



Interlinkages between Energy Consumption and Economic Growth: A Review, an ARDL Bounds Testing Approach

Sharif Bakar Kombo ^{a*}, Hafidh Ali Hafidh ^a and Ali Msellem Khamis ^a

^a Zanzibar University Research and Consultancy Center, Tanzania.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JENRR/2022/v10i430260

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/84770>

Original Research Article

Received 20 January 2022
Accepted 27 March 2022
Published 31 March 2022

ABSTRACT

In this study, we re-examine the discussions on the relationship between energy consumption and economic growth by replicating the autoregressive distributed lag (ARDL) bounds testing framework for Tanzania in Odhiambo [1,2], Journal of Energy Policy, and extending it to Kenya country from 1971 to 2014. We use two proxies of energy consumption (total energy consumption and electricity consumption for each country) and GDP growth rate as a proxy of economic growth for each country. The bound F-test reveal that our results are consistent with Odhiambo [1,2] findings that there is still a stable long-run relationship between each proxy of the energy consumption and economic growth for both Tanzania and Kenya. However, when extending the study to more recent data up to 2014, the results of the causality test are inconsistent with Odhiambo [1,2] findings for Tanzania only while being consistent with Kenya results for both two energy proxies and economic growth. The findings reveal the bi-directional causal relationship between each proxy of the energy consumption and economic growth in both short-run and long-run in Tanzania. Overall, the paper finds that the recent discoveries of the substantial natural gas and significant energy project spur economic growth in Kenya and Tanzania.

Keywords: ARDL; energy consumption; economic growth.

*Corresponding author: E-mail: shabkom82@gmail.com;

JEL classification: C01, C32, C33, O13, Q43

1. INTRODUCTION

The energy-growth inter-linkages provide significant policy inferences for economic growth and development. However, despite the extensive discussion in the literature, most studies provide mixed and conflicting outcomes which may result in misleading policy inferences. While some studies show that intensive energy use stimulates economic development, others indicate that rapid economic growth encourages more energy consumption (see, Ozturk [3,4]) for a literature survey. The inconsistency in outcomes could be due to the application of diverse methodological approaches; time-varying factors; and country heterogeneities or the choice of variables (see, e.g., [5,6,7,8] Kiviet, 1995).

Ever since the founding study of Kraft and Kraft [9], several studies¹ have examined the energy-growth nexus; however, to-date there's no conclusive debate as most studies provide mixed and conflicting outcomes. These inconsistencies are at the centre of a heated discussion in energy economics literature on the implications of energy in economic development. The causality between energy usage and growth has serious policy implications for climate change and global warming; environmental pollution; poverty alleviation; economic growth and development as well as sustainable development.

Our paper reexamines the energy-growth debate by replicating the framework in Odhiambo [1,2], *Journal of Energy Policy for Tanzania*. We extend the model to Kenya on recent data up to 2014, to account for the impacts of huge natural gas discoveries in Tanzania at Ruvu basin estimated at 2.17 trillion cubic feet, on economic growth as well as the big energy projects such as Mtwara – Dar-es-Salaam gas pipeline project (3,900 MW); Kinyerezi I dual project (150 MW); Kinyerezi II gas plant (240 MW); Kinyerezi III gas plant (300 MW); Mnazi Bay gas Plant (300 MW); and Kenya nuclear power signed with South Korea in 2016 with the projected output of 4,000 MW by 2033.

¹ See e.g., Abosedra & Baghestani [12] for the USA, Soytas & Sari [13] for G-7, Asafu-Adjaye [14] for Asian developing countries, Abosedra, Dah, and Ghosh [15] for Jordan, Lin and Moubarak [16] for China, Mezghani and Ben Haddad [17] for Saudi Arabia and Asafu [14].

Energy is critical to Kenya and Tanzania's future growth, but these countries remain inferior within the global energy system. While these countries have abundant energy resources to meet their domestic and global demand, over half of the households stay in darkness. Example, in Tanzania only 18.4% country's population has access to electricity compared to Kenya's 56 %. This is compounded by the high prices of energy resources; low connectivity; inadequate infrastructures; poor and unreliable energy supply as the main factors hindering the region to meet energy consumption needs. However, Kenya and Tanzania governments in collaborations with non-government stakeholders are increasing their efforts to find the solution by introducing different regulations, as well as removing of political barriers that will facilitate investment opportunities in the energy sector and improvement in the living standards of citizens in these countries. Unlocking access to energy resources in East Africa using efficient and effective ways could bring vast opportunities and improvements across economies.

