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The Impact of Financial Development on Fossil Energy Demand in West African Economic and Monetary Union (WAEMU) Countries: An Application of Pooled Mean Group Estimation on Non Stationary Panel Data

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Abstract

The objective of this study is to analyze the impact of financial development (variable of interest) on fossil energy demand (dependent variable) in West African Economic and Monetary Union (WAEMU) countries by Pooled Mean Group estimation on non-stationary dynamic panel data. We found that financial development and other control variables such as gross domestic product and industrialization impact significantly and positively fossil energy demand in WAEMU countries in the long run, the coefficient of urban population and foreign direct investment are also positive but not significant. In the short run however, only gross domestic product has a negative and significant impact on fossil energy demand in WAEMU countries.

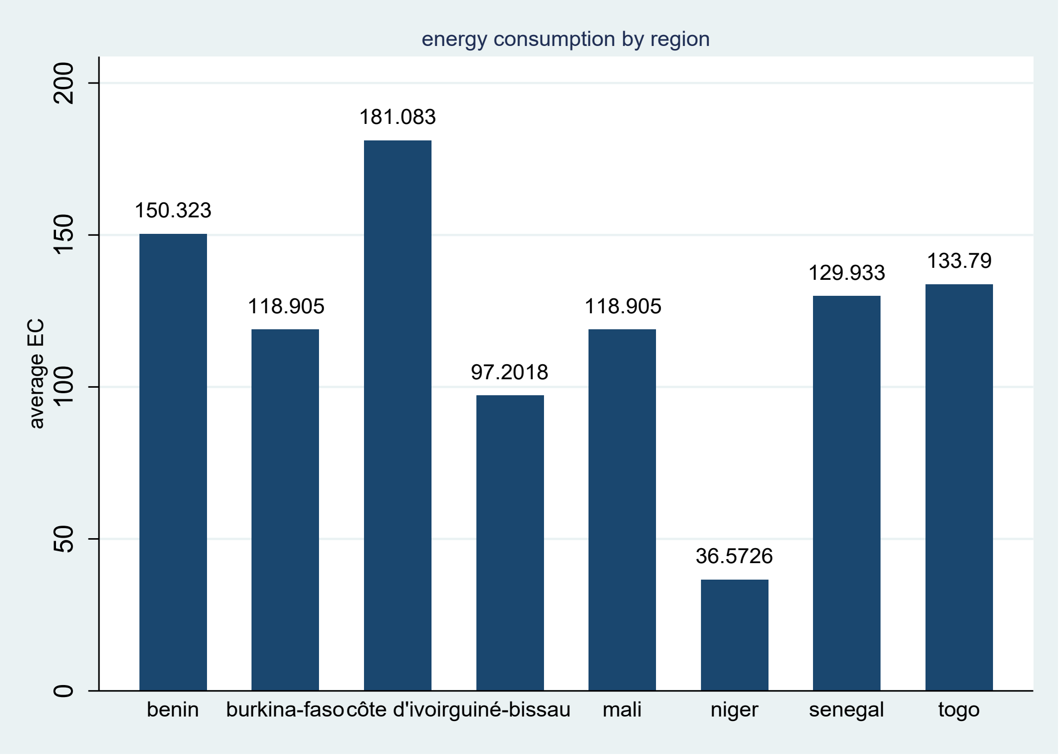
Keywords

Fossil Energy Demand, Financial Development, Pooled Mean Group Estimation, Dynamic Panels, WAEMU Countries

1. Introduction

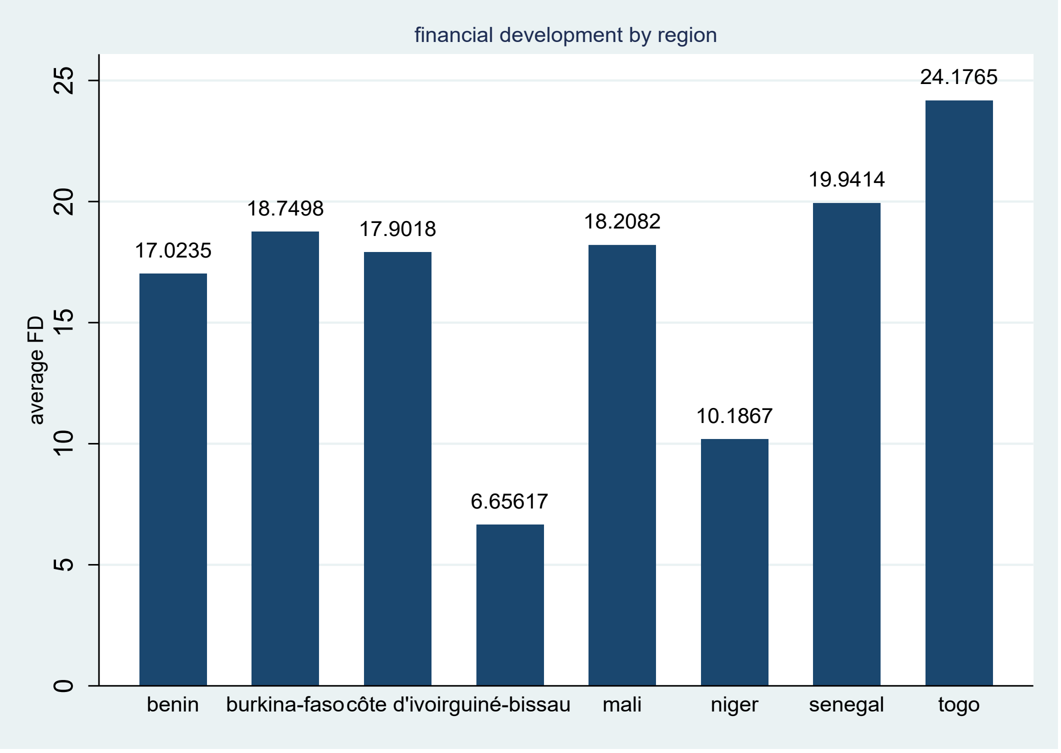
Financial development leads to the development of industrial economic activities which induce an increase in energy consumption. The first empirical study that advanced the introduction of financial development as an explanatory variable of energy consumption is that of (Karanfil, 2009). Increased financial development facilitates access to credit for public and private enterprises and stimulates economic growth, which has the immediate effect of boosting energy consumption (*lucas88.pdf*, s.d.; Sadorsky, 2011; Stern, 1989). The development of world economic growth means that most of the world's future emissions would be generated by developing countries (Jung et al., 2000). Progress in financial development, urbanization and industrialization leads to industrial transformations and changes in energy consumption models, which in turn increase energy use and emissions (Li & Lin, 2015). Since the 1970s, developing countries have undergone fast-paced urbanization industrialization and financial development, which has stimulated economic growth by catalyzing the increase in energy demand and the development of transformation activities in several sectors. The increase in energy demand accelerates the rapid growth of fossil fuel consumption and produces significant amounts of carbon dioxide (CO2) and other greenhouse gas (GHG) emissions. As developed countries have made most emissions in the past and currently have reached per capita emissions, the development of world economic growth means that most of the world's future emissions would be generated by developing countries. In the eight member states of the West African Economic and Monetary Union (WAEMU), despite significant efforts deployed in recent years by the public authorities, the population's energy service needs remain always dissatisfied, both in quantity and quality, thus compromising the development of these countries. The West African Economic and Monetary Union (WAEMU) countries have currently eight-member states which are Benin, Burkina Faso, Côte d'Ivoire, Guinea Bissau, Mali, Niger, Senegal and Togo. For more than a decade, WAEMU member states have experienced, to varying degrees, persistent difficulties in meeting their local electrical energy needs. Despite attempts at an individual or concerted response to this situation, WAEMU member states, with the exception of Côte d'Ivoire, are still experiencing many major disturbances in the distribution of electrical energy. There has been a large body of published research investigating the demand for energy in emerging economies but most of this research has focused on the relationship between energy consumption and income (Akinlo, 2008; Al-Iriani, 2006; Lee & Chang, 2008). After the crisis of COVID-19, the vulnerability of the economies of WAEMU member states has become one of the major concerns with regard to the surge in the price of oil and the structural nature of this development. The energy bill becomes more expensive and translates into loss of growth points and difficulties for households faced with inflation that is spreading in practically all sectors of activity. Between increasingly scarce wood and increasingly expensive oil, renewable energy sources deserve to be better financed by financial institutions to allow households and factories to have access to potential sources of energy.

