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Energy Consumption and Economic Growth: A Panel Causality Analysis in Eastern Africa

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ABSTRACT

Addressing current and future energy needs alongside economic growth has raised global concerns about the causal relationship between energy use and economic performance, particularly in developing regions facing energy deficits. This study examines this relationship in East Africa, where remarkable economic expansion has coincided with persistently low energy consumption, presenting a paradox over whether energy consumption is a driver or merely an outcome of economic growth. The analysis uses annual panel data from 13 countries for the period 2012-2021, applying an augmented neoclassical growth model as the analytical framework. The Dumitrescu and Hurlin panel causality test and a two-step system GMM estimator are employed to assess the nature of causality and the effects of energy on growth. Results reveal unidirectional causality from energy consumption to economic growth, supporting the growth hypothesis. Energy consumption has a positive effect, while energy prices exhibit a significant negative impact. Capital formation, though statistically significant, shows a negative relationship, suggesting inefficiencies or misallocation. Labor shows a causal link to growth, though not statistically significant in the dynamic model. The study recommends that regional energy-growth policy actions focus on expanding energy infrastructure to increase energy consumption, stabilizing prices, and improving capital investment to foster regional economic growth.

Keywords: Economic Growth, Energy Consumption, Causality, SGMM.
JEL Classifications: Q43; C33; O41; O55; Q48

1. INTRODUCTION

Energy is considered one of the key factors for stimulating economic growth in both developed and developing countries (Khan et al., 2021). It serves as fundamental enabler of development, aligning with the aspiration of Sustainable Development Goal 7, African Agenda 2063 and regional development agendas as stated in (Sissoko, 2017). These frameworks collectively recognise the pivotal role of energy in improving living standards, stimulating economic growth, and addressing a wide range social-economic and environmental challenges by 2030 (Nonet et al., 2022; Emma and Jennifer, 2021). Globally, energy is reported to play an important role as the primary input in production, and its used as a key indicator of growing economies (Mangla et al., 2020). It is widely reported that almost every stage in economic growth is closely tied to how energy is used in a given country (Xiaoman et al., 2021), but despite this, the dichotomous relationship between the consumption of energy and economic growth is still debatable (Lin and Zhou, 2022; Stern, 2019).

Some literature argues that there is a strong positive relationship between energy consumption and economic growth, on the other hand, others argue that the relationship between the said variables not always positive. In the positive relationship argument, it is raised that energy is a fundamental input for economic production, and its importance in driving economic growth cannot be overstated (Lin and Zhou, 2022). Across various sectors of the economy, including manufacturing, transportation, and agriculture, energy plays a

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pivotal role in enabling productivity and expansion. Increased energy consumption translates to greater productivity, which, in turn, acts as a catalyst for economic growth. Technological advancements and industrialization have further solidified this relationship. As economies develop and industrialize, their energy demands rise in tandem with their growth. This creates a positive feedback loop where higher energy consumption fuels economic expansion. Notably, energy-intensive industries, such as heavy manufacturing and mining, make substantial contributions to the Gross Domestic Product (GDP). Therefore, an increase in energy consumption within these sectors can significantly boost overall economic output.

In contrast, in the negative relationship argument, studies contend that there are diminishing returns to energy consumption. In other words, as a country consumes more energy, the additional economic benefits become smaller, making energy consumption less effective as a driver of growth. Additionally, concerns related to environmental constraints cannot be ignored. Rapid increases in energy consumption can lead to various environmental issues, including pollution and greenhouse gas emissions, which can have adverse economic consequences in the long run. Pursuing economic growth through increased energy consumption may, therefore, have negative and unsustainable effects on the environment, which could ultimately harm economic prospects. Moreover, energy price volatility presents a significant challenge. Fluctuations in energy prices can have destabilizing effects on the economy. Over-reliance on energy as the primary driver of growth can expose a country to economic vulnerabilities when energy prices exhibit volatility, leading to economic shocks and instability. Therefore, while there are undeniable positive aspects of the relationship between energy consumption and economic growth, these negative arguments highlight the need for a balanced and sustainable approach to energy policy and economic development.

Similarly, the substantial recent rise in global population, urbanization, industrialization, the adoption of alternative energy sources, and economic expansion has been noted as a driving force behind increased energy consumption (Zeraibi et al., 2020). This underscores the pressing necessity to address energy-related concerns, including energy security, efficient resource allocation, policy formulation and decision-making and equitable access to energy resources, both now and in the future. However, the empirical studies have shown that the decline in economic growth tends to lower the consumption of energy by people engaging in activities that use less energy, such as the service and knowledge-based sectors as opposed to the industrial sector that consumes a lot more energy (Nonet et al., 2022; Mangla et al., 2020). Conversely, other studies report that the extensive use of energy tends to harm the environment and affect the direction of economic growth (Xiaoman et al., 2021; Adom, et al., 2021; Abdollahi, 2020; Voumik and Sultana, 2022). For instance Wang et al. (2020), reported that economic growth in lower-income countries negatively and significantly impacts the consumption of energy (Belaid and Zrelli, 2019). Whereas, in developed countries there is a prevalent belief that higher energy consumption play a vital role in fostering economic growth (Waheed et al., 2019).

