. Figure 1C*(Panel III)* presents the likelihood ratio function diagram for the fifteen*(15)*West African countries.

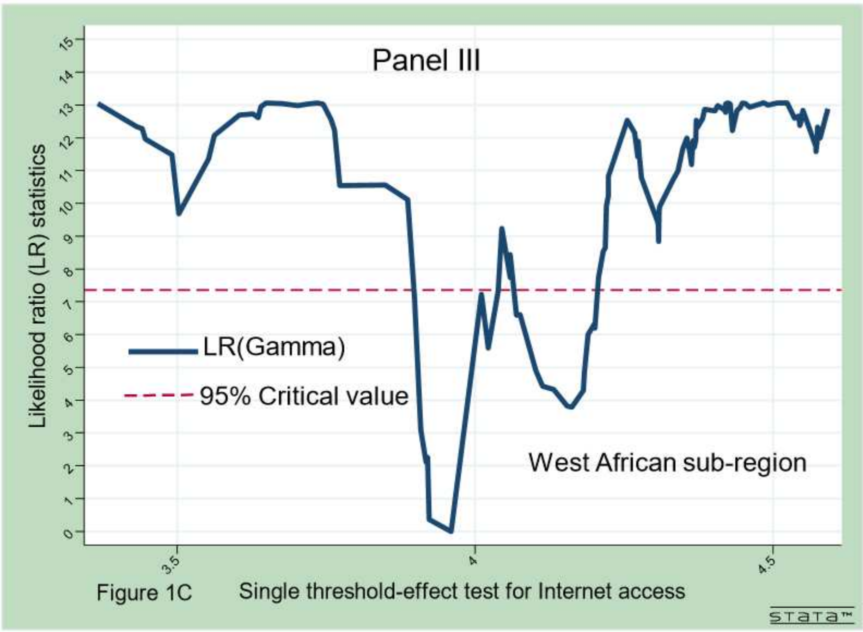

Figure 1C: WEST AFRICAN REGION

4.2 Threshold effect estimation

The empirical results of the equations (4–6) are reported in Table 5 which presents the results from the estimation of asymmetric internet threshold regression technique on economic growth. The F-statistics, the single $F_1(\gamma)$ threshold-effect, is achieved through 1000 bootstrap replications and 400 grids search to obtain the regimes bootstrap probability values for each of the three cluster samples. Using the full sample of 42 SSA countries in column 2, the *F-statistics* $F_1(\gamma)$ is found to be 19.92, and the parameter is significant at the 5% level. Similarly, the oil-producing region in column 4, the *F-statistics,* $F_1(\gamma)$ is found to be 18.64, and the parameter is also significant at the 5% level. On the other hand, for the West African region in column 6, the *F-statistics,* $F_1(\gamma)$ is found to be 11.39, and the parameter is observed to be not significant at the 10% level, respectively.

INSERT TABLE 5 HERE

The analytical estimates indicate overwhelming support for a single threshold effect and an asymmetric effect of internet subscription on economic growth. The critical value for the internet-threshold $\hat{\gamma}$ is found to be 3.55%, which helps to separate the total observations into the lower and upper regimes. The point estimates for the asymptotic threshold confidence intervals are within the range 16.05–21.19. Accordingly, the results are robust that the lower regime $I(internet_{it-1} \leq \hat{\gamma}_1)$ and the upper regime $I(internet_{it-1} > \hat{\gamma}_1)$ explain the overall changes. The total proportion of both regimes delineates the total variations in internet access on economic growth in the 42 SSA countries[11].

The coefficients of interest are those related to internet access. The point estimates indicate that internet subscription is positively related to economic growth in both regimes as measured by a one-period lag $internet_{it-1}$. The regime independent variable $internet_{it} I(internet_{it-1} \leq 3.55)$ results in a slope coefficient β_1 of 0.726 that is significant at the 1%, level, and the other $internet_{it} I(internet_{it-1} > 3.55)$ results in a slope coefficient β_2 of 0.337, which is also strongly significant at the 1%, level. These estimates provide evidence of a positive and certain (negative and certain) asymmetric effect of internet access on economic growth in the 42 SSA countries when the countries' internet access in the previous period is lower(higher) than the threshold effect value of 3.55%. This finding responded to the main objective of the article.

[11] A similar approach is adopted in the attendant literature (Abdulqadir 2020a, Abdulqadir, 2020b; Abdulqadir & Chua, 2020)

The robustness and sensitivity of our findings *(nonlinearity/asymmetry)* are also explored using auxiliary post-estimation through the marginal effect analysis as well as visualization the fitted values of our estimates. Figure 2 reports the fitted visual values of the marginal effect of economic growth and internet access.

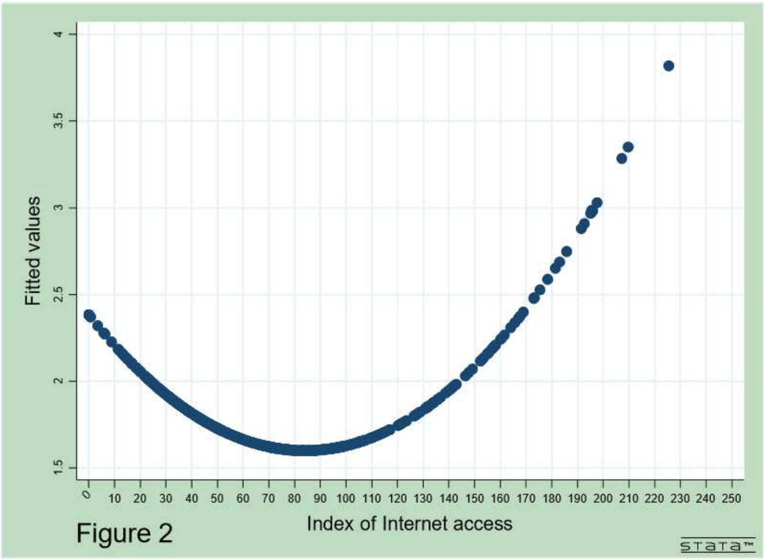

Figure 2: NONLINEARITY

The diagram in Figure 2 reports our data indicating nonlinearity or asymmetry, which corresponds to the initial results, as well as the best fit of the threshold regression model. The marginal effect of growth/internet declined at the initial stage to a point 90 on the internet axis and upsurges as internet access increases overtime.

