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Dongbei University of Finance and Economics, 217 Jianshan Street, Dalian, China P.R

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Dynamics between Financial development, Energy consumption and Economic growth in Sub-Saharan African countries: Evidence from an asymmetrical and nonlinear analysis

Diby François Kassi [a,*], Gang Sun[a], Yobouet Thierry Gnangoin[b], Akadje Jean Roland Edjoukou [c], Guy Roland Assamoi [d]

[a] *Dongbei University of Finance and Economics, School of Finance, 217 Jianshan Street, Dalian, China P.R*

[b] *Dongbei University of Finance and Economics, School of Economics, 217 Jianshan Street, Dalian, China P.R*

[c] *Dongbei University of Finance and Economics, School of Accounting, 217 Jianshan Street, Dalian, China P.R*

[d] *Dongbei University of Finance and Economics, School of International Economics, 217 Jianshan Street, Dalian, China P.R*

Abstract:

This paper analyzes the asymmetrical relationship between financial development, energy consumption and economic growth in twenty-one (21) sub-Saharan African (SSA) countries from 1990Q1 to 2014Q4. We used the nonlinear autoregressive distributed lag (NARDL) framework and asymmetrical causality tests to examine the relationship between the variables. First, the country-level analysis reveals that there is asymmetrical cointegration between the variables in some countries and mixed results of the causal effects of financial development and energy consumption on economic growth across countries. Second, the results of the panel data analysis confirm the asymmetrical cointegration in the SSA region, especially in lower-middle-income countries than in upper-middle-income countries. We find that positive changes in energy consumption significantly reduce economic growth, contrary to the negative changes in the long-term. Besides, positive shocks to financial development favor more economic growth than the adverse shocks in the long-term in the SSA region. However, financial development hurts economic growth, contrary to energy consumption in the short-term. Finally, the results show bidirectional causality between positive changes in energy consumption and economic growth, but unidirectional causality running from negative changes in energy consumption to economic growth in the SSA region. There is also bidirectional causality between positive and negative shocks to financial development and economic growth in SSA region, but mixed results across lower-income countries and upper-middle-income countries. Therefore, our study suggests that energy-saving policies such as renewable energies can be implemented in the SSA region to promote sustainable development. In addition, policy-makers should adopt an efficient allocation of the credits to the private sector supporting productive investments. They should also pay attention to the asymmetrical relationship between financial development, energy consumption and economic growth in most SSA countries in the conduct of economic policies.

JEL classification: Q43, G20, C13
Keywords: Financial development; Energy use; Economic growth; NARDL; Sub-Saharan Africa.

[*] Corresponding author: kassidiby17@gmail.com
217 Jianshan Street, Dalian 116025

1. Introduction

The relationship between financial development, energy consumption, and economic growth has drawn more attention in the past decades. The inevitableness of energy consumption in daily life and its essential role in the production process of goods and services are among the main reasons for the increasing interest of studies on the energy-growth nexus. Besides, the relatively low rates of economic growth in Sub-Saharan Africa (SSA), from 3.8% in 2009 to 2.7% in 2017[1], arouse the need to understand how financial development and energy consumption can participate to the promotion of sustainable development, especially in Africa. Following previous studies, the energy-growth nexus in the SSA region has led to mixed results which are organized into four hypotheses: the growth hypothesis or energy-led economic growth hypothesis (Wolde-Rufael, 2005; Fatai, 2014; Hamit-Haggar, 2016), the conservation hypothesis or growth-led energy hypothesis (Akinlo, 2008; Esso, 2010; Le, 2015), the feedback hypothesis (Ebohon, 1996; Kouakou, 2011; Gao and Zhang, 2014), and the neutral hypothesis (Huang et al., 2008; Zerbo, 2017). Similarly, there was no explicit agreement or unified conclusion on the finance-growth nexus in the SSA countries (Odhiambo, 2007; Aka, 2010; Hassan et al., 2011; Kagochi et al. 2013; Gupta et al., 2017; Ibrahim and Alagidede, 2018). Most of these studies did not consider the interaction between financial development, energy consumption, and economic growth, as well as the importance of asymmetrical and nonlinear relationship among these variables in the SSA region. Some recent studies instead investigated the nonlinear association between energy consumption and economic growth (Ranjbar et al., 2016; Gupta et al., 2017; Nyoni and Phiri, 2018) or between financial development and economic growth (Ibrahim and Alagidede, 2017; Ibrahim and Alagidede, 2018). Thus, these studies failed to include financial development in the energy-growth nexus while allowing for the likely asymmetrical relationships between these three variables due to the complexity of the economic system. Hence, it is crucial to know whether positive and negative changes in energy consumption, as well as positive and negative shocks to financial development, have similar effects on economic growth in order to draw appropriate economic and energy policies in the SSA region.

This study contributes to the empirical literature on the energy-growth nexus and finance-growth nexus by incorporating asymmetrical and nonlinear relationships between financial development, energy consumption and economic growth in the SSA countries. Notably, we examine the asymmetrical effects of financial development and energy consumption on economic growth in twenty-one (21) SSA countries on quarterly data from 1990 to 2014. The use of quarterly data helps to increase the number of observations to get more accurate results, in particular in the country-level analysis. We included three control variables such as gross fixed capital formation, labor force and trade openness following previous study on emerging countries (Shahbaz et al. 2017).

Our analysis is divided into two main parts: country-level analysis and panel data analysis.The country-level analysis employed the nonlinear autoregressive distributed lag (NARDL) framework in Shin et al. (2014) for the cointegration method while Granger

[1] Source: IMF, Common Surveillance database and IMF, World Economic Outlook database, October 2018.

non-causality tests by Toda and Yamamoto (1995) were used to examine the causal relationship among the variables for each country.

In the panel data analysis, we grouped the countries into three categories: eight (8) lower-income countries, eight (8) lower-middle-income countries, and five (5) upper-middle-income countries, according to the classification by income in the World Bank Atlas method.

This classification helps to understand how the relationship between financial development, energy consumption, and economic growth varies depending on the economic condition of these countries. Next, We used two-panel cointegration techniques; namely, Pedroni (1999, 2001) and Fisher-Johansen tests (Maddala and Wu, 1999) to examine whether there is a long-term relationship among the variables. In addition, the evidence of cointegration among the variables allows us to implement three alternative panel estimation methods: the Fully Modified Ordinary Least Squares (FMOLS) in Phillips and Hansen (1990), the Dynamic Ordinary Least Squares (DOLS) proposed by Saikkonen (1991), and the pooled mean group estimator (PMG) developed by Pesaran and Smith (1995) and Pesaran et al. (1999). Finally, we performed the panel causality tests developed by Dumitrescu and Hurlin (2012) for each category of countries, and the entire SSA region as well.

Overall, to the best of our knowledge, this study is the first to consider asymmetry and nonlinearity in both the energy-growth nexus and finance-growth nexus in the SSA countries. This study also analyzed the asymmetrical causality between financial development, energy consumption and economic growth in multivariate models allowing for country-level and panel data analyses. The findings of this study reveal interesting suggestions that help policy-makers to understand better the complexity of the relationship between financial development, energy consumption, and economic growth in order to implement appropriate strategies in the SSA countries.

The rest of this paper is structured as follows. Section 2 presents the empirical literature on the energy-finance-growth nexus in the SSA region. Section 3 describes the data and methodology of the study, whereas section 4 reveals the results and discussions of the findings. Finally, section 5 concludes the study and indicates the policy implications from the findings for sustainable development in the SSA countries.

2. Empirical literature review

The relationship between energy consumption, financial development, and economic growth has been the subject of much debate in recent years, particularly in Sub-Saharan African (SSA) countries seeking economic catch-up with developed countries. This section provides empirical studies on the relationship between energy consumption and economic growth, as well as the link between financial development and economic growth in the SSA region.

Following pioneered studies on developed countries (Kraft and Kraft, 1978; Yu and Hwang, 1984), the relationship between energy consumption and economic growth in the SSA region can be summarized into four hypotheses: the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutral hypothesis. The growth hypothesis indicates that there is unidirectional causality running from energy consumption to economic growth. Thus, Wolde-Rufael (2005) analyzed the relationship between energy demand and economic growth for 19 African countries using bounds testing approach to cointegration (Pesaran et al. 2001) and Granger non-causality test (Toda and Yamamoto, 1995) on data spanning from 1971 to 2001. He found a long-term relationship between energy consumption and economic growth per capita in eight (8) countries and validated the growth hypothesis in Cameroon, Morocco, and Nigeria. Many other studies supported the growth hypothesis that energy consumption caused economic growth in SSA countries (Wolde-Rufael, 2006; Mehra, 2007; Odhiambo, 2009; Dantama et al., 2012, Fatai, 2014; Hamit-Haggar, 2016, Ali et al., 2016, among others). However, other studies justified the conservation hypothesis, showing that economic growth caused energy consumption in SSA countries (Wold-Rufael, 2005; Akinlo, 2008; Esso, 2010; Le, 2015; Zerbo, 2017, among others). For instance, Akonlo, 2008 confirmed this hypothesis for the cases of Sudan and Zimbabwe over the period 1980-2003. Zerbo (2017) validated the conservation hypothesis in Sudan and Zambia during the period 1971-2013 by applying the autoregressive distributed lags (ARDL) in Pesaran et al. (2001) and causality tests by Toda and Yamamoto (2015) on multivariate models. The feedback hypothesis shows that there is bidirectional causality between energy consumption and economic growth (Ebohon, 1996; Akinlo, 2008; Kouakou, 2011; Esso, 2012; Gao and Zhang, 2014; Kassi et al., 2017). Gao and Zhang (2014) gave support to this hypothesis for 14 SSA countries from 1980 to 2009, whereas Kassi et al. (2017) found bidirectional causality between energy consumption from hydroelectric sources and economic growth in Cote d'Ivoire from 1971 to 2011. Nevertheless, the neutral hypothesis is more radical stating that there is no causality between energy consumption and economic growth (Akinlo, 2009, in Nigeria; Huang et al., 2008; Esso, 2010, in Cameroon, Kenya, Nigeria, and South Africa; Fatai, 2014, in the cases of Central and West African countries; Zerbo, 2017, among others). Zerbo (2017) confirmed the neutral hypothesis in Benin, Congo, Cote d'Ivoire, South Africa, Ghana, and Togo from 1971 to 2013.

Numerous studies have examined the finance-growth nexus resulting in mixed results across SSA countries (Agbetsiafa, 2004; Odhiambo, 2007; Aka, 2010; Keho, 2012; Le, 2015; Sahay et al., 2015b; Kassi, 2017; Ibrahim and Alagidede, 2017; Ibrahim and Alagidede, 2018, among others). The supply-leading hypothesis pioneered by Schumpeter (1911), stating that financial development (increasing supply of financial services) led to economic growth, has been confirmed by Agbetsiafa (2004) in Zambia, Togo, South Africa, Senegal, Nigeria, and Ghana. This hypothesis was also supported by Odhiambo (2007) in Tanzania, by Kassi et al. (2017) in Cote d'Ivoire, whereas Ibrahim and Alagidede (2018) found an inverted U-shaped relationship between financial development and economic growth in SSA countries from 1980 to 2014 using the generalized method of moments (GMM). However, other studies validated the demand-following hypothesis developed by Robinson (1952) showing that economic growth caused financial development in SSA countries (Odhiambo, 2010; Hassan et al., 2011; Demetriades and James, 2011, among others). Hassan et al., 2011 supported the growth-led finance hypothesis in the SSA countries from 1980 to 2007 by applying the Granger causality test in Toda and Yamamoto (1995). The feedback hypothesis contends that there is bidirectional causality between financial development and economic growth in SSA region (Acaravci et al., 2009; Aka, 2010; Kagochi et al. 2013). Thus, Kagochi et al. (2013) confirmed the feedback hypothesis in 7 selected SSA countries over the period 1991-2007 using the panel Granger causality in Hurlin and Venet (2001).

Another strand of studies emphasized the asymmetrical relationship between energy consumption, financial development, and economic growth in developed and emerging economies (Arac and Hasanov, 2014; Shahbaz et al., 2017; Kisswani, 2017; Shahbaz, 2018). For instance, Shahbaz et al. (2017) showed that only negative changes in energy consumption and financial development caused economic growth in India from 1960Q1 to 2015Q4. They used the multivariate nonlinear autoregressive distributed lags (NARDL) framework in Shin et al. (2014) and asymmetric causality tests in Hatemi-J (2012). Few studies have analyzed the asymmetrical relationship between energy consumption, financial development and economic growth in SSA countries. Most of the studies only examined the asymmetry between the energy-growth nexus and are country-level studies (Olayeni, 2012; Ranjbar et al., 2016; Gupta et al., 2017; Nyoni and Phiri, 2018) while other studies focused on the asymmetrical relationship between financial development and economic growth, neglecting energy consumption in this relationship (Ibrahim and Alagidede, 2017; Ibrahim and Alagidede, 2018). Ranjbar et al., 2016 used a bivariate model and found that negative changes in energy consumption reduced economic growth in South Africa over the period 1965-2012. Likewise, Nyoni and Phiri (2018) found that electricity consumption caused economic growth in South Africa from 1983Q1 to 2016Q4 over the long-term by employing asymmetric threshold cointegration and causality techniques, whereas there was bidirectional causality between the trend and cyclical components of the variables.

These studies fail to analyze together the asymmetrical relationships between energy consumption, financial development, and economic growth, but also the asymmetrical causalities among these variables in SSA countries. Hence, our study aims to fill the gap in the empirical literature by providing both country-level and panel data analyses allowing for asymmetrical relationships between energy consumption, financial development and economic growth in twenty-one (21) selected SSA countries from 1990Q1 to 2014Q4. We also analyzed non-linear causalities among these variables for each country, as well as in the SSA region while considering three sub-groups of countries according to the classification by income: the lower-income countries, the lower-middle-income countries, and the upper-middle-income countries.

3. Data, Modeling, and Methodology of the study

3.1. Data

This study analyzes the asymmetrical relationship between energy consumption, financial development, and economic growth in the sub-Saharan African (SSA) countries from 1990Q1 to 2014Q4. We use unbalanced panel data including twenty-one (21) SSA countries due to the availability of data for the period of study. We grouped these countries into three main categories following the classification by income according to the World Bank Atlas method in 2017. Thus, our sample is made up of eight (8) low-income economies, eight (8) lower-middle-income economies, and five (5) upper-middle-income economies. The low-income SSA economies, having a gross national income (GNI) per capita of $ 995 or less, comprise Benin, Congo democratic republic, Eritrea, Mozambique, Niger, Senegal, Tanzania, and Togo. The lower-middle-income countries are those with a GNI per capita ranging from $996 to $3.895. This group encompasses Angola, Cameroon, Congo republic, Cote d'Ivoire, Ghana, Kenya, Nigeria, and Sudan. The last group, concerning the upper-middle-income economies with a GNI per capita between $3.896 and $12.055, includes Botswana, Gabon, Mauritius, Namibia, and South Africa. First, this study utilized annual database from World Development Indicators (WDI, 2017) on gross domestic production (GDP) per capita (constant 2010, US $), energy consumption (energy use, kg of oil equivalent per capita), financial development (domestic credit to private sector, as % of GDP), gross fixed capital formation (% of GDP), labor force (total) and trade openness (trade, as %of GDP). Most of the empirical studies used these variables in their analyses (Menyah and Rufael, 2010; Sadorsky, 2010, Le, 2015; Shahbaz et al. 2017, Kahouli, 2017, among others). Second, we transformed the annual data into the quarterly data in order to increase the accuracy of the results for the country-level analysis as well as the panel data analysis. We used the quadratic-match sum option of the low-to-high-frequency technique in line with previous studies (Cheng et al. 2012, Sbia et al. 2014, Shahbaz et al. 2017, Kassi et al., 2018; Kassi et al., 2019). This technique implements an interpolation fitting a local quadratic polynomial so that the average of four next quarters is equal to the data observed in the corresponding year. All the variables were converted into the logarithmic form in order to obtain a normal distribution, reliable results, but also to facilitate the interpretation of the results (Shahbaz et al. 2016). The sample contains different periods, with the shortest ranging from 1996Q1 to 2010Q4 and the longest from 1990Q1 to 2014Q4, mainly due to the data available for some countries.

3.2. The base Model

The empirical model of this study derived from the theories of endogenous growth (Romer, 1986, Lucas, 1988, among others) where the technological progress is not exogenous, being related to various factors which thereby affect the level of output. Kaufmann and Azary-Lee (1991) pointed out the mutual dependency between physical capital and natural capital such as energy. Financial development also affects the level of production through the financing of the acquisitions of both physical and human capitals (King and Levin, 1993; Pagano, 1993), while the technological progress is transferred across countries through the trade openness. Thus, we started with an augmented Cobb-Douglas production function expressed as follows:

$$GDP_{it} = f(\mathrm{ENC}_{it}^{\beta}, \mathrm{FIN}_{it}^{\delta}, \mathrm{GFCF}_{it}^{\sigma}, \mathrm{LAB}_{it}^{\omega}, \mathrm{TRADE}_{it}^{\kappa}) \quad (1)$$

The dependent variable *GDP* represents the gross domestic product, which is related to the energy consumption (*ENC*), the level of financial development (*FIN*), gross fixed capital formation (*GFCF*), the labor force (*LAB*) and the trade openness (*TRADE*) in a particular country *i* at time *t*. Notably, we applied a logarithmic transformation to model (1) to obtain accurate and reliable results (Shahbaz et al. 2016). Our linear model is a similar version developed by Le (2015), with the incorporation of the labor force:

$$\ln\text{GDP}_{it} = \alpha_i + \beta_i \ln\text{ENC}_{it} + \delta_i \ln\text{FIN}_{it} + \sigma_i \ln\text{GFCF}_{it} + \omega_i \ln\text{LAB}_{it} + \kappa_i \ln\text{TRADE}_{it} + \varepsilon_{it} \quad (2)$$

Where *ln* denotes the logarithmic operator α_i is the constant term, while β_i, δ_i, σ_i, ω_i and κ_i are the coefficients of the corresponding variables to be estimated and ε_i is the error term that is assumed to be identically and independently distributed (iid).