While the discovery of potential large deposits of oil and gas and energy projects may lead to increase in energy supply in Kenya and Tanzania, it may not necessarily translate into economic growth. Although rising economic growth requires more energy inputs, however, it may lead to environmental pollution due to Green House Gas (GHG) and CO_2 emissions which affect economic growth. There is a trade-off between economic growth and environmental quality. While reducing energy consumption may be important in curbing Green House Gas (GHG) and CO_2 emissions which are the leading causes of global warming and climate change, it may reduce economic growth. Ozturk [4], for example, argues that, higher energy consumption lead to increase in CO_2 emissions which diminishes economic growth; however, [10,11] argue that adoption of efficient and high quality energy production technology as well as renewable energy might reduce emissions over time while maintaining economic growth. Striking abalance between reducing CO_2 emissions, while maintaining high economic growth, remains one of the key policy challenges faced by policy makers, within the Paris climate change agreement. This may deminish Kenya and Tanzania's prospects to spur economic growth from their vast energy resources unless efficient technologies and clean energy is adopted.

Using a recently developed non-parametric Granger non-causality [18,19,20] and ARDL bounds technique proposed by M. H. Pesaran and Shin [21] and advanced by M. H. Pesaran, Shin, and Smith [22] we re-examine energy-growth nexus for Kenya and Tanzania. The ARDL and non-Granger causality approaches have several intuitive and superior properties over panel and residual-based OLS and likelihood techniques (see, e.g., [23-28], which are frequently applied in examining causal relationships particularly between energy use and GDP growth. For example, it's well-known fact that the conventional cointegration approaches based on small finite samples yield low power. However, ARDL based tests provide improved power, efficiency and robustness even in small finite samples [22] (Pesaran, & Shin 1999). Moreover, under standard Granger causality test, there's a restriction that parameters estimates should be integrated of the similar order. In contrast, ARDL allows for testing variables under different integration orders except I(2). One of the conventional approaches that has been widely used in the time series and panel based studies is the Granger causality technique. However, it has potential weaknesses which may generate biased results. For example, this technique is not robust to parameters in small samples with endogenous variables. In small samples, it has been shown to yield low power. Moreover, in models with endogenous variables, it may not be suitable.

Beyond methodological issues, most literature on the energy-growth linkages, originate from studies in advanced and emerging market economies with limited coverage of East African countries except for a few existing studies, e.g., [29,30,31] for Africa; Akinlo [32] for sub-Saharan Africa; Odhiambo [1,2] for Tanzania; and Ouedraogo, [33] for West Africa). Considering the increasing industrialisation, urbanisation and the importance of the energy sector in the growth of East Africa's economies, it's imperative to explore further the impact of energy consumption on their growth trajectory.

In this paper, we consider a framework by Odhiambo [1,2], with slight modifications to revisit the energy-growth debate. The model assumes two factors: energy and GDP. Like many energy-growth models in literature, the model is a variant of the Cobb-Douglas production function. We extend this debate by re-examining the energy-growth nexus on a set of recent data up to 2014, to include Kenya. We

use two proxies of energy consumption (total energy consumption and electricity consumption per capita for each country) and GDP growth rate as a proxy of economic growth for each country.

Our results are consistent with those of Odhiambo [1,2], which indicate that there is still a cointegration relationship between real economic growth and total energy consumption and electricity consumption for both Kenya and Tanzania. Also, the results based on the error correction model show that there is a bi-directional short and long-run relationship between economic growth and total energy consumption as well as economic growth and electricity consumption for Tanzania, in contrast with Odhiambo [1,2] who find "a unidirectional causal flow from total energy consumption to economic growth and a prima-facie causal flow from electricity consumption to economic growth". However, the findings for Kenya are consistent with Odhiambo [1,2]. We extend this study to find if the proposed analyses have a disintegrating effect on recent data up to 2014 for capturing the impact of the recently substantial offshore discoveries of natural gas in Kenya and Tanzania. We find no effect with this regard.

The remaining part is structured as follows. Part 2 presents empirical and theoretical literature. Section 3 describes the data and model frameworks applied in the analysis building on Odhiambo [1,2], with modifications we made to extend its application to Kenya. Part 4 presents results, discussion of findings and conclusions.