Energy consumption is higher in Côte d'Ivoire than in other WAEMU countries due to the development of its industrial, infrastructure and agricultural sectors (**Figure 1**).



Source: Author's compilation using WDI (World Development Indicators), 2021.

Figure 1. Energy consumption in WAEMU countries.



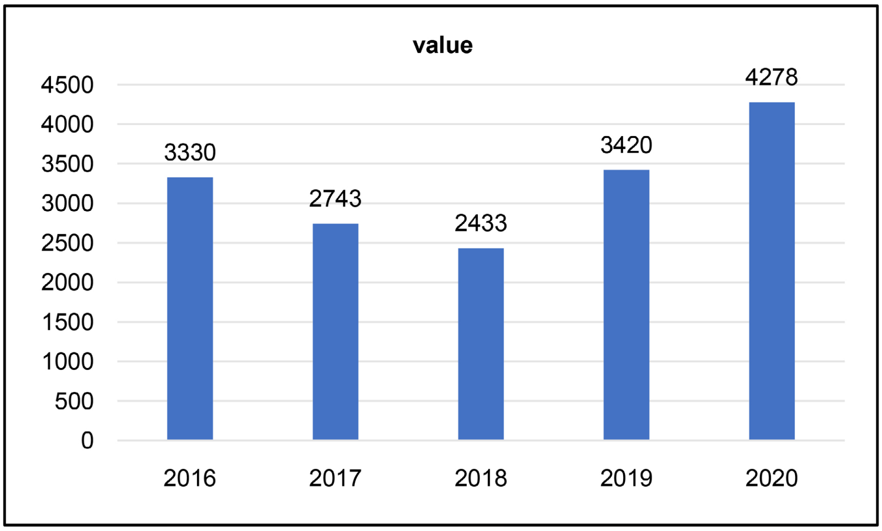
Source: Author's compilation using WDI (World Development Indicators), 2021.

Figure 2. Average domestic credit to private sector in WAEMU countries.

Recently, in certain Member States, the cumulative periods of load shedding sometimes exceed twelve hours per day. This energy crisis, which has finally become structural, is aggravated by the unfavorable international situation for oil-importing countries due to the continuous fluctuations in the price of petroleum products.

Financial development is more important in Togo than in other WAEMU countries because of the development of its banking and private sector (Figure 2).

Resulting directly from the implementation of development policies, State interventions on the Public Securities Market have increased in recent years (Figure 3). From 2016 to 2020, the annual volume of issues increased from 3330 to 4278 billion FCFA. The Regional Stock Exchange (BRVM) is common to all eight (8) countries of the West African Economic and Monetary Union (WAEMU). The BRVM is responsible for organizing the stock market, listing and trading securities and disseminating stock market information.

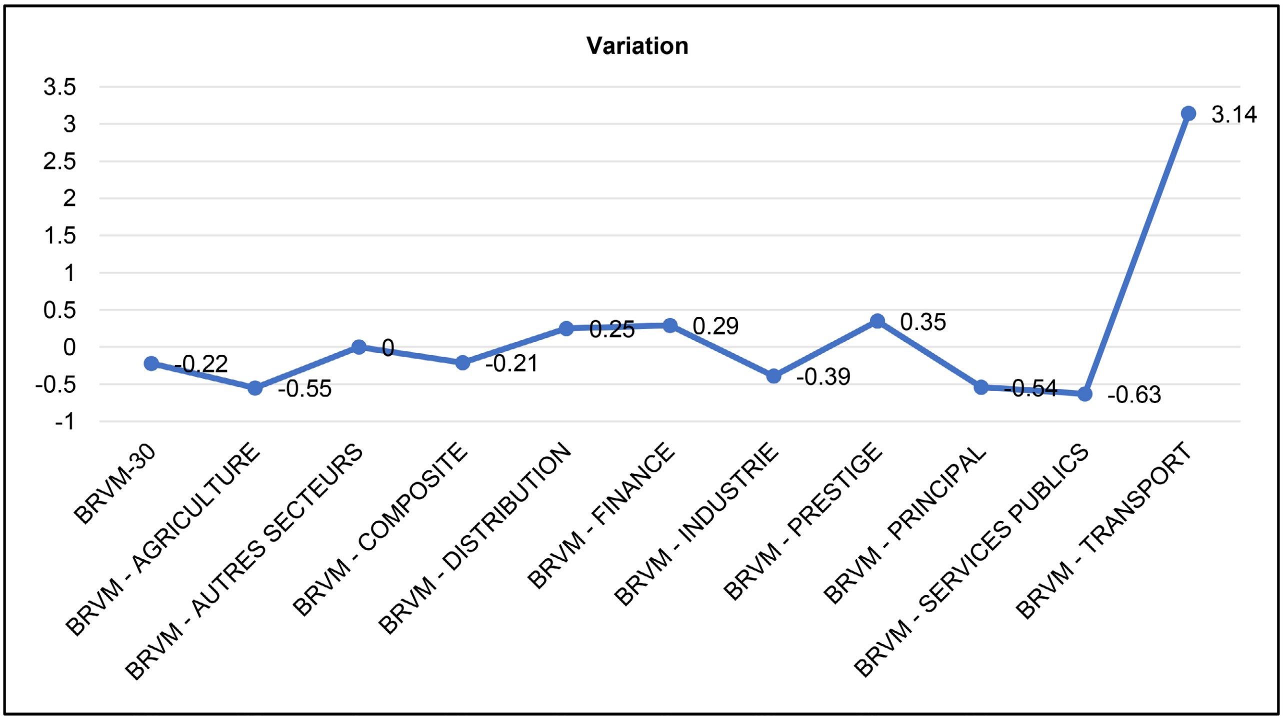


Source: WAEMU—Securities Agency, 2020.