Moreover, we differ from Le (2015) by considering the possibility of asymmetrical relationships between energy consumption, financial development, and economic growth, respectively. In particular, we employed the nonlinear autoregressive distributed lag (NARDL) technique developed by Shin et al. (2014) to examine whether a long-term relationship exists between energy consumption, financial development, and economic growth, as well as to investigate the asymmetrical effects of energy consumption and financial development on economic growth. This technique distinguishes the short and long-term asymmetrical effects of the explanatory variables on the dependent variable within an error correction framework. Moreover, the NARDL approach is still valid in the case of a multivariate model and a mixture of integrated variables of different orders: I (0) and I (1), unlike other traditional approaches (Engel and Granger, 1987; Johansen, 1988). Therefore, our NARDL model is a modified version similar to Shahbaz et al. (2017):

$$\begin{aligned}\Delta \ln\text{GDP}_{i,t} = {} & \beta_{0,i} + \varphi_i \ln\text{GDP}_{i,t-1} + \theta_{1,i}^{+} \ln\text{ENC}_{i,t-1}^{+} + \theta_{2,i}^{-} \ln\text{ENC}_{i,t-1}^{-} + \delta_{1,i}^{+} \ln\text{FIN}_{i,t-1}^{+} + \delta_{2,i}^{-} \ln\text{FIN}_{i,t-1}^{-} + \beta_{1,i} \ln\text{GFCF}_{i,t-1} \\ & + \beta_{2,i} \ln\text{LAB}_{i,t-1} + \beta_{3,i} \ln\text{TRADE}_{i,t-1} + \sum_{k=1}^{p1} \omega_{ik} \Delta \ln\text{GDP}_{i,t-k} + \sum_{k=0}^{q1} \sigma_{1,ik}^{+} \Delta \ln\text{ENC}_{i,t-k}^{+} + \sum_{k=0}^{q2} \sigma_{2,ik}^{-} \Delta \ln\text{ENC}_{i,t-k}^{-} \\ & + \sum_{k=0}^{q3} \eta_{1,ik}^{+} \Delta \ln\text{FIN}_{i,t-k}^{+} + \sum_{k=0}^{q4} \eta_{2,ik}^{-} \Delta \ln\text{FIN}_{i,t-k}^{-} + \sum_{k=0}^{q5} \alpha_{1,ik} \Delta \ln\text{GFCF}_{i,t-1} + \sum_{k=0}^{q6} \alpha_{2,ik} \Delta \ln\text{LAB}_{i,t-1} + \sum_{k=0}^{q7} \alpha_{3,ik} \Delta \ln\text{TRADE}_{i,t-1} + \zeta_{i,t}\end{aligned} \quad (3)$$

Where Δ is the difference operator, ENC^{+} and FIN^{+} denote the positive partial sums of energy consumption and financial development respectively, while ENC^{-} and FIN^{-} represent their negative partial sums; $\beta_{0,i}$ refers to each country's specific intercept;

$\varphi_i, \theta_{1,i}^{+}, \theta_{2,i}^{-}, \delta_{1,i}^{+}, \delta_{2,i}^{-}\ \beta_{1,i}, \beta_{2,i}, \beta_{3,i}, \omega_i, \sigma_{1,ik}^{+}, \sigma_{2,ik}^{-}, \eta_{1,ik}^{+}, \eta_{2,ik}^{-}, \alpha_{1,ik}, \alpha_{2,ik}$ *and* $\alpha_{3,ik}$ are the coefficients

to be estimated, and $\zeta_{i,t}$ ~IID (0,σ^2); p_1, q_1, q_2, q_3, q_4, q_5, q_6, and q_7 are the optimal lags selected by the Akaike information criterion (AIC). We employed the general-to-specific method with a maximum lag 6. This technique eliminates the non-significant lagged variables from the model in order to obtain accurate results.

We follow the framework of Shin et al. (2014) to construct the partial sums of energy consumption (financial development) variable into positive changes $lnENC^{+}$ (lnFIN^{+}) and negative changes lnENC^{-} (lnFIN^{-}) as follows:

$$\ln ENC_{i,t}^{+}=\sum_{k=1}^{q}\Delta\ln ENC_{i,\mathrm{k}}^{+}=\sum_{k=1}^{q}\max(\Delta\ln ENC_{i,k},0) \quad \mathit{and} \quad \ln ENC_{i,t}^{-}=\sum_{k=1}^{q}\Delta\ln ENC_{i,\mathrm{k}}^{-}=\sum_{k=1}^{q}\min(\Delta\ln ENC_{i,k},0),$$

$$\ln FIN_{i,t}^{+}=\sum_{k=1}^{r}\Delta\ln FIN_{i,\mathrm{k}}^{+}=\sum_{k=1}^{r}\max(\Delta\ln FIN_{i,k},0) \quad \mathit{and} \quad \ln FIN_{i,t}^{-}=\sum_{k=1}^{r}\Delta\ln FIN_{i,\mathrm{k}}^{-}=\sum_{k=1}^{r}\min(\Delta\ln FIN_{i,\mathrm{k}},0),$$

The long-term ERPT coefficients are calculated by

$$\Phi_i^{+}=-(\theta_{1,i}^{+}/\varphi_i),\Phi_i^{-}=-(\theta_{2,i}^{-}/\varphi_i),\Theta_i^{+}=-(\delta_{1,i}^{+}/\varphi_i),\Theta_i^{-}=-(\delta_{2,i}^{-}/\varphi_i),\mathrm{K}_i=-(\beta_{1,i}/\varphi_i),\mathrm{N}_i=-(\beta_{2,i}/\varphi_i) \text{ and } \mathrm{T}_i=-(\beta_{3,i}/\varphi_i)$$

Where: Φ^{+} and Θ^{+} are the long-term effects of the positive partial sums of energy consumption and financial development respectively, and Φ^{-} and Θ^{-} the corresponding long-term effects of their negative partial sums; Γ, N and Υ represent the effects of the gross fixed capital formation, labor force and trade openness on economic growth over the long-term, respectively.

3.3. Methodology and hypotheses development

This part presents two main approaches to examine the asymmetrical effects of energy consumption and financial development on economic growth in the SSA countries. We first performed the country-level methods for each of the twenty-one (21) SSA economies. Next, we applied the panel data techniques on the different groups of countries according to the income classifications as described in section 3.1, as well as on the entire SSA region. The following sections scrutinize the two approaches with more details.

3.3.1 The Country-level Analysis

First, this section begins with the descriptive statistics of variables and the implementation of three well-known unit root tests on each country's variables in order to avoid spurious results in the case of non-stationary variables. Thus, we performed the tests developed by Dickey and Fuller (1981), Phillips and Perron (1988), and Kwiatkowski et al. (1992). The null hypothesis (H_0) of the two first tests supposes that the variables have a unit root at the level, while the alternative hypothesis (H_1) assumes the existence of stationary variables at the first difference. On the contrary, the last test presumes the stationarity of the variables at the level (H_0) against the alternative hypothesis (H_1) of non-stationary variables. The tests were carried out following the Akaike Information Criteria (AIC) with a maximum of 12 lags.

Second, we applied the general-to-specific framework to estimate the NARDL model 3 for each country with a maximum of 6 lags. This technique eliminates the non-significant lagged variables from the model to obtain reliable results. We then examined the existence of a long-term relationship between the variables by using two methods, namely the *t*-test of Banerjee et al. (1998), and the *F*-test by Pesaran et al. (2001). The null hypothesis (H_0) of these tests states that there is no stable relationship (no cointegration) among the variables in the long-term. Thus, the first one (*t*-test) assumes that $\varphi_i = 0$, whereas the unilateral alternative hypothesis $\varphi_i < 0$, while the last one (*F*-test) supposes the null hypothesis

$\varphi_i = \theta_{1,i}^{+} = \theta_{2,i}^{-} = \delta_{1,i}^{+} = \delta_{2,i}^{-} = \beta_{1,i} = \beta_{2,i} = \beta_{3,i} = 0$, against the alternative *hypothesis 1* (H_1) that there

exists a long-term relationship among the variable $\varphi_i \neq \theta_{1,i}^{+} \neq \theta_{2,i}^{-} \neq \delta_{1,i}^{+} \neq \delta_{2,i}^{-} \neq \beta_{1,i} \neq \beta_{2,i} \neq \beta_{3,i} \neq 0$.

In general, there is a long-term relationship between the variables if the calculated coefficients of the t-test and F-test are higher than the upper limit of the critical values in Banerjee et al. (1998) and Pesaran et al. (2001), respectively. Notwithstanding what might be expected, evidence of the absence of long-term co-integration cannot be rejected when the t-statistic and the F-statistic fall below their lower critical limits.

Third, we investigated the asymmetrical relationship between energy consumption, financial development, and economic growth in the long-term by performing Wald tests on the long-term coefficients in the model (3):

Hypothesis 2a: $\Phi_i^{+} = \Phi_i^{-}$, and *Hypothesis 3a*: $\Theta_i^{+} = \Theta_i^{-}$

The *hypothesis 2a* supposes a symmetrical effect of energy consumption on economic growth, while the *hypothesis 3a* assumes that the relationship between financial development and economic growth is symmetrical in the long-term. When the results of Wald tests cannot reject the above hypotheses 2a and 3a of long-term symmetry, the NARDL model (3) is rewritten as follows:

$$\begin{aligned}\Delta \ln \mathrm{GDP}_{i,t} &= \beta_{0,i} + \varphi_i \ln \mathrm{GDP}_{i,t-1} + \theta_i \ln \mathrm{ENC}_{i,t-1} + \delta_i \ln \mathrm{FIN}_{i,t-1} + \beta_{1,i} \ln \mathrm{GFCF}_{i,t-1} + \beta_{2,i} \ln \mathrm{LAB}_{i,t-1} \\ &+ \beta_{3,i} \ln \mathrm{TRADE}_{i,t-1} + \sum_{k=1}^{p1} \omega_{1,ik} \Delta \ln \mathrm{GDP}_{i,t-k} + \sum_{k=0}^{q1} \alpha_{1,ik}^{+} \Delta \ln \mathrm{ENC}_{i,t-k}^{+} + \sum_{k=0}^{q2} \alpha_{2,ik}^{-} \Delta \ln \mathrm{ENC}_{i,t-k}^{-} \\ &+ \sum_{k=0}^{q3} \alpha_{3,ik}^{+} \Delta \ln \mathrm{FIN}_{i,t-k}^{+} + \sum_{k=0}^{q4} \alpha_{4,ik}^{-} \Delta \ln \mathrm{FIN}_{i,t-k}^{-} + \sum_{k=0}^{q5} \alpha_{5,ik} \Delta \ln \mathrm{GFCF}_{i,t-1} + \sum_{k=0}^{q6} \alpha_{6,ik} \Delta \ln \mathrm{LAB}_{i,t-1} + \sum_{k=0}^{q7} \alpha_{7,ik} \Delta \ln \mathrm{TRADE}_{i,t-1} + \mu_{i,t}\end{aligned} \quad (4)$$

Where: equation (4) indicates a model with long-term symmetry and short-term asymmetry.

In this case, $\Phi_i = -(\theta_i / \varphi_i)$ and $\Theta_i = -(\delta_i / \varphi_i)$ are the effects of energy consumption and financial development on economic growth in the long-term, respectively. On the contrary, the short-term symmetry is also tested by Wald tests:

Hypothesis 2b: $\sum_{k=0}^{q1} \alpha_{1,ik}^{+} = \sum_{k=0}^{q2} \alpha_{2,ik}^{-}$, and *Hypothesis 3b:* $\sum_{k=0}^{q3} \alpha_{3,ik}^{+} = \sum_{k=0}^{q4} \alpha_{4,ik}^{-}$

The *hypotheses 2b and 3b* suppose the symmetrical effects of energy consumption and financial development on economic growth in the short-term, respectively. We then estimated the restricted NARDL model (5) for each country where there is only short-term symmetry:

$$\Delta \ln \text{GDP}_{i,t} = \beta_{0,i} + \varphi_i \ln \text{GDP}_{i,t-1} + \theta_{1,i}^{+} \ln \text{ENC}_{i,t-1}^{+} + \theta_{2,i}^{-} \ln \text{ENC}_{i,t-1}^{-} + \delta_{1,i}^{+} \ln \text{FIN}_{i,t-1}^{+} + \delta_{2,i}^{-} \ln \text{FIN}_{i,t-1}^{-} + \beta_{1,i} \ln \text{GFCF}_{i,t-1}$$
$$+ \beta_{2,i} \ln \text{LAB}_{i,t-1} + \beta_{3,i} \ln \text{TRADE}_{i,t-1} + \sum_{k=1}^{p1} \omega_{1,ik} \Delta \ln \text{GDP}_{i,t-k} + \sum_{k=0}^{s1} \pi_{1,ik} \Delta \ln \text{ENC}_{i,t-k} + \sum_{k=0}^{s2} \pi_{2,ik} \Delta \ln \text{FIN}_{i,t-k}$$
$$+ \sum_{k=0}^{s3} \pi_{3,ik} \Delta \ln \text{GFCF}_{i,t-k} + \sum_{k=0}^{s4} \pi_{4,ik} \Delta \ln \text{LAB}_{i,t-k} + \sum_{k=0}^{s5} \pi_{5,ik} \Delta \ln \text{TRADE}_{i,t-k} + \nu_{i,t} \quad (5)$$

Where: Equation (5) describes the long-term asymmetry between energy consumption, financial development and economic growth associated with short-term symmetry.

Besides, the restricted Model (6) represents the case where the hypothesis of symmetry cannot be rejected both in the short and long-term:

$$\Delta \ln \text{GDP}_{i,t} = \beta_{0,i} + \varphi_i \ln \text{GDP}_{i,t-1} + \theta_i \ln \text{ENC}_{i,t-1} + \delta_i \ln \text{FIN}_{i,t-1} + \beta_{1,i} \ln \text{GFCF}_{i,t-1} + \beta_{2,i} \ln \text{LAB}_{i,t-1}$$
$$+ \beta_{3,i} \ln \text{TRADE}_{i,t-1} + \sum_{k=1}^{p1} \omega_{1,ik} \Delta \ln \text{GDP}_{i,t-k} + \sum_{k=0}^{u1} \gamma_{1,ik} \Delta \ln \text{ENC}_{i,t-k} + \sum_{k=0}^{u2} \gamma_{2,ik} \Delta \ln \text{FIN}_{i,t-k}$$
$$+ \sum_{k=0}^{u3} \gamma_{3,ik} \Delta \ln \text{GFCF}_{i,t-k} + \sum_{k=0}^{u4} \gamma_{4,ik} \Delta \ln \text{LAB}_{i,t-k} + \sum_{k=0}^{u5} \gamma_{5,ik} \Delta \ln \text{TRADE}_{i,t-k} + \xi_{i,t} \quad (6)$$

Next, we recursively obtained the dynamic multipliers depicting the asymmetrical responses of economic growth (GDP) to positive and negative changes in energy consumption and financial development over time, respectively.

Based on the results of the symmetry tests, we followed the procedure in Shin et al. (2014) after the estimation of the suitable NARDL models for each country:

$$dmENC_{i,k}^{+} = \sum_{k=0}^{\tau} \frac{\partial \Delta \ln GDP_{i,t+k}}{\partial \Delta \ln ENC_{i,t-1}^{+}} \quad , dmENC_{i,k}^{-} = \sum_{k=0}^{\tau} \frac{\partial \Delta \ln GDP_{i,t+k}}{\partial \Delta \ln ENC_{i,t-1}^{-}}, \quad \tau = 0,1,2,3...$$

$$dmFIN_{i,k}^{+} = \sum_{k=0}^{\tau} \frac{\partial \Delta \ln GDP_{i,t+k}}{\partial \Delta \ln FIN_{i,t-1}^{+}} \quad , dmFIN_{i,k}^{-} = \sum_{k=0}^{\tau} \frac{\partial \Delta \ln GDP_{i,t+k}}{\partial \Delta \ln FIN_{i,t-1}^{-}}, \quad \tau = 0,1,2,3...$$

Where: $s \to \infty, dmENC_{i,k}^{+} \to \Phi^{+}, dmFIN_{i,k}^{+} \to \Theta^{+}$ and $dmENC_{i,k}^{-} \to \Phi^{-}, dmFIN_{i,k}^{-} \to \Theta^{-}$ with Φ^{+} and Φ^{-} are the coefficients for the positive and negative levels of energy consumption in the long-term, respectively, while Θ^{+} and Θ^{-} denote the similar levels for financial development·

Finally, this section examined the direction of causality between energy consumption, financial development and economic growth in each of the 21 SSA countries. We implemented the procedure developed by Toda and Yamamoto (1995) because of its main advantages over other methods. This approach does not require variables to be stationary in the same order or co-integrated. Thus, it overcomes the concerns raised by non-stationarity and cointegration issues to provide reliable tests of assumptions about causality between variables. The procedure of Toda and Yamamoto (1995) estimates an augmented VAR model with variables in levels which are robust to the integration and cointegration properties of the series at an arbitrary order. This method supplements the correct VAR of order (k) with the maximum order of integration (m). Thus, the $(k + m)^{th}$ vector of the VAR is added as exogenous variables to the correct VAR of order k (Zapata and Rambaldi, 1997).

This Granger non-causality test of Toda and Yamamoto (1995) derives from the following VAR (k) models:

$$\ln GDP_t = \delta_0 + \sum_{i=1}^{k} \delta_{1i} \ln GDP_{t-i} + \sum_{j=k+1}^{m} \delta_{2j} \ln GDP_{t-j} + \sum_{i=1}^{k} \eta_{1i} \ln \mathrm{Z}_{t-i} + \sum_{j=k+1}^{m} \eta_{2j} \ln \mathrm{Z}_{t-j} + \varepsilon_{1t} \quad (7)$$

$$\ln \mathrm{Z}_t = \omega_0 + \sum_{i=1}^{k} \omega_{1i} \ln \mathrm{Z}_{t-i} + \sum_{j=k+1}^{m} \omega_{2j} \ln \mathrm{Z}_{t-j} + \sum_{i=1}^{k} \sigma_{1i} \ln \mathrm{GDP}_{t-i} + \sum_{j=k+1}^{m} \sigma_{2j} \ln \mathrm{GDP}_{t-j} + \varepsilon_{2t} \quad (8)$$

Where: $Z_t = \{\ln \mathrm{ENC}_t^+, \ln \mathrm{ENC}_t^-, \ln \mathrm{ENC}_t, \ln \mathrm{FIN}_t^+, \ln \mathrm{FIN}_t^-, \ln \mathrm{FIN}_t, \ln \mathrm{GFCF}_t, \ln \mathrm{LAB}_t, \text{or} \ln \mathrm{TRADE}_t\}$,

k and m are the optimal lag following the Akaike Information Criterion (AIC) and the maximum order of integration, respectively.

The causality analysis is then carried out by performing a modified Wald test on the coefficients of the endogenous lagged variables of the above-estimated VAR (k). The null hypothesis (H_0) of non-causality running from $\ln Z_t$ to $\ln GDP_t$ supposes H_0: $\eta_{1i} = 0$, while the non-causality from $\ln GDP_t$ to $\ln Z_t$ assumes H_0: $\sigma_{1i} = 0$. In other words, there is Granger causality (*hypothesis 4*) from $\ln Z_t$ to $\ln GDP_t$ if $\eta_{1i} \neq 0$, but the Granger causality from $\ln GDP_t$ to $\ln Z_t$ (*hypothesis 5)* implies $\sigma_{1i} \neq 0$.

3.3.2. The Panel data Analysis

This section details the methods used to analyze the asymmetrical relationship between energy consumption, financial development and economic growth in each of the three categories of countries according to the classification by income, as described above: lower-income countries, lower-middle-income countries, upper-middle-income countries; but also in the entire SSA countries.

As a starting point, we performed four-panel unit root tests, after presenting the descriptive statistics of the variables. Thus, we used the tests developed by Dickey and Fuller (1981), Phillips and Perron (1988), Im et al. (2003) and Levin et al. (2002). The first three tests suppose an individual unit root process, but the latter assumes a common unit root process. The null hypothesis (H_0) of these four tests presumes the non-stationarity of the variable, whereas the alternative hypothesis (H_1) indicates that the variable is stationary.

