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Drivers of Green Energy Consumption in the East African Community

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Abstract

The study examines the effects of environmental policy quality, GDP per capita, quality of policy and institutional frameworks, regulatory effectiveness, population growth, electricity access, and research and development investments on green energy consumption in the East African Community (EAC). The study employed the FMOLS and CCR models for analysis. Data was sourced from the World Development Indicators (WDI) and International Energy Agency (IEA) for the EAC from 2000 to 2022. The study found that regulatory quality, quality of environmental policies, and access to electricity have a positive and significant long-run effect on green energy consumption in the EAC. However, the study also found that GDP per capita and the Quality of Institutions and Policies do not have a long-run effect on green energy consumption in the EAC. Given the global attention to Green Energy Consumption as a solution to climate change and to meet energy needs, this study discloses less studied drivers of Green Energy Consumption (as a proxy of Green Energy Transition), especially "Quality of environmental policies" in the EAC. Furthermore, most existing studies focus on renewable energy consumption, which includes solid biomass such as charcoal and firewood, while this study covers green energy consumption.

Keywords: Climate Change, Energy Transition, Sustainability, FMOLS, CCR, EAC.

1.0 Introduction

Green Energy Consumption is the key proxy of Green Energy Transition (GET) (Muhire et al., 2024; Nawaz & Rahman, 2023; Sun et al., 2023; Sadiq et al., 2023; Zhang et al., 2023; Oluoch et al., 2023; Tudor & Sova, 2021; IEA, 2021). GET promises to meet energy needs and fulfil climate change commitments through the consumption of green energy and a decline in emissions. Thus, it represents a critical opportunity to safeguard the planet and build a more sustainable and equitable energy future (UNEP, 2022; UNDP, 2021; UNFCCC, 2018). The urgency of climate change mitigation and the pursuit of sustainable development have positioned the GET as a global priority (World Bank, 2023). In this study, GET is defined as the global shift of the energy sector from traditional, carbon-intensive energy and technologies to sustainable, green-energy alternatives that replenish naturally, with zero or minimal carbon emissions, ensuring long-term energy security and environmental sustainability (Muhire et al., 2024). Green energy resources include wind, solar, hydropower, geothermal and modern biomass while renewable energy includes all green energy sources plus the unsustainable solid biomass such as firewood and charcoal. GET is driven by the United Nation's Sustainable Development Goal 7, which calls for access to affordable and clean energy by 2030, and the Paris Agreement, which aims to limit global warming to 1.5°C above pre-industrial levels and achieve carbon neutrality by the middle of the 21st century.

Despite the critical importance of GET, traditional energy resources are still widely consumed globally. In fact, over 77% of global energy is sourced from traditional sources (IEA, 2021). Primarily, fossil fuels and unsustainable solid biomass are responsible for over 75% of Greenhouse Gas (GHG) emissions worldwide and drive climate change and global warming, which are existential threats to humanity in the 21st century (UNEP, 2022; Costello et al., 2009). Africa has enormous potential for green energy, such as solar, hydropower, geothermal, wind, and modern biomass (IRENA, 2021). Nevertheless, traditional or unsustainable solid biomass, mainly wood fuel and charcoal, dominates the continent's energy sector, leading to massive forest cover loss and other related consequences (UNEP, 2022). Similarly, the EAC has a diverse and substantial green energy landscape owing to its geography, including the Great Rift Valley, the Great Lakes, the Nile Basin and varied climatic zones (IRENA, 2022).

Regardless of EAC's green energy potential and commitment to promoting green energy (EAC Regional Energy Access Strategy, 2006), the current landscape of green energy consumption within the EAC is markedly low, averaging only 10%, with disparate figures across member states—Uganda at 22%, Tanzania at 16%, Rwanda at 8%, Kenya at 3.8% and Burundi at 1.5%, (IEA, 2022). Green energy resources, a part of renewable energy sources, encompass wind, solar, hydropower, geothermal, and modern biomass. In contrast, renewable energy includes all green energy sources and unsustainable solid biomass, such as firewood and charcoal. Within the EAC, renewable energy sources dominate final energy consumption, accounting for over 90%. However, unsustainable solid biomass in the form of charcoal or direct firewood alone accounts for over 80% of the total final energy consumption (IEA, 2023; IRENA, 2021; REN21, 2016).

The consumption of unsustainable solid biomass has led to pressing environmental issues, including deforestation and increased carbon dioxide emissions (Kyaw et al., 2020). Consequently, my study will focus on green energy consumption rather than the broader category of renewable energy consumption. Notably, EAC faces its share of challenges attributed to climate change, including intensified extreme weather events resulting in food, water, and energy insecurity, environmental degradation, biodiversity loss, tourism revenue decline, sea level rise, natural resource-based conflicts, infrastructure damage, and pest invasions (EAC, 2023).

Driven by the need to encourage green energy use, numerous studies (Khalfaoui et al., 2024; Weng et al., 2024; Petre & Doru, 2024; Sadiq et al., 2023; Chien et al., 2023; Mohammad & Sultana, 2022; Tudor & Sova, 2021; Oluoch et al., 2021; Vo & Vo, 2021; Li & Ullah, 2021; Rasoulinezhad & Saboori, 2018) have focused on identifying the factors that drive its consumption. This shift in energy research highlights the growing importance of green energy as a vital response to climate change and energy demands (UNEP, 2024). However, existing research reveals conflicting evidence on the impact of various factors on green energy consumption across different countries and regions (Kwakwa, 2020).