Accordingly, the diversity in economic structures, factor endowments, and consumption patterns across countries and regions necessitates specific, evidence-based research on the causal relationship between energy consumption and economic growth to inform appropriate policy actions. Notably, as economies grow and transition across sectors occur, varying levels of energy consumption emerge, giving rise to consequences for sustaining the economy Voumik and Sultana, 2022; Kober et al., 2020; Azam, 2020; Le, 2020; Jinying and Sisi, 2020; Saidi and Omri, 2020). However, with a gain scholarly attention regarding to causality relationship between energy consumption and economic growth due to its potential policy implications (Nonet et al., 2022; Mangla et al., 2020; Xiaoman et al., 2021; Adom et al., 2021) there still exists an elusive consensus on whether an increase in energy consumption supports economic growth or the otherwise. In addition, the existing findings has predicted four hypotheses, and each carrying diverse policy implications (Adedoyin, et al., 2020; Emirmahmutoglu et al., 2021; Cheng et al., 2021; Topcu et al., 2020). For instance, growth hypothesis aligns with economic growth prompting energy consumption, advocating for policies that stimulate energy consumption to foster economic growth Liao (2023; Hasan, 2022). Conversely, the conservation hypothesis suggests that economic growth drives energy consumption, underscoring that energy policies have no effects on economic growth, but rather changes in economic growth result in changes in energy consumption (Li and Leung, 2021; Li and Li, 2020).

The feedback hypothesis posits a bidirectional relationship between energy consumption and economic growth, assuming that they are interdependent (Cevik et al., 2021; Emirmahmutoglu et al., 2021; Ha and Ngoc, 2020). The neutrality hypothesis confirms that there is no causal relationship between energy consumption and economic growth. This implies that neither energy conservation policies nor policies that promote energy are likely to have a substantial impact on economic growth (Eyuboglu and Uzar, 2022; Keshavarzian and Tabatabaienasab, 2021; Ozcan and Ozturk, 2019; Belaid and Zrelli, 2019; Tamba et al., 2017). These together have sparked discussion about the causal relationship between the consumption energy and economic growth, and the importance of energy for economic growth in a given country or locality. We posit that crafting growth-energy policies without empirical evidence on causality and the directional relationship between these variables is akin to devising inappropriate measures for achieving stable economic growth and may yield undesired results.

1.1. Economic Growth and Consumption of Energy

Africa has an average economic growth rate of 5% and low consumption of energy (Zerihun and Sennoga, 2023)., where about 0.1 tonnes of oil per capita are consumed, significantly lower than the global average of 1.9 tonnes/capita (IEA, 2019; IEA, 2018). This is affirmed by Le et al. (2020), Ha and Ngoc (2020), Luciani (2020) and Kober et al. (2020b), who contend that Africa has the lowest consumption of energy despite the global increase of 2.3% in the consumption of energy. The region consumes about 3.3% of total global energy, which is less than other regions and unmatched by the rapid increase in population and economic growth (Ramachandran, 2021; Hafner et al., 2018). In addition, the average economic growth in African sub-regions is 5-6% in the East, 4.1% in the North, 3.7% in the West, 3.2% in Central Africa and 1.2% in Southern Africa, while the amount of energy they consume is 9%, 22%, 43%, 10% and 16%, respectively (IEA, 2019). This shows that these sub-regions have higher economic growth than other regions but consume less energy ((African Development Bank, 2021a; Warner and Jones, 2018)). However, the above results contradict the studies by Kober et al. (2020a) and Nwaka et al. (2020) which show that high economic growth tends to increase the consumption of energy because the industrial sector that consumes a large amount of energy has increased in size.

Furthermore, the East African region is expected to grow and remain economically strong in the coming years (Dye, 2022; Mangla et al., 2020), but energy remains a problem as several studies show (Hasan, 2022; Kim and Park; 2022; Manirambona et al., 2022; Kulindwa et al., 2018) that there is low energy consumption in most regions. The region boasts a diverse energy landscape, comprising traditional sources such as biomass and hydropower, alongside the implementation of various strategies and projects. Notable examples include the Stiegler's Gorge Dam in Tanzania, the crude oil pipeline linking Uganda and Tanzania, and the gas pipeline connecting Tanzania and Kenya. These initiatives have been established with the explicit aim of augmenting energy production and consumption in East Africa, with the overarching goal of promoting regional economic growth (Cannon and Mogaka, 2022; Dye, 2022; Items et al., 2019). The notable collaborations in energy projects across borders are believed to have the capacity to transform regional energy dynamics and stimulate economic growth. However, a crucial question remains unanswered: Does increased energy consumption result from economic growth, or is it a prerequisite for it within this particular region? The absence of a definitive answer to this question carries the risk of misleading decision-makers in formulating policy actions related to regional energy and growth, potentially leading to suboptimal outcomes (Eyuboglu and Uzar, 2022; Keshavarzian and Tabatabaienasab, 2021; Ha and Ngoc, 2020; Ozcan and Ozturk, 2019). Therefore, there is an urgent need for a thorough investigation into the causal relationship between energy consumption and economic growth within the specific context of this region.

Concurrently, the region has set ambitious development objectives, including the African Union's Agenda 2063 and the United Nations' Sustainable Development Goals, with a particular emphasis on enhancing energy resources. The realization of these aspirations significantly depends on the role that energy consumption plays in driving regional economic growth. However, East African nations routinely face various challenges related to energy accessibility, affordability, and reliability, all of which exert a substantial influence on regional productivity and have the potential to negatively impact economic growth. While there is a wealth of research on the causal connection between energy consumption and economic growth at the global and national levels such as Rahman (2021); Juodis et al. (2021); Emirmahmutoglu et al.(2021); Banday and Aneja (2020); Jalil and Rao (2019); Ozcan and Ozturk (2019), there is a lack of comprehensive exploration at the regional level, specifically in the context of East Africa. This study aims to bridge this gap by examining the potential benefits of regional collaboration in the domains of energy and economic prosperity. By shifting the focus beyond individual nations and considering the regional specificity, this study seeks to address the existing uncertainty surrounding the causal relationship between energy consumption and economic growth in the East Africa region.