Besides, we implemented two-panel cointegration techniques; namely, Pedroni (1999, 2001) and Fisher-Johansen tests (Maddala and Wu, 1999), to re-examine whether there is a long-term relationship between the variables in the different sub-groups of countries, as well as in the SSA region. Pedroni (1999) proposed seven tests for the case of multivariate models allowing for heterogeneous panels in the long-term cointegrating vectors, but also in the short-term dynamics. The tests are divided into two categories: the panel cointegration statistics (pooling along the within-dimension) and the group mean statistics (pooling along the between-dimension). The former includes three non-parametric statistics; namely, the variance ratio (v), the *rho*-statistic (Pedroni, 1997a), the *t*-statistic (similar to Phillips and Perron, 1988), and a parametric augmented Dickey and Fuller *t*-statistic (*adf*). The between-dimension category is made up of three statistics: the *rho* and *t* statistics in Phillips and Perron (1988), and the *t*-statistic (*adf*) in Dickey and Fuller (1981). The detailed documentation about these tests is available in the study by Pedroni (1999). The between-dimension tests are based on the average of the estimates for each country *i*, whereas the within-dimension tests pool the autoregressive coefficient from the heterogeneous panel units to examine the stationarity of the estimated residuals. The null hypothesis (H_0) of these tests supposes that there is no cointegration between the variables. However, the alternative *hypothesis 6* of cointegration assumes a common autoregressive coefficient across individuals for the within-dimension tests, but individual autoregressive coefficients for each country for the between-dimension. Besides, we also applied the trace test in the Fisher-Johansen panel cointegration method. Following Fisher (1932), Maddala and Wu (1999) combined the results from the individual tests in Johansen (1998) to derive a test statistic for the panel. The null hypothesis of the test is that there is at most *r* co-integrating vector (from *r* = 0 to *r* = *n-1,* where *n* is the number of endogenous variables).

Moreover, we employed two commonly used methods to estimate the panel coefficients in the presence of cointegration: the Fully Modified Ordinary Least Squares (FMOLS) and the Dynamic Ordinary Least Squares (DOLS) estimators. The FMOLS approach, developed by Phillips and Hansen (1990), is a non-parametric technique used in the case of I(1) and co-integrated variables to obtain asymptotically normal and unbiased long-term estimates due to the endogeneity and serial correlation problems. Many studies provided evidence of the superiority of FMOLS estimator over OLS method (Li and Maddala, 1997; Khalaf and Urga, 2014, among others). The FMOLS method assumes only a single co-integrating vector, and there is no cointegration among the explanatory variables themselves.

Following Pedroni (2001), we consider the panel co-integrated system, hereafter:

$$\begin{aligned} \ln GDP_{it} &= \delta_i + \gamma X_{it} + v_{it} \\ X_{it} &= X_{it-1} + \zeta_{it} \end{aligned} \qquad (9)$$

Where $X_{it} = (\text{lnENC}^{+}_{it}, \text{lnENC}^{-}_{it}, \text{lnFIN}^{+}_{it}, \text{lnFIN}^{-}_{it}, \text{lnGFCF}_{it}, \text{lnLAB}_{it}, \text{lnTRADE}_{it})'$, $(v_{it}, \zeta_{it})'$ is a stationary vector error with an asymptotic covariance matrix $\Pi_i = \begin{bmatrix} \Pi_{11i} & \Pi'_{21i} \\ \Pi_{21i} & \Pi_{22i} \end{bmatrix}$, Π_{11i} is the long-term variance of v_{it}; Π_{21i} is the 7x1 vector of the covariance between each of the ζ_{it} and v_{it}; Π_{22i} is the 7x7 long-term covariance between the ζ_{it}. $\Pi_i = \Pi^0_i + \Gamma_i + \Gamma'_i$, Π^0_i is the contemporaneous covariance and Γ_i is the weighted sum of autocovariances.

Let denotes Λ_i the lower triangular matrix of Π_i, and its components by:

$$\Lambda_{11i} = (\Pi_{11i} - \Pi^2_{21i} / \Pi_{22i})^{1/2}, \Lambda_{12i} = 0, \Lambda_{21i} = \Pi_{21i} / \Pi^{1/2}_{22i}, \Lambda_{22i} = \Pi^{1/2}_{22i}$$

Therefore, the pooled panel FMOLS estimator by Pedroni (2001) is given by:

$$\hat{\gamma} = \left(\sum_{i=1}^{N} \hat{\Lambda}_{22i}^{-2} \sum_{t=1}^{T} (X_{it} - \overline{X_i})^2\right)^{-1} \sum_{i=1}^{N} \hat{\Lambda}_{11i}^{-1} \hat{\Lambda}_{22i}^{-1} \left(\sum_{t=1}^{T} (X_{it} - \overline{X}_i) \ln GDP_{it}^{*} - T \hat{\lambda}_i\right) \quad (10)$$

Where: $\ln GDP_{it}^{*} = (\ln GDP_{it} - \overline{\ln GDP_i}) - \frac{\hat{\Lambda}_{21i}}{\hat{\Lambda}_{22i}} \Delta X_{it} + \frac{\hat{\Lambda}_{11i} - \hat{\Lambda}_{22i}}{\hat{\Lambda}_{22i}} \gamma (X_{it} - \overline{X}_i)$

$$\hat{\lambda}_i \equiv \hat{\Gamma}_{21i} + \hat{\Pi}^{o}_{21i} - \frac{\hat{\Lambda}_{21i}}{\hat{\Lambda}_{22i}} (\hat{\Gamma}_{22i} + \hat{\Pi}^{o}_{22i})$$

However, the DOLS technique proposed by Saikkonen (1991) relies on parametric regressions and includes the lags and leads of the first-differenced variables as regressors. The estimated coefficients by DOLS are obtained through the following regression, as suggested in Kao and Chiang (2001):

$$\ln GDP_{it} = \beta_i + X'_{it} \gamma + \sum_{j=-q}^{q} d_{ij} \Delta X_{it+j} + \sum_{|j|>q} d_{ij} \zeta_{it+j} + \mu_i \quad (11)$$

where: $v_{it} = \sum_{j=-\infty}^{\infty} d_{it} \zeta_{it+j} + \mu_i$ and $\sum_{j=-\infty}^{\infty} \|d_{ij}\| < \infty$

The FMOLS and DOLS methods generally perform better than OLS technique because they consider the endogeneity and small sample biases. However, the DOLS estimator outperforms the FMOLS estimator because DOLS is less biased, does not needs to employ a kernel estimator for the covariance matrix, as well as the non-parametric methods in heterogeneous panel (Kao and Chiang, 2001). For both the FMOLS and DOLS estimators, we alternatively implemented the homogeneous and heterogeneous panel approaches. The former uses the standard FMOLS and DOLS on the pooled sample after eliminating the deterministic components from the variables, whereas the latter considers the heterogeneity across panel units by weighting the individual estimates to compute the panel FMOLS and DOLS estimates.

Next, we performed the panel symmetry tests on the estimated coefficients of the positive changes $lnENC^{+}$ ($\ln FIN^{+}$) and negative changes $\ln ENC^{-}$ ($\ln FIN^{-}$) of energy consumption and financial development from the results of the FMOLS and DOLS estimators. Thus, we used the Wald tests and presented the appropriate models for a better analysis of the asymmetrical effects of energy consumption and financial development on the economic growth of each category of countries. The null hypothesis of the Wald test assumes symmetrical relationships between the variables, contrary to the alternative *hypothesis 7* of asymmetrical relationships among the variables.

Furthermore, we applied the pooled mean group estimator (PMG) developed by Pesaran and Smith (1995) and Pesaran et al. (1999) to analyze the asymmetrical effects of energy consumption and financial development on economic growth over the short and long-term. We used this estimator on the NARDL model (3) to allow the intercept and short-term coefficients, including the error term, to differ across countries, while imposing the long-term coefficients to be homogeneous for each country. Many reasons can justify the long-term constraint such as the standard technologies, budget constraints, monetary and economic unions across countries. Thus, this estimator uses the pooling and averaging of the individual coefficients to obtain the panel coefficients as follows:

Long-term homogeneity: $\hat{\phi}_i = -\hat{\beta}_i / \hat{\varphi}_i$, and $\hat{\phi}_i = \phi$ for i=1, 2, …, N

Short-term heterogeneity (averaging of the coefficients): $\hat{\lambda}_{MG} = N^{-1}\sum_{i=1}^{N}\hat{\lambda}_i$

Where $\hat{\phi}_i$ and $\hat{\lambda}_i$ are the long-term and the short-term estimates for each country i, respectively.

We performed the Wald tests again on these coefficients to analyze the asymmetrical relationship between the variables.

Finally, we examined the direction of causality between energy consumption, financial development and economic growth for each group of countries by implementing the Granger non-causality tests in Dumitrescu and Hurlin (2012). It is a technique that employs a simple Granger (1969) non-causality test in the context of heterogeneous panel models with fixed coefficients. This method considers the heterogeneity of the causal relationship between two variables, as well as that of the regression model across countries, to perform the Granger causality test. The null hypothesis of the test assumes that there is no causal relationship between two variables for any of the panel units (H_0^8: *homogeneous non-causality*), whereas the alternative *hypothesis 8* (H_1^8: *heterogeneous non-causality*) indicates a causal relationship from one variable to another for a subgroup of the panel units, at least one country of the panel under consideration. The non-causality test by Dumitrescu and Hurlin(2012) is applied to the following linear model:

$$y_{it} = \lambda_i + \sum_{p=1}^{P}\omega_i^{(p)} y_{i,t-p} + \sum_{p=1}^{P}\gamma_i^{(\mathrm{p})} x_{i,t-p} + \varepsilon_{i,t} \qquad (12)$$

Where: $P \in \mathbb{N}^*$ and $\gamma_i = (\gamma_i^{(1)},...,\gamma_i^{(\mathrm{P})})'$, the autoregressive coefficients $\omega_i^{(p)}$ and $\gamma_i^{(\mathrm{p})}$ can differ across countries. y_i and x_i are the dependent and independent variables, respectively. The hypotheses of the test can be formulated as follows:

$$H_0 : \gamma_i = 0, \forall i = 1,..., N$$

$$H_1 : \gamma_i = 0, \forall i = 1,..., N_1$$
$$\gamma_i \neq 0, \forall i = N_1 + 1, N_1 + 2,..., N$$

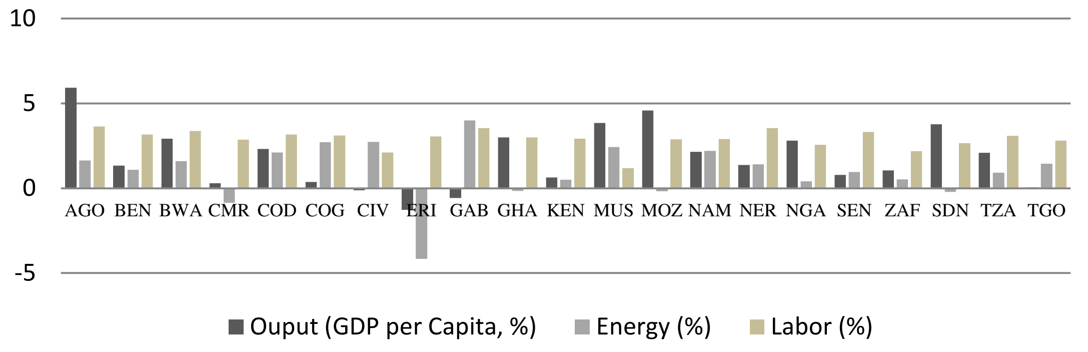
Where: the null hypothesis (H_0^8) supposes no causality from x to y across panel units, whereas, the alternative *hypothesis 8* (H_1^8) assumes that there is Granger causality from x to y for at least a subgroup of the panel.
The test used the average of the standard Wald statistics of each country for the Granger non-causality tests.

4. Results and Discussions

4.1. Results of the Country-level Analysis

This part starts with the results of the descriptive analysis of the variables by country in order to highlight the different economic characteristics from one country to another. Thus, Table 1 presents the descriptive statistics of the variables for each of the 21 SSA countries from 1990Q1 to 2014Q4. The income per capita (output) is higher in Gabon (10124.160 $), following by South Africa (6361.056$), Mauritius (6056.155$, associated with the highest income's volatility) and Botswana (5330.827$).

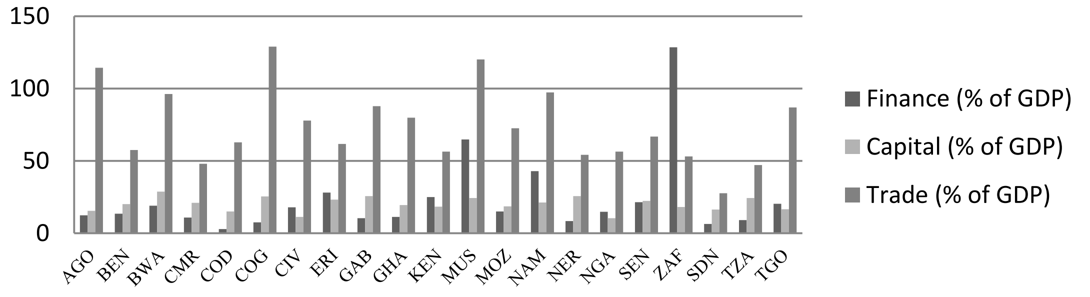
Figure 1: Average growth rates of Output , Energy and Labor force



Note: The horizontal axis denotes the countries as coded in Table 1, but the vertical one represents the average growth rates, expressed in percentage.

However, the lowest income (GDP) per capita has been recorded in Mozambique (303.161$), the Democratic Republic of Congo (319.899$) and Niger (342.517$). Besides, the income per capita has substantially increased in Angola (5.91%), Mozambique (4.59%), Mauritius (3.85%) and Sudan (3.76%), whereas it has declined in Eritrea by 1.27%, in Gabon and Cote d'Ivoire, respectively by 0.57% and 0.12%. Figure 1 shows the average growth in per capita income, energy consumption, and labor force. Energy consumption increased slightly in 16 countries, ranging from 0.40% (Nigeria) to 3.99% (Gabon), but decreased in the remaining five (5) countries, notably in Eritrea (-4.16%).

Figure 2: Average growth rates from 1990Q1 to 2014Q4



Note: See Figure 1

On average, the labor force has increased by more than 3% in most countries, ranging from 3.63% (Angola) to 1.18% (Mauritius). The financial system is further strengthened in South Africa where about 128.57% of the revenue generated by the economy has been allocated to the private sector in the form of domestic credit. However, the financial sector is less developed in the Democratic Republic of Congo, which is also one of the countries with the lowest per capita income growth. Figure 2 provides an overview of the disparity in financial depth, capital formation and trade openness between countries. Botswana has invested more in gross fixed capital formation (28.85%) than other countries, unlike Nigeria (10.46%). Global trade played an essential role in the economy of the Republic of Congo (129.14%), Mauritius (120.24%) and Angola (114.37%). However, Sudan remained the least open-economy in terms of globalization (27.70%) from 1990Q1 to 2014Q4.

Table 1. Descriptive statistics

		Output (US $)			Energy			Finance		Capital		Labor			Trade	
Country	Period	Mean	Std.Dev	Growth (%)	Mean	Std.Dev	Growth (%)	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	Growth (%)	Mean	Std.Dev
Angola (AGO)	2000Q1–2014Q4	2863.678	795.420	5.917	485.998	40.804	1.644	12.564	8.034	15.603	5.844	8704003	1356813	3.634	114.378	19.776
Benin (BEN)	1990Q1–2014Q4	703.076	65.165	1.325	347.688	36.804	1.086	13.465	5.438	20.267	4.469	2951458	649809	3.170	57.636	7.351
Botswana (BWA)	1990Q1–2014Q4	5330.827	1096.427	2.920	1009.408	87.550	1.594	19.202	7.192	28.851	3.270	708839	160135	3.366	96.336	9.575
Cameroon (CMR)	1990Q1–2014Q4	1230.177	105.314	0.291	387.472	34.013	-0.860	10.817	5.115	21.055	2.503	6968878	1424126	2.864	48.178	8.073
Congo D.R (COD)	2000Q1–2014Q4	319.899	35.712	2.307	320.193	32.958	2.107	2.896	1.954	15.188	6.344	23115049	3170539	3.166	62.976	19.603
Congo R. (COG)	1990Q1–2014Q4	2542.995	173.884	0.367	329.115	100.577	2.709	7.649	4.349	25.621	7.781	1400242	316990	3.101	129.145	25.417
Cote d'Ivoire(CIV)	1990Q1–2014Q4	1293.505	81.599	-0.121	450.286	88.027	2.735	17.901	7.344	11.416	2.806	6164839	817966	2.101	77.964	11.992
Eritrea (ERI)	1996Q1–2010Q4	559.234	49.200	-1.271	210.213	51.933	-4.165	28.180	7.532	23.216	10.346	1714569	241172	3.054	61.855	26.734
Gabon (GAB)	1990Q1–2014Q4	10124.160	1039.133	-0.577	1830.421	661.766	3.999	10.365	25.766	25.766	4.577	391683	102932	3.543	87.965	7.705
Ghana (GHA)	1990Q1–2014Q4	1094.650	249.490	2.988	335.967	45.440	-0.162	11.364	4.658	19.498	5.038	9040571	1952911	3.002	80.043	18.943
Kenya (KEN)	1990Q1–2014Q4	900.779	70.114	0.638	451.905	17.081	0.501	25.064	3.816	18.446	2.105	12786996	2472692	2.930	56.564	6.988
Mauritius (MUS)	1990Q1–2014Q4	6056.155	1663.897	3.856	868.123	162.149	2.438	64.874	20.845	24.348	2.901	526190	40241	1.187	120.249	7.690
Mozambique(MOZ)	1990Q1–2014Q4	303.161	105.474	4.591	409.131	13.544	-0.169	15.003	6.619	18.601	8.332	8892650	1722646	2.887	72.635	20.744
Namibia (NAM)	1991Q1–2014Q4	4350.258	769.486	2.137	618.914	80.776	2.196	42.945	6.881	21.326	4.222	670416	123967	2.902	97.528	10.759
Niger (NER)	2000Q1–2014Q4	342.517	18.996	1.365	131.261	9.803	1.410	8.495	3.611	25.708	10.288	5938175	899760	3.538	54.167	10.346
Nigeria (NGA)	1990Q1–2014Q4	1701.214	477.367	2.803	729.241	32.713	0.404	14.987	7.011	10.461	3.326	40570695	7360848	2.558	56.503	14.627
Senegal (SEN)	1990Q1–2014Q4	907.460	77.896	0.789	246.338	28.792	0.951	21.479	5.752	22.357	2.661	3166927	761998	3.314	66.805	7.447
South Africa (ZAF)	1990Q1–2014Q4	6361.056	775.907	1.050	2539.191	164.753	0.520	128.573	20.168	18.169	2.169	16620124	2455861	2.178	53.178	9.221
Sudan (SDN)	1990Q1–2014Q4	1176.057	334.459	3.767	384.656	17.114	-0.219	6.586	4.143	16.447	5.378	7999246	1324349	2.664	27.706	10.532
Tanzania (TZA)	1990Q1–2014Q4	576.657	111.936	2.084	411.515	39.372	0.927	9.240	3.565	24.342	5.967	16918494	3642396	3.090	47.294	8.895
Togo (TGO)	1990Q1–2014Q4	499.139	31.686	0.056	408.555	46.808	1.453	20.452	7.269	16.622	3.825	2413515	486899	2.799	86.987	16.627

Note: The variables are described in section 3.1. *Mean* and *Std.Dev* denote the average values and standard deviations of the variables, respectively, whereas *Growth* is the average growth rate of variables.