Despite numerous studies exploring factors influencing sustainable energy consumption, there remains a significant lack of comprehensive analyses specifically addressing green energy consumption, especially within the East African Community (EAC). Prior research, including that by Nabaweesi et al. (2023 and 2024), has predominantly concentrated on aspects such as financial development and governance impacts on renewable energy utilisation. This focus has left a gap in understanding the nuanced roles of other key factors, including environmental policy quality and national income, in driving green energy consumption.

The importance of green energy consumption cannot be overstated; it plays a critical role in reducing greenhouse gas emissions, mitigating the adverse effects of climate change, and enhancing energy security. Moreover, promoting green energy contributes to economic diversification and job creation within the EAC, making it essential for sustainable development (UNEP, 2022; Costello et al., 2009). Understanding the variables that positively influence green energy consumption—such as the quality of environmental policies, access to electricity, regulatory quality, and R&D investments—will yield insights necessary for shaping effective strategies for policymakers. The inconsistency in findings across different studies underscores the necessity for context-specific research. Therefore, this study aims to bridge the research gap by systematically investigating the effects of the quality of environmental policies, national income (GDP per capita), population growth, regulatory quality, quality of policy and institutions, access to electricity, and research and development expenditure on green energy consumption in the EAC. By focusing on these drivers, this research will provide valuable insights that facilitate effective policymaking and support the region's transition to a more sustainable energy future.

2.0 Review of literature

While renewable energy sources have gained traction to combat climate change, it is crucial to distinguish between renewable energy, which includes solid or traditional biomass, and genuinely sustainable green energy solutions. While technically renewable, as highlighted in the introduction, reliance on solid biomass, such as firewood and charcoal, carries significant environmental drawbacks, including deforestation and carbon emissions. This paper delves into the drivers of actual green energy consumption within the East African Community, examining the roles of environmental policy quality, GDP per capita, quality of policy and institutional frameworks, regulatory effectiveness, population growth, electricity access, and research and development investments.

Several empirical studies have examined the drivers of renewable energy consumption but have yielded mixed findings. For instance, earlier studies (Apergis & Payne, 2010; Sadorsky, 2009) have reported a positive correlation between income and renewable energy consumption. Recent studies, including Tudor and Sova (2021), studied the impact of relevant economic factors, including GDP per capita. They applied heterogeneous panel data fixed-effects estimation techniques, both static and dynamic, along with robust Driscoll-Kraay standard errors. The findings suggest that GDP per capita promotes green energy consumption. Oluoch et al. (2021) analysed data from 23 sub-Saharan African countries between 1998 and 2014. The study revealed a positive and significant effect of renewable energy consumption on GDP per capita.
Studies by Sadiq et al. (2023) and Chien et al. (2023) have indicated a positive link between economic growth and green energy transition. Sadiq et al. (2023) utilised time series data from China from 1981 to 2019 and found a positive correlation between economic growth and sustainable energy consumption. Similarly, Chien et al. (2023) investigated China's green energy transition from 1999 to 2019 and identified a significant positive effect of economic growth on energy transition through green energy consumption.

However, there are conflicting findings as well. Matei (2017) observed a negative association between income and renewable energy consumption. In a related study, Prempeh (2023) reported a negative impact of economic growth on green energy transition in Ghana. Similarly, Yu and Guo (2023), studying China's green energy transition from 2000 to 2020, concluded that economic growth negatively influences green energy transition in the long run.

Beyond economic factors, demographic trends like population growth also play a crucial role. Olalekan et al. (2020) investigated the key drivers of renewable energy consumption, focusing on the five most populous African nations. Their study, utilising Bayesian Model Averaging, highlights a crucial link between population growth and renewable energy consumption. Specifically, the study finds that population growth, alongside factors like urbanisation, energy use, and electricity consumption, are significant determinants of renewable energy consumption in these nations. Similarly, Vo and Vo (2021) employ a panel vector autoregressive model and Granger non-causality test to investigate the relationship between renewable energy usage and population growth in the ASEAN region. The study identifies population growth as a driver of increased renewable energy consumption, suggesting that growing populations necessitate a corresponding expansion of renewable energy sources.

The role of environmental policy and institutional quality is also paramount. Khalfaoui et al. (2024) used a CS-ARDL panel model for a sample of 69 low-income countries in Africa, Asia, Europe, and North America from 2005 to 2020 to examine the impact of environmental sustainability policies and institutions on green economic growth. The study found that effective environmental policies, particularly those encouraging a shift towards renewables, are crucial for fostering sustainable development and a green economy. Mohammad and Sultana (2022) examined the impacts of institutional quality on renewable energy from the perspective of emerging economies. The study revealed that institutional effectiveness positively and significantly affects renewable energy consumption.

Weng et al. (2024) analysed the impact of governance quality (regulatory quality and other five dimensions) on renewable and non-renewable energy consumption. The study results revealed that governance quality enhances renewable energy consumption. Furthermore, Ekundayo et al. (2022) investigated the impact of energy use and financial development mediated by regulatory quality on pollution reduction in 18 African countries between 1996 and 2017, using the Pooled Mean Group approach. Their research highlighted the crucial mediating role of regulatory quality. Specifically, they found that strong regulatory quality consistently led to significant reductions in pollution, both in the short and long term, by influencing how energy is used.