Further, when considering the theoretical landscape, the East African region stands out as uniquely characterized by substantial economic growth coexisting with relatively low energy consumption. This observation, though intriguing, contradicts the conventional expectation like that of Khan et al. (2021) higher economic growth results from increased energy consumption. It raises the possibility that increased energy consumption may not necessarily be a prerequisite for regional economic growth; instead, it might be a by-product. To emphasize energy consumption holistically, this study purposefully includes a wide range of energy sources, encompassing both renewable and non-renewable. This approach acknowledges the continued significance of all forms of energy in fostering economic growth and offers a comprehensive understanding of how total energy influences regional economic growth within the East African context. The inclusive approach enables the region to formulate policies that account for the diverse energy mix within its boundaries rather than focusing solely on individual energy types. By addressing the absence of empirical evidence, this study aims to facilitate informed decision-making regarding the specific region's energy-economic policy implications.

Furthermore, it is rational to acknowledge the increase in the economy attained when the main production inputs are present: labour and capital. These factors exert a direct and substantial influence on productivity and economic output, as consistently highlighted in growth theories; particularly those of neoclassical growth models (Cvetanović et al., 2019). This addition serves to enrich the exploration of the causal relationship between the core variable of interest. Besides, it is essential to recognize the critical role of energy prices. Variations in energy prices are known to impact the cost structures of both production sectors and households, subsequently influencing both energy consumption patterns and economic growth outcomes, thus, the study considers the influence of energy prices on the causal relationship between energy use and economic growth. It also examines the role of labour and capital in promoting regional economic growth, alongside energy consumption. By recognise the role of these key variables; the study aims to provide empirical evidence of how energy consumption, energy price, and primary inputs of production contribute to regional economic growth. Specifically, the study addresses two questions: (1) what are the types of causal relationships between energy consumption and economic growth, including whether energy drives economic growth, economic growth drives energy consumption, or if there is a bidirectional relationship? (2) What is the nature and robustness of the directional relationship between these core variables? Specifically, how consistent are the effects of changes in energy consumption on economic growth.

Lastly is how the energy consumption impact economic growth within the EA region, this is for robustness check, to confirm the magnitudes and directional relationship between energy consumption and economic growth in this region. Accordingly, this study offers several significant contributions to the field of economic analysis. Firstly, it stands out for its methodological rigor, characterized by the application of Dumitrescu and Hurlin's (2012) panel causality tests. These tests are chosen for their effectiveness in addressing common challenges encountered in panel analysis, such as cross-sectional dependency, unit heterogeneity, capturing dynamic relationships, and handling short panels. Notably, this methodology goes beyond the core variables of interest, incorporating crucial factors like labour, capital, and energy prices. This comprehensive approach enriches the study's insights, making them applicable to a broader spectrum of economic factors. One of the most compelling facts of this region is its presentation of a unique dilemma where the economy is experiencing growth despite relatively low energy consumption levels. However, our research has elucidated this phenomenon, showing that energy consumption is still a prerequisite for regional economic growth rather than merely a by-product.

Furthermore, the study extends its reach by exploring additional variables that enhance productivity and investigating the role of price in determining causality directions between energy consumption and economic growth. These variables shed light on how energy prices and productivity factors impact the dynamics of the core variables' relationship, contributing novel insights to the field. Despite the geographical focus on East Africa, the implications of this research extend to other developing economies facing similar challenges. The insights gleaned offer valuable lessons for regions in comparable situations, enriching not only practical applications but also the theoretical foundations of the field. These findings hold relevance in a broader range of contexts, making them valuable to a wider audience. Finally, this study transcends theoretical exploration and offers practical implications for policy and practice. It provides specific policy recommendations aimed at fostering economic growth in East Africa, emphasizing the strategic utilization of energy, capital, labour, and energy prices. These recommendations furnish actionable guidance to policymakers, investors, and stakeholders, highlighting the tangible real-world impact of the findings. The study is structured into several sections: Section 2 provides an overview of the literature, Section 3 outlines the methodology, Section 4 presents the results and discussion, and Section 5 draws conclusions.

2. REVIEW OF THE LITERATURE

2.1. Theoretical Background

This paper is grounded on the neoclassical growth theory which was presented by Solow (1957and 1956) to illustrate, within the East African context, the causal relationship between labour, capital, and energy and economic growth. The specific focus of the study is to determine whether energy consumption is the driving force behind economic growth or if it is economic growth that stimulates energy consumption. Historically, neo-classical theorists have lent substantial support to the Solow growth model, which postulates that economic growth hinges on the accumulation of both capital and labour. The theory presents the relationship between the inputs-outputs, details the factors influencing economic growth (Adom et al., 2021) and postulates that economic growth is a result of what is produced by labour, capital and technology (Ivanovski et al., 2021a; Jafri et al., 2021; Asif et al., 2021; Elorhor, 2019).