2. EMPIRICAL AND THEORETICAL SURVEY ON ENERGY-GROWTH NEXUS

Modern Energy besides labour and capital are critical inputs in the production process and play a significant role in economic growth and development see e.g: Stern [34,35], Asafu-Adjaye [14], Soyatas and Sari [13], Jumbe [36], Shiu & Lam [37], Mozumder & Marathe [38], Apergis and Payne [39], Ozturk [3,4], Gozgor, Lau, and Lu [40], Squalli [41] and Yoo [42]. An array of empirical and theoretical literature on the energy-growth nexus exists. However, most studies provide mixed outcomes. Until now, there's no agreement on the energy-growth nexus. While some studies conclude that there is no causation, others show a uni-directional relationship running from GDP - to - energy. Besides, others find uni-directional causation from energy-GDP. Moreover, some show a bi-

directional inter-linkage between energy and GDP growth. While others, e.g., Squalli, [41], provide mixed outcomes. For a summary of recent literature on energy-GDP inter-linkage, refer to Apergis & Payne, [39], Ozturk, [3,4], Yoo [42], Jebli & Youssef [43], Tiba & Omri, [44]; Payne, [45]. These differences have generated heated discussions in recent years about the nature, role and direction of causality between economic growth process and energy consumption activities.

The direction of causality between energy consumption and economic growth as well as economic growth and environmental pollution has significant policy implications. For instance, if the causality runs from energy consumption to economic growth, energy conservation policies may be implemented with little or no adverse effect on an economy's growth. Consequently, it's important to establish the direction of causality, to determine whether any reduction or increase in energy consumption may have adverse effects on Economic growth or environmental quality. A number of studies show that energy and GDP are integrated and energy use Granger causes GDP when capital and other production inputs are added in the model². However, there are mechanisms that can weaken this link between energy and economic growth like technological change and shift from poor quality energy sources to higher quality energy like electricity, solar, etc., in developing and developed countries.

The theoretical interlinkages between GDP growth and energy provide four possible propositions; neutrality, feedback, growth and conservation, see, Ozturk [3,4], Apergis and Payne [39], Chen, et al. [46], and Alper and Oguz [47], for a review. Each of these hypothesis has critical implications for energy and economic policy. For example, the neutrality hypothesis shows that there is no causal link between energy consumption and economic growth, thus reducing energy consumption does not affect economic growth or vice versa. The growth hypothesis suggests that energy consumption is an essential component in growth, either directly or indirectly as a complement to capital and labour in the production process. Hence, a reduction in energy consumption would cause a decrease in real GDP growth. Thus, the economy is called 'energy dependent' and energy conservation policies may be

implemented with adverse effects on real GDP. Hence, energy conservation policies would not have any impact on real GDP³. By contrast, the conservation hypothesis asserts that policies focussed towards lower energy consumption may have little or no adverse effect on real GDP. This hypothesis is based on a uni-directional causal association running from real GDP to energy consumption.

The feedback hypothesis, on the other hand argues that energy consumption and real GDP affect each other simultaneously. This hypothesis is based on a bi-directional causal link between energy consumption and real GDP growth. Thus, it suggests that policy makers should take into account the feedback effect of real GDP on energy consumption by implementing regulations to reduce energy use. This recommends that Economic growth should be decoupled from energy consumption to circumvent the negative effects of a reduction in energy use on economic development. A change from less efficient and less polluting alternatives may stimulate economic growth (see, for example, Costantini and Martini, [48]).

Several studies have investigated the energy-GDP nexus using different frameworks, which provide mixed outcomes. Bakirtas and Akpolat [49] using Dumitrescu-Hurling panel Granger causality, investigates the inter-linkages between energy utilisation, urbanisation and GDP growth from 1971 to 2014 for Colombia, India, Indonesia, Kenya, Malaysia, and Mexico. Their findings show a panel bi-directional Granger causation between energy use and GDP growth.

Bah and Azam [51] using ARDL bounds test and Toda-Yamamoto Granger causality technique examine this relationship for South Africa for the period of 1971 to 2012. They find no relationship between electricity use and GDP growth. Tang, Tan, and Ozturk [52] using neoclassical Solow growth framework investigates this relationship for Vietnam between 1971 and 2011. They find a unidirectional causality link from energy to GDP growth.

Saidi, Rahman, & Amamri [53] using, a panel of 53 global countries, explore the interlinkage between GDP growth and energy utilisation for

² Stern (2010)

³ Ansgar Belke, Christian Dreger, and Frauke de Haan [50] *Energy Consumption and Economic Growth – New Insights into the Cointegration Relationship*, Ruhr Economic Papers #190

the period 1990 to 2014, employing a VECM model. They find a positive long-run link between GDP growth and energy consumption. Their results further show a bidirectional Granger causal link between energy consumption and GDP growth. Moreover, when the data are separated according to regions such as American region, European region, Africa and Middle East region, they find both short and long-run bi-directional causation between energy use and GDP growth for America, Africa and the Middle East. For Europe, they find both short and long run unidirectional link from energy use to GDP growth.