Research and Development is another critical factor influencing the transition to renewable energy through green energy consumption. Petre and Doru (2024) employed a panel data approach to analysing the impact of R&D investments on the renewable energy transition in the European Union. The study results showed that R&D expenditure positively affects renewable energy consumption. A similar study by Li and Ullah (2021) investigated the influence of R&D intensity on renewable energy consumption with evidence from selected Asian economies. The study results indicated that R&D expenditure significantly and positively affects renewable energy consumption in the short and long run. Electricity access is another critical driver of green energy consumption and sustainable development.

As highlighted by Sokona et al. (2012), policymakers must move beyond a narrow focus on "energy access" and adopt a more nuanced approach that considers the "dual nature of the energy system" and encompasses broader energy transition goals. This requires engaging a diverse range of actors across sectors to develop effective institutions and innovative policy frameworks capable of navigating the complexities of this fragmented energy landscape.

The importance of widespread electricity access is underscored by Ulsrud's (2020) research on decentralised solar power in Sub-Saharan Africa. The study reveals that a lack of access can hinder the overall energy transition, as large population segments rely on traditional, often unsustainable energy sources. This continued reliance on inefficient and environmentally damaging energy sources, as highlighted by Oseni (2012), underscores the pressing necessity to increase the availability of green and sustainable energy systems. Renewable energy alternatives, in particular, hold the potential to drive economic development and environmental sustainability. Furthermore, Mulugetta et al. (2019) emphasise that ensuring access to "adequate, reliable, and clean energy services" is not only crucial for a successful energy transition but also fundamental for achieving the broader Sustainable Development Goals. Therefore, addressing the challenge of energy access is paramount for promoting both sustainable development and a successful transition to renewable energy sources.

The review highlights an intricate relationship of various factors affecting green energy consumption. While economic growth, population dynamics, and electricity access are crucial, the role of effective environmental policies, robust institutions, and targeted research and development cannot be overstated. Nonetheless, there is a considerable gap in research regarding the understanding of the phenomenon in the specific context of the East African Community. The paper aims to address the gap by investigating the drivers of green energy consumption within this region, providing valuable insights for policymakers and stakeholders invested in promoting a sustainable energy future for East Africa. In addition, this study will add to the ongoing discussion regarding the relationship between environmental policy quality, national income, quality of policy and institutional frameworks, regulatory quality, population growth, electricity access, Research and Development investments and green energy adoption, particularly within the context of developing economies.

3.0 Methods and Materials

3.1 Data

This study adopted longitudinal and causal research designs using time-series cross-sectional (TSCS) panel datasets covering the EAC countries of Uganda, Kenya, Tanzania, Rwanda, and Burundi. The study utilised data from the World Development Indicators (WDI) and the International Energy Agency (IEA) from 2000 to 2022. Panel data effectively captures common trends and individual group dynamics, surpassing the capabilities of time series or cross-sectional datasets.

3.2 Specification of the empirical model

For this study, a multivariate linear regression model is specified in which the dependent variable is Green Energy Consumption (gec) as % of total final energy consumption; the independent variables include national income, whose proxy variable is GDP ($gdpka$) in current US dollars, Population Growth ($pngth$) (annual %), Regulatory Quality Index ($regqty_{it}$), the Quality of Environmental Policies, whose proxy is the CPIA Policy and Institutions for Environmental Sustainability Rating Index ($cpiapiesr$), Quality of Institutions & Policy Index, whose proxy is (CPIA Business Regulatory Environment) ($cpiabre$), an Index for Research & Development Expenditure ($index$) and Access to Electricity in per cent.

The primary econometric model takes the form:

$$gec_{it} = \alpha_0 + \alpha_1 gdpka_{it} + \alpha_2 pngth_{it} + \alpha_3 regqty_{it} + \alpha_4 cpiapiesr_{it} + \alpha_5 cpiabre_{it} + + \alpha_6 rde_{it} + \alpha_7 ate_{it} + \mathrm{u}_{it} \ldots \quad (2);$$

Where;

i is country, t is the period and u_{it} is the error term.

α_0 is a constant,

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7$ are model parameters to be estimated such that α_0, $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7 > 0$

3.3 Pre-model estimation diagnostic tests

Pre-model estimation diagnostic tests such as normality, multicollinearity, cross-sectional dependence, unit root testing and cointegration were conducted. Normality tests were conducted to check if the dependent variable was normally distributed, and multicollinearity was run to check for highly correlated independent variables. Furthermore, cross-sectional dependency was carried out to check for the dependency variables in the cross-sections. On the other hand, unit root tests were carried out to know the stationarity of variables in the panel data set. Finally, Cointegration tests were conducted to establish the existence or absence of long-run equilibrium relationships between (nonstationary) series.

3.4 Specification of the variables

Table 1: Specification of the variables

Variables	Description	Units	Sources	Some studies that have used the variables
Gec	Green Energy Consumption	Percentage share of green energy in total final energy consumption	IEA	All below
gdpka	National income (GDP per capita)	In current US dollars	WDI	Apergis & Payne, 2010; Sadorsky, 2009; Tudor & Sova (2021)
pngth	Population growth	Annual Percent	WDI	Olalekan et al., 2020; Vo & Vo (2021
regqty	Regulatory quality	Index	WDI	Ekundayo et al., 2022
cpiapiesr	Quality of environmental policies (CPIA Policy & Institutions for Environment & Sustainability)	Index	WDI	Khalfaoui et al.,2024; Mohammad & Sultana, 2022
cpiabre	Quality of Institutions & Policy (CPIA Business Regulatory Environment)	Index	WDI	Weng et al., 2024
Ate	Access to electricity	Percentage of the population	WDI	Mulugetta et al., 2019
Rde	Research and Development expenditure	Percentage of GDP	WDI	Petre & Doru, 2024; Li & Ullah, 2021

Source: Author

4.0 Results and Discussion

4.1 Results from multicollinearity checks in the models for the study

To avoid the possibility of inefficient regression estimates arising from redundant regressors in the empirical model, the study conducted multicollinearity checks on all the independent variables included in the final model. The variance inflation factors (VIFs) for each independent variable were estimated and examined. The mean VIF in excess of 10 (i.e., VIF >10) was considered an indicator of severe multicollinearity (see Kim, 2019). **Table 2** summarises the estimates of the variance inflation factors (VIFs) for each independent variable and the mean VIF for all the independent variables included the final model for the study.