4.3 Short-run estimates of the two-step difference GMM

The empirical results of the equations (7–13) are reported in Table 6, and it presents the summary of the *two-step* difference GMM results between internet access and economic growth indicators. Column 1 presents the two-step difference GMM estimates of internet access and economic growth indicators, with interaction terms and without a robust option. Column 2 reports the two-step difference GMM estimates of internet access and economic growth indicator, with interaction terms, robust options. Column 3 shows the two-step difference GMM estimates of internet access and economic growth indicator, with interaction terms, predetermined variable and robust options.

INSERT TABLE 6 HERE

The results of the diagnostic tests reveal that all the models are appropriately specified. The Sargan test does not reject the over-identification restriction, and the absence of second-order serial correlation is not rejected. The one period lagged dependent variable is statistically significant at the 1% level in all the models, and the instruments are lower in numerical value than the groups. Considering the models in the 1st to 3rd columns, the coefficient of internet access is positive and statistically significant at the 1%, level, only for the two-step difference GMM model with the predetermined variable in the 3rd column. The coefficients of income per capita are negative and statistically significant at the 1%, level respectively, in all the models. The coefficients of private sector credit are negative and statistically significant at the 1% level respectively, in the 1stcolumn, and at a 10% level, in the 2nd and 3rd columns. The coefficients of the interaction between private sector credit and internet access are positive and statistically significant at the 1%, level respectively, in the 1st column, and at the 5% level in the 2nd and 3rd columns. These implied that private sector credit being an indicator of finance resource has a negative and significant relationship with internet subscription, but when interacted, the magnitude changes to positive and is statistically significant at the1% and 5%, levels, respectively[12].

The coefficients of trade are negative but not statistically significant in all the models, but when interacted with internet access in the 1stcolumn, the magnitude changes to positive and is statistically significant at the 10% level. This finding implies that the overpowering impact of trade is still positive in the industry[13].The coefficients of government expenditure are positive but not statistically significant in all the models aligned with prior expectations. However, when interacted with internet access in the 1st column, the magnitude changes to negative and is statistically significant at the 10% level. This implies that the impact of government regulations in internet models for the 42 sub-Saharan African countries is weak. This result uncovers the negative impact of government regulations in Sub-Sahara Africa, which the previous studies had overlooked (Amusa and Oyinlola, 2019; Kimaro *et al.,* 2017; Kodongo and Ojah, 2016; Oyinlola *et al.,* 2020), and hence, such uncovering constitute another contribution to the literature.

Also, the article explores the robustness of the empirical results using the auxiliary composition of covariates reported in Table 7. This approach is obtained through excluding credits, trade, government, and deflator from the specification in the two-step difference

[12]See Asongu and Odhiambo (2020a) who have established the effect of internet on foreign direct investment and growth in 25 sub-Sahara African countries.
[13]See Freund and Weinhold (2004) who also reported evidence that internet stimulates trade using time series and panel frameworks. According to the evidence, a 10 percent movement in the growth of internet in a country results to approximately 0.2 percent growth in exports. Choi (2010) revealed that internet enhances trade transactions.

GMM model with a predetermined variable, a reference to Table 6 in the 3rd column. We also found that the results are consistent but greatly improved compared to the initial findings.

INSERT TABLE 7 HERE

4.4 Results of the marginal effect of internet access on growth via omitted covariates.

Table 8 displays the marginal effects of internet access on economic growth via private sector credit, trade openness, government expenditure, and inflation-deflator. The mean elasticity of economic growth with respect to internet access via government consumption expenditure is 0.0628, higher than all the other covariates. For instance, the mean elasticity of economic growth with respect to internet access via private sector credit is -0.1077. The mean elasticity of economic growth with respect to internet access via trade openness is -0.0123, whereas via the inflation-deflator, it is only 0.0145. In summary, our finding has overwhelmingly supported government consumption expenditure to enhance more significant growth with respect to the internet access channel, followed by the inflation-deflator and the indicator of variation in tariff regime.

INSERT TABLE 8 HERE

5.0 Conclusion and policy implications

This article examines the threshold effect of internet access on economic growth in 42 sub-Saharan African countries over the period 2008–2018. The dynamic panel threshold regression is utilized to test the presence on a significant threshold-effect following asymptotic *1000* bootstrap replications and together with *400* grids search. The results revealed a statistically significant single internet threshold-effect at 3.55% on economic growth. The findings corroborate with the results in Albiman and Sulong (2017) that found a significant threshold-value of 5% for internet penetration in SSA countries.

A two-step difference generalized method of moments (GMM) is used for the estimations of the short-run coefficients on a panel data, which corrects for the omitted variable bias of cross-sectional regression. The results show that internet access is positive and statistically significant in explaining economic growth in SSA countries. These results are robustly significant when controlling for the lagged level of GDP growth, income per capita, and the effects of private sector credit, trade openness, government consumption, and inflation-deflation. The result also validates the findings Albiman and Sulong (2016) and Njoh (2018) for the significant impact of ICT on economic growth, and those of other studies (see Aker & Mbiti, 2010; David, 2019; Forenbacher et al., 2019; Haftu, 2019; Hasbi & Dubus, 2020) for the significant effect of telecommunication on economic growth in SSA countries.

The results also revealed significant interaction terms in the sensitivity analysis of the covariates omitted in the auxiliary *two-step* difference GMM regression with predetermined internet access. All the interaction terms appeared to be statistically significant in all the models. The marginal effect of internet access evaluated at the minimum and maximum levels of government regulation and tariffs regime are positive and statistically significant.

The policy implication of the results could be drawn from the statistical significance of our empirical estimates. The results further indicate that the effect of internet on growth is subject to the regulations and tariff regime, which by implication suggests that the governments in SSA countries should regulate the industry for quality service delivery through competitions and product development. The significant joint impact of government regulations and tariff regimes is paramount in the operation of the telecommunication industry in SSA countries. These empirical results offer policy makers and managers in the industry with a suitable strategy for policy formulation. Future studies can be oriented towards a comprehensive review of research focused on the link between internet-growth in developing countries in general and SSA countries in particular.

Data availability statement

The data that support the findings of this article are available from the corresponding author upon request.