The neoclassical growth model underscores the importance of capital accumulation and its efficient utilization in driving economic growth (Cvetanović et al., 2019). Likewise, the interaction between capital and labour within an economy plays a pivotal role in determining the output level, with technology serving to enhance productivity (Solow, 1957; Solow, 1956). Within this framework, labour and capital were regarded as key factors of production, given their comprehensive contributions to productive capacity. This encompasses not only augmented production but also the facilitation of technological innovation and an overall enhancement of economic performance. Although the traditional neoclassical theory did not include energy in the production function but, this study advances the claim that energy use is a key factor in economic growth and acts as a catalyst. It operates through various mechanisms, including its indispensable role in industrial production and its contribution to domestic activities, which subsequently lead to increased productivity and foster economic growth. This assertion is grounded in the prevailing belief that energy serves as a universal input across nearly all sectors of production.

Additionally, Azam (2020) included energy consumption along with capital and labour, as inputs in the model used for analysis, stressing the importance of energy as one of the most important components of production: An essential driver of robust economic growth (Asif et al., 2021). Similarly, recent economic growth studies, such as those by Shahzad et al. (2022); Khan et al. (2020); Lawal et al. (2020); Appiah et al. (2019); Baz et al. (2019); Tamba et al. (2017) and Cook and Davíðsd (2021) have underscored the central role of energy consumption in fostering economic growth. These studies have also recognized the intricate interplay among various macroeconomic factors, including energy costs, human capital, sectoral consumption, and energy production, in stimulating economic growth over time in alignment with the studies (Pickering et al., 2022; Manirambona et al., 2022; Kim and Park, 2022; Ivanovski et al., 2021b; Yusuf et al., 2020; Merrill and Orlando, 2020; Dye, 2022; Cvetanović et al., 2019). Therefore, this study adopts the augmented growth theory, which incorporates energy consumption and its price, as it is widely acknowledged that energy prices exert a significant influence on economic growth, as evidenced by their impact on various aspects of economic activity.

The foundational framework of this study entails the development of a model that explicitly integrates energy as a primary determinant of economic growth within the neo-classical framework (Azam, 2020; Topcu et al., 2020). Moreover acknowledges the relationship between the consumption of energy and economic growth within several studies since the seminal work by Kraft and Kraft (1978) as cited by Cannon and Mogaka (2022) and Kim and Park, (2022). A seminal contributions has invigorated debate on the nuanced impacts of economic growth on energy consumption and vice versa. Thus, the current study delves into the relationship between these variables, a subject that has been extensively discussed in the body of current literatures including of Gyamfi et al. (2022); Bekun et al. (2021); Shaari et al. (2021); Salari et al. (2021); Rahman et al. (2021); Gorus and Aydin, (2019). Within this well-established discourse, our primary emphasis lies in understanding the causal relationship between energy consumption and economic growth within diverse economic contexts. It is essential to recognize that variations in economic systems, energy resources, consumption patterns, and energy-growth policy actions prevail across different countries and regions (Ivanovski et al., 2021b; Mahmood et al., 2019).

Qing et al. (2023); Ollier et al. (2022); Ehigiamusoe et al., 2020; Uche-Soria and Monroy, 2020), giving rise to nuanced impacts and policy implications. Therefore, the need for region-specific empirical evidence to comprehensively understand the energy-growth relationship becomes apparent. Therefore, the study employed the augmented neoclassical growth theory to model the relationship between inputs and outputs based on the conventional neoclassical production function (Khan et al., 2020; Kim and Park, 2022). In this context, the Gross Domestic Product (GDP) is determined by labour, physical capital, the overall energy consumption, and its associated price, as outlined in the theoretical equation (1).

$$Y_{it} = \beta_0+\beta_1 C_{it}+\beta_2 L_{it}+\beta_3 EC_{it}+\beta_4 EP_{it}+\varepsilon_{it} \quad (1)$$

Where, the $Y_{i,t}$ represents per capita GDP in East African countries during different time periods, denoted by the subscripts i and t. The variables $C_{i,t}$, $L_{i,t}$, $EC_{i,t}$, and $EP_{i,t}$ are associated with physical capital, labour, energy consumption, and energy price, respectively, for each country and time period, and the term $\varepsilon_{i,t}$ stands for the error term, specific to each country and time period.

2.2. Empirical Review

This study recognizes the presence of numerous studies that investigate the relationship between energy consumption and economic growth, shedding light on the intricate dynamics within this nexus. Some of these studies propose that declining economic growth is associated with decreased energy consumption, particularly in sectors that rely less on energy inputs (Nwaka et al., 2020; Salari et al., 2021), others underscore the potentially adverse environmental consequences of excessive energy use, exerting influence over economic growth (Qing et al., 2023; Ollier et al., 2022; Topcu et al., 2020; Rahman et al., 2020). This complex relationship has spurred scholarly discourse, with a growing body of research delving into the type and direction of the relationship between economic growth and energy consumption (Kim and Park, 2022; Ramachandran, 2021; AFDB, 2021; Yusuf et al., 2020; Ehigiamusoe et al., 2020; Soria and Monroy, 2020; Li and Li, 2020; Saidi and Omri, 2020). However, the current research findings continue to be contradictory and inconclusive.