Table 2: VIFs of the independent variables in the final model:

Variable	VIF	1/VIF
Regulatory Quality ($regqty$)	12.39	0.081
Quality of environmental policies (CPIA Bus. Regulatory Environment ($cpiabre$))	6.83	0.146
The logarithm of GDP per capita ($loggdpc$)	5.84	0.171
Access to electricity (ate)	3.12	0.320
Quality of environmental policies (CPIA Policy & institutions for Sust. Rating ($cpiapiesr$))	2.97	0.337
Mean VIF	**6.23**	**0.211**

Source: Compiled by the author.

As indicated in **Table 2**, the estimates of the VIFs show that in the primary model, the variable regulatory quality ($regqty$) has a VIF value above the threshold of VIF of 10 (VIF = 12.39 >10 for regulatory quality). Apart from the regulatory quality variable, the rest have their respective VIF estimates of less than 10. However, considering the mean VIF for all the independent variables collectively (Mean VIF= 6.23), the estimated mean VIF is less than 10. This suggests that all the independent variables may be included in the final model while tolerating moderate multicollinearity.

After the multicollinearity and unit root tests, ***the final Econometric model is*:**

$gec_{it} = \alpha_0 + \alpha_1 loggdppc_{it} + \alpha_2 regqty_{it} + \alpha_3 cpiapiesr_{it} + \alpha_4 cpiabre_{it} + \alpha_5 ate_{it} + u_{it}$..(3)

Equation (3), which forms the final model for the study, excludes two variables: a variable on Research and Development Expenditure (rde) which has been excluded on the grounds of having quite a large number of missing observations in the data set at hand and a variable population growth ($pngth$) which has been excluded on the grounds of failing to be integrated.

4.2. Test for cross-sectional in/dependence in the model

The study tested for cross-sectional in/dependence in the panel model using the Breusch-Pagan (BP) test for cross-sectional independence. This approach to testing for cross-section in/dependence is appropriate in panel data models where T>N (Breusch & Pagan, 1980), which is consistent with the panel data dimensions for empirical analysis of the study. The null hypothesis tested is whether the errors are independent across cross-sections or there is cross-sectional independence, which implies that the cross-sectional units are not contemporaneously correlated. The results from the Breusch-Pagan (BP) test for cross-sectional independence are summarised in **Table 3.**

Table 3: Results from the Breusch-Pagan (B-P) LM test for cross-sectional dependence in the model

Panel Model	B-P LM Chi-sq, stat.	p-value
Fixed effects	13.504	0.1589
Random effects	14.952	0.1034

Source: Author's compilation.

For both the Fixed Effects and Random Effects models, the estimated chi-square statistics from the Breusch-Pagan LM test for cross-sectional in/dependence, as indicated in **Table 3**, do not reject the null hypothesis of across cross-sectional independence at all the conventional testing levels. Therefore, the cross-section in/dependence test results suggest evidence of cross-sectional independence in the final panel model.

One key implication of the absence of cross-sectional dependence in the empirical panel model is that the first-generation panel unit root tests may be implemented on the panel variables to test their stationarity. Secondly, implementing Fixed or Random Effects estimators on the empirical panel model can yield unbiased and consistent estimates (Pesaran, 2006).

4.3 Panel unit root test results

Given that the empirical panel data for this study has some gaps and that the time dimension is greater than the cross-sectional dimension (T >N), this study employed the Fisher-type (Choi, 2001) panel unit root test, which is appropriate for panels with such characteristics. **Table 4**. shows a summary of the results from the Fisher-type (Choi, 2001) panel unit root testing procedure, which has been employed on variables in the empirical panel model.

Table 4: The Fisher-type (Choi, 2001) panel unit root test results on all the panel variables in the final model