Furthermore, Table 2 reports the results of the stationarity analysis for each variable by country. We performed the three unit root tests by Dickey and Fuller (1981), Phillips and Perron (1988), and Kwiatkowski et al. (1992), as described in Section 3.3.1, using a model with constant and no trend. In most cases, we found that the variables are not stationary at the level, but have become so after the first difference at the 1% significance level. Thus, the NARDL framework can be applied to examine the cointegration between the variables because none of them is I (2) or integrated at order 2.

Next, we analyzed whether there was a long-term relationship between the variables based on the unrestricted NARDL (3) and the restricted NARDL models (4), (5) and (6). Following the NARDL model (3), Table 3 shows that the calculated t_{BDM} or F_{PSS} statistics are higher than the upper limit of the corresponding critical values in Banerjee et al. (1998) and Pesaran et al. (2001) in the case of 10 SSA countries. The results of the restricted NARDL models (4-6) also corroborate this finding. Therefore, we cannot reject the alternative *hypothesis 1* and conclude that there is a long-term relationship between the variables in these ten (10) countries, namely in Angola, the Democratic Republic of Congo, Côte d'Ivoire, Gabon, Ghana, Mauritius, Namibia, Sudan, and Tanzania. In other words, there is a cointegration relationship between financial development, energy consumption, and long-term economic growth only in these ten (10) countries.

Also, the study of asymmetrical relationships between financial development, energy consumption, and economic growth was conducted following Wald tests from the estimation of the NARDL model (3), as highlighted in section 3.3.1. This test examined whether the estimated coefficients of the positive and negative sums of financial development and energy consumption have similar effects on economic growth in the short or long-term. In most cases, Table 4 showed that the Wald tests were significant at the 1% level in the case of financial development and energy consumption in the short-term (rejection of *hypotheses 2b and 3b*) and long-term (rejection of *hypotheses 2a and 3a*) for four (4) countries (Cameroon, the Democratic Republic of Congo, Cote d'Ivoire, and Ghana). Thus, financial development and energy consumption have asymmetrical effects on economic growth in Cameroon, the Democratic Republic of Congo, Cote d'Ivoire, and Ghana, both in the short and long-term. Similarly, we found only five (5) cases of asymmetry in the short-term coefficients of financial development and energy consumption (rejection of *hypotheses 2b and 3b*). In other words, there is an asymmetrical relationship between financial development and economic growth, and between energy consumption and economic growth only in the short-term in Angola, Botswana, Eritrea, Niger, and Nigeria. Table 4 revealed the asymmetrical relationship between financial development, energy consumption, and econometric growth only in the long-term in Gabon. There was an only short-term asymmetry between energy consumption and economic growth in Benin and Senegal, while only financial development has an asymmetrical effect on economic growth in the short-term in Kenya.

Table 2. Unit root tests

		lnGDP			lnENC			lnFIN			lnGFCF			lnLAB			lnTRADE		
Countries	Hypo.	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS
Angola	H_0:I(0)	-1.854	-1.178	0.883	-0.680	-0.647	0.881	-1.823	-2.549	0.940	-2.473	-2.493	0.190***	0.102	0.128	0.964	-0.219	0.066	0.908
	H_0:I(1)	-1.788	-8.415***	0.177***	-7.815***	-7.829***	0.071***	-3.797***	-8.562***	0.304***	-7.516***	-7.516***	0.160***	-3.220**	-32.547***	0.274***	-7.929***	-7.959***	0.147***
Benin	H_0:I(0)	0.274	0.491	1.198	-0.739	-0.746	0.746	-1.085	-1.094	0.661***	-1.557	-1.557	0.882	-0.908	-1.067	1.217	-1.754	-1.813	0.236***
	H_0:I(1)	-3.515***	-11.102***	0.121***	-9.862***	-9.862***	0.149***	-9.799***	-9.799***	0.386***	-9.981***	-9.981***	0.065***	-1.670	-23.127***	0.138***	-9.833***	-9.833***	0.084***
Botswana	H_0:I(0)	-0.011	0.412	1.207	-0.804	-0.804	0.994	-0.799	-0.987	1.120	-1.870-	-1.912	0.488***	0.278	0.869	1.207	-1.882	-1.955	0.388***
	H_0:I(1)	-10.790***	-11.305***	0.101***	-9.983***	-9.984***	0.082***	-3.429**	-10.232***	0.066***	-9.800***	-9.800***	0.154***	-3.406**	-20.773***	0.192***	-9.800***	-9.800***	0.088***
Cameroon	H_0:I(0)	-0.927	-0.458	0.780	-0.053	-0.634	0.985	-0.761	-2.555	0.229***	-1.672	-1.680	0.907	1.528	0.301	1.217	-2.453	-2.506	0.882
	H_0:I(1)	-2.792*	-9.809***	0.786	-4.687***	-10.005***	0.110***	-5.036***	-9.844***	0.741	-5.652***	-9.868***	0.047***	-1.489	-26.478***	0.081***	-9.820***	-9.820***	0.057***
Congo Dem. Rep	H_0:I(0)	0.942	3.131	0.915	0.055	0.192	0.689	-1.404	-0.605	0.866	-0.989	-1.539	0.709	1.051	0.595	0.964	-2.445	-2.443	0.686
	H_0:I(1)	-2.895*	-8.413***	0.392***	-7.786***	-7.790***	0.250***	-3.078**	-7.893***	0.123***	-4.883***	-7.498***	0.092***	-2.741*	-28.991***	0.314***	-7.576***	-7.576***	0.247***
Congo Rep	H_0:I(0)	-0.539	-0.547	0.446***	0.102	0.114	0.703***	-1.256	-1.263	0.398***	-2.060	-2.152	0.114***	-1.114	-0.396	1.215	-2.312	-2.312	0.600***
	H_0:I(1)	-9.818***	-9.818***	0.539***	-9.900***	-9.900***	0.473***	-9.798***	-9.798***	0.525***	-9.856***	-9.856***	0.103***	-1.796	-20.745***	0.102***	-9.923***	-9.923***	0.121***
Cote d'Ivoire	H_0:I(0)	-1.961	-1.802	0.645***	-0.784	-0.784	1.117	-2.425	-2.252	0.560***	-1.235	-1.257	0.208***	-0.538	-3.032**	1.169	-1.800	-1.711	0.516***
	H_0:I(1)	-3.084**	-9.804***	0.381***	-9.960***	-9.960***	0.047***	-1.916	-9.894***	0.703***	-9.894***	-9.894***	0.137***	-2.415	-12.356***	0.385***	-4.130***	-9.800***	0.456***
Eritrea	H_0:I(0)	-0.375	-0.366	0.837	-2.188	-2.207	0.796	-0.380	-0.364	0.852	0.325	-0.618	0.849	-1.597	-0.880	0.954	-1.255	-1.321	0.876
	H_0:I(1)	-7.642***	-7.643***	0.149***	-7.752***	-7.755***	0.163***	-7.708***	-7.710***	0.107***	-6.331***	-7.606***	0.109***	-1.498	-10.864***	0.196***	-2.531	-7.874***	0.157***
Gabon	H_0:I(0)	-1.090	-1.090	1.001	-0.593	-0.587	1.057	-2.076	-2.176	0.140***	-1.509	-1.896	0.373***	0.415	2.754	1.205	-1.856	-1.957	0.277***
	H_0:I(1)	-9.866***	-9.866***	0.139***	-1.686	-9.977***	0.110***	-9.799***	-9.799***	0.151***	-4.442***	-9.850***	0.069***	-1.167	-16.022***	0.518***	-9.803***	-9.803***	0.164***
Ghana	H_0:I(0)	0.978	2.724	1.136	-1.118	-1.123	0.667***	-0.943	-0.926	1.069	-2.303	-2.380	0.332***	-0.538	0.051	1.217	-2.273	-2.272	0.458***
	H_0:I(1)	-2.498	-11.626***	0.324***	-9.805***	-9.805***	0.217***	-10.083***	-10.085***	0.065***	-9.801***	-9.801***	0.083***	-1.401	-24.078***	0.082***	-9.943***	-9.943***	0.181***
Kenya	H_0:I(0)	0.112	1.090	0.693***	1.468	0.994	0.659***	-1.508	-1.517	0.952	-1.708	-1.793	0.513***	0.224	-0.560	1.201	-1.871	-1.992	0.294***
	H_0:I(1)	-2.934**	-9.939***	1.012	-3.024**	-9.922***	0.584***	-6.776***	-9.948***	0.042***	-4.715***	-9.802***	0.191***	-1.644	-15.434***	0.117***	-9.816***	-9.816***	0.096***

Table 2. Unit root tests (Cont.)

		lnGDP			lnENC			lnFIN			lnGFCF			lnLAB			lnTRADE		
Countries	Hypo.	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS
Mauritius	H_0:I(0)	-0.048	-0.170	1.214	-0.848	-0.792	1.196	-1.217	-1.237	1.189	-1.177	-1.916	0.850	-0.432	-1.256	1.181	-2.015	-2.105	0.743
	H_0:I(1)	-2.588*	-19.999***	0.078***	-2.187	-11.611***	0.142***	-10.556***	-10.629***	0.083***	-7.546***	-9.917***	0.048***	-2.278	-14.050***	0.175***	-9.837***	-9.837***	0.037***
Mozambique	H_0:I(0)	-1.323	-0.054	1.191	-1.612	-2.449	0.226***	-0.229	-0.229	0.631***	-1.053	-1.122	0.405***	1.722-	-3.430**	1.205	-0.975	-0.975	0.846
	H_0:I(1)	-2.423	-11.231***	0.106***	-1.839	-9.824***	0.780	-9.842***	-9.842***	0.485***	-9.823***	-9.823***	0.251***	-1.512	-15.120***	0.460***	-9.899***	-9.899***	0.078***
Namibia	H_0:I(0)	0.390	1.096	1.206	-1.073	-1.217	1.225	-1.214	-6.117***	0.932	-1.527	-1.527	1.089	0.340	-0.778	1.296	-1.912	-1.753	0.475***
	H_0:I(1)	-2.319	-10.495***	0.410***	-6.502***	-10.018***	0.053***	-5.798***	-9.900***	0.477***	-6.317***	-9.800***	0.062***	-1.785***	-16.452***	0.131***	-3.867***	-9.609***	0.064***
Niger	H_0:I(0)	0.664	-0.289	0.799	-1.439	-1.799	0.302***	-0.946	-0.946	0.796	-1.597	-1.455	0.910	2.052	0.575	0.964	-1.530	-1.265	0.753
	H_0:I(1)	-1.759	-7.756***	0.134***	-7.412***	-7.517***	0.100***	-7.633***	-7.633***	0.081***	-2.856*	-8.372***	0.255***	-0.841	-32.244***	0.314***	-2.461	-7.630***	0.188***
Nigeria	H_0:I(0)	0.116	0.529	1.068	-1.236	-1.242	0.965	-2.273	-2.330	0.449***	-1.628	-1.610	0.313***	1.578	0.260	1.217	0.199	-0.629	0.620***
	H_0:I(1)	-3.718***	-10.267***	0.415***	-9.863***	-9.863***	0.058***	-4.296***	-9.810***	0.070***	-2.208	-9.798***	0.234***	-1.605	-26.626***	0.068***	-6.473***	-9.896***	0.184***
Senegal	H_0:I(0)	0.026	0.095	1.119	-1.017	-1.017	1.016	-0.768	-0.778	0.470***	-1.611	1.966	1.021	0.485	1.352	1.199	-2.635*	-2.307	0.956
	H_0:I(1)	-10.161***	-10.166***	0.276***	-9.864***	-9.864***	0.080***	-9.810***	-9.810***	0.439***	-7.430***	-9.872***	0.034***	-1.483	-15.399***	0.279***	-5.806***	-9.852***	0.030***
South Africa	H_0:I(0)	-0.612	0.466	1.106	-1.393	-1.407	0.880	-1.451	-1.449	1.363	-1.982	-1.525	0.449***	-1.518	-2.527	1.201	1.065	-1.711	1.065
	H_0:I(1)	-2.812*	-10.273***	0.489***	-9.830***	-9.830***	0.058***	-9.617***	-9.67***	0.052***	-3.273**	-9.798***	0.305***	-2.988**	-12.745***	0.329***	0.072***	-9.927***	0.072***
Sudan	H_0:I(0)	2.926	1.488	1.192	-1.564	-3.045**	0.793	-0.778	-0.778	0.812	-1.508	-1.970	0.770	-0.576	-2.996**	1.188	-1.604	-1.613	0.586***
	H_0:I(1)	-3.222**	-13.387***	0.500***	-5.639***	-9.809***	0.042***	-9.808***	-9.808***	0.282***	-6.791***	-9.806***	0.076***	-2.584	-12.522***	0.371***	-9.802***	-9.802***	0.266***
Tanzania	H_0:I(0)	-0.043	1.313	1.132	-0.453	-0.453	1.117	-1.535	-1.158	0.400***	-0.807	-0.814	0.546***	0.760	-0.038	1.216	-1.696	-1.739	0.182***
	H_0:I(1)	-1.994	-11.104***	0.432***	-2.838*	-2.838*	0.331***	-3.579***	-9.797***	0.409***	-9.814***	-9.814***	0.281***	-2.080	-24.298***	0.055***	-9.798***	-9.798***	0.093***
Togo	H_0:I(0)	-2.367	-2.449	0.076***	-1.509	-1.507	1.006	-1.102	-1.121	0.309***	-1.250	-2.206	0.403***	-1.108	-0.811	1.214	-0.989	-0.995	1.031
	H_0:I(1)	-9.798***	-9.798***	0.126***	-9.948***	-9.948***	0.071***	-9.812***	-9.812***	0.230***	-5.997***	-9.798***	0.317***	-1.449	-18.579***	0.171***	-9.861***	-9.861***	0.065***

Note: ADF: Augmented Dickey-Fuller; PP : Phillips-Perron ; KPSS: Kwiatkowski-Phillips-Schmidt-Shin; Hypo: Null hypothesis; *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 3. Cointegration tests

Countries	Unrestricted NARDL		Restricted NARDLs					
	NARDL model [3]		NARDL model [4]		NARDL model [5]		NARDL model [6]	
	S_TA & L_TA		S_TA & L_TS		S_TS & L_TA		S_TS & L_TS	
	t_{BDM}	F_{PSS}	t_{BDM}	F_{PSS}	t_{BDM}	F_{PSS}	t_{BDM}	F_{PSS}
Angola †	1.727	10.131***	1.808	11.786***	0.875	6.758***	1.277	8.814***
Benin	-1.690	1.125	-1.962	1.330	-2.155	1.166	-2.077	1.509
Botswana	-1.331	0.594	-1.307	0.678	-3.313	2.068	-2.844	1.991
Cameroon	-2.344	1.498	-1.273	1.153	-3.391	1.926	-2.554	1.541
Congo Dem.Rep †	-3.311	3.599**	-0.034	0.652	-3.554	5.314***	-1.589	1.087
Congo Rep.	-3.080	1.660	-1.810	1.037	-2.848	1.441	-1.870	1.063
Cote d'Ivoire	-4.857**	4.994***	-2.776	2.197	-4.061	3.597*	-4.658**	4.869**
Eritrea	-2.608	1.254	-2.442	1.620	-2.570	1.195	-2.734	1.622
Gabon	-4.110	3.365*	-0.670	0.648	-2.899	1.783	-1.709	1.319
Ghana	-9.691***	15.631***	-0.664	0.445	-3.526	2.068	-3.097	2.904
Kenya	-1.817	1.233	-0.934	0.875	-1.590	0.869	-1.092	0.815
Mauritius	-4.779**	4.702**	0.299	1.227	0.339	2.118	2.397	2.513
Mozambique	-2.781	1.412	-0.820	2.002	-0.410	0.299	-1.027	3.099
Namibia	-5.489***	6.417***	-3.866*	5.176***	-3.991	3.261	-1.469	0.750
Niger †	-4.426*	3.758*	-4.463**	4.692**	-4.536*	3.311	-4.876***	4.954**
Nigeria	-1.503	2.452	-1.560	3.050	-0.449	0.734	-0.552	0.970
Senegal	-1.393	1.004	-1.106	1.233	-1.653	1.090	-1.400	1.204
South Africa	-1.649	1.188	-0.119	0.470	-2.150	1.287	-1.317	0.658
Sudan	-4.940**	4.351**	-2.548	2.425	-1.655	1.308	-2.691	1.559
Tanzania	-5.104**	4.299**	-0.586	3.973*	-2.786	9.694***	-4.414**	13.661***
Togo	-3.029	1.943	-1.843	0.799	-2.149	0.937	-2.273	1.248

Note: S_TA: Short-term Asymmetry; L_TA: Long-term Asymmetry; S_TS: Short-term Symmetry and L_TS denote Long-term Symmetry models; t_{BDM} and F_{PSS} denote the Banerjee et al (1998) t-test and the Pesaran et al (2001) F-test respectively. Given, the small sample size, we use the critical values of Narayan (2005) following the specific sample size of each country (see Appendix A Table A.1). For instance, we use the critical values with n = 80 observations for countries with n ≥ 80. For these countries, the critical values [lower bound: I(0); upper bound: I(1)] for F_{PSS} test with k = 7 (k being the number of explanatory variables in the model namely *lnENC⁻*, *lnENC⁺*, *lnFIN⁻*, *lnFIN⁺*, *lnGFCF*, *lnLAB* and *lnTRADE)* for models [2] and [4] are [3.233; 4.760] at 1% , [2.476; 3.746] at 5% and [2.129; 3.289] at 10% significance levels. However, the similar critical values with k = 5 (*lnENC, lnFIN, lnGFCF, lnLAB* and *lnTRADE)* for models [3] and [5] are [3.725; 5.163] at 1% , [2.787; 4.015] at 5% and [2.355; 3.500] at 10%. The corresponding critical values for t_{BDM} using t-Bounds test with k = 7 for models [2] and [4] are: [-3.43; -5.19] at 1%, [-2.86; -4.57] at 5% and [-2.57; -4.23] at 10%. The similar critical values for t_{BDM} with k = 5 for models [3] and [5] are [-3.43; -4.79] at 1%, [-2.87; -4.19] at 5% and [-2.57; -3.86] at 10%. Values reported in the table are t-statistics for t_{BDM} test and F-statistics for F_{PSS}. The models have been estimated following Campa and Goldberg, 2005; Delatte et al, 2012 by using the general-to-specific approach (uni-directional method and p-value backwards 10% significance level as stopping criteria) with maximum lag length 6 for most countries. The symbol † denotes the use of maximum lag 3 for the dependent variable and maximum lag 2 for the independent variables for the countries with less observations. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. The results are Authors' computations by using Eviews 9.