The existing empirical evidence have demonstrated three possibilities: unidirectional relationships (Kirikkaleli et al., 2021; Rahman and Velayutham, 2020; Rahman et al., 2020); bidirectional relationships as reported by Humbatova et al. (2020); Zaidi and Ferhi, (2019), and the absence of causal relationships (Shahbaz et al., 2017; Shahbaz et al., 2020; Toumi and Toumi, 2019). Studies have reported and argued with great concern that no causal relationship with robust results should be assumed between the consumption of energy and economic growth in a given region or country (I. Khan et al., 2022; M. B. Khan et al., 2022; Acheampong et al., 2021a; Rahman, 2021; Akadiri et al., 2019; Tamba et al., 2017). In turn the researcher observed that each type of causality supports a unique hypothesis and suggests a different course for the formulation of policy. For instance, the unidirectional relationship that is supported by the growth hypothesis maintains that it runs from energy consumption to economic growth, suggesting that the former drives the latter, meaning that the consumption of energy has a positive impact on economic growth. Therefore, it is imperative for policies to prioritize the consumption of more energy to foster economic growth (Rahman and Velayutham, 2020; Zaidi and Ferhi, 2019).

Similarly, the one-way relationship described earlier finds support in the conservation hypothesis, which posits that economic growth leads to increased energy consumption. In other words, as the economy expands, energy consumption tends to rise. As a result, there is a need for policies that promote energy conservation to enhance economic growth. On the contrary, the bidirectional causality type supports the feedback hypothesis, suggesting that energy consumption and economic growth mutually influence each other. In contrast, the absence of a causal relationship between these variables gives rise to a neutral hypothesis, which calls for the simultaneous implementation of policies that conserve energy and promote economic growth (Ho and Ho, 2021). The existing empirical studies have employed a variety of econometric methods, including panel approaches and time series over different periods in several datasets and yield comflicting results across regions and time periods (Bekun and Alola, 2022; Eyuboglu and Uzar, 2022; Awodumi and Adewuyi, 2020; Azam, 2020).

Lawal et al. (2020) employed system generalized methods of moments (SGMM) to study the consumption of energy and economic growth in sub-Saharan Africa and found a bi-directional relationship between them, similar to Tamba et al. (2017) in Cameroon, Baz et al. (2019) in Pakistan and Latief et al. (2020) in members of the Union for the Mediterranean. On the other hand, Saad and Taleb, (2018) employed the Granger causality test to study the consumption of energy and economic growth and reported mixed results, While the results demonstrated a bi-directional causal relationship in the community variables under study over the long term, whilst the short-term results suggested a unidirectional causal association between economic growth and energy use. The study by Khan et al. (2022) and Anser et al. (2021) employed the Dumitrescu and Hurlin test and found a bidirectional causal relationship running from the consumption of energy to economic growth and a unidirectional causal relationship running in the same direction as the bidirectional one.

Studies by Odhiambo (2021), employed autoregresive distributive lags in disaggredated energy data and found a causal bidirectional relationship, however, only in the short run a unidirectional causality from energy consumption to economic growth. According to study conducted by Zheng and Walsh (2019), employed SGMM and found no causality in either direction between the consumption of energy and economic growth. Some other stidies found an association between the consumption of energy and economic growth are Ollier et al. (2022); Cheng et al. (2021); Topcu et al.(2020); Adedoyin et al. (2020); IEA, 2019). Although, the study by Yang et al. (2022) used non-linear autoregressive distributed lags (NARDL) with only labour and capital as the control variables in seven Eastern countries to examine the relationship between the variables in question and found a causal, reciprocal between the consumption of energy and economic growth in Sudan and Ethiopia. Accordingly, we argue that it is unfeasible for a country or region to implement an appropriate growth-energy policy in the absence of empirical evidence regarding the existence of causality and the direction of the relationship between the consumption of energy and economic growth.

Many existing studies have overlooked the regional nuances that significantly influence policy decisions. Our study addresses this gap by emphasizing the need for region-specific empirical evidence to comprehensively understand the energy-growth relationship. The East African region was selected because it exhibits a unique economic trajectory, characterized by relatively low energy consumption and distinct socio-economic factors that are expected to drive higher energy consumption, as observed in studies like (Jiatao et al., 2021; Shahbaz et al., 2017; Lopez and Weber, 2017; Roodman, 2009; Arellano and Bover, 1995). This regional context provides valuable insights that enrich the broader discussion on the topic and highlights the importance of considering the region's sole characteristics and policy implications. Our research not only contributes to the broader discourse on the energy-growth relationship but also takes into account other important factors, including labour, price, and capital. This approach equips regional stakeholders with evidence-based insights to formulate effective energy and economic policies.

3. DATA AND METHODOLOGY

3.1. Data

This study employed annual panel data to investigate causal relationships, directions, and impacts among key variables in the East African region. The analysis covered 13 countries: Burundi, Comoros, Djibouti, Ethiopia, Kenya, Madagascar, Mauritius, Mozambique, Rwanda, South Sudan, Sudan, Tanzania, and Uganda. These countries were chosen based on their proximity within East Africa, the availability of relevant data, and the need to capture the diverse economic and energy dynamics present in the region. East Africa is renowned for its economic and energy diversity, and the selection of countries aimed to capture this diversity while acknowledging shared traits among them. This approach ensures the applicability of findings to the broader East African context without assuming complete uniformity among the selected countries. Additionally, data quality is pivotal to the study's success. The selection focused on countries with current, accessible, and reliable data concerning variables of interest: GDP per capita for economic growth, total energy consumption (EC), labor force (L), growth of capital formation (C), and energy price (EP) from the consumer price index. This meticulous selection guarantees the use of the most up-to-date and trustworthy information.