Variable being tested	Levels			First Difference			OOI
	Fisher-type statistic	Estimated statistic	p-value	Fisher-type statistic	Estimated statistic	p-value	
green energy consumption (gec)	P	6.7317	0.7505	P	57.6570***	0.0000	I(1)
	Z	0.2777	0.6094	Z	-6.0061***	0.0000	
	L*	0.2526	0.5988	L*	-7.2265***	0.0000	
	Pm	-0.7308	0.7676	Pm	10.6564***	0.0000	
The logarithm of GDP per capita ($logdpc$)	P	5.7935	0.8323	P	28.6230***	0.0000	I(1)
	Z	0.4094	0.6589	Z	-3.4008***	0.0000	
	L*	0.3714	0.6435	L*	-3.4792***	0.0000	
	Pm	-0.9406	0.8265	Pm	4.1642***	0.0000	
Regulatory Quality ($regqty$)	P	9.8173	0.4567	P	48.2205	0.0000	I(1)
	Z	0.1388	0.5552	Z	-5.0794	0.0000	
	L*	0.1477	0.5582	L*	-5.9995	0.0000	
	Pm	-0.0409	0.5163	Pm	8.5464	0.0000	
Quality of environmental policies (CPIA Policy & institutions for Sust. Rating ($cpiapiesr$))	P	7.0656	0.7192	P	46.5297***	0.0000	I(1)
	Z	1.2598	0.8961	Z	-4.5131***	0.0000	
	L*	1.6120	0.9411	L*	-5.6071***	0.0000	
	Pm	-0.6562	0.7441	Pm	8.1683***	0.0000	
Quality of Institutions & Policy (CPIA Bus. Regulatory Environment ($cpiabre$))	P	4.1180	0.9419	P	26.7886***	0.0000	I(1)
	Z	1.5203	0.9358	Z	-3.1255***	0.0000	
	L*	1.5300	0.9316	L*	-3.1727***	0.0000	
	Pm	-1.3153	0.9058	Pm	3.7541***	0.0000	
Access to electricity (ate)	P	3.2367	0.9753	P	52.4293***	0.0000	I(1)
	Z	2.3378	0.9903	Z	-5.1267***	0.0000	
	L*	2.3414	0.9869	L*	-6.4936***	0.0000	
	Pm	-1.5123	0.9348	Pm	9.4875***	0.0000	

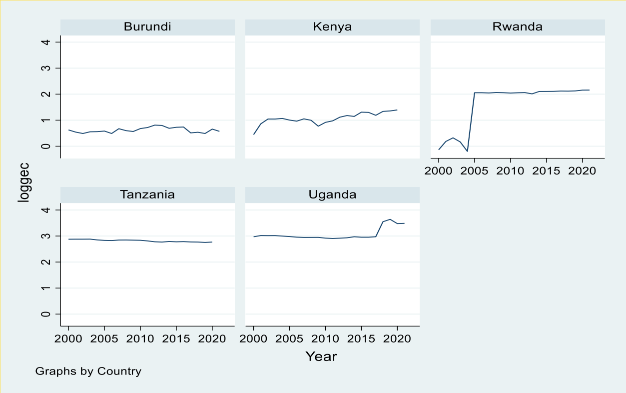
Source: Author's compilation. ***p<0.01. P=Inverse chi-squared; Z= Inverse normal; L* = Inverse logit; Pm = Modified inv. chi-squared, OOI=Order of Integration.

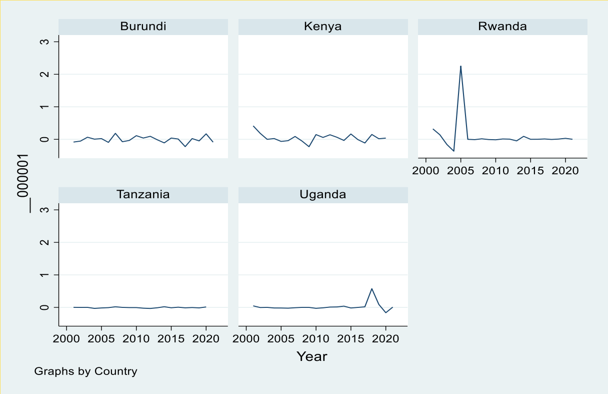
The Fisher-type (Choi, 2001) panel unit root test results summarised in **Table 4** indicate that for all the model variables in the final model, all the four Fisher-type statistics (P, Z, Pm & L*) do not reject the null hypothesis of having a unit root in levels but reject the null hypothesis of having a unit root in the first difference of the variables. This result suggests that all the model variables in the final model are non –stationary in levels but become stationary in their first differences, implying that all the variables in the final model are integrated of order one, I(1).

4.4 The panel line plots on variables in the panel model

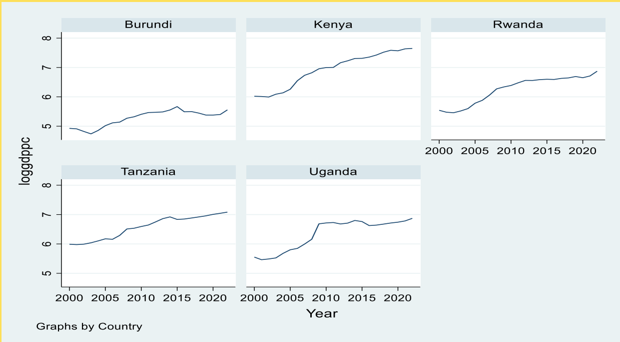
To augment the parametric-based Fisher-type (Choi, 2001) panel unit root test results summarised in Table 4, the study further generated line plots for the variables in the panel model. Figure 4.3 indicates the line plots for each variable in the panel model in which the line plots are generated for the sample over the study period and are displayed by country, first in levels and then in differences where applicable.