Pinzón [54] using a dynamic Granger causality test and Vector autoregressive (VAR) model examine the link between energy and GDP growth in Ecuador for the period 1970–2015. His findings show a unidirectional dynamic causal link from energy consumption to GDP growth. Odhiambo [1,2], examine the energy-growth nexus for Tanzania and South Africa using ARDL and a trivariate causality test. His studies confirm bi-directional causal linkages between electricity use and GDP growth and employment to growth for South Africa. For Tanzania, he finds a steady long-run connection between energy use and GDP growth. Akinlo [32], investigates the energy-growth nexus for a sample of 11 African countries using an ARDL technique. He finds a substantial positive long-run effect on GDP growth for Senegal, Ghana, Sudan, and Kenya. He further ascertains a bi-directional link between the energy-economic growth nexus in Senegal, Gambia and Ghana using VECM. For Sudan and Zimbabwe, he confirms that GDP growth Granger causes energy use. However, for Cote D'Ivoire and Cameroon, he finds a neutrality thesis, while no causality for Togo, Nigeria and Kenya. When we extend the model of Odhiambo [1] to 2014, we find similar results for Tanzania.

3. METHODOLOGY AND DATA

3.1 Data

We use an extended data set of GDP and energy consumption from the World Bank and International Energy Agency (IEA) for the period 1971 to 2014 for Kenya and Tanzania. The variables include: real output per capita, as an indicator of economic growth, expressed as (Y_{it}) for each country i at period t , expressed in 2000 constant USD. Further, we apply two additional proxies of energy consumption, namely total oil

energy utilization per capita (EC), stated in Kilogram of oil equivalent, plus electricity consumption per capita (ELEC), expressed in Kilowatt hour (kWh) of electric power consumption per capita all standardised in (PPP) 2000 constant U.S. dollars and expressed in natural logarithms. The data for energy consumption per capita was taken from the International Energy Agency (IEA) statistics on energy, while data on GDP is from World Bank development indicators.

3.2 Unit Root Test

It's a well-known fact that conventional cointegration and unit root tests based on small finite samples yield low power (see, e.g., Campbell and Perron, (1991) and Cochrane, (1991)). However, ARDL based tests provide improved power even in small finite samples [22] (Pesaran, & Shin 1999). Moreover, under standard Granger causality test, there's a restriction that parameters estimates should be integrated of the similar order, in contrast, ARDL allows for testing variables under different integration orders except $I(2)$.

After conducting the stationary tests to certify the preconditions of ARDL, we applied two unit root tests, the Augmented Dickey-Fuller (ADF), Dickey & Fuller (1979) and Phillips-Perron test (PP), Phillips & Perron (1988). The outcomes of the unit root tests, show that variables taken into consideration have different integration orders $I(0)$ and order $I(1)$, but no variable is integrated in order $I(2)$ ⁴. These tests certify the pre-condition for ARDL model, proposed by M. H. Pesaran & Shin [21].

The ARDL approach is founded on a joint distribution of F or Wald statistics for cointegration. The distribution of F-statistics is non-conventional based on the assumption no cointegration between the observed variables under the null hypothesis. This can be stated as; ($H_0: \alpha_0 Y_{it} = \alpha_1 Y_{it-1} = \beta_0 EC_{it} = \beta_1 EC_{it-1} = \gamma_0 ELEC_{it} = \gamma_1 ELEC_{it-1} = 0$), suggesting that there's no cointegration among the observed variables in Eq. (1), against the alternative premise ($H_1: \alpha_0 Y_{it} \neq \alpha_1 Y_{it-1} \neq \beta_0 EC_{it} \neq \beta_1 EC_{it-1} \neq \gamma_0 ELEC_{it} \neq \gamma_1 ELEC_{it-1} \neq 0$). The above equations can further be decomposed below.

⁴ The unit roots test applied is programmed as a function in E views 9, and it is available upon request.

4. RESULTS AND DISCUSSION

4.1 Specification of the Cointegration Model

Specification:

$$\Delta Y_{it} = \alpha + \beta \chi_{it} + v_{it}$$

$$\Delta \chi_{it} = \beta + \theta Y_{it} + \varepsilon_{it}$$

Where Y_{it} is the real GDP per capita (constant 2011 PPP USD), X_t , is energy usage expressed in kWh electric power consumption per capita or oil equivalent, v_{it} and v_{it} are two uncorrelated error terms respectively. v_t and ε_t are i.i.d $N(0, \sigma)$. Our model can further be decomposed and specified below;