Table 4. Symmetry tests

	Energy consumption		Financial development		Conclusion
Country	Short-term tests (W_{ST}) $H_0: \sum_k^s \theta_{i,k}^- = \sum_k^t \theta_{i,k}^+$	Long-term tests (W_{LT}) : $H_0: \Omega^- = \Omega^+$	Short-term tests (W_{ST}) $H_0: \sum_k^u \gamma_{i,k}^- = \sum_k^v \gamma_{i,k}^+$	Long-term tests (W_{LT}) : $H_0: \Gamma^- = \Gamma^+$	*Unrestricted* & *Restricted* NARDL models
Angola	67.170***	2.097	17.855***	0.047	Rest. NARDL model [4]
Benin	43.837***	0.040	2.249	0.551	Rest. NARDL model [a]
Botswana	28.266***	0.633	22.403***	0.003	Rest. NARDL model [4]
Cameroon	32.644***	3.462*	110.973***	6.899**	Unr. NARDL model [3]
Congo Dem. Rep	104.872***	22.250***	33.922***	5.834**	Unr. NARDL model [3]
Congo Rep.	8.624***	8.743***	0.020	0.141	Rest. NARDL model [b]
Cote d'Ivoire	4.011**	6.222**	32.739***	6.197**	Unr. NARDL model [3]
Eritrea	3.854*	0.004	5.800**	0.643	Rest. NARDL model [4]
Gabon	1.345	19.257***	1.933	10.755***	Rest. NARDL model [5]
Ghana	65.491***	6.475***	7.066***	26.639***	Unr. NARDL model [3]
Kenya	1.910	1.336	3.885*	0.181	Rest. NARDL model [c]
Mauritius	24.184***	2.312	230.632***	133.963***	Rest. NARDL model [d]
Mozambique	2.136	12.668***	8.794***	2.439	Rest. NARDL model [e]
Namibia	50.986***	0.217	13.328***	17.156***	Rest. NARDL model [d]
Niger	4.859**	0.274	9.852***	1.651	Rest. NARDL model [4]
Nigeria	3.371*	1.984	64.421***	1.037	Rest. NARDL model [4]
Senegal	10.439***	0.001	-	0.997	Rest. NARDL model [a]
South Africa	12.621***	0.349	177.970***	6.974**	Rest. NARDL model [f]
Sudan	3.344*	5.328**	43.377***	0.925	Rest. NARDL model [g]
Tanzania	2.664	110.752***	4.501**	23.570***	Rest. NARDL model [h]
Togo	0.036	0.694	21.231***	3.472*	Rest. NARDL model [i]

Note: The tests were performed using the unrestricted model NARDL [3] as a reference model. The last column (Conclusion) shows the appropriate model for each country following the results of the Wald tests. The NARDL models [a] - [i] represent other restricted NARDL models indicating different cases of asymmetry between energy consumption, financial development and economic growth in the short or/and long-term as a result of the Wald tests. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. The results are calculations of the authors using Eviews 9.

However, we found asymmetrical relationships between financial development and economic growth both in the short and long-term (rejection of *hypotheses 3a and 3b*), but only an asymmetrical relationship between energy consumption and economic growth in the short-term (rejection of *hypothesis 2b*) in Mauritius and Namibia. Likewise, there are many other cases of asymmetry between financial development, energy consumption and economic growth in the short-term (Mozambique, South Africa, and Togo) or the long-term (Mozambique, Sudan and Tanzania).

Furthermore, we estimated the appropriate NARDL model using the results of the Wald tests for each country, as indicated in the last column of Table 4. The suitable NARDL model examines the asymmetrical effects of energy consumption and financial development on economic during the short-term and long-term in each country. Thus, Table 5 shows the results of the selected NARDL model for each country. In the long-term, a positive shock in energy consumption leads to a positive effect on economic growth in six (6) countries (the democratic republic of Congo, the republic of Congo, Cote d'Ivoire, Gabon, Ghana, and Tanzania), but to non-significant and adverse effects in three (3) countries (Cameroon, Mozambique and Sudan). Likewise, a negative shock to energy consumption also has a positive effect on economic growth in five (5) countries (Cameroon, the democratic republic of Congo, the Republic of Congo, Ghana, and Mozambique), whereas it induces a decrease of economic growth in Cote d'Ivoire, Gabon, Sudan, and Tanzania. These effects are significant, mostly at the 1% level, in the case of the democratic republic of Congo, the Republic of Congo, Cote d'Ivoire, Gabon and, Ghana in the long-term. However, energy consumption has a symmetrical effect on economic growth in twelve (12) countries, which is positive in nine (9) countries (Angola, Botswana, Eritrea, Kenya, Mauritius, Niger, Nigeria, South Africa, and Togo) but contrary in three (3) countries (Benin, Namibia, and Senegal). An uncontrolled increase of the domestic credit to the private sector significantly reduces economic growth in 5 countries (Cameroon, the democratic republic of Congo, Cote d'Ivoire, Ghana, and Namibia), but stimulates economic growth in five (5) countries (Gabon, Mauritius, South Africa, Tanzania, and Togo), significantly only in Mauritius in the long-term. Nevertheless, a restrictive policy of credit to the private sector favors the economic growth in 6 countries, namely in Cameroon, the democratic republic of Congo, Cote d'Ivoire, Ghana, Namibia, and Tanzania. This positive effect is significant in these countries, in most cases at the 5% level, except for Cote d'Ivoire and Tanzania. A 1% decrease in the domestic credit to the private sector significantly hurts economic growth by around 0.08%, 0.63% and 0.49% in Gabon, Mauritius, and South Africa, respectively at the 5% level, while this similar shock leads to a non-significant decrease in economic growth in Togo by 0.23% over the long-term. We also found that financial development had a symmetrical effect on economic growth in eleven (11) countries in the long-term. This effect was positive in Angola, Eritrea, Niger, Nigeria, and Sudan, but harmful in the case of Benin, Botswana, the republic of Congo, Kenya, Mozambique, and Senegal. In most cases, Table 5 indicates that gross fixed capital formation and labor force have positive effects on economic growth in fifteen (15) countries and sixteen (16) countries respectively, contrary to trade openness in twelve (12) countries in the long-term.

The short-term analysis highlights many cases of asymmetrical effects of energy consumption and financial development on economic growth and reveals similar findings to the long-term analysis. Energy consumption exerts an asymmetrical effect on economic growth in fifteen (15) countries. Thus, an increase in energy consumption causes economic growth to rise significantly in six (6) countries (Angola, Benin, the democratic republic of Congo, Cote d'Ivoire, Senegal, and Sudan), whereas this effect is negative in eight (8) countries (Botswana, Cameroon, the Republic of Congo, Ghana, Mauritius, Namibia, Nigeria, and South Africa). On the contrary, Table 5 indicates that a decrease in energy consumption has a significant and positive effect on the economic growth of 10 countries, but an adverse effect in five (5) countries during the short-term. Energy consumption has a symmetrical and positive effect on economic growth in Gabon, Kenya, Mozambique, Tanzania, and Togo. In the same vein, the relationship between financial development and economic growth is asymmetrical in 17 countries in the short-term. We found that a positive shock to financial development significantly reduced economic growth in 9 countries, but had a significant positive effect at the 1% level in 6 countries (Botswana, Mauritius, Mozambique, South Africa, Tanzania, and Togo). Likewise, Table 5 reveals that a negative shock to financial development reduces economic growth in 8 countries, whereas it leads to a significant increase in economic growth in 6 countries in the short-term. Besides, domestic investments in terms of fixed capital, labor force, and trade openness boosted economic growth in most countries in the short-term.

The dynamic multipliers also confirm the asymmetrical relationships between energy consumption, financial development and economic growth in many countries because the asymmetry line (the difference between positive and negative changes of these variables) departs from the horizontal axis as described by the figures 3 and 4. The dynamic multipliers indicate that negative changes in energy consumption have more significant effects on economic growth than positive changes of energy consumption in the democratic republic of Congo, Cote d'Ivoire, Gabon, Sudan, and Tanzania. Similarly, negative changes in financial development have a greater impact on economic growth than positive changes in the democratic republic of Congo, Gabon, Ghana, Mauritius, Namibia, and Tanzania in the long-term.

Finally, Table 6 presents the results of the causality analysis for each country following the tests in Toda and Yamamoto (1995) and the outcomes of the symmetry tests. The tests were implemented with the optimal lag based on the Akaike Information Criteria (AIC). The results gave support to the alternative *hypotheses 4 and 5* in many countries. We found that a positive shock in energy consumption Granger caused economic growth in two (2) countries (the democratic republic of Congo, and Ghana), whereas economic growth led to positive changes in energy consumption in three (3) countries (Angola, the Republic of Congo, and Eritrea). However, a negative shock to energy consumption significantly led to economic growth in the democratic republic of Congo and South Africa, but economic growth induced a decrease in energy consumption in Mozambique and Tanzania.

Table 5. Estimations of the NARDL models

	NARDL Long-term coefficients										Diagnostics tests			
Countries	Adj. speed	$lnENC^{+}:\Phi_i^{+}$	$lnENC^{-}:\Phi_i^{-}$	$lnENC:\Phi$	$lnFIN^{+}:\Theta_i^{+}$	$lnFIN^{-}:\Theta_i^{-}$	$lnFIN:\Theta_i$	$lnGFCF:K_i$	$lnLAB:N_i$	$\ln TRADE:T_i$	F.stat	$\overline{R}^2$	$\chi^2_{SC}(2)$	Arch (1)
Angola	0.139^{*}			7.653			1.071^{***}	-0.249	-7.945^{*}	-1.626	10.435^{***}	0.765	0.758	0.517
Benin	-0.066			-0.182			-0.032	0.072	0.485^{***}	0.115	10.033^{***}	0.590	0.162	0.330
Botswana	-0.046			0.078			-0.025	0.022	1.120^{**}	-0.456	28.018^{***}	0.830	0.032	1.643
Cameroon	-0.132^{**}	-0.663	0.196		-0.228^{*}	0.183^{***}		-0.147^{*}	1.441^{***}	-0.081^{*}	38.884^{***}	0.886	0.495	0.289
Congo D.Rep	-0.264^{***}	0.121^{*}	17.615^{***}		-0.032^{**}	0.050^{*}		0.037^{***}	1.308^{***}	-0.029^{***}	108.795^{***}	0.972	0.659	0.056
Congo Rep.	-0.117^{*}	0.109	0.620^{***}				-0.003	0.011	0.587	-0.019	13.661^{***}	0.668	0.007	0.548
Cote d'Ivoire	-0.230^{***}	0.110^{*}	-0.401^{**}		-0.252^{***}	0.001		0.322^{***}	-0.517	-0.186^{***}	17.617^{***}	0.812	4.388^{**}	0.058
Eritrea	-0.226^{**}			0.125			0.100	0.071	0.133	0.077	3.453^{***}	0.275	0.061	0.012
Gabon	-0.180^{***}	0.236^{***}	-0.294^{***}		0.021	-0.083^{**}		0.129^{***}	-0.891^{***}	0.142	24.799^{***}	0.827	0.360	0.887
Ghana	-0.596^{***}	0.731^{***}	0.136^{***}		-0.058^{***}	0.119^{***}		-0.111^{***}	1.057^{***}	-0.090^{***}	24.345^{***}	0.863	0.419	0.096^{*}
Kenya	-0.040			0.685			-0.051	0.192	0.378	0.227	11.190^{***}	0.602	0.105	2.037
Mauritius	-0.248^{***}			0.649^{***}	0.246^{***}	-0.634^{***}		0.428^{***}	0.514^{***}	0.108^{**}	58.790^{***}	0.946	3.241^{**}	1.173
Mozambique	-0.013	-22.174	25.906				-0.220	0.369	13.927	0.0001	25.047^{***}	0.813	0.109	0.396
Namibia	-0.204^{***}			-0.142	-0.825^{***}	0.929^{**}		-0.059	2.150^{***}	0.236^{**}	6.378^{***}	0.661	4.832^{**}	7.000^{***}
Niger	-0.494^{***}			0.132^{*}			0.124^{***}	0.069	0.169	-0.367^{***}	3.442^{***}	0.361	1.959	2.357
Nigeria	-0.019			2.985			0.809	0.095	2.821^{*}	-1.000	45.092^{***}	0.926	0.688	0.404
Senegal	-0.037			-0.008			-0.221	-0.107	0.505	0.138	5.082^{***}	0.323	0.365	0.554
South Africa	-0.067			0.059	0.089	-0.493^{**}		0.129	-0.128	0.176	49.022^{***}	0.933	0.310	1.007
Sudan	-0.101^{**}	-0.266	-0.356				0.051	-0.129^{*}	1.573^{**}	-0.097^{**}	17.331^{***}	0.809	0.879	0.313
Tanzania	-0.100^{*}	0.464	-1.966		0.243	0.277		0.018	0.871	-0.090	20.125^{***}	0.853	5.872^{***}	4.399^{**}
Togo	-0.175^{**}			0.398	0.146	-0.230		0.138	-1.088	-0.165	3.467^{***}	0.320	0.020	0.182

Table 5. Estimations of the NARDL models (Cont.)

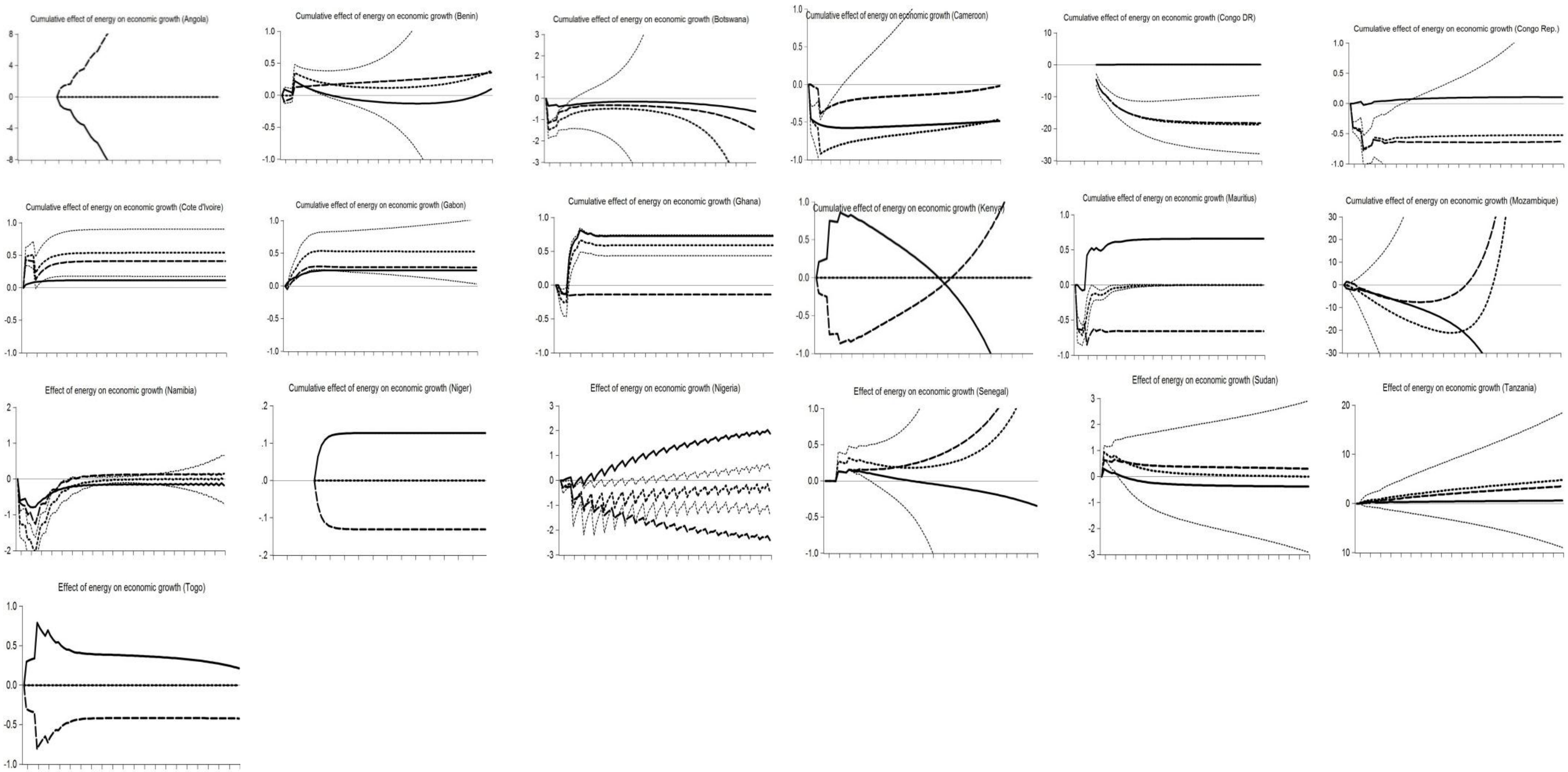
	NARDL Short-term coefficients									
Countries	$\ln GDP_i : \sum \omega_{ik}$	$\ln ENC_i^+ : \sum \sigma_{i,k}^+$	$\ln ENC_i^- : \sum \sigma_{i,k}^-$	$\ln ENC_i : \sum \sigma_{i,k}$	$\ln FIN_i^+ : \sum \eta_{i,k}^+$	$\ln FIN_i^- : \sum \eta_{i,k}^-$	$\ln FIN_i : \sum \eta_{i,k}$	$\ln GFCF_i : \sum \alpha_{1i,k}$	$\ln LAB_i : \sum \alpha_{2i,k}$	$\ln TRADE_i : \sum \alpha_{3i,k}$
Angola	-2.324^{***}	2.294^{***}	-1.575^{***}		-0.149^{***}	-		-0.128^{***}	-0.571	0.345^{***}
Benin		0.289^{***}	-0.059					0.140^{***}	0.030	0.057^{***}
Botswana	0.257^{***}	-0.347^{***}	0.520^{***}		0.129^{***}	-0.239^{***}		0.016	0.493^{***}	0.207^{***}
Cameroon		-0.462^{***}	0.314^{***}		-0.192^{***}	0.229^{***}			-7.564^{**}	-0.056^{***}
Congo D.Rep	-0.438^{***}	0.144^{***}	10.290^{***}		-0.015^{***}	0.063^{***}		0.037^{***}	0.899^{***}	-0.030^{***}
Congo Rep.	-0.315^{***}	-0.065^{*}	0.787^{***}					-0.081^{***}	1.035^{***}	
Cote d'Ivoire		0.047	-0.149	-	-0.077^{*}	0.246^{***}		0.033	0.085	-0.051^{**}
Eritrea					-0.117			0.069^{***}		0.059^{*}
Gabon	0.299^{***}	-	-	0.009	-	-		0.098^{***}	-7.607^{**}	0.214^{***}
Ghana	0.193^{***}	-1.551^{***}	0.092^{***}	-	-0.052^{***}	-0.142^{***}		0.156^{***}	0.855^{***}	-0.056^{***}
Kenya	0.282^{***}			0.627^{***}		-0.072^{**}		0.181^{***}		-0.015
Mauritius	-0.343^{***}	-0.280	0.903^{***}	-	0.194^{***}	-0.730^{***}		-0.278^{***}	0.632^{***}	0.027
Mozambique	0.458^{***}			0.237	0.112^{***}	-0.155^{**}		0.095^{***}	0.526^{*}	-0.233^{***}
Namibia	-0.329	-1.723^{***}	2.906^{***}	-	-0.260^{***}	-			-2.880^{**}	0.096^{*}
Niger		-	0.169^{*}		-0.094^{***}	0.075^{*}			0.516^{***}	0.274^{***}
Nigeria	-0.052	-0.420^{*}	0.594^{**}			0.017		0.034^{***}	-45.136^{***}	0.037^{*}
Senegal	0.323^{***}	0.139^{***}	-0.127^{**}					0.006		
South Africa	0.164^{**}	-0.013	0.774^{***}		0.322^{***}	-0.252^{***}		-0.007	-0.445^{***}	0.209^{***}
Sudan	0.167^{**}	0.292^{***}	-0.643^{***}	-	-0.004	0.326^{***}		-0.132^{***}	0.360	-0.186^{***}
Tanzania	-1.488^{***}	-	-	0.363^{***}	0.037^{**}	-0.153^{***}		0.031^{**}	-13.417^{***}	-0.008
Togo	0.234^{*}			0.675^{***}	0.127^{***}	-0.292^{***}			7.447^{*}	-0.175^{**}

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. The results are calculations of the authors using Eviews 9.