References

Abdulqadir, I. A. (2020a). Growth threshold-effect on renewable energy consumption in major oil-producing countries in sub-Saharan Africa: a dynamic panel threshold regression estimation. *International Journal of Energy Sector Management*. https://doi.org/10.1108/IJESM-04-2020-0004

Abdulqadir, I. A. (2020b). The nonlinearity of exchange rate pass-through on currency invoice: A quantile, GMM, and threshold effect-test from sub-Sahara African economies. *International Journal of Finance and Economics*. https://doi.org/10.1002/ijfe.2226

Abdulqadir, I. A., & Chua, S. Y. (2020). Asymmetric impact of exchange rate pass-through into employees' wages in sub-Saharan Africa: panel non-linear threshold estimation. *Journal of Economic Studies*. https://doi.org/10.1108/JES-03-2019-0128

Abdulqadir, I. A., Chua, S. Y., & Saidatulakmal, M. (2020). Investigation of optimal inflation targets for 15 major oil-exporting Sub-Saharan African countries. *Journal of Economics, Finance and Administrative Science*, *25*(49). https://doi.org/10.1108/JEFAS-12-2018-0136

Aguilar, D., Agüero, A., & Barrantes, R. (2020). Network effects in mobile telecommunications markets: A comparative analysis of consumers' preferences in five Latin American countries. *Telecommunications Policy*, *44*(5), 101972. https://doi.org/10.1016/j.telpol.2020.101972

Aker, J. C., & Mbiti, I. M. (2010). Mobile Phones and Economic Development in Africa. *Journal of Economic Perspectives*, *24*(3), 207–232. https://doi.org/10.1257/jep.24.3.207

Albiman, M. M., & Sulong, Z. (2016). The role of ICT use to the economic growth in the Sub-Saharan African region (SSA). *Journal of Science and Technology Policy Management*, *7*(3), 306–329.

Albiman, M. M., & Sulong, Z. (2017). The linear and non-linear impacts of ICT on economic growth, of disaggregate income groups within the SSA region. *Telecommunications Policy*, *41*(7–8), 555–572. https://doi.org/10.1016/j.telpol.2017.07.007

Amusa, K., & Oyinlola, M. A. (2019). The effectiveness of government expenditure on economic growth in Botswana. *African Journal of Economic and Management Studies*, *10*(3), 368–384. https://doi.org/10.1108/AJEMS-03-2018-0081

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of errorcomponents models. *Journal of Econometrics*, *68*(1), 29–51. https://doi.org/10.1016/0304-4076(94)01642-D

Asongu, S. A., & Nwachukwu, J. C. (2016a). Foreign aid and governance in Africa. *International Review of Applied Economics*, *30*, 69–88.

Asongu, S. A., & Nwachukwu, J. C. (2016b). The role of governance in mobile phones for inclusive human development in Sub-Saharan Africa. *Technovation*, *55–56*, 1–13.

Asongu, S.A.,, & Odhiambo, N. M. (2020a). Foreign direct investment, information technology, and economic growth dynamics in Sub-Saharan Africa. *Telecommunications Policy*, *44*(1), 101838. https://doi.org/10.1016/j.telpol.2019.101838

Asongu, S. A., & Odhiambo, N. M. (2020b). Inequality and gender inclusion: Minimum ICT policy thresholds for promoting female employment in Sub-Saharan Africa. *Telecommunications Policy*, *44*(4), 101900. https://doi.org/10.1016/j.telpol.2019.101900

Asongu, S. A.,, & Acha-anyi, P. N. (2019). The Murder Epidemic : A Global Comparative Study. *International Criminal Justice Review*, 29(2), 105-120.https://doi.org/10.1177/1057567718759584

Asongu, S. A.,, Le Roux, S., & Biekpe, N. (2017). Environmental degradation, ICT, and inclusive development in Sub-Saharan Africa. *Energy Policy*, *111*(September), 353–361. https://doi.org/10.1016/j.enpol.2017.09.049

Attari, M. I. J., & Javed, A. Y. (2013). Inflation, economic growth, and government expenditure of Pakistan: 1980-2010. *Procedia Economics and Finance*, *5*(13), 58– 67. https://doi.org/10.1016/s2212-5671(13)00010-5

Badran, M. F. (2012). The impact of broadband infrastructure on Economic growth in some Arab and emerging countries. Topics in Middle Eastern and African Countries. *Electronic Journal*, *14*, 278–310. http://www.luc.edu/orgs/meea/

Barro, R. J. (1997). Determinants of Economic Growth. *The MIT Press*, *76*(6), 154. https://doi.org/10.2307/1061363

Beck, T., Demirgu¨c¸-Kunt, A., & Levine, R. (2003). Law and finance: Why does legal origin matter? *Journal of Comparative Economics*, *31*, 653–675.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143. https://doi.org/doi.org/10. 1016/s0304-4076(98)00009-8

Boateng, A., Asongu, S. A., Akamavi, R., & Tchamyou, V. S. (2018). Information asymmetry and market power in the African banking industry. *Journal of Multinational Financial Management*, 44(March), 69-83 https://doi.org/10.1016/j. mulfin.2017.11.002

Brambor, T., Clark, W. R., & Golder, M. (2006). Understanding interaction models: Improving empirical analyses. *Political Analysis*, *14*(1), 63–82. https://doi.org/10.1093/pan/mpi014

Castaldo, A., Fiorini, A., & Maggi, B. (2018). Measuring (in a time of crisis) the impact of broadband connections on economic growth: An OECD panel analysis. *Applied Economics*, *50*(8), 838–854.

Chakraborty, C., & Nandi, B. (2003). Privatization, telecommunications, and growth in selected Asian countries: An econometric analysis. *Communications and Strategies*, *52*, 31–47.

Chakraborty, C., & Nandi, B. (2011). ‘Mainline’ telecommunications infrastructure, levels of development and economic growth: Evidence from a panel of developing countries. *Telecommunications Policy*, *35*(5), 441–449.

Choi, C., & Yi, M. H. (2009). The effect of the Internet on economic growth: Evidence from cross-country panel data. *Economics Letters*, *105*(1), 39–41.