4.2 Energy and GDP Growth

$$\Delta \ln Y_{it} = \alpha + \sum_{i=1}^k \lambda \Delta \ln Y_{it-1} + \sum_{j=0}^n \psi \Delta \ln EC_{it-1} + \lambda \Delta \ln Y_{it} + \psi \Delta \ln EC_{it} + \varepsilon_{it}$$

$$\Delta \ln EC_{it} = \beta + \sum_{j=0}^n \eta \Delta \ln EC_{it-1} + \sum_{i=1}^k \zeta \Delta \ln Y_{it-1} + \eta \Delta \ln EC_{it} + \zeta \Delta \ln Y_{it} + u_{it}$$

4.3 Electricity Use and GDP Growth

$$\Delta \ln Y_{it} = \phi + \sum_{i=1}^k \delta \Delta \ln Y_{it-1} + \sum_{j=0}^n \gamma \Delta \ln ELEC_{it-1} + \delta \Delta \ln Y_{it} + \gamma \Delta \ln ELEC_{it} + \mu_{it}$$

$$\Delta \ln ELEC_{it} = \varphi + \sum_{j=0}^n \tau \Delta \ln ELEC_{it-1} + \sum_{i=1}^k \xi \Delta \ln Y_{it-1} + \tau \Delta \ln ELEC_{it} + \xi \Delta \ln Y_{it} + \epsilon_{it}$$

4.4 Specification of ECM Model between Energy and GDP Growth

$$\Delta \ln Y_{it} = \alpha + \sum_{i=1}^k \lambda \Delta \ln Y_{it-1} + \sum_{j=0}^n \psi \Delta \ln EC_{it} + ECM_{it-1} + \varepsilon_{it}$$

$$\Delta \ln EC_{it} = \beta + \sum_{j=0}^n \eta \Delta \ln EC_{it} + \sum_{i=1}^k \zeta \Delta \ln Y_{it-1} + ECM_{it-1} + \varepsilon_{it}$$

4.5 Specification of ECM Model between Electricity and GDP Growth

$$\Delta \ln Y_{it} = \phi + \sum_{i=1}^k \delta \Delta \ln Y_{it-1} + \sum_{j=0}^n \gamma \Delta \ln ELEC_{it} + ECM_{it-1} + \varepsilon_{it}$$

$$\Delta \ln ELEC_{it} = \varphi + \sum_{j=0}^n \tau \Delta \ln ELEC_{it-1} + \sum_{i=1}^k \xi \Delta \ln Y_{it} + ECM_{it-1} + \varepsilon_{it}$$

The most efficient model provides the estimates of the associated Error Correction Model (ECM).

$$ECT_t = \varepsilon_t = y_t - \sum_{i=1}^k \theta_i \chi_{it} - \psi' \omega_{it}$$

Where ECT_t is the error correction term, ε_t , the residual, y_t , the real GDP per capita and χ_{it} is the energy consumption per capita expressed as, (kg of oil equivalent per capita or kWh electric power consumption per capita).

5. EMPIRICAL ANALYSIS

5.1 Test of Cointegration

The results of the long-run relationship between two energy proxies and economic growth using ARDL cointegration analysis, based on F-test for Kenya and Tanzania country are presented in Table 1. We applied a Bayesian Akaike Information Criterion (AIC), to select the optimal lag length, using an automatic selection after imposing a maximum eight lags on each variable.

We apply the same empirical framework as in Odhiambo [1,2] but with extension to Kenya country and recent data up to 2014. The estimates of the bounds test are described in Table 1 for each country. With the extension to recent data for Tanzania in both models, we find consistent results with Odhiambo [1,2] when economic growth (Y) is applied as the dependent variable since the calculated F-statistics is higher than the critical value. However, when the total energy consumption and electricity consumption are used as a dependent variable, our results are inconsistent with Odhiambo [1,2] findings, since still the calculated F-statistics is higher than the critical value for both models. This implies that for using the recent data, there is homogenous cointegration vector between total energy consumption, electricity consumption and

economic growth of Tanzania. The results are presented in Table 1.

Similarly, for Kenya, the results indicate that when the recent data up to 2014, the calculated F-statistics is higher than the critical value for model regardless which variables are used as dependent variables. Therefore, in the long-run, the finding implies that Kenya and Tanzania have the unique impact factors for energy use and economic growth.

5.2 Analysis of Causality Test Based on Error-correction Model

Having found that the long-run relationship between (Y, ENC) in model 1 and (Y, ELEC) in model 2 is the consistency of Odhiambo [1,2] for the recent data for both Kenya and Tanzania. We have all evidence to examine the causality between total energy consumption and economic growth, and electricity consumption and economic growth for Kenya and Tanzania by incorporating the lag error-correction term in our model.