Figure 4.3: Panel line plots for the variables in the panel model for the study

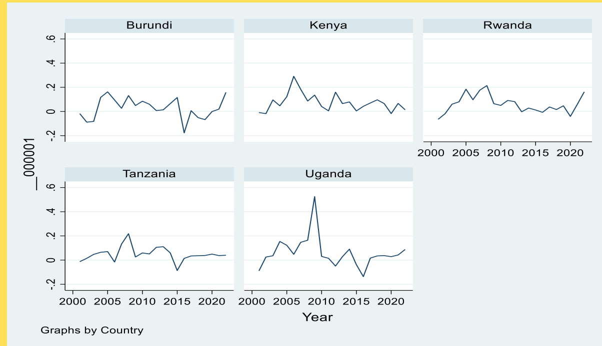




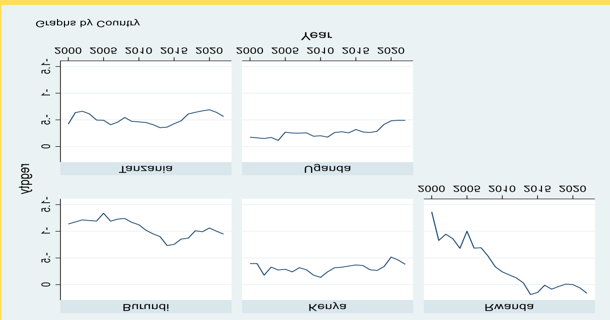
Panel data line plots for "*loggec*" in levels



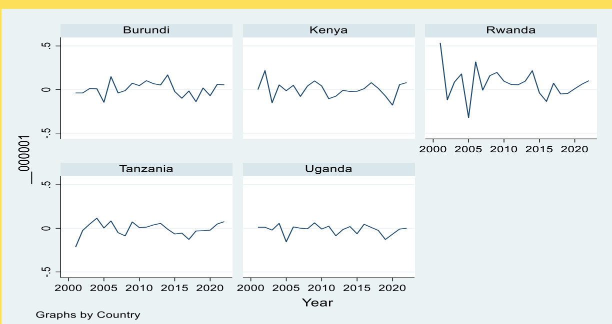
Panel data line plots for "*loggec*" in first difference



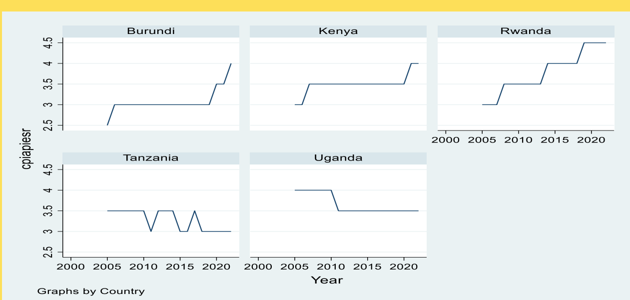
Panel data line plot for "*loggdpc* in levels



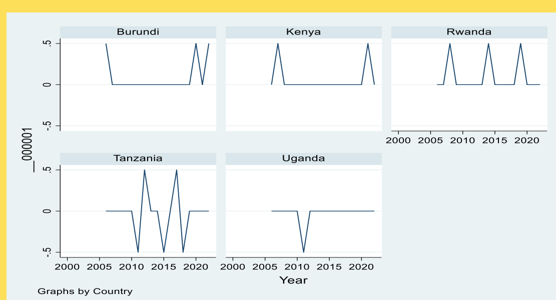
Panel data line plot for "*loggdpc*" in first difference



Panel data line plot for "*regqty* in levels



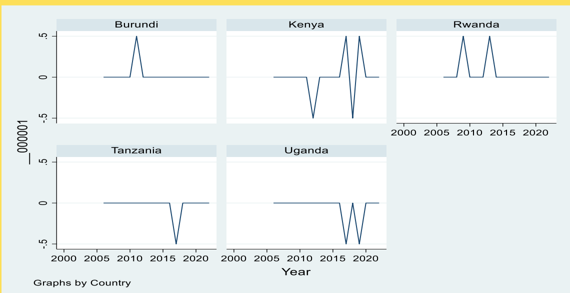
Panel data line plot for "*regqty*" in first difference



Panel data line plots for “*cpiapiesr*” in levels

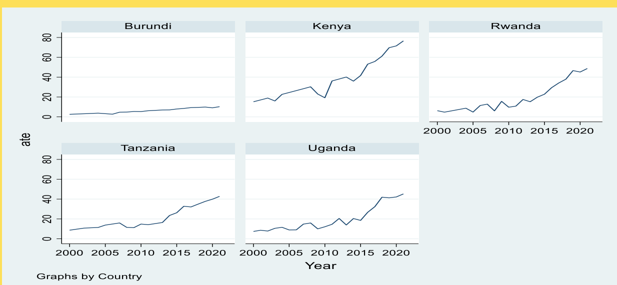
Panel data line plots for “*cpiapiesr*” in first

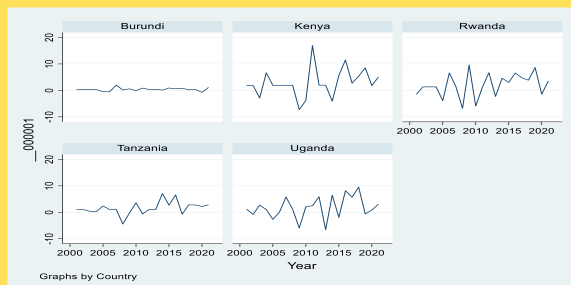
difference



Panel data line plot for “*cpiabre*” in levels

Panel data line plot for “*cpiabre*” in first difference





Panel data line plot for “*ate*” in levels

Panel data line plot for “*ate*” in first difference

Figure 4.3 shows the panel line plots for each of the variables in the panel model, showing the non-stationarity of the variables in levels and stationarity of the variables in the first differences. The line plots thus validate the order of integration of the panel model variables produced by the parametric Fisher-type (Choi, 2001) panel unit test results summarised in **Table 4**.