Choi, C.(2010). The effect of the Internet on service trade. *Economics Letters*, *109*(2), 102–104. https://doi.org/10.1016/j.econlet.2010.08.005

Choi, C., Yi, M. H., & Hoon Yi, M. (2009). The effect of the Internet on economic growth:

Evidence from cross-country panel data. *Economics Letters*, *105*(1), 39–41. https://doi.org/10.1016/j.econlet.2009.03.028

Cieslik, A., & Kaniewska, M. (2004). Telecommunications infrastructure and regional economic development: The case of Poland. *Regional Studies*, *38*(6), 713–725.

Correa, L. (2006). The economic impact of telecommunications diffusion on UK productivity growth. *Information Economics and Policy*, *18*(4), 385–404.

Crandall, R., Lehr, W., & Litan, R. (2007). *In The effects of broadband deployment on output and employment: A cross-sectional analysis of U.S. Data (Vol. 6). Washington*. The Brookings Institution Issues in Economic Policy. https://www.brookings.edu/research/the-effects-of-broadband-deployment-on-output-and- employment-across-sectional-analysis-of-us-data/

Czernich, N., Falck, O., Kretschmer, T., & Woessmann, L. (2011). Broadband infrastructure and economic growth. *Economic Journal*, *121*(552), 505–532.

Datta, A., & Agarwal, S. (2004). Telecommunications and economic growth: A panel data approach. *Applied Economics*, *36*(15), 1649–1654. https://doi.org/10.1080/0003684042000218552

David, O. O. (2019). Nexus between telecommunication infrastructures, economic growth, and development in Africa: Panel vector autoregression (P-VAR) analysis. *Telecommunications Policy*, *43*(8), 101816. https://doi.org/10.1016/j.telpol.2019.03.005

De Bruijn, M., Nyamnjoh, F., & Brinkman, I. (2009). Introduction. In *Mobile Phones: The New Talking Drums of Africa, De Bruijn M, Nyamnjoh F, Brinkman I (eds)*. African Studies Centre.Leiden.

Donou-Adonsou, F. (2019). Technology, education, and economic growth in Sub-Saharan Africa. *Telecommunications Policy*, *43*(4), 353–360. https://doi.org/10.1016/j.telpol.2018.08.005

Elgin, C. (2013). Internet usage and the shadow economy: Evidence from panel data. *Economic Systems*, *37*(1), 111–121. https://doi.org/10.1016/j.ecosys.2012.08.005

Farhadi, M., Ismail, R., & Fooladi, M. (2012). Information and communication technology use and economic growth. *PLoS One*, *7*(11), e48903.

Fernandez, C. G. (2003). Inflation and economic growth in the long run. *Economics Letters*, *80*, 167–173.

Ford, G. S. (2018). Is faster better? Quantifying the relationship between broadband speed and economic growth. *Telecommunications Policy*, *42*(9), 766–778.

Forenbacher, I., Husnjak, S., Cvitić, I., & Jovović, I. (2019). Determinants of mobile phone ownership in Nigeria. *Telecommunications Policy*, *43*(7), 101812. https://doi.org/10.1016/j.telpol.2019.03.001

Frankfurter, Z., Kokoszka, K., Newhouse, D., Silwal, A. R., & Tian, S. (2020). *Measuring Internet in Access in Sub-Saharan Africa (SSA)* (Issue 31). https://openknowledge.worldbank.org/handle/10986/34302

Freund, C. L., & Weinhold, D. (2004). The effect of the Internet on international trade. *Journal of International Economics*, *62*(1), 171–189. https://doi.org/10.1016/S0022-

1996(03)00059-X

Ghosh, S. (2016). How important is mobile telephony for economic growth? Evidence from MENA countries. *Info*, *18*(3), 58–79.

Gómez-Barroso, J. L., & Marbán-Flores, R. (2020a). Telecommunications and economic development – The 20th century: The building of an evidence base. *Telecommunications Policy*, *44*(2). https://doi.org/10.1016/j.telpol.2019.101904

Gómez-Barroso, J. L., & Marbán-Flores, R. (2020b). Telecommunications and economic development – The 21st century: Making the evidence stronger. *Telecommunications Policy*, *44*(2), 101905. https://doi.org/10.1016/j.telpol.2019.101905

Gruber, H., & Koutroumpis, P. (2011). Mobile telecommunications and the impact on economic development. *Economic Policy*, *26*(67), 387–426.

Haftu, G. G. (2019). Information communications technology and economic growth in Sub-Saharan Africa: A panel data approach. *Telecommunications Policy*, *43*(1), 88–99. https://doi.org/10.1016/j.telpol.2018.03.010

Hansen, B. (1996). Inference When a Nuisance Parameter Is Not Identified Under the Null Hypothesis. *Econometrica*, *64*(2), 413–430.

Hansen, B. (1999). Threshold effects in non-dynamic panels : Estimation, testing, and inference. *Journal of Econometrics*, *93*(93), 345–368.

Hansen, B. (2000). Sample Splitting and Threshold Estimation. *Econometrica*, *68*(3), 575–603.

Hasbi, M., & Dubus, A. (2020). Determinants of mobile broadband use in developing economies: Evidence from Sub-Saharan Africa. *Telecommunications Policy*, *44*(5), 101944. https://doi.org/10.1016/j.telpol.2020.101944

Haynes, K. E., Yilmaz, S., & Dinc, M. (2006). *Regional telecommunications investment impacts and efficiency considerations*. In B. Johansson, C. Karlsson, & R. Stough (Eds.), The emerging digital economy – entrepreneurship, clusters, and policy (pp. 239–262) Springer.

Katz, R. L., Vaterlaus, S., Zenhausern, P., & Suter, S. (2010). The impact of broadband on jobs and the German economy. *Intereconomics/Review of European Economic Policy*, *45*(1), 26–34.

Kimaro, E. L., Keong, C. C., & Sea, L. L. (2017). Government Expenditure, Efficiency and Economic Growth: A Panel Analysis of Sub Saharan African Low Income Countries. *African Journal of Economic Review*, *5*(2), 34–54.

Kodongo, O., & Ojah, K. (2016). Does infrastructure really explain economic growth in Sub-Saharan Africa? *Review of Development Finance*, *6*(2), 105–125. https://doi.org/10.1016/j.rdf.2016.12.001

Kongaut, C., & Bohlin, E. (2017). Impact of broadband speed on economic outputs: An empirical study of OECD countries. *Economic and Business Review*, *3*(2), 12–32.