The study dataset spans from 2012 to 2021, aligning with statistical test requirements for a balanced dataset and ensuring the inclusion of the most recent data. Moreover, the data processing and measurement procedures were conducted as follows: GDP per capita for economic growth was calculated by dividing the total GDP of each country by its population size for each year in the dataset, representing economic growth per capita. Total energy consumption (EC) data were directly sourced from the U.S. Energy Information, and represent the total energy consumption in Terajoules for each country over the specified time period. The labor force (L) data were obtained from the Global Economy database, representing the total working-age population in each country for the respective years. Gross capital formation (C) was calculated as a percentage of GDP, reflecting the proportion of a country's GDP allocated to capital formation. Consumer price index (EP) data were sourced from the World Development Indicators, representing price levels relative to the base year 2010. These measurements and calculations were conducted consistently across all selected countries and years, ensuring uniformity and reliability in the dataset. However, energy consumption, energy price, and labor force were transformed into their natural logarithmic forms (LnEnergy, LnPrice, and LnLabor, respectively) as shown in Table 1.

3.2. Methodology

3.2.1. Estimation strategies

The panel causality (Dumitrescu and Hurlin's 2012) and the Generalised Methods of Moments (GMM) estimation models were employed in this study. In the first step of ascertaining the existence of causality and directional relationship among the variables of interest, researcher employed the panel-unit root test while accounting for cross-sectional dependence (Sheikh and Hassan, 2023). This step is essential before conducting the causality test because it establishes the stationarity of the dataset (Pesaran, 2021). Panel unit root testing is essential to avoid spurious regression results in time-series or panel contexts (Sheikh and Hassan, 2023). To detect whether the panel dataset is affected by cross-sectional dependence, the Breusch-Pagan LM and Pesaran CD tests were first conducted. This is particularly important in regional blocs such as East Africa, where countries are economically and geographically interconnected.

Table 1: Description of variables

Variables	Units of measurement	Source
GDP per capita growth	Annual percentage	https://databank.worldbank.org/source/world-development-indicators
Consumer price index	2010=100	https://databank.worldbank.org/source/world-development-indicators
Gross capital formation	Percentage of GDP	https://databank.worldbank.org/source/world-development-indicators
Total energy consumption	Terajoules	https://www.eia.gov/international/data/world
Labour force	Total working group	https://www.theglobaleconomy.com/rankings/labor_force

Following the detection of cross-sectional dependence, the study employed the second-generation Cross-sectionally Augmented IPS (CIPS) test instead of the earlier Levin-Lin-Chu (LLC) and Hadri LM tests. The CIPS test is preferred for its robustness in panels with interdependencies and non-synchronous shocks, and it confirmed that the variables are stationary in level or first difference. This replacement ensures that the stationarity conditions were tested using methods appropriate for panels with cross-sectional correlation (Ahmad et al., 2020). Next, the study employed the Dumitrescu and Hurlin Granger causality test to ascertain causality types, and directional relationships among the variables. This test was selected due to several advantages suited to the research context. First, it possesses the capability to handle cross-sectional dependencies, which is crucial in a region like East Africa where economies may be interconnected. Moreover, the test makes effective use of panel data, encompassing multiple dimensions of data across time and entities.

Additionally, it accounts for heterogeneity among the countries, recognizing that each has unique characteristics that could influence the energy consumption and economic growth dynamic. Its ability to deliver reliable and robust causal inference results, while accommodating these complex regional variations, renders it an invaluable tool for this study (Lopez and Weber, 2017). The dynamic effects of energy consumption on economic growth were further examined using the GMM framework. However, the ordinary least square (OLS) and fixed effect (FE) were employed to decide which dynamic panel model to be used between difference generalised methods of moments (DGMM) and system generalised methods of moments (SGMM) as narrated by (Bond and Arellano, 1991). The study opted for the two-step difference and system-GMM instead of the one-step approach because the statistical test based on the two-step estimator is asymptotically more powerful (Coskun and Vardar, 2016). Similarly, it is more efficient and robust in relation to heteroskedasticity and autocorrelation.

Furthermore, the two-step SGMM was chosen over the difference GMM because it possesses the ability to address endogeneity issues in variables, as mentioned by (Arellano and Bover, 1995; Roodman, 2009). It is said that in two-step SGMM the instruments are developed by differences and level information (Hakimi and Inglesi-Lotz, 2020). The introduction of the level equation from a double equation system tends to increase the number of instruments and provides more information than in the difference GMM (Roodman, 2009). It also controls bias and inefficient estimates Φ in finite samples whenever the dependent variables are close to a random walk (i.e., Φ->1), and it is acute when the period is small (small T, large N). Therefore, this study met the SGMM estimation criteria. Finally, diagnostic checks were performed to validate the estimation results and ensure the strength of the instruments used in both the two-step SGMM and two-step DGMM, as recommended by (Hansen-Singleton, 1982), Hansen-Singleton, (1982) and Sargan, (1985).

3.2.2. Study estimation models

3.2.2.1. Dumitrescu and Hurlin (2012) causality model

To establish the existence and direction of causality between the outcome variable (GDP per capita, denoted by Y) and the explanatory variables, physical capital (C), labor (lnL), energy price (lnEP), and energy consumption (lnEC), Dumitrescu and Hurlin (2012) panel Granger non-causality test was employed, as expressed in Equation (2). This test is preferred for heterogeneous panel data due to its ability to account for both heterogeneity and cross-sectional dependence, making it more appropriate for the East African context than alternatives like Juodis et al. (2021). The null hypothesis (H_0) states that there is no homogeneous causality across cross-sectional units, while the alternative hypothesis (H_1) assumes the presence of causality in at least some countries.

$$Y_{i,t} = \alpha_i + \sum_{k=1}^{K} (Y_{ik} Y_{i,t-k}) + \sum_{k=1}^{K} (\beta_{ik}\, \beta_{i,k} X_{i,t-k}) + \varepsilon_{it} \quad (2)$$

Where, $Y_{i,t}$ represents per capita GDP, α_i is the country-specific intercept, and are coefficients for lagged variables. These lagged variables are and This equation is applied across East African countries and time periods (i = 1–N, t = 1–T), and the coefficients are time-invariant. The lag order K is consistent for all countries, and the panel data is balanced.