Besides, Table 6 shows that there is unidirectional causality running from positive changes in financial development to economic growth in the democratic republic of Congo, Niger, South Africa, and Sudan, while there is unidirectional causality running from economic growth to positive changes in financial development in Angola, Gabon, and Mauritius. The negative changes in financial development caused economic growth in Niger, whereas the opposite direction was documented in Cameroon, Cote d'Ivoire, Eritrea, Mozambique, Tanzania, and Togo. We also found bidirectional causality between negative changes in financial development and economic growth in Angola and the democratic republic of Congo. The negative changes in financial development are similar to the cumulative decreases of the domestic credits to the private sector in these countries. Table 6 also reveals that an analysis neglecting asymmetries provides evidence of unidirectional causality running from energy consumption to economic growth in Angola, Kenya, and Mozambique, and conversely in the Republic of Congo and Eritrea. Similarly, there is unidirectional causality running from financial development to economic growth in Niger and Sudan, whereas economic growth Granger causes financial development in seven (7) countries (Angola, Botswana, Eritrea, Mauritius, Mozambique, Senegal, and Tanzania).

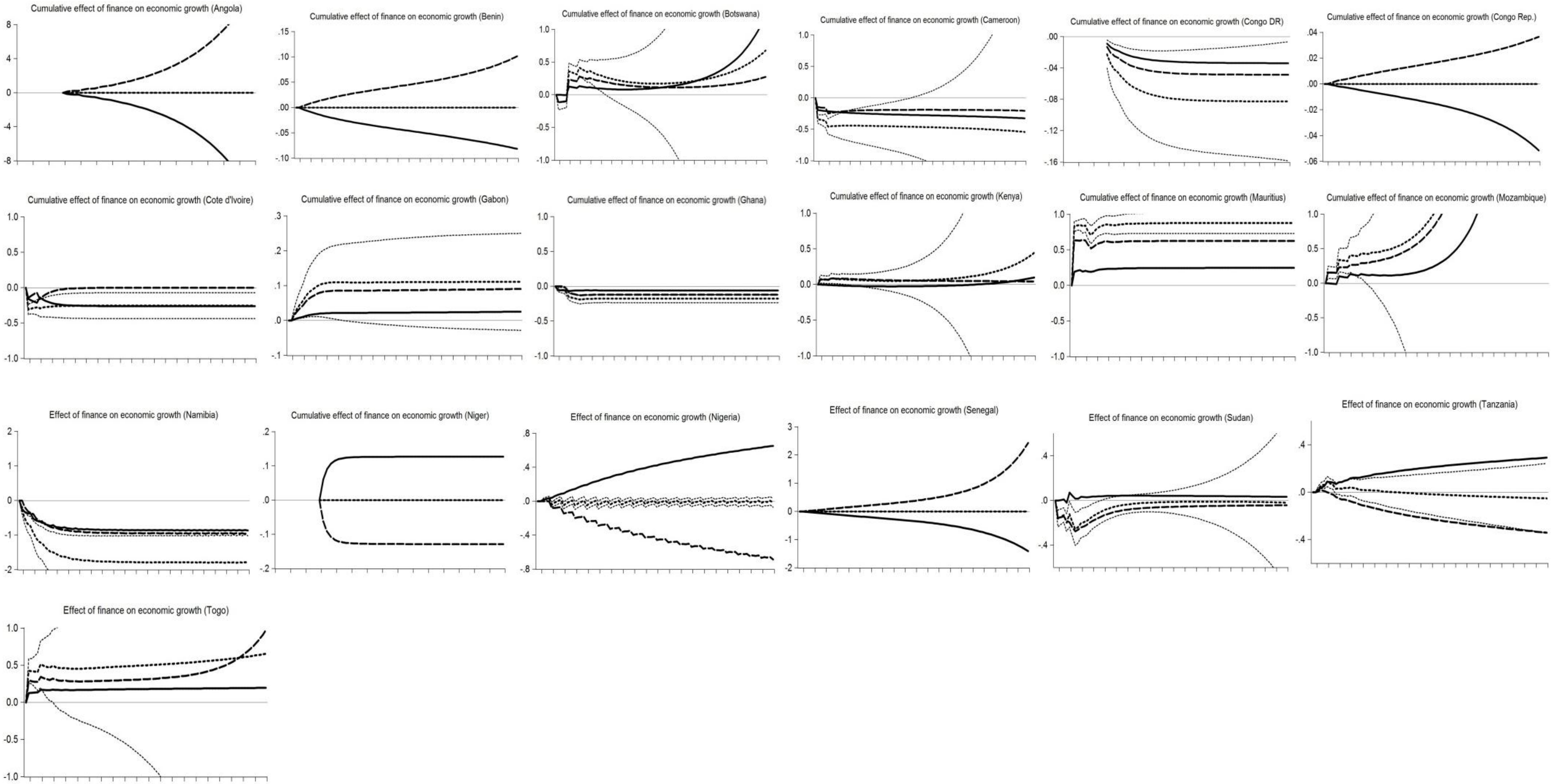
Overall, the country-by-country analysis indicates that financial development and energy consumption have asymmetrical effects on economic growth in most cases. For policy-makers, the findings reveal the importance of considering asymmetries in the analysis of the relationship between these variables. In general, our findings show that energy consumption is a driving force for economic growth in many countries in the long-term, confirming its essential role as a critical input in the production process of these countries. Most African countries are developing countries in the quest for industrialization and development through the diversification of economic activities across different sectors of activity, which are increasingly consuming energy. Thus, this political will and the use of energy-intensive inputs and products were among the main drivers of economic growth in certain SSA countries in the long-term. However, the increasing energy consumption (positive changes) hampered economic growth in many countries during the short-term. This evidence may be due to specific problems related to high energy consumption, such as environmental degradation, global warming, public health problems that are detrimental to the quality of the workforce, and other factors of production necessary for economic growth. On the contrary, restrictive or controlled energy consumption (negative changes) has more positive effects on the economic growth of many countries. Besides, the estimated coefficients of the effect of negative changes in energy consumption on economic growth are more substantial than in the case of positive changes in energy consumption. This finding implies that energy conservation technologies (renewable energies), paying more attention to environmental issues, can be the main driver of economic growth alongside sustainable development. There are mixed results about the effect of financial development on economic across countries. The uncontrolled increase of the domestic credits to the private sector (positive changes in financial development) significantly hurt economic growth in Cameroon, the democratic republic of Congo, Cote d'Ivoire, Ghana, and Namibia in the long-term, while the positive effect is non-significant in Gabon, South Africa, Tanzania, and Togo.

Figure 3: Dynamic cumulative effects of energy consumption on economic growth in the SSA countries



Note: The solid line depicts the effect of positive changes in energy consumption on economic growth, while the long-dashed line indicates the effect of negative changes in energy consumption on economic growth. The asymmetry line, or the difference between the positive and negative changes in energy consumption, is described by the short-dashed line. The other lines are the upper and lower bands for asymmetry.

Figure 4: Dynamic cumulative effects of financial development on economic growth in the SSA countries



Note: The solid (long-dashed) line depicts the effect of a positive shock (negative shock) in financial development on economic growth. The asymmetry line, or the difference between the positive and negative changes in energy consumption, is described by the short-dashed line. The other lines are the upper and lower bands for asymmetry.

Table 6. Results of the Causality analysis using the tests in Toda and Yamamoto (1995)

Null hypothesis	Lags	$E^{+} \rightarrow Y$	$Y \rightarrow E^{+}$	$E^{-} \rightarrow Y$	$Y \rightarrow E^{-}$	$E \rightarrow Y$	$Y \rightarrow E$	$F^{+} \rightarrow Y$	$Y \rightarrow F^{+}$	$F^{-} \rightarrow Y$	$Y \rightarrow F^{-}$	$F \rightarrow Y$	$Y \rightarrow F$
Angola [†]	3	6.976	29.322***	2.844	3.687	9.556*	7.045	7.599	88.461***	11.237**	22.683***	7.793	62.413***
Benin	5	5.623	0.213	2.858	1.405	1.298	0.449	-	-	-	-	1.216	0.293
Botswana	5	2.438	7.627	1.395	4.700	2.869	0.561	8.648	6.984	5.911	0.700	5.019	13.780**
Cameroon	5	2.835	1.918	0.552	3.887	-	-	1.268	8.757	5.842	73.438***	-	-
Congo Dem.Rep	3	35.610***	0.551	15.673***	4.810	-	-	17.893***	0.877	20.375***	20.467***	-	-
Congo Rep.	5	1.418	9.665*	0.114	2.118	0.914	10.393*	-	-	-	-	6.722	4.447
Cote d'Ivoire	5	0.862	0.832	2.304	2.399	-	-	1.689	1.907	3.637	17.820***	-	-
Eritrea	5	6.004	9.743**	0.083	5.645	1.800	10.032*	0.136	4.399	1.870	14.043***	2.762	19.138***
Gabon	5	0.886	2.087	2.653	7.697	1.252	6.101	1.905	10.786*	2.282	0.654	2.166	0.941
Ghana	5	26.548***	8.255	1.817	0.168	-	-	0.870	0.076	9.201	0.722	-	-
Kenya	5	-	-	-	-	16.741***	0.767	1.254	4.288	0.840	1.371	1.423	5.415
Mauritius	5	0.180	3.982	1.477	0.812	1.246	1.470	2.083	23.305***	1.851	6.796	1.211	44.477***
Mozambique	5	2.064	4.314	5.890	22.653***	24.545***	4.977	1.368	7.940	0.556	23.757***	0.119	27.148***
Namibia	5	6.058	4.580	2.330	1.615	5.172	3.306	6.569	3.674	0.105	0.045	9.147	3.530
Niger	3	7.221	5.102	5.715	0.439	0.677	0.983	26.769***	0.341	18.476***	0.726	17.436***	0.359
Nigeria	5	2.877	0.628	0.828	1.293	5.293	0.874	1.537	0.811	1.853	0.468	0.166	0.343
Senegal	5	4.643	1.115	2.613	2.695	0.576	1.565	-	-	-	-	0.248	19.663***
South Africa	5	5.781	0.804	10.758*	2.364	0.715	5.650	39.667***	0.621	0.773	0.118	-	-
Sudan	5	0.166	1.960	0.656	0.047	0.257	0.149	9.734*	6.542	0.653	5.278	11.007*	2.124
Tanzania	5	1.467	5.930	5.838	13.923**	8.174	1.600	5.118	3.758	0.568	12.081**	2.025	14.172**
Togo	5	-	-	-	-	1.567	2.286	3.801	0.615	0.330	34.498***	-	-

Note: $Y = \ln GDP$, $E = \ln ENC$, $E^{+} = \ln ENC^{+}$, $E^{-} = \ln ENC^{-}$, $F = \ln FIN$, $F^{+} = \ln FIN^{+}$, $F^{-} = \ln FIN^{-}$ · $E \rightarrow Y$ supposes causality running from E to Y. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The results are calculations of the authors.

For most of these countries, this negative effect of excessive credits to the private sector on economic growth may be due to weak institutional quality, flexible banking regulation and lack of investment oversight. Rousseau and Wachtel (2011) showed that an overly rapid financial deepening or excessive credit growth might cause inflation and a weakening of banking systems, leading to financial crises that hold back economic growth. Similarly, Berkes et al. (2012) and Arcand et al. (2015) found that there was a threshold from which financial development had a negative effect on economic growth. However, the negative changes in the domestic credits to private sector exert a more significant positive effect on economic growth in these countries. These findings highlight the fact that loans readily available to the private sector do not necessarily make it possible to make productive investments or are not appropriately managed to generate economic growth. The lack of a rigorous process of credits allocation to the private sector by banks (examination of the borrower's ability to repay the loan, investment monitoring and low cost of borrowing) can lead to inefficient use of these funds to generate productive investments in these countries. The restrictive or controlled credit policy of banks to the private sector (negative shock to financial development) and its positive effect on the economic growth of some sub-Saharan African countries may be justified by a monetary policy based on price stability. In the case of countries in CFA francs' zone[1], the maintenance of the fixed exchange rate regime with the euro obliges the monetary authorities to restrict the granting of credit to the private sector.

This policy may also indicate a clear desire to avoid credit risk due to the underdeveloped financial system in most African countries. Thus, this restrictive or selective credit policy, based on the efficiency of the allocation, requires the private sector to generate productive investments in the long-term because of the sometimes high-interest rates on borrowing and other coercive measures. The adverse effects of financial development (both positive and negative changes) on economic growth in several countries in the short-term denote an inefficient use of funds borrowed by the private sector to make productive investments in these countries. Nevertheless, growth in domestic credits to the private sector (positive changes) stimulated economic growth in Botswana, Mauritius, South Africa, Tanzania and Togo, while a restrictive credit policy (negative changes) slowed economic growth. Thus, a controlled expansionary credit policy supports the economic growth of these countries. One reason may be that most of them have a relatively developed financial system (South Africa and Mauritius, as illustrated in Figure 2) compared to the other countries and that their private sector uses the funds effectively to generate productive investments in the short and long-term. The asymmetrical effects of energy consumption and financial development on economic growth in most countries, especially in Cote d'Ivoire, Gabon, and Tanzania, are in line with the studies of Shahbaz et al. (2017) and Kisswani (2017) for the cases of India and Asian countries, respectively.

[1] In this study, these countries are: Benin, Cameroon, the Republic of Congo, Cote d'Ivoire, Gabon, Niger, Senegal, and Togo.

4.2. Results of the Panel Analysis

This section presents the results of the relationships between energy consumption, financial development and economic growth in the different sub-groups of countries following the income classification mentioned in section 3.1. These sub-groups represent eight (8) low-income economies, eight (8) lower-middle-income economies, and five (5) upper-middle-income economies.

First, we started with the descriptive statistics of variables for each sub-group of countries, indicating different characteristics from one sub-group to another over time. Thus, Table 7 shows that the growth of the income per capita (GDP, per capita) is almost similar in the upper-middle-income and lower-middle-income countries around 1.87% on average, a bit greater than that of the lower-income countries. On average, the output per capita increased by almost 1.75% in the selected SSA countries from 1990Q1 to 2014Q4. Energy consumption was also higher and grew faster in the upper-middle-income countries (about 2.15%) than in the lower-middle-income countries (0.80%) and the lower-income countries (0.57%). Similarly, the levels of financial development, gross fixed capital formation, and trade openness were higher and more improved in the upper-middle-income countries than in the others. However, the labor force was relatively abundant in the lower-middle-income countries (11862351 workers) but increased faster in the lower-income countries (3.10%) over the years. On average, the levels of output per capita and energy consumption approximated 2450 US $ and 641.620 kg of oil equivalent per capita, respectively, whereas domestic credits to the private sector were about 24.03% (as % of GDP) in the SSA countries during the period 1990Q1-2014Q4. The significance of the statistics of Jarque-Bera at the 1% level, and the high values of the skewness of variables (not near zero, in absolute values) indicate that the variables do not follow a normal distribution in each sub-group. These results highlight the possibility of asymmetrical relationships among the variables, as well as the importance of using a logarithmic transformation of the variables to ensure accurate results (Shabhaz et al. 2017).

Also, we performed the panel unit root analysis by using the tests developed by Dickey and Fuller (1981), Phillips and Perron (1988), Im et al. (2003), and Levin et al. (2002). The results of these different tests for each sub-group of countries are depicted in Table 8. In most of these tests, we found that all variables were stationary at the first difference at the 1% level of significance in the different sub-groups of countries, as well as in the entire SSA region. This evidence also confirmed our previous results of stationary variables in each country (see Table 2).

Table 7. Descriptive statistics for average variables

Countries	Output GDP_t	Growth GDP (%)	Energy ENC_t	Growth ENC (%)	Finance FIN_t	Capital $GFCF_t$	Labor LAB_t	Growth LAB (%)	Trade $TRADE_t$
Lower-income									
Mean	547.424	1.518	326.504	0.573	15.203	20.685	7765253	3.104	64.523
Standard deviation	213.690	4.017	99.340	5.704	8.903	7.371	7149703	0.639	19.523
Skewness	0.383	0.158	-0.563	-0.985	0.639	0.793	1.242	0.562	0.654
Jarque-Bera	27.400***	1389.569***	52.590***	4383.297***	46.438***	76.586***	178.436***	87.177***	52.791***
Observations	680	648	680	648	680	680	680	648	680
Lower-middle-income									
Mean	1533.893	1.871	442.137	0.800	13.409	17.409	11862351	2.814	71.675
Standard deviation	707.828	4.419	134.634	6.266	8.012	6.657	11977250	0.749	34.915
Skewness	1.299	1.962	1.039	1.850	0.832	1.032	2.052	-0.248	0.689
Jarque-Bera	239.631***	3713.172***	142.354***	3569.209***	90.491***	558.098***	869.901***	17.612***	62.383***
Observations	760	728	760	728	760	760	760	728	760
Upper-middle-income									
Mean	6461.381	1.875	1379.294	2.149	52.662	23.711	3808556	2.633	90.999
Standard deviation	2261.022	3.375	778.794	6.760	44.213	5.094	6539244	1.577	23.642
Skewness	0.735	-0.817	0.780	1.198	0.950	0.432	1.587	0.469	-0.431
Jarque-Bera	48.881***	148.995***	69.702***	1851.542***	76.034***	16.746***	217.628***	356.248***	18.962***
Observations	496	476	496	476	492	496	496	476	496
All countries									
Mean	2449.820	1.748	641.620	1.067	24.037	20.174	8359918	2.869	74.114
Standard deviation	2691.968	4.033	596.439	6.240	28.825	7.028	9767222	1.018	29.371
Skewness	1.604	0.946	2.449	0.900	2.823	0.587	2.208	0.091	0.496
Jarque-Bera	1084.064***	6262.155***	4263.934***	9131.628***	7832.897***	185.218***	4068.577***	5010.355***	83.915***
Observations	1936	1852	1936	1852	1932	1936	1936	1852	1936

Note: The detailed description of variables is presented in section 3.1. *Mean* denotes the average values of the variables, whereas *Growth* is the average growth rate of the variables. *** p <0.01; ** p <0.05; * p <0.1.

Besides, the panel cointegration analysis has been carried out for each sub-group of countries to examine whether there is a long-term relationship among the variables. As described in section 3.3.2, we used the tests developed by Pedroni (1999, 2001) and Fisher-Johansen (Maddala and Wu, 1999).