Koutroumpis, P. (2009). The economic impact of broadband on growth: A simultaneous approach. *Telecommunications Policy*, *33*(9), 471–485.

Kpodar, K., & Andrianaivo, M. (2011). *ICT, Financial Inclusion, and Growth Evidence from*

African Countries. International Monetary Fund. https://books.google.com.ng/books?id=FvEewuKhJqAC

Lam, P. L., & Shiu, A. (2010). Economic growth, telecommunications development, and productivity growth of the telecommunications sector: Evidence around the world. *Telecommunications Policy*, *34*(4), 185–199.

Madden, G., & Savage, S. J. (2000). Telecommunications and economic growth. *International Journal of Social Economics*, *27*(7–10), 893–906.

Mahler, D. G., Montes, J., & Newhouse, D. L. (2019). *Internet access in Sub-Saharan Africa*(Issue i). http://documents.worldbank.org/curated/en/518261552658319590/Internet-Access-in-Sub-Saharan-Africa

Mankiw, G. N., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of welfare growth. *The Quarterly Journal of Economics*, *107*(2), 407–437. https://doi.org/10.1515/bejm-2012-0042

Mwakatumbula, H. J., Moshi, G. C., & Mitomo, H. (2019). Consumer protection in the telecommunication sector: A comparative institutional analysis of five African countries. *Telecommunications Policy*, *43*(7), 101808. https://doi.org/10.1016/j.telpol.2019.02.002

Myovella, G., Karacuka, M., & Haucap, J. (2020). Digitalization and economic growth: A comparative analysis of Sub-Saharan Africa and OECD economies. *Telecommunications Policy*, *44*(2), 101856. https://doi.org/10.1016/j.telpol.2019.101856

N'dri, L. M., & Kakinaka, M. (2020). Financial inclusion, mobile money, and individual welfare: The case of Burkina Faso. *Telecommunications Policy*, *44*(3), 101926. https://doi.org/10.1016/j.telpol.2020.101926

Nadiri, M. I., Nandi, B., & Akoz, K. K. (2018). Impact of modern communication infrastructure on productivity, production structure, and factor demands of US industries: Impact revisited. *Telecommunications Policy*, *42*(6), 433–451.

Njoh, A. J. (2018). The relationship between modern Information and Communications Technologies (ICTs) and development in Africa. *Utilities Policy*, *50*(April), 83–90. https://doi.org/10.1016/j.jup.2017.10.005

Noh, Y. H., & Yoo, K. (2008). Internet, inequality, and growth. *Journal of Policy Modeling*, *30*(6), 1005–1016.

Oyinlola, M. A., Adedeji, A. A., Bolarinwa, M. O., & Olabisi, N. (2020). Governance, domestic resource mobilization, and inclusive growth in sub-Saharan Africa. *Economic Analysis and Policy*, *65*, 68–88. https://doi.org/10.1016/j.eap.2019.11.006

Porter, G., Hampshire, K., Abane, A., Munthali, A., Robson, E., Mashiri, M., & Tanle, A. (2012). Youth, mobility, and mobile phones in Africa: findings from a three-country study. *Journal of Information Technology for Development*, *18*(2), 145–162.

Porter, G., Hampshire, K., Milner, J., Munthali, A., Robson, E., De lannoy, A., Bango, A., Gunguluza, N., Mashiri, M., Tanle, A., & Abane, A. (2016). Mobile Phones and Education in Sub-Saharan Africa: From Youth Practice to Public Policy. *Journal of International Development*, *28*(June 2015), 22–39. https://doi.org/10.1002/jid.3116

Pradhan, R. P., Arvin, M. B., & Hall, J. H. (2016). Economic growth, development of telecommunications infrastructure, and financial development in Asia, 1991–2012. *The Quarterly Review of Economics and Finance*, *59*, 25–38.

Qiang, C. Z. W., Rossotto, C., & Kimura, K. (2009). *Economic impacts of broadband*. In 2009 information and communications for development: Extending reach and increasing impact (pp. 35–50). Washington D.C: World Bank. Available at: https://openknowledge.worldbank.org/handle/10986/2636.

Qureshi, S., & Najjar, L. (2017). Information and communications technology use and income growth: Evidence of the multiplier effect in very small island states. *Information Technology for Development*, *23*(2), 212–234.

Robb, G., & Hawthorne, R. (2019). Net neutrality and market power: The case of South Africa. *Telecommunications Policy*, *43*(9), 101814. https://doi.org/10.1016/j.telpol.2019.03.003

Rohman, I. K., & Bohlin, E. (2012). Does broadband speed really matter as a driver of economic growth? Investigating OECD countries. *International Journal of Management and Network Economics*, *2*(4), 336–356.

Roller, L. H., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *American Economic Review*, *91*(4), 909–923.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*, 1002–1037.

Romer, P. M. (1990). Endogenous technical change. *Journal of Political Economy*, *98*(5), S71–S101 Part 2.

Roodman, D. (2009a). A note on the theme of too many instruments. *Oxford Bulletin of Economics and Statistics*, *71*(1), 135–158. https://doi.org/10.1111/j.1468-0084.2008.00542.x

Roodman, D. (2009b). How to do xtabond2 : An introduction to and differenceGMM in Stata. *The Stata Journal*, *9*(1), 86–136.

Sezer, S., & Abasiz, T. (2016). The effect of information and communication technologies on economic growth in OECD countries. *Annals of the "Constantin Brancusi" University of Targu Jiu, Economy Seriesi" University of Targu Jiu, Economy Series*, *1*(6), 31–36.Shiu, A., & Lam, P. L. (2008). Causal relationship between telecommunications and economic growth in China and its regions. *Regional Studies*, *42*(5), 705–718.

Tchamyou, V. S. (2017). The Role of Knowledge Economy in African Business. Journal of the Knowledge Economy, 8(4), 1189–1228.

Tchamyou, V. S., (2019). The Role of Information Sharing in Modulating the Effect of Financial Access on Inequality. Journal of African Business, 23(3), 317-338.

Tchamyou, V. S. (2020). Education, Lifelong learning, Inequality and Financial access:Evidence from African countries. Contemporary Social Science, 15(1), 7-25.