3.2.2.2. Arellano-Bond generalized method of moments models

To examine the effects of energy consumption on economic growth, the study employed the Arellano-Bond Generalized Method of Moments (GMM) estimation framework, drawing from an augmented production model consistent wit Kim and Park, (2022); Cheng et al. (2021); Ivanovski et al. (2021c). The general form of the model is presented in Equation (3):

$$Y_{it} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 Z_{i,t-1} + \beta_3 X_{i,t-1} + \varepsilon_{i,t}$$

$$i = 1, 2,\ldots, N;\ t = 1,2,\ldots,T\ldots\ldots\ldots\ldots \quad (3)$$

Y_{it} represents GDP, $Z_{i,t-1}$ represents the explanatory variable, $X_{i,t-1}$ represents the control variable, $Y_{i,t-1}$ denotes the lagged values of GDP and $\varepsilon_{i,t}$ represents the error term specific to individual countries and specific time periods.

To control for endogeneity, unobserved heterogeneity, and serial correlation, the dynamic panel GMM estimator was applied using both level and first-difference specifications. The functional forms are provided in Equations (4a) and (4b):

$$Y_{it} = \beta_0 Y_{i,t-1} + \beta_1 C_{it} + \beta_2 lnL_{it} + \beta_3 lnEC_{it} + \beta_4 lnEP_{it} + \varepsilon_{it} \quad (4a)$$

$$\Delta Y_{it} = \beta_0 \Delta Y_{i,t-1} + \beta_1 \Delta C_{it} + \beta_2 \Delta lnL_{it} + \beta_3 \Delta lnEC_{it} + \beta_4 \Delta lnEP_{it} + \Delta\varepsilon_{it} \quad (4b)$$

Where Y_{it} is real GDP, $Y_{i,t-1}$ represents lagged real GDP, C_{it} is capital formation, lnL_{it}, $lnEC_{it}$, and $lnEP_{it}$ represent the natural logarithms of labor force, energy consumption, and energy price respectively, Δ is the difference of one period and ε_{it} is error term while the subscript i denotes the country, and t denotes the period.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics and Correlation Matrix

Table 2 presents the descriptive statistics for the panel data covering 13 East African countries from 2012 to 2021. The average

Table 2: Descriptive statistics

Variable	Obs	Mean	Standard deviation	Min	Max
GDP	130	−1.768	14.828	−93.42	10.493
Capital	130	23.989	15.868	−7.712	110.893
LnPrice	130	5.323	1.067	4.196	10.024
LnLabor	130	15.477	1.721	12.145	17.839
LnEnergy	130	11.029	1.495	7.77	12.871

GDP per capita growth rate across the sample is −1.768, with a standard deviation of 14.828, indicating substantial cross-country heterogeneity. The minimum value of −93.42, observed in South Sudan, reflects severe economic contraction, while the maximum value of 10.493, recorded in Rwanda, denotes robust economic growth. This wide variation suggests that in some countries, population growth may be outpacing economic performance on a per capita basis.

The mean value of gross capital formation is 23.989, ranging from −7.712 to 110.893, indicating substantial variation in investment levels across countries. The mean values for consumer prices, labor force size, and energy consumption are 5.323, 15.477, and 11.029, respectively, reflecting notable cross-country differences in economic structure and resource utilization. These descriptive statistics provide important contextual insight into the region's macroeconomic characteristics. The core empirical analysis centers on panel estimation techniques, namely the Dumitrescu and Hurlin (2012) panel causality test and the two-step System Generalized Method of Moments (SGMM) estimator, as both are well-suited to addressing unobserved heterogeneity, endogeneity, and dynamic relationships in panel data.

Table 3 presents the Pearson correlation matrix, which explores the statistical relationships among the study variables. A moderate negative correlation is observed between GDP per capita growth and price (−0.772), suggesting that higher price levels are associated with weaker economic performance. In contrast, GDP per capita growth exhibits positive but relatively weak correlations with capital formation (0.395), labor (0.022), and energy consumption (0.139). Importantly, none of the pairwise correlations exceed the commonly accepted threshold of 0.8, and the mean variance inflation factor (VIF) remains below 2.7, indicating that multicollinearity is not a concern in the subsequent model estimations.