Table 8. Unit root tests

	Im, Pesaran, and Shin W-stat, (IPS)		Augmented Dickey-Fuller Fisher Chi-square, (ADF)		Phillips-Perron Fisher Chi-square, (PP)		Levin, Lin, and Chu t-stat, (LLC)	
Variables	$H_0: I(0)$	$H_0: I(1)$	$H_0: I(0)$	$H_0: I(1)$	$H_0: I(0)$	$H_0: I(1)$	$H_0: I(0)$	$H_0: I(1)$
Lower-income countries								
$\ln GDP$	3.782	-11.217***	5.176	127.237***	4.631	251.403***	1.287	-8.581***
$\ln ENC$	1.282	-17.175***	5.060	202.635***	11.525	278.462***	0.456	-20.600***
$\ln ENC^{+}$	5.407	-14.110***	1.371	156.363***	0.924	249.090***	0.747	-16.200***
$\ln ENC^{-}$	0.892	-12.485***	12.555	146.058***	77.568***	214.778***	-0.694	-13.132***
$\ln FIN$	2.242	-20.015***	4.266	228.780***	3.676	285.262***	1.057	-23.457***
$\ln FIN^{+}$	3.342	-12.256***	5.587	143.044***	5.008	238.413***	0.868	-12.560***
$\ln FIN^{-}$	-1.708**	-23.222***	26.577**	247.186***	39.621***	270.791***	-4.739***	-26.748***
$\ln GFCF$	3.782	-11.217***	5.176	127.237***	4.631	251.403***	1.287	-8.581***
$\ln LAB$	2.953	-145.985***	8.511	177.083***	10.506	180.764***	-1.793**	-177.627***
$\ln TRADE$	-0.698	-20.689***	15.794	241.596***	14.291	283.145***	-0.698	-23.228***
Lower-middle-income countries								
$\ln GDP$	4.402	-6.356***	5.348	69.141***	3.389	253.621***	3.566	0.085
$\ln ENC$	3.135	-17.440***	3.918	205.693***	10.508	278.741***	3.028	-17.775***
$\ln ENC^{+}$	6.584	-13.372***	0.999	126.162***	0.659	257.774***	2.698	-15.296***
$\ln ENC^{-}$	1.248	-17.971***	8.957	184.215***	11.551	233.393***	-2.240**	-21.267***
$\ln FIN$	0.884	-17.234***	8.723	203.635***	15.866	283.982***	-0.274	-17.170***
$\ln FIN^{+}$	3.193	-6.005***	3.290	77.061***	8.488	226.232***	0.559	-0.115
$\ln FIN^{-}$	-1.411*	-11.791***	24.210*	153.249***	33.741***	252.402***	-3.327***	-12.887***
$\ln GFCF$	-0.991	-18.113***	17.281	218.586***	19.042	284.431***	-0.560	-15.963***
$\ln LAB$	1.330	-222.182***	21.761	147.365***	21.761	147.365***	-3.274***	-288.320***
$\ln TRADE$	-0.790	-21.084***	18.073	228.008***	17.906	282.182***	-1.062	-21.292***
Upper-middle-income-countries								
$\ln GDP$	3.056	-10.585***	1.193	75.180***	0.864	132.563***	0.565	-9.996***
$\ln ENC$	1.375	-11.488***	3.087	103.311***	3.024	151.530***	-0.375	-13.031***
$\ln ENC^{+}$	3.196	-6.640***	1.707	41.822***	2.288	112.403***	0.168	-5.538***
$\ln ENC^{-}$	1.447	-4.128***	3.134	36.599***	1.912	119.106***	-0.817	0.484
$\ln FIN$	-1.235	-16.240***	20.505**	130.525***	33.412***	159.649***	-1.854**	-16.808***
$\ln FIN^{+}$	1.738	-5.884***	2.376	57.012***	23.859***	111.373***	-0.778	6.434
$\ln FIN^{-}$	1.153	-11.316***	5.343	72.351***	5.356	115.004***	-1.477*	-14.043***
$\ln GFCF$	-0.294	-12.158***	7.958	122.863***	9.346	171.060***	0.671	-9.231***
$\ln LAB$	3.267	-2.095**	1.648	21.210**	5.654	92.103***	1.137	24.508
$\ln TRADE$	-0.932	-18.370***	10.769	149.909***	11.120	172.268***	-0.005	-20.796***

Table 8. Unit root tests (Cont.)

	Im, Pesaran, and Shin W-stat, (IPS)		Augmented Dickey-Fuller Fisher Chi-square, (ADF)		Phillips-Perron Fisher Chi-square, (PP)		Levin, Lin, and Chu t-stat, (LLC)	
Variables	$H_0: I(0)$	$H_0: I(1)$	$H_0: I(0)$	$H_0: I(1)$	$H_0: I(0)$	$H_0: I(1)$	$H_0: I(0)$	$H_0: I(1)$
All countries								
$\ln GDP$	6.466	-16.542***	11.767	280.212***	8.744	632.082***	2.851	-12.490***
$\ln ENC$	3.474	-28.304***	15.003	528.691***	23.960	707.655***	1.409	-32.203***
$\ln ENC^{+}$	8.318	-20.295***	4.152	325.748***	3.905	603.800***	1.944	-22.622***
$\ln ENC^{-}$	2.021	-21.773***	24.660	360.339***	91.024***	560.398***	-2.299**	-24.557***
$\ln FIN$	1.000	-30.005***	36.366	540.780***	56.034*	727.384***	-0.776	-32.209***
$\ln FIN^{+}$	4.967	-13.181***	10.905	252.172***	36.964	564.660***	0.449	-4.022***
$\ln FIN^{-}$	-0.833	-26.162***	52.593	435.103***	74.735***	600.443***	-5.113***	-30.395***
$\ln GFCF$	0.065	-28.070***	32.180	554.558***	39.623	734.689***	1.176	-23.857***
$\ln LAB$	7.280	-2.265***	7.680	56.595*	30.075	420.233***	2.261	130.773***
$\ln TRADE$	-0.822	-35.800***	43.352	645.655***	42.732	735.574***	-0.463	-37.612***

Note: IPS: test in Im et al. (2003); ADF: test in Dickey and Fuller (1981); PP: test in Phillips and Perron (1988); LLC: test in Levin et al. (2002). The hypothesis I(0) assumes that the variables are stationary at the level (integrated of order 0), whereas the hypothesis and I(1) supposes that the variables are stationary at the first difference (integrated of order 1). The optimal lag for the tests is determined automatically by the Akaike Information Criteria. *** p <0.01; ** p <0.05; * p <0.1.

Table 9 presents the results of the panel cointegration tests in each sub-group of countries. Concerning the tests in Pedroni (1999, 2001), we found that the *rho*-statistic and *adf*-statistic of the within-dimension (Panel statistics) were significant respectively at the 10% and 1% levels, whereas the *rho*-statistic, *t*-statistic and *adf*-statistic of the within-dimension were significant in all the different sub-groups.

Table 9. Panel Cointegration Tests

	Pedroni Tests							Johansen-Fisher	
	Panel Statistics (Within-dimension)				Group Statistics (Between-dimension)			H_0: No cointegration (None)	
Countries	v	rho	t	adf	rho	t	adf	Trace Test	P-Value
Lower-income	-1.924	1.540*	1.118	3.480***	2.529***	1.614*	4.253***	89.230***	0.000
Lower-middle income	-0.569	1.509*	0.924	1.569*	2.531***	1.596*	2.353***	120.600***	0.000
Upper-middle income	-1.447	1.403*	0.900	2.987***	2.058**	1.370*	3.395***	76.380***	0.000
All Countries	-1.374	-1.829	-3.796	2.615***	-2.715	-4.790	3.096***	299.400***	0.000

Note: We used the unrestricted model allowing for both asymmetries in Energy and Finance: $\ln GDP = f(\ln ENC^{+}, \ln ENC^{-}, \ln FIN^{+}, \ln FIN^{-}, \ln GFCF, \ln LAB, \ln TRADE)$. *** p<0.01; ** p<0.05; * p<0.1. The optimal lag for the tests is determined automatically by the Akaike Information Criteria with a maximum of 4 lags.

Only the *adf*-statistic was significant in all countries at the 1% level. Also, the *Trace* statistic of the Johansen-Fisher method is significant at the 1% level in all the sub-groups, as well as in the entire SSA region. Therefore, we cannot reject the alternative *hypothesis 6* of cointegration. These results confirm the existence of cointegration among the variables, i.e., there is a long-term relationship between energy consumption, financial development and economic growth in the different categories of countries and the entire SSA countries.

Furthermore, we examined the asymmetrical relationship between energy consumption, financial development, and economic growth by performing Wald tests based on the estimations of the unrestricted NARDL model using three alternative estimators, as described in section 3.3.2. These estimators are the dynamic ordinary least squares (DOLS), the fully modified ordinary least squares (FMOLS), both allowing for homogeneity and heterogeneity across panel units, as well as the pooled mean group (PMG). We employed these estimators to ensure the robustness of our results using different approaches. Table 10 presents the results of the symmetry tests using these different estimators.

Table 10. Panel Symmetry Tests

	Lower-income		*Lower-middle-income*		*Upper-middle-income*		*All countries*	
	Unrest Model	Decision	Unrest Model	Decision	Unrest Model	Decision	Unrest Model	Decision
Homogeneity								
DOLS estimator								
Wald lnENC	60.865***	A	11.465***	A	0.161	S	44.274***	A
Wald lnFIN	0.631	S	47.461***	A	1.316	S	20.612***	A
FMOLS estimator								
Wald lnENC	96.532***	A	15.738***	A	0.058	S	54.107***	A
Wald lnFIN	0.848	S	65.554***	A	702.600	S	23.418***	A
Heterogeneity								
DOLS estimator								
Wald lnENC	85.673***	A	25.391***	A	0.234	S	154.625***	A
Wald lnFIN	0.039	S	68.497***	A	1.298	S	40.843***	A
FMOLS estimator								
Wald lnENC	14917.87***	A	555.011***	A	61.482***	A	6951.932***	A
Wald lnFIN	15.878***	A	47.205***	A	107.356***	A	6.829***	A
PMG estimator								
Wald lnENC	4.196**	A	0.606	S	4.744**	A	33.534***	A
Wald lnFIN	0.426	S	20.298***	A	4.969**	A	5.921**	A

Note: The Wald tests were performed using the results of the estimation of the following unrestricted (*Unrest.*) NARDL model: lnGDP = f($lnENC^+$, $lnENC^-$, $lnFIN^+$, $lnFIN^-$, lnGFCF, lnLAB, lnTRADE). We also used the Dynamic Ordinary Least Squares (DOLS), the Fully Modified Ordinary Least Squares (FMOLS), and the Pooled Mean Group (PMG) estimators. The null hypothesis of the test in *Wald lnENC* (respectively in *Wald lnFIN*) assume that the estimated coefficients of $\ln ENC^+$ and $\ln ENC^-$ (respectively of $\ln FIN^+$ and $\ln FIN^-$) are statistically identical (hypothesis of symmetrical effect). The letters A and S indicate asymmetry and symmetry, respectively. The symbols ***, **, and * indicate rejection of the null hypothesis respectively at the 1%, 5%, and 10% levels of significance.

Thus, the results of the DOLS and FMOLS reject the null hypothesis of symmetry in favor of the alternative *hypothesis 7* of asymmetry only in energy at the 1% level of significance when allowing for homogeneity in lower-income countries. Thus, energy consumption had an asymmetrical effect on economic growth, contrary to financial development in the lower-income countries. This finding was confirmed by the results of the PMG estimator, except for the FMOLS estimator in the case of heterogeneity which indicates that energy consumption and financial development have asymmetrical effects on economic growth at the 1% level in lower-income countries. Besides, Table 10 also shows that these three estimators confirm the asymmetrical relationship between energy consumption, financial development and economic growth at the 1% level of significance in all cases in lower-middle-income countries, except for energy consumption according to the PMG estimator. However, there are mixed results for the upper-middle-income countries, in which we found asymmetrical relationships among variables at the 5% level following the results of the PMG estimator and the FMOLS estimator allowing for heterogeneity, contrary to the others cases. Overall, these three different estimators reject the null hypothesis of symmetry at the 1% level in the entire SSA region. In other words, energy consumption and financial development have asymmetrical effects on economic growth at the 1% level of significance in the entire SSA region selected in this study.

Based on the conclusions of the symmetry tests (see Table 10), we hereafter estimated the appropriate NARDL models for each sub-group of countries, as well as for the entire SSA region. Thus, Table 11 shows the results of the DOLS estimator allowing for homogeneity and heterogeneity across countries of the different sub-groups. We found that a positive shock to energy consumption significantly reduced economic growth at the 1% level, while a negative shock to energy consumption significantly increased economic growth at the 1% level in lower-income countries, and lower-middle-income countries (not significantly in the case of a negative shock), except for the upper-middle-income countries. This result was consistent both in the cases of homogeneity and heterogeneity across countries. Financial development had a symmetrical positive effect on economic growth in the lower-income countries and the upper-middle-income countries. The effect was non-significant in the case of homogeneity across countries but became significant in the case of heterogeneity across countries. However, Table 11 indicates that the asymmetrical effect of financial on economic growth is positive and significant at the 1% level both after positive and negative shocks to financial development in the lower-middle-income countries. The homogeneity and heterogeneity methods provided similar results. Following the results of homogeneous DOLS, the gross fixed capital formation had a non-significant positive effect economic growth only in the lower-income countries, contrary to the other sub-groups. Labor force positively and significantly influenced economic growth in the lower-income countries and the lower-middle-income countries, but the effect is negative in the upper-middle-income countries. We found a positive relationship between trade openness and economic growth in the lower-income countries (non-significant effect) and the upper-middle-income countries (significant effect), whereas this relationship was negative and significant in the lower-middle-income countries. Similarly, the heterogeneous DOLS showed similar results, except the fact that the relationship between the labor force and economic growth became positive in the upper-middle-income countries, whereas trade openness had a significant negative on economic growth in the lower-income countries. Overall, Table 11 reveals that a 1% increase in energy consumption reduces significantly economic growth approximately by 0.22%, whereas a 1% decrease in energy consumption influence positively economic growth by 0.32% in the entire SSA region according to the results of the homogeneous DOLS.

Table 11. Results of the dynamic ordinary least squares (DOLS)

	Lower-income	Lower-middle-income	Upper-middle-income	All countries
Homogeneity				
ln ENC^{+}	-0.752***(-6.37)	-0.251***(-5.34)		-0.217***(-4.96)
ln ENC^{-}	0.617***(4.92)	0.052 (0.58)		0.321***(4.14)
ln ENC	-	-	0.021 (0.23)	-
ln FIN^{+}	-	0.269***(14.16)		0.207***(11.10)
ln FIN^{-}	-	0.051**(2.30)		0.089***(4.40)
ln FIN	0.027 (1.27)	-	0.549 (11.24)	
ln $GFCF$	0.055 (1.63)	-0.074***(-2.76)	-0.048 (-0.54)	-0.007 (-0.27)
ln LAB	1.206***(11.04)	0.175**(2.08)	-0.077 (-0.64)	0.533***(6.63)
ln $TRADE$	0.032 (0.70)	-0.137***(-3.78)	0.418***(3.77)	-0.058**(-2.09)
Adjusted R^2	0.948	0.980	0.889	0.987
Observations	669	708	482	1896
Heterogeneity				
ln ENC^{+}	-0.419***(-4.42)	-0.247***(-6.63)		-0.177***(-6.68)
ln ENC^{-}	0.654***(8.33)	0.106 (1.41)		0.338***(7.23)
ln ENC	-	-	0.008 (0.09)	-
ln FIN^{+}	-	0.258***(15.88)		0.186***(14.16)
ln FIN^{-}	-	0.058***(3.72)		0.081***(8.06)
ln FIN	0.054***(3.74)		0.472***(9.70)	-
ln $GFCF$	0.136***(5.04)	-0.068***(-2.78)	-0.040 (-0.48)	0.017 (1.00)
ln LAB	0.921***(13.27)	0.234***(3.52)	0.056 (0.50)	0.526***(12.11)
ln $TRADE$	-0.107***(-3.39)	-0.127***(-4.11)	0.281***(2.87)	-0.074***(-3.87)
Adjusted R^2	0.941	0.980	0.885	0.987
Observations	669	708	482	1896

Note: *** p<0.01; ** p<0.05; * p<0.1

Both positive and negative shocks to financial development had significant positive effects on economic growth, but the effects were higher in the wake of positive shocks to financial development. Gross fixed capital formation and trade openness negatively affect economic growth, contrary to the labor force. Similarly, the heterogeneous DOLS provides similar results, except that the relationship between gross fixed capital formation and economic turns to be positive but non-significant.

Next, Table 12 shows the results of the fully modified ordinary least squares (FMOLS) in the different categories of countries. We found similar results to those in the DOLS concerning the case of homogeneity across countries. However, the results of the FMOLS differ to those of the DOLS in few cases concerning the hypothetical heterogeneity across countries. Table 12 indicates that financial development has an asymmetrical effect on economic growth in lower-income countries contrary to the results of the DOLS. Both positive and negative shocks to financial development favored economic growth in lower-income countries. Energy consumption and financial development have asymmetrical positive effects on economic growth, respectively. Besides these few exceptions, the results of the FMOLS corroborate those of the DOLS estimator.

Table 12. Results of the fully modified ordinary least squares (FMOLS)

	Lower-income	*Lower-middle-income*	*Upper-middle-income*	*All countries*
Homogeneity				
$\ln ENC^{+}$	-0.936^{***}(-7.97)	-0.274^{***}(-6.23)		-0.231^{***}(-5.45)
$\ln ENC^{-}$	0.696^{***}(5.64)	0.055 (0.67)		0.337^{***}(4.54)
$\ln ENC$	-	-	0.056 (0.65)	-
$\ln FIN^{+}$	-	0.276^{***}(16.59)		0.216^{***}(12.35)
$\ln FIN^{-}$	-	0.044^{**}(2.13)		0.097^{***}(5.05)
$\ln FIN$	0.030 (1.38)	-	0.580^{***}(12.53)	
$\ln GFCF$	0.061^{*}(1.80)	-0.084^{***}(-3.54)	-0.071 (-0.92)	-0.011 (-0.49)
$\ln LAB$	1.383^{***}(13.52)	0.170^{**}(2.22)	-0.137 (-1.22)	0.578^{***}(7.75)
$\ln TRADE$	0.027 (0.62)	-0.133^{***}(-4.32)	0.464^{***}(4.51)	-0.058^{**}(-2.25)
Adjusted R^2	0.945	0.980	0.887	0.987
Observations	672	712	486	1909
Heterogeneity				
$\ln ENC^{+}$	-0.797^{***}(-77.87)	-0.168^{***}(-16.06)	0.084^{***}(8.18)	-0.164^{***}(-30.35)
$\ln ENC^{-}$	0.624^{***}(59.81)	0.093^{***}(9.35)	0.155^{***}(13.76)	0.306^{**}(54.40)
$\ln ENC$		-	-	-
$\ln FIN^{+}$	0.008 (0.77)	0.202^{***}(19.69)	0.330^{***}(22.66)	0.139^{***}(22.53)
$\ln FIN^{-}$	0.067^{***}(5.26)	0.092^{***}(7.97)	0.484^{***}(37.34)	0.117^{***}(18.12)
$\ln FIN$			-	-
$\ln GFCF$	0.064^{***}(4.18)	-0.052^{***}(-4.13)	-0.052^{***}(-2.90)	0.004 (0.55)
$\ln LAB$	1.304^{***}(130.79)	0.201^{***}(20.90)	0.160^{***}(15.12)	0.517^{***}(100.13)
$\ln TRADE$	-0.030^{*}(-1.79)	-0.138^{***}(-9.30)	0.404^{***}(19.18)	-0.049^{***}(-5.50)
Adjusted R^2	0.941	0.972	0.880	0.985
Observations	672	712	485	1909

Note: *** $p<0.01$; ** $p<0.05$; * $p<0.1$

Moreover, we estimated the appropriate NARDL model for each sub-group of countries by using the pooled mean group (PMG) estimator and following the results of the panel symmetry tests. Table 13 exposes the long-term and short-term results of the PMG estimator.