Tchamyou, V. S., & Asongu, S. A. (2017). Information Sharing and Financial Sector Development in Africa. *Journal of African Business*, *18(7), pp. 24-49*

Tchamyou, V. S., Erreygers, G., & Cassimon, D. (2019). Technological Forecasting & Social Change Inequality , ICT, and financial access in Africa. *Technological Forecasting &*

Social Change, ,139(February), pp. 169-184.

The Economist. (2013). *E-Education: a long-overdue technological revolution is at last underway. Leaders, Briefing: education technology. 29/06/2013 pp 29-31.*

Thompson, H. G., & Garbacz. (2007). Mobile, fixed line, and Internet service effects on global productive efficiency. *Information Economics and Policy*, *19*(2), 189–214.

Torero, M., Chowdhury, S. K., & Bedi, A. S. (2006). *Telecommunications infrastructure and economic growth: A cross-country analysis.* In M. Torero, & J. von Braun (Eds.), Information and communication technologies for development and poverty reduction: The potential of telecommunications (pp. 21–63). Baltimore: Johns Hopkins University Press.

Valkenburg, P., & Peter, J. (2011). Online communication among adolescents. An integrated model of its attractions, opportunities, and risks. *Journal of Adolescent Health*, *48*(2), 121–127.

Vu, K. M., & Asongu, S. A., (2020). Backwardness advantage and economic growth in theinformation age: A cross-country empirical study. Technological Forecasting and Social Change, 159(October), 120197.

Vu, K., Hanafizadeh, P., & Bohlin, E. (2020). ICT as a driver of economic growth: A survey of the literature and directions for future research. *Telecommunications Policy*, *44*(2), 101922. https://doi.org/10.1016/j.telpol.2020.101922

Ward, M. R., & Zheng, S. (2016). Mobile telecommunications infrastructure and economic growth: Evidence from China. *Telecommunications Policy*, *40*(2–3), 89–101.

Waverman, L., Meschi, M., & Fuss, M. (2005). The impact of telecoms on economic growth in developing countries. *Vodafone Policy Paper Series*, *Number 2*.

Whitacre, B., Gallardo, R., & Strover, S. (2014). Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship. *Telecommunications Policy*, *38*(11), 1011–1024.

World Bank. (2020). World Development Indicators. *WDI*. data.worldbank.org/country/ sub-Saharan Africa

Yang, S. C., & Olfman, L. (2006). The effects of international telecommunication investment: Wireline and wireless technologies, 1993-1998. *Telecommunications Policy*, *30*(5–6), 278–296.

Yilmaz, S., & Dinc, M. (2002). Telecommunications and regional development: Evidence from the US states. *Economic Development Quarterly*, *16*(3), 211–228.

Zahra, K., Azim, P., & Mahmood, A. (2008). Telecommunication infrastructure development and economic growth: A panel data approach. *Pakistan Development Review*, *47*(4), 711–726.

Highlights

- The article investigates an asymmetric effect of internet access on economic growth in Sub-Saharan Africa (SSA) countries.
- Principal Component Analysis is utilized to aggregate the index of internet access in SSA countries.
- A threshold effect test is conducted using Hansen's dynamic threshold model with an asymptotic confidence interval.
- A two-step difference generalized method of moments (GMM) is also applied to estimate the short run and the long-run parameters.
- We discovered a statistically significant internet threshold-effect of 3.55% for economic growth in SSA countries.

Tables

Table 2a. Matrix of correlations Full sample

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Growth	1.000						
(2) Internets	0.018	0.018					
(3) Income per capita	-0.144	-0.144	-0.144				
(4) Credits	-0.029	-0.029	-0.029	-0.029			
(5) Trade	-0.013	-0.013	-0.013	-0.013	-0.013		
(6) Government	-0.035	-0.035	-0.035	-0.035	-0.035	-0.035	
(7) Deflator/Tariff	0.109	0.109	0.109	0.109	0.109	0.109	0.109

Note: The variables are defined as follows: Growth = gross domestic product divided by midyear population, GDP per capita (constant 2010 US$), Internet = principal component of Internet subscriptions, PSC % of GDP = private sector credits as percentage of GDP, Trade = sum of exports and imports as percentage of GDP, GCE = gross domestic consumptions percentage of GDP, Inflation = consumer prices. List of the sample countries: Angola, Benin ,Botswana ,Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Rep, Chad, Comoros ,Congo, Dem. Rep, Congo, Rep., Cote d'Ivoire, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia,Malawi,Mali,Mauritania,Mauritius,Namibia,Niger,Nigeria,Rwanda,Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

Table 2b. Matrix of correlations Oil producing states/region

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Growth	1.000						
(2) Internets	0.001	1.000					
(3) Income per capita	-0.351	0.257	1.000				
(4) Credits	-0.075	0.536	0.231	1.000			
(5) Trade	-0.112	-0.061	0.241	-0.086	1.000		
(6) Government	-0.264	0.262	0.367	0.531	0.288	1.000	
(7) Deflator/Tariff	0.172	-0.132	-0.171	-0.073	-0.308	-0.258	1.000

Note: The variables are defined as follows: Growth = gross domestic product divided by midyear population, GDP per capita (constant 2010 US$), Internet = principal component of Internet subscriptions, PSC % of GDP = private sector credits as percentage of GDP, Trade = sum of exports and imports as percentage of GDP, GCE = gross domestic consumptions percentage of GDP, Inflation = consumer prices. List of the sample countries: Angola, Cameroon, Chad, Congo, Dem. Rep, Congo, Rep., Cote d'Ivoire, Equatorial Guinea, Gabon, Gambia, Ghana, Malawi, Niger, Nigeria, Sao Tome and Principe, South Africa, Sudan, and Zambia.

Table 2c. Matrix of correlations West African region

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Growth	1.000						
(2) Internets	0.046	1.000					
(3) Income per capita	-0.141	0.543	1.000				
(4) Credits	-0.018	0.531	0.357	1.000			
(5) Trade	0.022	0.272	0.434	-0.058	1.000		
(6) Gov	-0.069	0.293	0.229	0.296	0.361	1.000	
(7) Deflator/Tariff	0.093	-0.163	-0.099	-0.122	-0.049	-0.139	1.000

Note: The variables are defined as follows: Growth = gross domestic product divided by midyear population, GDP per capita (constant 2010 US$), Internet = principal component index of Internet subscriptions, Income per capita = gross domestic product per capita divided by midyear population, Credits = private sector credits as percentage of GDP, Trade = sum of exports and imports as percentage of GDP, Gov = gross domestic consumptions percentage of GDP, Deflator = tariffs.. List of the sample countries: Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire,Gambia,Ghana,Guinea,Guinea-Bissau,Liberia,Mali,Mauritania,Niger,Nigeria,Sierra Leone, and Togo.