The results presented in Table 2 show the short and long-run causality outcomes between total energy consumption and economic growth, and electricity consumption and economic growth using joint significance of the lagged difference of the explanatory variables using the Wald test presented by F-statistic and coefficient of the lagged error-correction term. For Tanzania, a bi-directional causal relationship between total energy consumption and economic growth as

well as between economic growth and electricity consumption for the recent update data in both short-run and long-run. The long-run coefficient of the error-correction term in Model 1 is negative and statistically significant as expected, as well as the short-run factor of F-statistics of joint wald test is statistically significant. However, in Odhiambo [1,2] found only unidirectional casual flow running from total energy consumption to economic growth in Tanzania as well as just a short-run causality running from electricity consumption to economic growth. Therefore, there is evidence of feedback hypothesis in Tanzania between two proxies of energy consumption and economic growth.

On the hand of Kenya, denoting a unidirectional causal relationship running from total energy consumption to economic growth in both short-run and long-run. The long-run causality is supported by error correction term which is negative and statistically significant. Also, the short-causality is supported by F-statistics which is statistically significant. However, the reverse causality flow from economic growth to total energy consumption is rejected for both short-run and long run. Besides, only long-run causality between electricity consumption and economic growth are supported by a negative and statistically significant coefficient. While the short-run causality is rejected for electricity consumption and economic growth of Kenya. A summary causality for Kenya and Tanzania for our two proxies of energy consumption and economic growth are reported in Table 3.

Table 1. Bound F-test for cointegration

Country	Dependent variable	Function	F-test statistics
Model 1: Total energy consumption and economic growth			
Kenya	Y	Y (EC)	4.568*
	EC	EC (Y)	4.984*
Tanzania	Y	Y (EC)	7.052***
	EC	EC (Y)	5.371*
Model 2: Electricity consumption and economic growth			
Kenya	Y	Y (ELEC)	8.873***
	ELEC	ELEC (Y)	12.378***
Tanzania	Y	Y (ELEC)	8.875***
	ELEC	ELEC (Y)	13.904***
Critical bound value	I(0) Bound		I(1) Bound
10%	4.05		4.49
5%	4.68		5.15
2.5%	5.3		5.83
1%	6.1		6.73

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Critical bounds values Pesaran et al., [22]

Table 2. Granger non-Causality test

Country	Dependent Variable	Causality flow	F-Statistics	t-Test on ECM	R ²
Model 1: Total energy consumption and economic growth					
Kenya	Y	EC → Y	14.774 (0.01)**	-0.486***	0.37
	EC	Y → EC	1.945 (0.172)		0.52
Tanzania	Y	EC → Y	3.390 (0.004)**	-0.614***	0.48
	EC	Y → EC	9.258 (0.004)**		0.72
Model: Electricity Consumption and economic growth					
Kenya	Y	EC → Y	2.287 (0.117)	-0.293***	0.71
	EC	Y → EC	0.007 (0.932)		0.34
Tanzania	Y	EC → Y	55.711 (0.001)***	-0.221***	0.64
	EC	Y → EC	7.237 (0.003)**		0.67

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

Table 3. Summary of the causality test

Country	Causality	General conclusion
Total energy consumption and economic growth		
Kenya	Unidirectional casual flow running from total energy consumption to economic growth	Total energy consumption Granger – causes economic growth
Tanzania	Bi-directional casual flow between total energy consumption and economic growth	Total energy consumption and economic growth are Granger - causes to each other
Electricity Consumption and economic growth		
Kenya	No short-run casual flow between electricity consumption and economic growth	Electricity consumption Granger – causes economic growth only in the long-run
Tanzania	Bi-directional casual flow between electricity consumption and economic growth	Electricity consumption and economic growth are Granger -causes to each other

6. CONCLUSION

Several studies have investigated the causality between energy consumption and economic growth, however, to date it's inconclusive. The differences in outcomes could be due to country heterogeneities, application of different methodologies, and inefficiency of estimators or common biases inherent in the commonly applied techniques. Understanding the interlinkages between energy consumption and economic has significant inferences on the design of optimal policies for growth, environmental conservation and sustainable development.

In this paper, we replicate an ARDL bounds technique, and Granger non-causality applied Odhiambo [1,2] to re-examine the energy-economic growth nexus in Tanzania, and we

extend the model by including Kenya and using the recent data to 2014.

Our findings reveal that using bound F-test for cointegration; the results are consistent with Odhiambo [1,2] findings when economic growth is used as a dependent variable for both Tanzania and Kenya. However, when the total energy consumption and electricity consumption are applied as a dependent variable, our results are inconsistent with Odhiambo [1,2] findings for both Tanzania and Kenya.