Figure 3. Overview of the evolution of the volume (billion FCFA) of issues of financial securities between 2016 and 2020.

The transport sector is the driving sector of the BRVM in the WAEMU countries (Figure 4). The governments of these countries must boost public investment by revolutionizing modern transport infrastructure to revitalize the economy of the sub-region, the same is true in other sectors where there is a downward variation in the BRVM index as in agriculture and industry.

The main objective of the paper is to study the impact of financial development on energy consumption for the specific case of WAEMU countries. The paper starts by introduction (section 1), and then presents the theoretical and empirical framework (section 2). Section 3 details the empirical model, data, and methodology. Sections 4 reports the empirical results, and finally section 5 offers the conclusions and policy implications.



Source: WAEMU—Securities Agency, 2023.

Figure 4. Last BRVM update: Tuesday, April 18, 2023 - 10:45 p.m.

2. Theoretical and Empirical Framework

The energy use in Africa is very weak because of the poor supply of modern technology despite the important deposits of energy resources resulting in frequent power blackouts, limited access to clean energy sources and increased use of unclean energy sources in African countries. The improvement of financial development makes it easier for consumers to become indebted and therefore to buy expensive products and consume more energy (houses, refrigerators, cars…). The improvement of financial development makes it easier for consumers to become indebted and therefore to buy expensive products and consume more energy (houses, refrigerators, cars…) and hence the tendency of energy demand increases as a result of economic production improvement due to more access to domestic credit to private sector. According to the literature, financial development is an important and significant factor of energy consumption as it allows individuals, households, and firms to demand more energy when access to credit is available (Ma & Fu, 2020). Access to energy is a major problem in developing countries because of poverty, insufficient purchasing power and low income. However, the development of the financial sector through the economy credit is for households, enterprises and governments, a source of funding for access to solar energy, hydroelectric energy, and thermal energy. The link between financial development and energy consumption can be positive or negative in case of shocks of energy prices. Some researchers support the idea that financial development stimulates economic activity and the result is an increase in energy demand (Bekhet et al., 2017; Gaies et al., 2019; Islam et al., 2013; Kahouli, 2017; Sadorsky, 2010; Shahbaz & Lean, 2012) have found a positive link between financial development and energy consumption whereas some of them have found a negative impact (Ali et al., 2015; Mahalik & Mallick, 2014; Zeren & Koc, 2014). Karanfil (2009) has used financial development as an explanatory variable of energy consumption in his study. The author justified his idea by the fact that the relationship between energy consumption and economic growth cannot appear only under a bivariate model. So, he suggested to introduce one of the indicators of financial development such as domestic credit to private sector or market capitalization to the model. The more the financial sector is widely developed the more it attracts the foreign direct investments and the more it catalyzes urbanization, industrialization, economic growth and improves energy consumption (Bayar et al., 2021). Energy consumption in factories allow the increase of productivity and push enterprises to require new technologies through financial institutions in seeking economic growth efficiency increases which in turns improves the financial development of the country (Haider & Adil, 2019; Ma & Fu, 2020; Mahalik & Mallick, 2014; Muhammad Awais et al., 2012; Rehman & Rashid, 2017; Sadorsky, 2011; Sbia et al., 2017). There is evidence of bi-directional linkage between financial development and energy consumption (Gungor & Simon, 2017; Roubaud & Shahbaz, 2018; Sadraoui et al., 2019). Ahmed (2017) found a positive impact of financial development on energy consumption in Brazil, Russia, India, China, and South Africa. Gómez and Rodríguez (2019) found negative effect between financial development and energy consumption with panel data from 1971 to 2015 in the North American Free Trade Agreement. Sadraoui et al. (2019) concluded that financial development influences significantly energy consumption and economic growth in the Middle East and North Africa regions from 2000 and 2018. Roubaud and Shahbaz (2018) studied the link between financial development and energy consumption and the result revealed the correlation of the two phenomena in Pakistan from 1972 to 2014. Nkalu et al. (2020) confirmed that there is a unidirectional causality from financial development to energy consumption and economic growth. Odhiambo (2019) got the same results as these latter in South Africa. Haider and Adil (2019) brought out the presence of cointegration as well as non-linear/long-run nexus among financial development, trade openness, and industrial energy use or consumption in India from 1971 to 2016. Odusanya et al. (2021) got both short-run and long-run positive and significant relationship between financial development and energy use in Nigeria using time-series data from 1971 to 2014. Abidin et al. (2015) revealed significant long-run relationship in all the independent variables which include energy consumption, financial development, trade, and foreign direct investment in some Asian economies.