4.5 Panel Cointegration Test Results

Having found cross-sectional independence in the final panel model and that all the model variables were integrated of order one, I (1), this study adopted the Pedroni cointegration test (Pedroni, 2004) which is a residual–based panel cointegration test that is robust in panels with medium N and large T dimensions and having one or more nonstationary explanatory variables. The Pedroni cointegration tests the null hypothesis of no cointegration in all panels against the alternative hypothesis that the variables are cointegrated in all the panels. The Pedroni cointegration test produces three statistics: Modified Phillips–Perron t statistic, Phillips–Perron t statistic and Augmented Dickey-Fuller t statistic. The null hypothesis of no cointegration is rejected if all the estimated statistics or the majority (or two-thirds) of the estimated statistics have p-values less than 0.05. Table 5 summarises the cointegration test results from the Pedroni cointegration test on the panel model specified to address this study.

Table 5: The Pedroni cointegration test results on the panel model

The Pedroni statistic	Estimated statistic value	p-value
Modified Phillips-Perron t	1.9186**	0.0275
Phillips-Perron t	- 4.1796***	0.0000
Augmented Dickey-Fuller t	- 4.0146***	0.0000

Source: Generated by the author. ** p<0.05; *** p<0.01.

As indicated in **Table 5**, all three test statistics from the Pedroni cointegration test reject the null hypothesis of no cointegration at a 5 per cent level of significance in favour of the alternative hypothesis of the existence of cointegration in all panels. The cointegration test results summarised in Table 5 suggest cointegration among the variables in the panel model.

4.6 Regression estimates of the model

Based on the fact that the unit root tests showed that all the variables in the panel model were integrated of order one, I (1) and that the cointegration test confirmed the presence of cointegrating relations in the empirical panel model, this study implements the panel cointegration estimation techniques that reveal long run causal relationships between the variables in the empirical panel model. Out of the three commonly implemented fully efficient estimations for cointegration regression, that is, fully modified ordinary least squares (FMOLS), canonical cointegration regression (CCR), and the dynamic ordinary least squares (DOLS), this study adopts the first two methods, i.e., FMOLS and CCR. Because there are some gaps in the panel data, this study could not estimate the DOLS efficiently because the DOLS method uses leads and lags of the differenced regressors (which is feasible when the panel data has no gaps) in its process to get rid of the long-run correlation between the cointegration equation error and the regressor innovations. The study then chooses the final model between the FMOLS and CCR using the Hausman specification test under the null hypothesis that the FMOLS is a preferred model. **Table 6** shows a summary of the regression estimates from the FMOLS and CCR panel models as well as results from the Hausman specification tests.

Table 6: FMOLS and CCR panel regression estimates

Dependent variable: Logarithm of electricity consumption $(loggec)$						
	Model 1: FMOLS			**Model 2: CCR**		
Independent variable	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value
First lag of logarithm of green energy consumption $(L.loggec)$	**0.4640*** **	0.037456	0.0000	**0.6289*** **	0.208758	0.0025
Logarithm of GDP per capita $(logdpc)$	-0.0179	0.011279	0.1115	-0.0184	0.015738	0.2430
Regulatory Quality $(regqty)$	**0.6063*** **	0.074602	0.0000	**0.8160*** **	0.279822	0.0035
Quality of environmental Policies (CPIA Policy & institutions for Sust. Rating) $(cpiapiesr)$	**0.1544*** **	0.017564	0.0000	**0.1504*** **	0.030459	0.0000
Quality of Institutions & Policy (CPIA Bus. Regulatory Environment $(cpiabre)$	-0.0448*	0.027199	0.0993	0.0575	0.140193	0.6814
Access to electricity (ate)	**0.0160*** **	0.000650	0.0000	**0.0178*** **	0.002547	0.0000
Constant	1.1886***	0.235593	0.0000	0.3370	1.1417976	0.7678
R-square		0.910			0.892	
Adj. R-square		0.851			0.821	
Hausman, Ho: FMOLS is a preferred model						
Chi2 = 0.50; Prob > Chi2 = 0.9979						

Source: Author’s compilation. *P<0.1; ** p<0.05; *** p<0.01

4.6.1 Interpretation of the Regression Estimates from the Preferred Model and Discussion

The estimated chi-square statistic from the Hausman specification test, as indicated in the regression estimates summarised in Table 6, does not reject the null hypothesis that the FMOLS is a preferred model at a 5 per cent level of significance. Consequently, this study considers the regression estimates of the FMOLS estimator for interpretation and discussion. The FMOLS estimator produces long-run estimates of the regression model, providing vital insights into the factors influencing green energy consumption in the East African Community. The green energy transition is a long-term phenomenon, making long-run estimates preferred.

The long-run regression estimates from the preferred FMOLS model reveal that the estimated coefficients on regulatory quality, the quality of environmental policies (CPIA Policy & Institutions for Sustainability rating), access to electricity, and the first lag of the logarithm of green energy consumption are all positive and statistically significant at the 5 per cent level. Notably, regulatory quality has an estimated long-run coefficient of 0.6063 with a p-value of 0.000, indicating a positive and significant long-run effect on green energy consumption in the EAC. This underscores the crucial role of regulatory quality in promoting green energy adoption. Effective regulatory frameworks, including clear policies and incentives for renewable energy, can stimulate investment and facilitate the transition towards cleaner energy sources, aligning with existing literature emphasising the importance of supportive regulatory environments for green energy development (Weng et al., 2024; Mohammad & Sultana, 2022; Ekundayo et al., 2022).