Also, the findings reveal the bi-directional causal relationship between total energy consumption and economic growth as well as between electricity consumption and economic growth for the recent update data to 2014 in both short-run and long-run in Tanzania, which is slightly different from Odhiambo [1,2] findings. However, the Odhiambo [1,2] findings are consistent with

Kenya results for both two energy proxies and economic growth.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Odhiambo NM. Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. *Energy Policy*. 2009a;37(2):617-622. DOI: <https://doi.org/10.1016/j.enpol.2008.09.077>
2. Odhiambo NM. Electricity consumption and economic growth in South Africa: A trivariate causality test. *Energy Economics*. 2009b;31:635–640. Available:<https://doi.org/10.1016/j.eneco.2009.01.005>
3. Ozturk I. A literature survey on energy–growth nexus. *Energy Policy*. 2010;38(1):340-349. DOI: <https://doi.org/10.1016/j.enpol.2009.09.024>
4. Ozturk I. A literature survey on energy–growth nexus. *Energy Policy*. 2010;38:340–349.
5. Enno Siemsen, Aleda Roth, Pedro Oliveira. Common method bias in regression models with linear, quadratic, and interaction effects, organizational research methods. 2010;13(3):456-476.
6. Philip M Podsakoff, Scott B MacKenzie, Jeong-Yeon Lee, Nathan P Podsakoff. Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*. 2003;88(5):879-903. DOI: 10.1037/0021-9010.88.5.879
7. Dag Tjostheim, Jostein Paulsen. The bias of some commonly-used time series estimates. *Biometrika*. 1983;70(2):389-399.
8. Maxwell SE, Cole DA. Bias in cross-sectional analyses of longitudinal mediation. *Psychological Methods*. 2007;12(1):23.
9. Kraft J, Kraft A. On the relationship between energy and GNP. *J. Energy Development*. 1978;3:401-403.
10. Greening Lorna A, Greene David L, Carmen Difiglio. Energy efficiency and consumption — the rebound effect — a survey, *Energy Policy*; 2000. Available:[https://doi.org/10.1016/S0301-4215\(00\)00021-5](https://doi.org/10.1016/S0301-4215(00)00021-5)
11. Sorrel S. Reducing energy demand: A review of issues, challenges and approaches *Renewable and Sustainable Energy Reviews*. 2015;47:74-82. Available:<https://doi.org/10.1016/j.rser.2015.03.002>
12. Abosedra S, Baghestani H. New evidence on the causal relationship between United States energy consumption and gross national product. *The Journal of Energy and Development*. 1989;285-292.
13. Ugur Soytas, Sari R. Energy consumption and GDP: causality relationship in G-7 countries and emerging markets, *Energy Economics*. 2003;25(1):33-37. Available:[https://doi.org/10.1016/S0140-9883\(02\)00009-9](https://doi.org/10.1016/S0140-9883(02)00009-9)
14. Asafu-Adjaye. The Relationship between energy consumption, energy prices and economic growth: Time series evidence from asian developing countries *energy economics*. 2000;22(6):615-625. DOI: 10.1016/S0140-9883(00)00050-5
15. Abosedra S, Dah A, Ghosh S. Electricity consumption and economic growth, the case of Lebanon. *Applied Energy*. 2009;86(4):429-432.
16. Lin B. Moubarak M. Renewable energy consumption – Economic growth nexus for China. *Renewable and Sustainable Energy Reviews*. 2014;40:111-117.
17. Mezghani I, Ben Haddad H. Energy consumption and economic growth: An empirical study of the electricity consumption in Saudi Arabia. *Renewable and Sustainable Energy Reviews*. 2017; 75:145-156.
18. Hiemstra C, Jonathand D Jones. Testing for linear and nonlinear granger causality in the stock price-volume relation. *The Journal of Finance*. 1994;49(5):1639-1664. Available:<https://doi.org/10.1111/j.1540-6261.1994.tb04776.x>
19. Cees Diks, Valentyn Panchenko. A note on the hiemstra-jones test for granger non-causality. 2005;9(2).
20. Cees Diks, Valentyn Panchenko. A new statistic and practical guidelines for nonparametric Granger causality testing. *Journal of Economic Dynamics & Control*. 2006;3:1647–1669. DOI: 10.1016/j.jedc.2005.08.008
21. Pesaran MH, Shin Y. An autoregressive distributed lag modelling approach to