3. Data and Methodology

3.1. Data Source and Justification of the Choice of Variables

The study utilized balanced and cylindrical panel data of 8 countries of WAEMU from 1975 to 2018 obtained from World Development Indicators. The data includes the dependent variable which is CO_2 emissions (metric tons per capita) used as proxy variable of fossil energy consumption, carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring, it is the sum of exports and imports of goods and services measured as a share of gross domestic product (% of GDP). Reducing carbon dioxide (CO_2) emissions has become an effective way to address climate change and therefore it is necessary to study the factors that are likely to significantly influence CO_2 emissions. The interest variable is the domestic credit to private sector (% of GDP) used as proxy variable of financial development. Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable, that establish a claim for repayment. For some countries these claims include credit to public enterprises. The financial corporations include monetary authorities and deposit money banks, as well as other financial corporations where data are available (including corporations that do not accept transferable deposits but do incur such liabilities as time and savings deposits). Examples of other financial corporations are finance and leasing companies, money lenders, insurance corporations, pension funds, and foreign exchange companies. Financial development affects the demand for energy because it allows consumers to access easier and cheaper loans of money to invest more in economic activities. The financial sector plays an important role in the mobilization and use of savings, facilitation of transactions, and monitoring resources towards productive activities in developing countries. Among the control variables we do have the gross domestic product (constant 2015 US$) used as proxy variable of economic growth, the industry value added used as proxy variable of industrialization, the foreign direct investment and the urban population. GDP per capita (constant 2015 US$) is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Economic growth and CO_2 emissions are intertwined because economic activities require the use of fossil fuels, therefore, economic growth is one of the main factors affecting CO_2 emissions. Limiting global warming to below 1.5 degrees will require "rapid, profound and unprecedented changes", including "deep reductions" in non-CO_2 emissions such as methane. The industry value added comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Industrialization and foreign direct investment (in current U.S. dollars) are important factors that strongly influence the fossil energy demand of developing countries. Both variables affect not only the evolution of labor market dynamics but also the volatility of macroeconomic variables, financial supply, international trade integration, technological impact, human capital formation and improvement of economies of scale leading to more fossil energy consumption. Foreign direct investment refers to direct investment equity flows in the reporting economy. It is the sum of equity capital, reinvestment of earnings, and other capital. Direct investment is a category of cross-border investment associated with a resident in one economy having control or a significant degree of influence on the management of an enterprise that is resident in another economy. Ownership of 10 percent or more of the ordinary shares of voting stock is the criterion for determining the existence of a direct investment relationship. Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects. Urbanization impacts could be observed via population migration and growing size, the extension of the transport network and intensification of industrial and service activities, the expansion of public utilities such as health and education for urban citizens. As energy consumption increases, the level of carbon emissions invariably increases due to economic activities for enhanced GDP.

3.2. Justification of the Pooled Mean Group Method

In the first step of our investigation, we developed the equation that is shown below to serve as the basic model:

$$\mathrm{CO2EMT}_{i,t} = \alpha_{0i} + \alpha_1 \mathrm{DCP}_{i,t} + \alpha_2 \mathrm{URP}_{i,t} + \alpha_3 \mathrm{GDP}_{i,t} + \alpha_4 \mathrm{FDI}_{i,t} + \alpha_5 \mathrm{IND2}_{i,t} + \varepsilon_{i,t} \quad (1)$$

The indice i denotes the country ($i = 1, \cdots, 8$), t denotes the time period ($t = 1975, \cdots, 2018$), α_{0i} are the country specific effects, $\varepsilon_{i,t}$ is the error term whose variance is heterogeneous across countries, CO2EMT is the dependent variable which is the CO2 emissions in metric tons per capita, $X_{i,t}$ is the vector of related determinants such as domestic credit to private (DCP), urban population (URP), gross domestic product (GDP), foreign direct investment (FDI) and industrialization (IND2).

We apply the Pooled Mean Group (PMG) approach of (Pesaran et al., 2000) to examine the relationship between fossil energy demand and select related determinants for 8 WAEMU countries.

According to (Pesaran et al., 2000), panel ARDL can be employed to estimate the models with variables that are I(0), I(1), or both I(0) and I(1). Even in case of the possible endogeneity problem the coefficients of ARDL estimation are considered consistent, as the model includes lags of both dependent and independent variables. The traditional estimation methods of panel data by Ordinary Least Squares, Fixed Effects or Random Effects lead to non-convergent estimators. To overcome this endogeneity problem, authors employ the generalized method of moments (GMM) which has some worries such as the homogeneity of the coefficients (common effects from one country to another), except for the constant that captures the specific effects and it ignores the properties of unit root and cointegration of the series and hence, it is difficult to clearly state whether the results provide long-term effects or spurious results. In our study, the number of countries is less important than the period in our dynamic panel, hence the use of GMM estimators is not appropriate. For all these reasons, we decided to use the Pooled Mean Group method because its estimator has an advantage in the treatment of dynamic panels for which the number of temporal observations T is greater than that of individuals N (T > N) (Pesaran et al., 2000). It offers the possibility of estimating a long-term relationship between different variables, without prior precautions regarding stationarity or even the existence of a cointegration relationship between them.

3.3. Stationarity Test

The methodology of unit root test depends on the nature of data, in panel data, we do have two types of unit root tests: first generation tests and second-generation tests. The first-generation tests, the most used in the literature are the tests of (*Levine, Lin, & Chu, 2002. Unit Root… - Google Scholar*, s. d.; Maddala & Wu, 1999; Pesaran et al., 2004) which rely on the tests of (Dickey, 2014) with the null hypothesis of non-stationarity and the heterogeneity between the individuals in the panel. However, the most widely used second-generation tests are the tests of (Choi, 2001; Pesaran et al., 2004; Phillips & Sul, 2003) with the presumption of interdependence between individuals and this hypothesis is admitted as an advantage for better studying the properties of panels (Guillaumin, 2011). In our study, we run the Levin-Lin-Chu (LLC) unit-root test which may be describe as an ADF regression for panel dataset in the following format:

$$\Delta y_{i,t} = \alpha_i \gamma_i y_{i,t-1} + \sum_{j=1}^{p} \varphi_j \Delta y_{i,t-j} + \varepsilon_{i,t} \quad (2)$$

The coefficient $\gamma_i = \rho_i$ and the method examines whether the unit root hypothesis is valid: H_0: $\gamma_i = 0$ ($\rho_i = 1$) against H_1: $\gamma_i < 0$ ($\rho_i < 1$).

3.4. Cointegration Test

Kao (1999) utilizes the Dickey-Full and Augmented Dickey-Fuller types in which the null hypothesis tests is the absence of cointegration based on the two-step procedure of (Engle & Granger, 1987). Kao (1999) relies on the fact that cointegrating vectors are homogeneous between individuals unlike that of (Pedroni, 1999) but, these tests do not admit for heterogeneity under the alternative hypothesis to be taken into account and are only valid for a bivariate system. Based on the Monte Carlo simulations, Gutiérrez (2003) concludes that Kao's tests are superior to Pedroni's tests and provide better estimates in the case of small sample size and hence many researchers prefer the use of Kao cointegration test.

3.5. Model Specification

The PMG technique provides efficient estimator because it permits us to master dynamic heterogeneous panels by involving a long-run relationship between fossil energy demand and the considered determinants compared to other developed procedures, such as for example the dynamic panel GMM method, that exclude long-run linkages among variables. This is of great interest as the variables under consideration are cointegrated.