Table 3. Descriptive Statistics Full sample

Variable	*Obs*	*Mean*	*Std.Dev.*	*Min*	*Max*
(1) Growth	462	1.815	4.338	-36.557	18.066
(2) Internets	458	75.168	42.631	0.668	225.48
(3) Income per capita	462	2663.225	3551.248	210.804	20532.95
(4) Credits	444	23.57	25.558	2.66	150.974
(5) Trade	456	75.013	35.506	19.101	225.023
(6) Government	434	14.891	6.254	2.047	40.444
(7) Deflator/Tariff	462	6.944	9.812	-29.691	95.409

Table 4. Summary Results of the threshold identification and inference

Samples	(1) Threshold (TR) estimate $\hat{\gamma}$	(3) Likelihood ratio (LR)	(4) P-values	(5) Critical value 10%; 5%; 1%
Sub-Saharan African countries (Full sample)	3.5510	19.92	0.0140	13.51; 16.05; 21.19
Oil-Producing states/region	3.5481	18.64	0.0164	11.79; 14.93; 20.86
West African region	3.9171	11.39	0.1320	12.34; 15.28; 21.46

Note: the p-values are obtained from 1000 bootstrap replications for all samples.

Table 5. Results of dynamic panel threshold estimations dependent variable economic growth (Sub-Saharan Africa, period 2008-2018)

Growth	Full Sample		Oil Producing States/Region		West African Sub-Region	
	(1)	(2)	(3)	(4)	(5)	(6)
Log. Income per capita	0.814*	0.965*	1.129	0.756	4.227***	4.772***
	(0.467)	(0.501)	(0.840)	(0.922)	(0.961)	(1.062)
Log. Credits	0.00934	-0.0766	-0.0369	-0.266**	-0.0134	-0.300***
	(0.0421)	(0.0555)	(0.0902)	(0.125)	(0.0626)	(0.110)
Log. [Credits × Internet]	-	1.21e-05*	-	2.95e-05**	-	3.60e-05***
	-	(6.31e-06)	-	(1.45e-05)	-	(1.33e-05)
Log. Trade	0.155*	0.0934	0.0777	-0.110	0.410**	0.340
	(0.0924)	(0.107)	(0.213)	(0.262)	(0.186)	(0.229)
Log. [Trade × Internet]	-	2.86e-05	-	-1.12e-05	-	5.01e-05
	-	(2.40e-05)	-	(6.02e-05)	-	(6.05e-05)
Log. Gov	0.00209	0.108*	0.0215	0.208*	-0.0101	0.0742
	(0.0425)	(0.0563)	(0.0858)	(0.121)	(0.0784)	(0.102)
Log. [Gov × Internet]	-	-2.04e-05**	-	-2.95e-05**	-	-1.64e-05
	-	(8.03e-06)	-	(1.38e-05)	-	(1.11e-05)
Deflator/Tariffs	0.00663	0.0176*	0.00192	-0.00428	0.0110	0.0854***
	(0.00499)	(0.00933)	(0.00767)	(0.0173)	(0.0129)	(0.0273)
Deflator × Log. Internets	-	-0.000176	-	7.55e-05	-	-0.000963***
	-	(0.000134)	-	(0.000241)	-	(0.000313)
H0: Internets No threshold (TR= 0)	0.317***	0.726***	0.0427	0.0373	0.178	0.117
	(0.106)	(0.259)	(0.255)	(0.289)	(0.126)	(0.153)
H0: Internets One threshold (TR= 1)	0.114	0.337***	-0.235	-0.279	-0.00785	-0.0576
	(0.0854)	(0.120)	(0.216)	(0.260)	(0.111)	(0.155)
H0: Internets Two threshold (TR= 2)		0.142		-0.177		-0.135
		(0.106)		(0.261)		(0.167)
Constant	-6.555**	-7.660**	-7.402	-3.559	-30.43***	-33.13***
	(3.275)	(3.653)	(6.051)	(6.967)	(6.586)	(7.526)
Observations	462	462	176	176	165	165
R-squared	0.059	0.096	0.120	0.164	0.161	0.278
Number of countries	42	42	16	16	15	15

The variables are defined as follows: Growth Lagged = one year lagged variable of economic growth, Internet = principal component index of Internet subscriptions, Income per capita = gross domestic product per capita divided by midyear population, Credits = private sector credits as percentage of GDP, Trade = sum of exports and imports as *percentage of GDP, Gov = gross domestic consumptions percentage of GDP, Deflator = tariffs, and H0 = null hypothesis and all the variables except the inflation deflator are in natural logarithm. Figures in the parentheses are t-statistics, ***, ** and, * indicate significant at the 1%, 5%, and 10% levels, respectively. Time dummies were jointly significant and are not reported here to save space.*

Table 6. Summary of the Difference GMM Results (with time dummies). Dependent variable economic growth (Sub-Saharan Africa, period 2008-2018) Full Sample