- cointegration analysis. *Econometric Society Monographs*. 1998;31:371-413.
22. Pesaran MH, Shin Y, Smith RJ. Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*. 2001;16(3):289-326.
 23. Granger CW. Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*. 1969;37(3):424-438.
 24. Johansen S. Statistical analysis of cointegration vectors. *Journal of economic dynamics and control*. 1988;12(2-3):231-254.
 25. Engle RF, Granger CW. Co-integration and error correction: Representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*. 1987;251-276.
 26. Phillips PC. Optimal inference in cointegrated systems. *Econometrica: Journal of the Econometric Society*. 1991; 283-306.
 27. Johansen S. Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: Journal of the Econometric Society*. 1991;1551-1580.
 28. Johansen S, Juselius K. Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. *Oxford Bulletin of Economics and statistics*. 1990;52(2):169-210.
 29. Wolde-Rufael Y. Disaggregated industrial energy consumption and GDP: The case of Shanghai, 1952–1999. *Energy Economics*. 2004;26(1):69-75.
 30. Wolde-Rufael Y. Electricity consumption and economic growth: A time series experience for 17 African countries. *Energy Policy*. 2006;34(10):1106-1114.
 31. Wolde-Rufael Y. Energy consumption and economic growth: The experience of African countries revisited. *Energy Economics*. 2009;31(2):217-224.
 32. Akinlo AE. Energy consumption and economic growth: evidence from 11 Sub-Saharan African countries. *Energy Economics*. 2008;30(5):2391-2400.
 33. Ouedraogo NS. Energy consumption and economic growth: Evidence from the economic community of West African States (ECOWAS). *Energy Economics*. 2013;36:637-647.
 34. Stern DI. Energy and economic growth in the USA: A multivariate approach. *Energy Economics*. 1993;15(2):137-150.
 35. Stern DI. The role of energy in economic growth. *Annals of the New York Academy of Sciences*. 2011;1219(1):26-51.
 36. Jumbe CB. Cointegration and causality between electricity consumption and GDP: Empirical evidence from Malawi. *Energy Economics*. 2004;26(1):61-68.
 37. Shiu A, Lam PL. Electricity consumption and economic growth in China. *Energy Policy*. 2004;32(1):47-54.
 38. Mozumder P, Marathe A. Causality relationship between electricity consumption and GDP in Bangladesh. *Energy Policy*. 2007;35(1):395-402.
 39. Apergis N, Payne JE. Energy consumption and economic growth in Central America: evidence from a panel cointegration and error correction model. *Energy Economics*. 2009;31(2):211-216.
 40. Gozgor G, Lau CKM, Lu Z. Energy consumption and economic growth: New evidence from the OECD countries. *Energy*. 2018;153:27-34.
 41. Squalli J. Electricity consumption and economic growth: Bounds and causality analyses of OPEC members. *Energy Economics*. 2007;29(6):1192-1205.
 42. Yoo SH. Electricity consumption and economic growth: Evidence from Korea. *Energy Policy*. 2005;33(12):1627-1632.
 43. Jebli MB, Youssef SB. Output, renewable and non-renewable energy consumption and international trade: Evidence from a panel of 69 countries. *Renewable Energy*. 2015;83:799-808.
 44. Tiba S, Omri A. Literature survey on the relationships between energy, environment and economic growth. *Renewable and Sustainable Energy Reviews*. 2017; 69:1129-1146.
 45. Payne JE. Survey of the international evidence on the causal relationship between energy consumption and growth. *Journal of Economic Studies*. 2010;37(1):53-95.
 46. Chen ST, Kuo HI, Chen CC. The relationship between GDP and electricity consumption in 10 Asian countries. *Energy Policy*. 2007;35(4):2611-2621.
 47. Alper A, Oguz O. The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. *Renewable and Sustainable Energy Reviews*. 2016;60:953-959.

48. Valeria Costantini, Chiara Martini. The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegrated panel data, *Energy Economics*. 2010; 32(3):591-603.
49. Bakirtas T, Akpolat AG. The relationship between energy consumption, urbanisation, and economic growth in new emerging-market countries. *Energy*. 2018;147:110-121.
50. Belke Ansgar, Dreger Christian, de Haan Frauke. Energy consumption and economic growth – new insights into the cointegration relationship, *ruhr economic working paper*, No. 2010;190.
51. Bah MM, Azam M. Investigating the relationship between electricity consumption and economic growth: Evidence from South Africa. *Renewable and Sustainable Energy Reviews*. 2017; 80:531-537.
52. Tang CF, Tan BW, Ozturk I. Energy consumption and economic growth in Vietnam. *Renewable and Sustainable Energy Reviews*. 2016;54:1506-1514.
53. Saidi K, Rahman MM, Amamri M. The causal nexus between economic growth and energy consumption: New evidence from the global panel of 53 countries. *Sustainable Cities and Society*. 2017;33:45-56.
54. Pinzón K. Dynamics between energy consumption and economic growth in Ecuador: A granger causality analysis. *Economic Analysis and Policy*. 2018; 57:88-101.

© 2022 Kombo et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/84770>