Equation (1) is transformed into a panel ARDL (*p*, *q*1, *q*2, *q*3, *q*4, *q*5) equation, in which p stands for the lags associated with the dependent variable and *q* stands for the lags associated with the independent variables as following:

$$\begin{aligned} \ln \mathrm{CO2EMT}_{it} &= \alpha_i + \sum\nolimits_{j=1}^{p} \varphi_{ij} \ln \mathrm{CO2EMT}_{it-j} + \sum\nolimits_{j=0}^{q1} \beta_{ij} \ln \mathrm{DCP}_{it-j} \\ &+ \sum\nolimits_{j=0}^{q2} \gamma_{ij} \ln \mathrm{URP}_{it-l} + \sum\nolimits_{j=0}^{q3} \delta_{ij} \ln \mathrm{GDP}_{it-j} \\ &+ \sum\nolimits_{j=0}^{q4} \lambda_{ij} \ln \mathrm{FDI}_{it-j} + \sum\nolimits_{j=0}^{q5} \pi_{ij} \ln \mathrm{IND2}_{it-j} + \varepsilon_t \end{aligned} \tag{3}$$

The dynamic specification model of Equation (2) illustrating the short-run and long-run context is given by the following equation:

$$\begin{aligned} \Delta \ln \mathrm{CO2EMT}_{it} &= \alpha_i + \sum\nolimits_{j=0}^{q1} \Delta\theta_{1,ij} \ln \mathrm{DCP}_{it-j} + \sum\nolimits_{j=0}^{q2} \theta_{2,ij} \Delta \ln \mathrm{URP}_{it-l} \\ &+ \sum\nolimits_{j=0}^{q3} \theta_{3,ij} \Delta \ln \mathrm{GDP}_{it-j} + \sum\nolimits_{j=0}^{q4} \theta_{4,ij} \Delta \ln \mathrm{FDI}_{it-j} \\ &+ \sum\nolimits_{j=0}^{q5} \theta_{5,ij} \Delta \ln \mathrm{IND2}_{it-j} + \sum\nolimits_{j=1}^{p} \varphi_{ij} \ln \mathrm{CO2EMT}_{it-j} \\ &+ \sum\nolimits_{j=0}^{q1} \beta_{ij} \ln \mathrm{DCP}_{it-j} + \sum\nolimits_{j=0}^{q2} \gamma_{ij} \ln \mathrm{URP}_{it-l} \\ &+ \sum\nolimits_{j=0}^{q3} \delta_{ij} \ln \mathrm{GDP}_{it-j} + \sum\nolimits_{j=0}^{q4} \lambda_{ij} \ln \mathrm{FDI}_{it-j} \\ &+ \sum\nolimits_{j=0}^{q5} \pi_{ij} \ln \mathrm{IND2}_{it-j} + \varepsilon_{it} \end{aligned} \tag{4}$$

where, Δ is the first difference of variables. The short-run coefficients are denoted by θ_1, θ_2, θ_3, θ_4, and θ_5. While φ is the error correction term that is expected to be significantly negative, the long-run coefficients are denoted by β, γ, δ, λ, and π. In PMG estimation the long-run coefficients are not allowed to vary across countries, but it allows the short-run coefficients and error variances to differ. Given the optimal lag orders p and q selected by the Schwarz information criterion, maximum likelihood estimators are found to be consistent and normally distributed asymptotically (Pesaran et al., 2000).

4. Empirical Findings

4.1. Diagnostic Tests

In Table 1, test for the variance inflation factor (VIF) is first performed to further check that the assumption of negligible multicollinearity was satisfied, as shown in Table 1. The results reveal that none of the independent variables has a VIF greater than 10. The assumption is satisfied since the criterion for spotting multicollinearity is met. As per previous literature, a VIF > 10 or a 1/VIF < 0.10 indicates trouble.

Table 1. Multicollinearity test.

Variables	VIF	1/VIF
LndDCP	1.08	
LnURP	1.29	
LnGDP	1.07	
LnIND2	1.24	
LnFDI	1.18	
Mean VIF	1.17	

Source: author's compilation using WDI (World Development Indicators), 2021.

In Table 2, the null hypothesis of Breusch-Godfrey LM test indicates that there is no serial correlation.

Table 2. Breusch-Godfrey LM test for autocorrelation.

H0: no autocorrelation	
chi2	Prob > chi2
1.572	0.2099

Source: author's compilation using WDI (World Development Indicators), 2021.

In Table 3, the test rejects the null hypothesis which assumes that the model is homoscedastic. To address this issue, the PMG estimation is applied based on the characteristics of the sample data used in this study.

Table 3. Modified Wald test for groupwise heteroskedasticity.

H0: no constant variance	
chi2	Prob > chi2
511.12	0.0000

Source: author's compilation using WDI (World Development Indicators), 2021.

The unit-root test given in Table 4 shows that the dependent variable fossil energy consumption (LnCO2EMT) and the main independent variable of interest which is the domestic credit to private (LndDCP) are stationary at first difference and are integrated of order un meaning they are I(1). The other independent variables such as urban population (LnURP), gross domestic product (LnGDP), industrialization (IND2) and foreign direct investment (LnFDI) are stationary at level and are integrated of order 0 meaning they are I(0).

Table 4. Levin-Lin-Chu (LLC) unit-root test.

Variables	Stationary at level		Stationary in first difference		Order of integration
	LLC	Probability	LLC	Probability	
LnCO2EMT			−7.8761	0.0000	I(1)
LndDCP			−7.3969	0.0000	I(1)
LnURP	−2.0877	0.0184			I(0)
LnGDP	−6.4592	0.0000			I(0)
LnIND2	−3.3346	0.0004			I(0)
LnFDI	−3.6679	0.0001			

Source: author's compilation using WDI (World Development Indicators), 2021.

After determining the existence of the cointegration relationship, it is then appropriate to estimate the cointegration relationship efficiently based on the Pooled-Mean Group estimation, mean group estimation (MG) and dynamic fixed effects (DFE). To do this, the estimator is designed on the assumption that the model constant, as well as the short-term coefficients and error variances, may differ across individuals, while the long-term coefficients are constrained to be identical across countries.

The Hausman test will be used for the selection of the best model which provides efficient and consistent estimator with the assumption that slope coefficients are homogenous.

The outcomes of the cointegration analysis are shown in Table 5. We can see that most of the values of probability are less than 0.05, and as a result, we can draw the conclusion that there is a cointegrating connection between the variables.

Table 5. Kao test for cointegration.

H0: No cointegration Ha: All panels are cointegrated		
	Statistic	p-value
Modified Dickey-Fuller t	−4.4774	0.0000
Dickey-Fuller t	−3.0384	0.0012
Augmented Dickey-Fuller t	−1.5824	0.0568
Unadjusted modified Dickey-Fuller t	−4.7688	0.0000
Unadjusted Dickey-Fuller t	−3.1171	0.0009

Source: author's compilation using WDI (World Development Indicators), 2021.