Concerning the long-term analysis, the results showed that positive changes in energy consumption had non-significant positive effects on economic growth, contrary to negative changes in energy consumption in lower-income countries. Financial development and labor force were harmful to economic growth, whereas gross fixed capital formation and trade openness positively influenced economic growth in lower-income countries. Energy consumption had a symmetrical positive effect on economic growth, but a positive shock in financial development had a significant negative impact on economic growth, in contrast to the negative shock to financial development in lower-middle-income countries. These results contrast with those of upper-middle-income countries where energy consumption had asymmetrical effects on economic growth, but also positive and negative shocks to financial development had different effects on economic growth. The labor force and the gross fixed capital formation significantly supported economic growth in lower-middle-income countries and upper-middle-income countries. The relationship between trade openness and economic growth was non-significant and negative in lower-middle-income countries, but positive and significant at the 10% level in upper-middle-income countries. We also found that positive and negative changes in energy consumption had positive effects on economic growth in the SSA countries, whereas a positive shock to financial development had a significant adverse effect on economic growth at the 5% level, contrasting with the negative shock to financial development in the SSA region in the long-term.

Table 13. Panel estimations using Pooled mean group (PMG)

	Lower-income	Lower-middle-income	Upper-middle-income	All countries
Long-term				
$\ln ENC^{+}$	0.486 (1.38)	-	-0.471 (-1.14)	1.673***(8.29)
$\ln ENC^{-}$	-0.062 (-0.21)	-	2.141**(2.09)	0.169 (1.07)
$\ln ENC$	-	0.015 (0.14)		-
$\ln FIN^{+}$	-	-0.230**(-2.53)	0.336 (1.57)	-0.230**(-2.31)
$\ln FIN^{-}$	-	0.144***(2.63)	-0.466**(-1.99)	0.065 (1.01)
$\ln FIN$	-0.006 (-0.15)	-		-
$\ln GFCF$	0.321***(2.72)	0.305***(3.77)	0.155 (0.83)	0.229***(3.37)
$\ln LAB$	-0.236 (-0.63)	0.853***(4.14)	0.799*(1.71)	0.408*(1.93)
$\ln TRADE$	0.173 (1.22)	-0.074 (-1.09)	0.754*(1.70)	0.105 (1.59)
Short-term				
$ect(-1)$	-0.021**(-2.31)	-0.029**(-2.11)	-0.018 (-0.82)	-0.052***(-5.16)
$\Delta \ln ENC^{+}$	-0.029 (-0.15)	-	0.122 (1.25)	0.063 (0.64)
$\Delta \ln ENC^{-}$	1.232 (1.49)	-	-0.014 (-0.06)	0.635 (1.20)
$\Delta \ln ENC$	-	-0.008 (-0.09)		
$\Delta \ln FIN^{+}$	-	-0.009 (-0.43)	0.049 (1.55)	-0.019 (-0.60)
$\Delta \ln FIN^{-}$	-	0.199 (1.26)	-0.207***(-2.92)	-0.008 (-0.18)
$\Delta \ln FIN$	-0.012 (-1.28)	-		
$\Delta \ln GFCF$	0.011 (0.57)	0.000 (0.003)	0.040 (0.72)	0.021 (1.17)
$\Delta \ln LAB$	0.455 (1.46)	0.694**(2.16)	0.123 (0.38)	0.449***(2.84)
$\Delta \ln TRADE$	-0.010 (-0.41)	0.012 (0.35)	0.071 (1.59)	0.012 (0.64)
Constant	0.176**(2.27)	-0.212**(-2.16)	-0.117 (-0.84)	0.0003(0.06)
Observations	672	712	485	1909

Note: Selected Model: NARDL (1, 1, 1, 1, 1, 1, 1, 1); model selection method: Akaike info criterion (AIC) with maximum lags 4. * p <0.1, ** p<0.05, *** p<0.01

In the short-term, the effects of energy consumption on economic growth were opposed to the similar long-term effects in all three categories of countries. However, the results concerning the relationship between financial development and economic growth are identical to those found in the long-term in all sub-groups of countries. Besides, Table 13 indicates that gross fixed capital formation, labor force, and trade openness have positive but not significant effects on the short-term economic growth of the three categories of countries, except for the non-significant negative effect of trade openness on economic growth in the lower-income countries. With regards to the entire SSA region, energy consumption had an asymmetrical positive effect on economic growth, contrary to both positive and negative shocks on financial development. Gross fixed capital formation, labor force, and trade openness have been positively correlated with short-term economic growth, similar to the long-term effects in the SSA region. However, the short-term effects were not significant, and their magnitudes were smaller than in the long-term in most cases.

Finally, we carried out the panel causality analysis between variables for each category of countries following the tests developed by Dumitrescu and Hurlin (2012). The null hypothesis (H_0^8) of no causality is rejected in many cases, in favor of the alternative *hypothesis 8* of causality among the variables. Thus, Table 14 shows that there is bidirectional causality between positive changes in energy consumption and economic growth in lower-income countries and lower-middle-income countries at the 1% level of significance, whereas there is unidirectional causality running from economic growth to positive changes in energy consumption in upper-middle-income countries. We also found bidirectional causality between negative changes in energy consumption and economic growth in lower-middle-income countries and upper-middle-income countries, but unidirectional causality from negative changes in energy consumption to economic growth in lower-income countries. However, financial development does not cause economic growth, but instead economic growth drives financial development in lower-income countries at the 1% level. Table 14 indicates bidirectional causality between positive shocks to financial development and economic growth in lower-middle-income and upper-middle-income countries at the 1% level. There is also bidirectional causality between negative shocks to financial development and economic growth in lower-middle-income countries. Besides, bidirectional causality was found between gross fixed capital formation and economic growth in the lower-income countries at the 1% level, whereas there is unidirectional causality running from gross fixed capital formation to economic growth in lower-middle-income countries, but unidirectional causality from economic growth to gross fixed capital formation in upper-middle-income countries at the 1% level of significance. We found bidirectional causality between the labor force and economic growth at the 1% level in lower-income countries and upper-middle-income countries, but unidirectional causality from the labor force to economic growth in lower-middle-income countries at the 1% level of significance. There is only unidirectional causality running from trade openness to economic growth in all three categories of countries at the 1% level.

Overall, the panel causality analysis revealed bidirectional causality between positive changes in energy consumption and economic growth at the 1% level, but unidirectional causality from negative changes of energy consumption to economic growth at the 5% level in the SSA region. Also, there were bidirectional causalities between positive shocks in financial development and economic growth, as well as between negative shocks in financial development and economic growth at the 1% level of significance. In the SSA region, we also found bidirectional causalities between gross fixed capital formation and economic growth, but also between the labor force and economic growth at the 1% level. However, there was unidirectional causality running from trade openness to economic growth at the 1% level of significance.

To sum up, the panel analysis showed that there was an asymmetrical relationship between energy consumption and economic growth in lower-income countries, lower-middle-income countries, but mixed results in upper-middle-income countries. Similarly, we found more evidence of asymmetrical effects of financial development on economic growth in lower-middle-income countries, contrary to the lower-income countries and upper-middle-income countries where there were mixed results. In most cases, positive changes in energy consumption hurt significantly economic growth, unlike the negative changes in energy consumption in lower-income countries and lower-middle-income countries. Also, financial development significantly increased economic growth in the long-term in the three categories of countries. Overall, the results indicated asymmetrical relationships between energy consumption, financial development and economic growth in the SSA region. Besides, positive changes in energy consumption significantly hampered economic growth, whereas negative changes in energy consumption significantly boosted economic growth at the 1% in the long-term in the SSA region. Both positive and negative shocks to financial development increased economic growth in the long-term in the SSA region. Nevertheless, energy consumption (positive and negative changes) had non-significant positive effects on economic growth, but financial development (positive and negative shocks) non-significantly reduced economic growth in the short-term in the SSA region. Negative changes in energy consumption and positive shock to financial development have higher effects on economic growth than positive changes in energy consumption and adverse shocks to financial development respectively in the SSA region.

Our results suggest the use of renewable energies to combat the adverse effects of increasing energy consumption on long-term economic growth. The increase in energy consumption raises many concerns, such as environmental pollution and public health problems, which negatively affect factors of production and, consequently, economic growth in the long term. Moreover, energy-saving policies can be further implemented in the SSA region, as restrictive energy use (negative changes) does not hinder economic growth. These results also support the use of renewable energy and other more energy-efficient methods, while respecting environmental preservation and long-term sustainable development. Furthermore, the relatively low level of financial development in the sub-Saharan region hampers economic growth in the short term, particularly in lower-income and middle-income countries. The long-term positive effects of financial development on economic growth imply the need to improve the financial system of the region further. The results also highlight the need to strengthen financial inclusion and access to credits to finance productive investments, to accelerate the development of SSA regions, particularly in low-income and middle-income countries.

Table 14. Results of the Panel Causality Tests by Dumitrescu and Hurlin (2012)

	Lower-income			Lower-middle-income			Upper-middle-income			All countries		
Null hypothesis	W-Stat	Zbar-Stat	P-value	W-Stat	Zbar-Stat	P-value	W-Stat	Zbar-Stat	P-value	W-Stat	Zbar-Stat	P-value
$\ln ENC^{+}$ does not cause $\ln GDP$	11.123	4.871***	0.000	13.709	7.051***	0.000	7.367	1.484	0.137	11.487	8.499***	0.000
$\ln GDP$ does not cause $\ln ENC^{+}$	9.798	3.788***	0.000	15.011	8.125***	0.000	11.317	4.097***	0.000	12.071	9.281***	0.000
$\ln ENC^{-}$ does not cause $\ln GDP$	10.738	4.556***	0.000	7.959	2.314**	0.020	12.735	5.035***	0.000	8.669	4.723**	0.000
$\ln GDP$ does not cause $\ln ENC^{-}$	4.116	-0.857	0.391	3.131	-1.663*	0.096	10.152	3.326***	0.000	5.109	-0.046	0.962
$\ln ENC$ does not cause $\ln GDP$	-	-	-	-	-	-	3.435	-1.116	0.264	-	-	-
$\ln GDP$ does not cause $\ln ENC$	-	-	-	-	-	-	15.514	6.873***	0.000	-	-	-
$\ln FIN^{+}$ does not cause $\ln GDP$	-	-	-	11.926	5.582***	0.000	30.192	16.574***	0.000	14.544	12.592***	0.000
$\ln GDP$ does not cause $\ln FIN^{+}$	-	-	-	14.783	7.936***	0.000	16.668	7.632***	0.000	15.592	13.997***	0.000
$\ln FIN^{-}$ does not cause $\ln GDP$	-	-	-	8.156	2.476**	0.013	6.985	1.230	0.218	7.610	3.303***	0.001
$\ln GDP$ does not cause $\ln FIN^{-}$	-	-	-	7.381	1.837*	0.066	6.621	0.990	0.322	8.409	4.373***	0.000
$\ln FIN$ does not cause $\ln GDP$	4.983	-0.148	0.882	-	-	-	19.626	9.586***	0.000	-	-	-
$\ln GDP$ does not cause $\ln FIN$	19.270	11.531***	0.000	-	-	-	14.585	6.254***	0.000	-	-	-
$\ln GFCF$ does not cause $\ln GDP$	8.806	2.976***	0.002	10.396	4.321***	0.000	6.595	0.973	0.330	9.231	5.475***	0.000
$\ln GDP$ does not cause $\ln GFCF$	9.514	3.555***	0.000	5.024	-0.104	0.916	18.112	8.591***	0.000	10.419	7.067***	0.000
$\ln LAB$ does not cause $\ln GDP$	25.114	16.309***	0.000	12.627	6.160***	0.000	21.065	10.545***	0.000	19.169	18.790***	0.000
$\ln GDP$ does not cause $\ln LAB$	9.220	3.315***	0.000	6.668	1.250	0.211	14.794	6.397***	0.000	11.622	8.678***	0.000
$\ln TRADE$ does not cause $\ln GDP$	13.334	6.678***	0.000	12.194	5.803***	0.000	21.672	10.946***	0.000	15.106	13.348***	0.000
$\ln GDP$ does not cause $\ln TRADE$	4.381	-0.640	0.521	5.959	0.666	0.505	4.685	-0.289	0.772	5.214	0.094	0.924

Note: The optimal lag is 5 following the Akaike Information Criterion (AIC). * p <0.1, ** p<0.05, *** p<0.01

Besides, the mixed asymmetrical effects of financial development on economic growth across countries reveal that financial regulations and controlled credit allocations to the private sector are needed in the SSA region. Finally, policymakers should pay attention to the asymmetrical relationship between energy consumption, financial development and economic growth in the conduct of economic policies in the sub-Saharan region.

Although the results of the positive effects of financial development on economic growth are similar to that in Le (2015) in the long-term, our study differs from his findings since we found asymmetrical effects of energy consumption and financial development on economic growth in the SSA region. Besides, our study reveals that only negative changes in energy consumption have a positive effect on economic growth contrary to positive changes in energy consumption. We also considered both country-level and panel data analyses while allowing for asymmetrical and nonlinear causality in the relationship between energy consumption, financial development and economic growth in the SSA region, unlike many studies in that region (Wolde-Rufael, 2005; Le, 2015; Kassi et al. 2017).

5. Conclusion and policy implications

This study examined the asymmetrical relationship between financial development, energy consumption, and economic growth in twenty-one (21) selected SSA countries from 1990Q1 to 2014Q4. We considered both country-level analysis and panel data analysis following the income classification into lower-income countries, lower-middle-income countries, and upper-middle-income countries. The country-level analysis used the NARDL framework of cointegration in Shin et al. (2014) and the Granger non-causality test in Toda and Yamamoto (1995). The panel analysis employed the DOLS and FMOLS methods allowing for homogeneity and heterogeneity across countries, but we also used the PMG method and the causality tests by Dumitrescu and Hurlin (2012).

Concerning the country-level analysis, we found that there is a long-term relationship between financial development, energy consumption and economic growth in many countries. Besides, the country-level analysis showed few cases of asymmetrical relationships between energy consumption and economic growth (9 countries), as well as between financial development and economic growth (10 countries) with mixed results across countries in the long-term. However, there were many cases of asymmetry in the energy-growth nexus (15 countries), but also in the finance-growth nexus (17 countries) during the short-term. Positive changes in energy consumption had a significantly negative effect of economic growth, whereas the negative changes in energy consumption had a significant positive effect on economic growth in most cases in the short-term. Although there were mixed results in the finance-growth nexus, both positive and negative shocks to financial development significantly reduced economic growth in most countries during the short-term. We also found unidirectional causality from positive changes in energy consumption to economic growth in the democratic republic of Congo and Ghana, but reverse sense in Angola, the Republic of Congo, and Eritrea. Negative changes in energy consumption Granger caused economic growth in the democratic republic of Congo and South Africa, but this causality was inversed in Mozambique and Tanzania. There was unidirectional causality from positive shocks of financial development to economic growth in the democratic republic of Congo, Niger, South

Africa, and Sudan, but from economic growth to positive shocks of financial development in Angola, Gabon and Mauritius. The country-level analysis indicated bidirectional causality between negative shocks to financial development and economic growth in Angola and the democratic republic of Congo. There was unidirectional causality from negative changes of financial development to economic growth in Niger, but from economic growth to negative shocks of financial development in Cameroon, Cote d'Ivoire, Eritrea, Mozambique, Tanzania, and Togo.The results of the panel analysis also confirmed the long-term relationship between the variables. In most cases, there was an asymmetrical relationship between energy consumption, financial development and economic growth in lower-middle-income countries, and mixed results in upper-middle-income countries, but an asymmetrical relationship between energy consumption and economic growth in lower-income countries. Although the PMG estimator indicated mixed results, the DOLS and FMOLS estimators showed that positive changes in energy consumption significantly hampered economic growth, contrary to the negative changes in energy consumption in lower-income countries and lower-middle-income countries, except in upper-middle-income countries where the mixed results indicate that energy consumption had positive effect on economic growth in the long-term. However, both positive and negative shocks to financial development were beneficial to economic growth in all categories of countries. The effects of financial development on economic growth were relatively higher in the upper-middle-income countries, similarly to those of energy consumption in the lower-income countries in the long-term.

Overall, the results of the panel analysis revealed that the increasing energy consumption (positive changes) reduced economic growth, contrary to restrictive energy consumption (negative changes), but positive shocks to financial development had a more significant positive effect on economic growth compared to the adverse shocks in the SSA region in the long-term. Nevertheless, both positive and negative changes in energy consumption had a positive effect on economic growth, contrary to those of financial development in the SSA region during the short-term. Besides, we found bidirectional causality between positive changes in energy consumption and economic growth in the SSA region, especially in lower-income countries and lower-middle-income countries, but unidirectional causality from negative changes of energy consumption to economic growth in the SSA region. There was bidirectional causality between negative changes in energy consumption and economic growth in lower-middle-income countries and upper-middle-income countries. However, there was bidirectional causality between positive changes of financial development and economic growth, as well as bidirectional causality between negative changes of financial development and economic growth in the SSA region, in particular in lower-middle-income countries. The results only indicated bidirectional causality between positive changes in financial development and economic growth, but no causality between negative changes in financial development and economic growth in upper-middle-income countries. There was also unidirectional causality running from economic growth to financial development in lower-income countries.

Thus, our study contributes to the empirical literature by considering the asymmetrical relationship between financial development, energy consumption and economic growth in both the country-level and panel data analyses while allowing for different categories of countries in the SSA region unlike previous studies (Wolde-Rufael, 2005; Le, 2015; Kassi et al. 2017). Accordingly, our findings suggest that policy-makers should consider the asymmetrical relationship between financial development, energy consumption and economic growth in the elaboration of economic policies in the SSA region. Notably, energy-saving policies can be further implemented in the SSA region, as restrictive energy use (negative changes) does not hinder economic growth. Our study supports the use of renewable energies to promote economic growth since they may contribute to the environment protection and sustainable development in the SSA region. Moreover, although both positive and negative changes of financial development enhance economic growth in the SSA region, the mixed results across countries show the need to improve the development of the financial sector further to support economic growth in the SSA countries. Our findings suggest an efficient allocation of the credits to the private sector coupled with the supervision of productive investments, especially in the lower-income countries having weak financial development. Policy-makers should improve the credit regulatory and supervision frameworks because the free increasing credits to the private sector hinder economic growth in some SSA countries (Arcand et al., 2012). However, the increased access to credits supports economic growth in some SSA countries. In the conduct of energy and economic programs, policy-makers must also consider the different level of economic development among the SSA countries

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