VARIABLES	(1) Two-Step Difference GMM	(2) Two-Step Difference GMM (with Robust SE)	(3) Two-Step Difference GMM (predetermined variable: Internet access)
$Growth_{i,t-1}$ Lagged	0.320***	0.329***	0.330***
	(0.0518)	(0.0902)	(0.0723)
Log. Internet.	0.101	0.108	0.213***
	(0.0651)	(0.0861)	(0.0778)
Log. Income per capita	-0.166***	-0.163***	-0.168***
	(0.0466)	(0.0526)	(0.0486)
Log. Credits	-0.120***	-0.115*	-0.108*
	(0.0430)	(0.0649)	(0.0588)
Log. [Credits × Internet]	1.53e-05***	1.53e-05**	1.18e-05**
	(4.33e-06)	(5.94e-06)	(5.47e-06)
Log. Trade	-0.0146	-0.00771	-0.0135
	(0.0704)	(0.0981)	(0.0903)
Log. [Trade × Internet]	1.49e-05*	1.41e-05	1.68e-05
	(7.76e-06)	(1.13e-05)	(1.31e-05)
Log. Gov	0.0444	0.0416	0.0628
	(0.0308)	(0.0398)	(0.0385)
Log. [Gov × Internet]	-9.50e-06*	-8.88e-06	-1.07e-05
	(5.36e-06)	(7.72e-06)	(7.60e-06)
Deflator/Tariffs	0.00951	0.0107	0.0136
	(0.00830)	(0.0128)	(0.0112)
Deflator × Log. Internets	-0.000101	-0.000117	-0.000128
	(0.000121)	(0.000185)	(0.000168)
Sargan test χ^2	0.620	0.565	0.430
Hansen test χ^2	0.158	0.110	0.379
AR(1)	0.000	0.001	0.001
AR(2)	0.161	0.172	0.192
No. of instruments	30	30	36
No. of Groups	42	42	42
Observations	420	420	420

*Notes: All models are estimated using the Roodman (2009) GMM estimations (Stata xtabond2 commands). The variables are defined as follows: $Growth_{i,t-1}$ lagged = one year lagged variable of economic growth, Internet = principal component index of Internet subscriptions, Income per capita = gross domestic product per capita divided by midyear population, Credits = private sector credits as percentage of GDP, Trade = sum of exports and imports as percentage of GDP, Gov = gross domestic consumptions percentage of GDP, Deflator = tariffs, and Log = logarithm. Figures in the parentheses are t-statistics, ***, ** and, * indicate significant at the 1%, 5%, and 10% levels, respectively. Time dummies were jointly significant and are not reported here to save space.*

Table 7. Sensitivity analysis of the Difference GMM Results (Predetermined: Internet). Dependent variable economic growth (Sub-Saharan Africa, period 2008-2018)

	(1)	(2)	(3)	(4)
VARIABLES	Two-Step Difference GMM (predetermined variable: Internet)	Two-Step Difference GMM (predetermined variable: Internet)	Two-Step Difference GMM (predetermined variable: Internet)	Two-Step Difference GMM (predetermined variable: Internet)
	PSC % of GDP *omitted*	Trade % GDP *omitted*	GCE % GDP *omitted*	Inflation *omitted*
Growth $_{i,t-1}$ Lagged	0.253***	0.317***	0.333***	0.320***
	(0.0799)	(0.0764)	(0.0763)	(0.0720)
Log. Internet.	0.103	0.206***	0.206***	0.197**
	(0.154)	(0.0743)	(0.0634)	(0.0798)
Log. Income per capita	-0.334**	-0.155***	-0.177***	-0.192***
	(0.138)	(0.0475)	(0.0497)	(0.0434)
Log. Credits	-	-0.136**	-0.104**	-0.115*
	-	(0.0519)	(0.0509)	(0.0640)
Log. [Credits × Internet]	-	1.47e-05**	1.14e-05**	1.19e-05*
	-	(5.65e-06)	(4.65e-06)	(5.97e-06)
Log. Trade	-0.167	-	0.0463	-0.0212
	(0.302)	-	(0.0690)	(0.0849)
Log. [Trade × Internet]	0.000178*	-	1.61e-06	1.81e-05
	(9.29e-05)	-	(1.03e-05)	(1.38e-05)
Log. Gov	0.123	0.0563*	-	0.0647
	(0.0937)	(0.0330)	-	(0.0420)
Log. [Gov × Internet]	-4.45e-05*	-8.54e-06	-	-1.16e-05
	(2.61e-05)	(6.36e-06)	-	(8.12e-06)
Deflator/Tariffs	0.0118	0.0126	0.0145	-
	(0.0131)	(0.0109)	(0.0111)	-
Deflator × Log. Internets	-4.13e-05	-0.000119	-0.000159	-
	(0.000184)	(0.000165)	(0.000168)	-
Sargan test χ^2	0.714	0.420	0.486	0.372
Hansen test χ^2	0.711	0.421	0.485	0.318
AR(1)	0.001	0.001	0.001	0.001
AR(2)	0.467	0.188	0.194	0.173
No. of instruments	32	34	34	34
No. of Groups	42	42	42	42
Observations	420	420	420	420

*Notes: All models are estimated using the Roodman (2009) GMM estimations (Stata xtabond2 commands). The variables are defined as follows: Growth$_{i,t-1}$ lagged = one year lagged variable of economic growth, Internet = principal component index of Internet subscriptions, Income per capita = gross domestic product per capita divided by midyear population, Credits = private sector credits as percentage of GDP, Trade = sum of exports and imports as percentage of GDP, Gov = gross domestic consumptions percentage of GDP, Deflator = tariffs, and Log = logarithm. Figures in the parentheses are t-statistics, ***, ** and, * indicate significant at the 1%, 5%, and 10% levels, respectively. Time dummies were jointly significant and are not reported here to save space.*

Table 8. The marginal effect of Internet access on economic growth via private sector credit, trade, government, and inflation models using equations (14),(15), (16), and (17)Full Sample

Models	Credits			Trade			Government			Deflator/Tariff		
	$\frac{\partial \ln growth}{\partial \ln telecoms_{it}} \approx -0.108 + 1.18e05 credit_{it}$			$\frac{\partial \ln growth}{\partial \ln telecoms_{it}} \approx -0.0135 + 1.68e05 trade_{it}$			$\frac{\partial \ln growth}{\partial \ln telecoms_{it}} \approx 0.0628 - 1.07e05 governement_{it}$			$\frac{\partial \ln growth}{\partial \ln telecoms_{it}} \approx 0.0136 - 1.28e04 tariffs_{it}$		
	Mean	**Minimum**	**Maximum**	**Mean**	**Minimum**	**Maximum**	**Mean**	**Minimum**	**Maximum**	**Mean**	**Minimum**	**Maximum**
Elasticities	-0.10772	-0.10797	-0.10622	-0.01229	-0.01323	-0.00977	0.062959	0.062822	0.063233	0.014489	0.0098	0.025812

Note: the specification utilized to compute the marginal effect is from (Table (5) column 4). The original values of private sector credit, trade, government, and tariffs are from the raw dataset (mean, maximum, and minimum).