4.2. The Results of Pooled Mean Group Estimation (PMG), Mean Group Estimation (MG) and Dynamic Fixed Effects (DFE) and the Hausman Specification Test for Selection between PMG, MG and DFE Model

The MG estimator is obtained by estimating N regressions independently and then averaging the coefficients obtained. Pesaran and Smith (1995) show that the MG estimator is a consistent estimator of the mean of the parameters. However, it does not take into account the panel dimension of the data and the fact that some coefficients may be the same for some groups of individuals. On the other hand, the DFE estimator is obtained by stacking all the data and imposing homogeneity of all the coefficients, with the exception of the constant. Indeed, if the hypothesis of similarity of the coefficients in the long run is accepted, the PMG estimator increases the precision of the estimates compared to the MG estimator and the DFE estimator (Table 6).

Table 6. Long-run and short-run results of the tree models.

Dependent variable LnCO2EMT	Pooled mean group (PMG) model	Dynamic fixed effects (DFE) model	Mean group (MG) model
Long-run coefficients of independent variables			
LndDCP	0.4409263*	0.2568218**	0.287836*
LnURP	0.270126	0.2568218	−2.000496
LnGDP	0.0580601*	0.0654817	0.1281261**
LnIND2	0.0634414***	0.0654817	0.2793378*
LnFDI	0.0268949	0.0888345***	−0.0073544
Short-run coefficients of independent variables			
ΔLndDCP	−0.3633886	−0.0025865	0.0102347
ΔLnURP	−0.3633886	−0.1422459	−31.7603
ΔLnGDP	−0.3633886**	−0.0191076***	−0.042671*
ΔLnIND2	0.1854466	0.0554482	0.1788835
ΔLnFDI	−0.0041943	−0.0048214	−0.0003851
Error correction coefficient	−0.3633886*	−0.1793904*	−0.5815064*

Source: author's compilation using WDI (World Development Indicators), 2021; Legend: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 7 displays the results of homogeneity test of Blomquist, Westerlund and reveals that slope coefficients are homogenous. The homogeneity of the long run coefficient implied by the PMG technique cannot be assumed before estimation and as such a post estimation test is required. If the long run homogeneity holds, the PMG estimate is said to be more efficient in comparison to the MG estimates but when the long run homogeneity fails to hold, the estimates of the PMG becomes inefficient compared to the MG technique. Hausman test result proves that there exists long run homogeneity for the WAEMU countries and hence the PMG technique is appropriate.

Table 7. Homogeneity test of Blomquist, Westerlund.

H0: slope coefficients are homogenous		
	Delta	p-value
	−1.723	0.085
adj.	−1.915	0.055
HAC Kernel: quadratic spectral (QS) with average band with 5 Variables partial led out: constant		

Source: Author's compilation using WDI (World Development Indicators), 2021.

In **Table 8**, we conducted the Hausman test for selection between PMG, DFE and MG estimations. The result indicates that PMG estimator is preferred than DFE estimator and both of two are preferred than MG estimator. As the PMG estimator predominates the DFE estimator because it permits heterogeneity in short-run coefficients, it should be relied upon among the three estimators. Based on the results of the Hausman test, the null hypothesis of slope homogeneity is accepted with a p-value of 0.3237 (greater than 0.05) and the method to be recommended in consequence is that of the PMG.

Table 8. Hausman test for selection between PMG, DFE and MG.

MG and DFE	MG and PMG	DFE and PMG
H0: MG estimator is efficient and consistent while DFE is not efficient	H0: PMG estimator is efficient and consistent while MG is not efficient	H0: PMG estimator is efficient and consistent while DFE is not efficient
p-value = 0.0151 < 0.05	p-value = 0.0583 > 0.05	p-value = 0.3237 > 0.05

Source: Author's compilation using WDI (World Development Indicators), 2021.

From the PMG model, there is evidence that financial development (variable of interest), gross domestic product and industrialization contribute information in the prediction of fossil energy consumption in WAEMU countries. After the estimation, we find that the elasticity of the long-run coefficients of financial development, gross domestic product, and industrialization are 0.4409263, 0.0580601, and 0.0634414, respectively. This indicates that when other elements remain constant, an increase of 1% in financial development, gross domestic product, and industrialization would lead to an increase of 0.44%, 0.058% and 0.063% in fossil energy consumption, respectively in WAEMU countries. This result confirms the findings of Ma and Fu (2020), Nkalu et al. (2020), who found that financial development has significant and positive influence on energy consumption. The result is in convenience with the theory of economic literature according to Furuoka (2015) because a strong financial system grants more credit access to more investors leading to more production with high technology. The elasticity of the long-run coefficient of urban population is not significant hence, the nexus between fossil energy demand and population could be subject to ambiguity as some researchers found no significant effect of population on energy consumption (Sekantsi & Motlokoa, 2015). Indeed, an increasing energy consumption could disrupt energy supply which may lead to untimely power deficit (Ahmed, 2017). This result confirms the findings of Lefatsa et al. (2021) and is conducive with the theory of economic literature. Industrialization processes stimulates huge energy consumption due to the need of energy to fuel machinery and the increasing automation of productive techniques (Liu, 2009; Sadorsky, 2011). The explanation could be that the rise of production diversification encourages firms to invest in new high technological industrial equipments (Mahalik & Mallick, 2014; Muhammad Awais et al., 2012; Shahbaz & Lean, 2012). The elasticity of the long-run coefficient of foreign direct investment is not significant meaning that foreign direct investment doest not have much impact on fossil energy consumption in WAEMU countries. In the short-run, only gross domestic product influences negatively and significantly fossil energy consumption in WAEMU countries meaning that the benefits of growth, such as economies of scale in goods and services, help reduce environmental damage and these countries can help reduce fossil energy consumption and environmental degradation by financing ecological low carbon investments in industries.

5. Conclusion and Policy Implication

The objective of the study is to analyze the impact of financial development (variable of interest) on fossil energy consumption (dependent variable) in WAEMU countries. We used PMG model to examine the impact of financial development on energy consumption including other control variables like urban population, gross domestic product, industrialization and foreign direct investment. The study confirms through the model that all variables impact significantly and positively fossil energy consumption in WAEMU countries except foreign direct investment and urban population meaning that the amount of foreign direct investment is not significantly high and sufficient to influence fossil energy consumption in WAEMU countries. Policy implication resulting in strengthening the financial sector through domestic credit to private sector and other financial indicators like money supply, liquid liabilities, domestic credit to banking sector in new low carbon investments could reduce fossil energy consumption in WAEMU countries.

Governments should undertake soft policy reforms to encourage capital investment conducive to energy consumption by allowing private industrial investments to expand and provide access to green energy. Improving the energy efficiency of buildings, vehicles, industrial processes, appliances, and equipment is the most immediate and cost-effective way to optimize energy use in WAEMU countries. The WAEMU countries should encourage FDI to allow the transfer of technology—particularly in the form of new varieties of capital inputs—that cannot be achieved through financial investments or trade in goods and services so as to promote competition in the domestic input market.