Additionally, the quality of environmental policies showed an estimated long-run coefficient of 0.1544 with a p-value of 0.000. This finding suggests that well-designed policies promoting environmental sustainability, such as carbon pricing mechanisms or renewable energy targets, can effectively incentivise the adoption of green energy technologies. Furthermore, access to electricity demonstrated a significant long-run effect with an estimated coefficient of 0.0160 and a p-value of 0.000. This highlights the importance of electricity access in enabling green energy consumption, particularly in rural and underserved areas. The studies by Ulsrud (2020), Mulugetta et al. (2019), Sokona et al. (2012), and Oseni (2012) support this view, suggesting that expanding electricity access forms a foundation for increased adoption of green energy solutions. Conversely, the estimated long-run coefficients on the logarithm of GDP per capita and the quality of institutions and policies related to the business regulatory environment were statistically insignificant at the 5 per cent level. The insignificance of these coefficients suggests that GDP per capita and the Quality of Institutions and Policy (CPIA Business Regulatory Environment) do not exert a long-run effect on green energy consumption in the EAC. Interestingly, while the study revealed a negative correlation between national income (GDP per capita) and green energy consumption, this relationship, although not statistically significant, indicates that as national income increases, green energy consumption may decline, which appears counterintuitive. This finding parallels the observations made in existing studies, including Matei (2017), which noted an inverse association between income and sustainable energy utilisation. In particular, Prempeh (2023) indicated a negative influence of economic growth on green energy technology adoption in Ghana.

Similarly, research by Yu and Guo (2023) on China's green energy transition suggested that economic growth adversely affects green energy consumption. These insights imply that national income alone may not be sufficient to drive a transition to green energy and emphasise the need to consider multiple influencing factors. Higher income levels might lead to a greater reliance on conventional energy sources, especially when existing infrastructure supports fossil fuels. Households may prioritise immediate needs, such as healthcare and housing, consuming a significant portion of their income, which limits the financial resources available for investing in green technologies. In the context of the East African Community, allocating income towards essential services often restricts opportunities for green energy investment. Families burdened by substantial out-of-pocket expenses for healthcare and education may perceive green energy as a luxury rather than a necessity.

Without strong governmental policies and incentives promoting green energy adoption, the short-term benefits of investments in healthcare and education can overshadow the long-term advantages of green energy. This complex interplay between income allocation and energy consumption emphasises the need for tailored policies that balance economic growth with environmental sustainability, encouraging investment in green technologies while simultaneously addressing pressing social needs. Finally, the lack of a significant relationship between the quality of institutions and policies related to the business regulatory environment and green energy consumption suggests that while a conducive business environment is vital for overall economic development, it may not be the primary driver of green energy adoption in the EAC context.

These findings collectively highlight the multifaceted nature of green energy consumption drivers and the importance of considering a comprehensive approach to policy-making that incorporates regulatory quality, environmental policies, and socioeconomic factors.

6. Conclusions and policy recommendations

This study provides valuable insights into the factors influencing green energy consumption in the East African Community. The empirical findings from the FMOLS model highlight the crucial role of regulatory quality and environmental policies in promoting green energy adoption. The research underscores the multifaceted nature of green energy adoption in the East African Community. While a conducive business environment and national income are important factors, they are not sufficient on their own. Instead, the study reveals that targeted policies and investments are crucial for driving a sustainable energy transition. Specifically, robust regulatory frameworks, clear incentives, and ambitious environmental policies are essential for attracting investment and promoting the adoption of green technologies. Moreover, expanding electricity access, particularly in underserved regions, is fundamental for creating a foundation for broader green energy uptake. Ultimately, a comprehensive approach prioritising economic development and environmental sustainability is critical for unlocking the full potential of green energy in the EAC.

Based on these conclusions, policymakers in the EAC should foster a robust green energy transition through a multi-pronged policy approach. First, demand for green energy must be actively cultivated through comprehensive environmental policies. This includes implementing robust carbon pricing mechanisms, ambitious renewable portfolio standards, stringent energy efficiency standards, and targeted incentives for households and businesses to choose green energy options like rooftop solar installations. Second, ensuring the accessibility and reliability of green energy is crucial. This requires prioritising expanding electricity access using green sources, particularly in underserved areas, and modernising grid infrastructure to accommodate increasing shares of variable renewable energy.

Furthermore, fostering regional collaboration is essential. Harmonising energy policies across EAC countries will facilitate cross-border green electricity trade, attract larger-scale investments, and share best practices. Finally, public awareness campaigns are vital to educate consumers about the benefits of green energy and encourage informed choices. Complementing this, investing in training programs for a local workforce skilled in green energy technologies will support widespread adoption, create green jobs, and stimulate economic growth. By implementing these policy recommendations, the EAC can create an enabling environment for green energy investments, accelerate its transition to a sustainable energy future, and contribute to global efforts to combat climate change.

The study acknowledges several limitations that provide avenues for further research. Firstly, the analysis primarily focused on a macro-level examination of green energy consumption in the EAC. Future studies could delve into specific country-level contexts within the EAC to uncover nuanced challenges and opportunities. Secondly, the research primarily relied on secondary data and literature. Gathering primary data through interviews with policymakers, consumers, the general public, and other stakeholders could provide richer insights into potential drivers of green energy consumption in the EAC. Furthermore, the study's geographical scope only considered Uganda, Kenya, Tanzania, Rwanda and Burundi. Future studies can include the newly admitted member states such as South Sudan, the Democratic Republic of Congo and Somalia.

Overall, the study's findings suggest that policymakers in the EAC should prioritise the development of robust regulatory frameworks, strong environmental policies, and improved electricity access to effectively promote green energy consumption and achieve a sustainable energy future.

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