To achieve the general objective of developing the energy sector, Member States must comply with the following main rules:

- combating financial market distortions and barriers to competition in economic activities in the energy sector,
- adoption and implementation of the necessary and the appropriate legislative provisions to deal with any unilateral and concerted anti-competitive behavior in the financial and energy sector,
- investment financing in high technology production and distribution in the energy sectors to help reduce energy costs,
- WAEMU countries should encourage open access, without any discrimination, to sources of production and electrical transmission equipment,
- WAEMU countries should take the necessary measures to facilitate the transit of energy materials and products without distinction as to the origin, destination or ownership of these energy materials and products and facilitate the interconnection of energy transport equipment,
- WAEMU countries should encourage and create stable, fair, favorable, and transparent conditions for carrying out investments in the field of energy.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Abidin, I. S. Z., Haseeb, M., Azam, M., & Islam, R. (2015). Foreign Direct Investment, Financial Development, International Trade and Energy Consumption: Panel Data Evidence from Selected ASEAN Countries. *International Journal of Energy Economics and Policy, 5,* Article No. 3.

Ahmed, K. (2017). Revisiting the Role of Financial Development for Energy-Growth-Trade Nexus in BRICS Economies. *Energy, 128,* 487-495. https://doi.org/10.1016/j.energy.2017.04.055

Akinlo, A. E. (2008). Energy Consumption and Economic Growth: Evidence from 11 Sub-Sahara African Countries. *Energy Economics, 30,* 2391-2400. https://doi.org/10.1016/j.eneco.2008.01.008

Ali, H. S., Yusop, Z. B., & Hook, L. S. (2015). Financial Development and Energy Consumption Nexus in Nigeria: An Application of Autoregressive Distributed Lag Bound Testing Approach. *International Journal of Energy Economics and Policy, 5,* 816-821.

Al-Iriani, M. A. (2006). Energy-GDP Relationship Revisited: An Example from GCC Countries Using Panel Causality. *Energy Policy, 34,* 3342-3350. https://doi.org/10.1016/j.enpol.2005.07.005

Bayar, Y., Ozkaya, M. H., Herta, L., & Gavriletea, M. D. (2021). Financial Development, Financial Inclusion and Primary Energy Use: Evidence from the European Union Transition Economies. *Energies, 14,* Article No. 3638. https://doi.org/10.3390/en14123638

Bekhet, H. A., Matar, A., & Yasmin, T. (2017). CO_2 Emissions, Energy Consumption, Economic Growth, and Financial Development in GCC Countries: Dynamic Simultaneous Equation Models. *Renewable and Sustainable Energy Reviews, 70,* 117-132. https://doi.org/10.1016/j.rser.2016.11.089

Choi, I. (2001). *Unit Root Tests for Cross-Sectionally Correlated Panels.* Mimeo, Kookmin University.

Dickey, D. G. (2014). Dickey-Fuller Tests. In M. Lovric (Ed.), *International Encyclopedia of Statistical Science* (pp. 385-388). Springer. https://link.springer.com/referenceworkentry/10.1007/978-3-642-04898-2_210

Engle, R. F., & Granger, C. W. J. (1987). Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica, 55,* Article No. 251. https://doi.org/10.2307/1913236

Furuoka, F. (2015). Financial Development and Energy Consumption: Evidence from a Heterogeneous Panel of Asian Countries. *Renewable and Sustainable Energy Reviews, 52,* 430-444. https://doi.org/10.1016/j.rser.2015.07.120

Gaies, B., Kaabia, O., Ayadi, R., Guesmi, K., & Abid, I. (2019). Financial Development and Energy Consumption: Is the MENA Region Different? *Energy Policy, 135,* Article ID: 111000. https://doi.org/10.1016/j.enpol.2019.111000

Gómez, M., & Rodríguez, J. C. (2019). Energy Consumption and Financial Development in NAFTA Countries, 1971-2015. *Applied Sciences, 9,* Article No. 302. https://doi.org/10.3390/app9020302

Guillaumin, C. (2011). *Chocs externes et perspective d'union monétaire en Asie de l'Est: Les enseignements d'un modèle VAR structurel.* https://www.academia.edu/51353006/Chocs_externes_et_perspective_dunion_mon%C3%A9taire_en_Asie_de_lEst_les_enseignements_dun_mod%C3%A8le_VAR_structurel

Gungor, H., & Simon, A. U. (2017). Energy Consumption, Finance and Growth: The Role of Urbanization and Industrialization in South Africa. *International Journal of Energy Economics and Policy, 7,* 268-276.

Gutiérrez, L. H. (2003). The Effect of Endogenous Regulation on Telecommunications Expansion and Efficiency in Latin America. *Journal of Regulatory Economics, 23,* 257-286. https://doi.org/10.1023/a:1023412226826

Haider, S., & Adil, M. H. (2019). Does Financial Development and Trade Openness Enhance Industrial Energy Consumption? A Sustainable Developmental Perspective. *Management of Environmental Quality: An International Journal, 30,* 1297-1313. https://doi.org/10.1108/meq-03-2019-0060

Islam, F., Shahbaz, M., Ahmed, A. U., & Alam, M. M. (2013). Financial Development and Energy Consumption Nexus in Malaysia: A Multivariate Time Series Analysis. *Economic Modelling, 30,* 435-441. https://doi.org/10.1016/j.econmod.2012.09.033

Jung, T. Y., La Rovere, E. L., Gaj, H., Shukla, P. R., & Zhou, D. (2000). Structural Changes in Developing Countries and Their Implication for Energy-Related CO_2 Emissions. *Technological Forecasting and Social Change, 63,* 111-136.

https://doi.org/10.1016/s0040-1625(99)00052-9

Kahouli, B. (2017). The Short and Long Run Causality Relationship among Economic Growth, Energy Consumption and Financial Development: Evidence from South Mediterranean Countries (SMCs). *Energy Economics, 68,* 19-30. https://doi.org/10.1016/j.eneco.2017.09.013

Kao, C. (1999). Spurious Regression and Residual-Based Tests for Cointegration in Panel Data. *Journal of Econometrics, 90,* 1-44. https://doi.org/10.1016/s0304-4076(98)00023-2

Karanfil, F. (2009). How Many Times Again Will We Examine the Energy-Income Nexus Using a Limited Range of Traditional Econometric Tools? *Energy Policy, 37,* 1191-1194. https://doi.org/10.1016/j.enpol.2008.11.029

Lee, C.-C., & Chang, C.-P. (2008). The Influence of Financial Development on Energy Consumption: Worldwide Evidence. *Resource and Energy Economics, 30,* 50-65.

Lefatsa, P. M., Sibanda, K., & Garidzirai, R. (2021). The Relationship between Financial Development and Energy Consumption in South Africa. *Economies, 9,* Article No. 158. https://doi.org/10.3390/economies9040158

Levine, A., Lin, C., & Chu, C. (2002). *Unit Root...*. Google Scholar. https://scholar.google.com/scholar?hl=fr&as_sdt=0%2C5&q=Levine%2C+A.%2C+Lin%2C+C.+and+Chu%2C+C.%2C+2002.+Unit+Root+Tests+in+Panel+Data%3A+Asymptot-ic+and+Finite+Sample+Properties.+Journal+of+Econometrics%2C+108%281%29%2C+pp.+1-24&btnG=

Li, K., & Lin, B. (2015). Impacts of Urbanization and Industrialization on Energy Consumption/CO_2 Emissions: Does the Level of Development Matter? *Renewable and Sustainable Energy Reviews, 52,* 1107-1122. https://doi.org/10.1016/j.rser.2015.07.185

Liu, Y. (2009). Exploring the Relationship between Urbanization and Energy Consumption in China Using ARDL (Autoregressive Distributed Lag) and FDM (Factor Decomposition Model). *Energy, 34,* 1846-1854. https://doi.org/10.1016/j.energy.2009.07.029

Lucas88.pdf (s.d.). https://www.sfu.ca/~kkasa/lucas88.pdf

Ma, X., & Fu, Q. (2020). The Influence of Financial Development on Energy Consumption: Worldwide Evidence. *International Journal of Environmental Research and Public Health, 17,* Article No. 1428. https://doi.org/10.3390/ijerph17041428

Maddala, G. S., & Wu, S. (1999). A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test. *Oxford Bulletin of Economics and Statisticas, 61,* 631-652. https://doi.org/10.1111/1468-0084.0610s1631

Mahalik, M. K., & Mallick, H. (2014). Energy Consumption, Economic Growth and Financial Development: Exploring the Empirical Linkages for India. *The Journal of Developing Areas, 48,* 139-159. https://doi.org/10.1353/jda.2014.0063

Muhammad Awais, B., Jianjun, Z., & Kashif, I. (2012). *The Effect of Financial Development on Ecological Footprint in BRI Countries: Evidence from Panel Data Estimation*.

Nkalu, C. N., Ugwu, S. C., Asogwa, F. O., Kuma, M. P., & Onyeke, Q. O. (2020). Financial Development and Energy Consumption in Sub-Saharan Africa: Evidence from Panel Vector Error Correction Model. *Sage Open, 10,* 1-12. https://doi.org/10.1177/2158244020935432

Odhiambo, M. N. (2019). Energy Consumption and Financial Development in South Africa: An Empirical Investigation. *Ekonomski Pregled, 70,* 41-61. https://doi.org/10.32910/ep.70.1.3

Odusanya, I., Osisanwo, B. G., & Tijani, J. O. (2021). Financial Development and Energy Consumption Nexus in Nigeria. *Acta Universitatis Danubius. OEconomica, 12,* 155-165.

Pedroni, P. (1999). Critical Values for Cointegration Tests in Heterogeneous Panels with

Multiple Regressors. *Oxford Bulletin of Economics and Statistics, 61,* 653-670. https://doi.org/10.1111/1468-0084.61.s1.14

Pesaran, M. H., & Smith, R. (1995). Estimating Long-Run Relationships from Dynamic Heterogeneous Panels. *Journal of Econometrics, 68,* 79-113.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2000). Structural Analysis of Vector Error Correction Models with Exogenous I(1) Variables. *Journal of Econometrics, 97,* 293-343. https://doi.org/10.1016/s0304-4076(99)00073-1

Pesaran, M. H., Shin, Y., & Smith, R. P. (2004). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association, 94,* 621-634. https://doi.org/10.2307/2670182

Phillips, P. C. B., & Sul, D. (2003). Dynamic Panel Estimation and Homogeneity Testing under Cross Section Dependence. *The Econometrics Journal, 6,* 217-259. https://doi.org/10.1111/1368-423x.00108

Rehman, M. U., & Rashid, M. (2017). Energy Consumption to Environmental Degradation, the Growth Appetite in SAARC Nations. *Renewable Energy, 111,* 284-294. https://doi.org/10.1016/j.renene.2017.03.100

Roubaud, D., & Shahbaz, M. (2018). *Financial Development, Economic Growth, and Electricity Demand: A Sector Analysis of an Emerging Economy*. MPRA Paper, Article 87212. https://ideas.repec.org//p/pra/mprapa/87212.html

Sadorsky, P. (2010). The Impact of Financial Development on Energy Consumption in Emerging Economies. *Energy Policy, 38,* 2528-2535. https://doi.org/10.1016/j.enpol.2009.12.048

Sadorsky, P. (2011). Energy Consumption, Output and Trade in South America. *Energy Economics, 34,* 476-488. https://doi.org/10.1016/j.eneco.2011.12.008

Sadorsky, P. (2011). Financial Development and Energy Consumption in Central and Eastern European Frontier Economies. *Energy Policy, 39,* 999-1006. https://doi.org/10.1016/j.enpol.2010.11.034

Sadraoui, T., Hamlaoui, H., Youness, Z., & Ben Sadok, I. (2019). A Dynamic Panel Data Analysis for Relationship between Energy Consumption, Financial Development and Economic Growth. *International Journal of Econometrics and Financial Management, 7,* 20-26. https://doi.org/10.12691/ijefm-7-1-3

Sbia, R., Shahbaz, M., & Ozturk, I. (2017). Economic Growth, Financial Development, Urbanisation and Electricity Consumption Nexus in UAE. *Economic Research-Ekonomska Istraživanja, 30,* 527-549. https://doi.org/10.1080/1331677x.2017.1305792

Sekantsiand, L., & Motlokoa, M. (2015). Evidence on the Nexus between Electricity Consumption and Economic Growth through Empirical Investigation of Uganda. *Review of Economic and Business Studies, 8,* 149-165. https://doi.org/10.1515/rebs-2016-0020

Shahbaz, M., & Lean, H. H. (2012). Does Financial Development Increase Energy Consumption? The Role of Industrialization and Urbanization in Tunisia. *Energy Policy, 40,* 473-479. https://doi.org/10.1016/j.enpol.2011.10.050

Stern, N. (1989). The Economics of Development: A Survey. *The Economic Journal, 99,* 597-685. https://doi.org/10.2307/2233764

Zeren, F., & Koc, M. (2014). The Nexus between Energy Consumption and Financial Development with Asymmetric Causality Test: New Evidence from Newly Industrialized Countries. *International Journal of Energy Economics and Policy, 4,* 83-91.