4.2. Cross-Sectional Dependence and Panel Unit Root

To ensure the robustness of the panel analysis and avoid spurious regression results, the study first tests for the presence of cross-sectional dependence among the countries. Evidence from both the Breusch-Pagan LM test and the Pesaran CD test confirms significant cross-sectional dependence. In light of this, the Cross-sectionally Augmented IPS (CIPS) test, a second-generation panel unit root test, is employed to assess the stationarity properties of the variables. This test is appropriate in the presence of cross-country correlation, which is common in regional groupings such as Eastern Africa. As shown in Table 4, not all variables are stationary at level. For instance, GDP were found to be stationary in level in both constant and constant with trend. In contrast, capital, labor, energy, and price showed mixed results in level but were also

Table 3: Pairwise correlations

Variables	GDP	Capital	LnPrice	LnLabour	LnEnergy
GDP	1.000				
Capital	0.395***	1.000			
LnPrice	−0.772***	−0.249**	1.000		
LnLabor	0.022	0.336***	0.241**	1.000	
LnEnergy	0.139	0.492***	0.183**	0.743***	1.000
VIF		1.56	1.26	2.29	2.69
Mean VIF		0.639	0.796	0.436	0.371
1/VIF					1.95

***P<0.01, **P<0.05, *P<0.1

confirmed to be stationary at first difference under both constant and trend specifications, confirming their integration of order one. Therefore, the results support the use of panel models that are compatible with variables integrated of order zero or one, provided none is integrated of order two (Roodman, 2009; Bond, 2002). On this basis, the study applies the Dumitrescu and Hurlin (2012) panel causality test and the two-step system GMM estimator, both of which account for cross-sectional dependence, dynamic relationships, endogeneity, and country-specific heterogeneity.

4.3. Dumitrescu and Hurlin Panel Causality Results

Table 5 presents the Dumitrescu and Hurlin (2012) panel causality test results, which reveal several unidirectional causal relationships among the study variables. The first notable relationship is from energy consumption to GDP, which is statistically significant at the 1% level, with a P = 0.0078. This indicates that increases in energy consumption contribute to economic growth in the region. However, no reverse causality from GDP to energy was detected, suggesting that energy consumption serves as a driver rather than an outcome of economic performance. The second significant causal link is from price to GDP, with a P = 0.0001, and from price to capital, with a P = 0.0071; both are statistically significant at the 1% level. These results imply that energy prices influence both economic growth and investment behavior. Rising prices may dampen GDP by increasing production costs and reducing consumer purchasing power, while also affecting capital accumulation by altering cost structures and investment returns.

A third causal pathway is observed from labor to GDP and to price, with P = 0.0004 and 0.0002, respectively, both significant at the 1% level. These findings underscore the productive role of labor in driving economic activity and influencing inflationary trends. The absence of reverse causality from GDP to labor further reinforces the view that labor supply is an exogenous input in the region's growth dynamics. Additionally, the study shows bidirectional causality between capital and GDP, with both directions significant at the 1% level and P = 0.0002 from capital to GDP and 0.0007 from GDP to capital, indicating mutual feedback effects. This suggests that while capital formation drives GDP growth, economic expansion also stimulates further investment, reinforcing cyclical growth mechanisms. Furthermore, capital is found to Granger-cause energy consumption, with a P = 0.0284, and labor is found to cause capital formation, with a P = 0.0441; both are significant at the 5% level. These findings highlight the central role of capital in shaping resource utilization and productive capacity in Eastern Africa.

Table 4: Cross-sectional dependence and panel unit root

Variables	Cross-section dependency (CD)		Cross-sectionally augmented IPS (CIPS) panel unit root			
	Breusch-Pagan LM test	Pesaran CD test	CIPS panel unit root		CIPS first difference	
	Test statistics	Test statistics	Constant	Constant and trend	Constant	Constant and trend
GDP	219.191***	12.142***	−2.812***	−3.562**		
Capital	160.435***	2.810***	−1.396	−2.405	−2.558**	−2.623
LnPrice	721.751***	18.449***	−0.531	−0.375	−0.615	−2.714*
LnLabor	711.417***	26.541***	−2.012	−1.866	−1.857	−3.291**
LnEnergy	409.906***	12.867***	−2.053	−1.782	−2.348*	−2.138

Significance levels: ***1%, **5%, *10%

Table 5: Causality test results

Dumitrescu and Hurlin (2012) - Lag order: 1			
Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.
LnEnergy does not homogeneously cause GDP	3.9732	2.6586	0.0078**
GDP does not homogeneously cause lnEnergy	0.82653	−0.72395	0.4691
LnLabor does not homogeneously cause GDP	7.6464	6.60718	0.0004***
GDP does not homogeneously cause lnLabor	1.38953	−0.11875	0.9055
LnPrice does not homogeneously cause GDP	7.17619	6.10172	0.0001***
GDP does not homogeneously cause lnPrice	1.57126	0.0766	0.9389
Capital does not homogeneously cause GDP	19.1032	18.9228	0.0002***
GDP does not homogeneously cause Capital	4.65129	3.38754	0.0007***
LnLabor does not homogeneously cause lnEnergy	2.08283	0.62652	0.531
LnEnergy does not homogeneously cause lnLabor	1.34302	−0.16874	0.866
LnPrice does not homogeneously cause lnEnergy	1.7508	0.2696	0.7875
LnEnergy does not homogeneously cause lnPrice	2.9629	1.57257	0.1158
Capital does not homogeneously cause lnEnergy	3.53854	2.19137	0.0284**
LnEnergy does not homogeneously cause Capital	2.47665	1.04987	0.2938
LnPrice does not homogeneously cause lnLabor	2.3921	0.95898	0.3376
LnLabor does not homogeneously cause lnPrice	10.754	9.94779	0.0002***
Capital does not homogeneously cause lnLabor	1.857	0.38376	0.7012
LnLabor does not homogeneously cause Capital	3.373	2.01342	0.0441**
Capital does not homogeneously cause lnPrice	2.62232	1.20646	0.2276
LnPrice does not homogeneously cause Capital	4.00653	2.69444	0.0071**

Significance levels: ***1%, **5%, *10%

Collectively, the results indicate that energy consumption, labor, and price are key drivers of economic growth in the region. These findings are consistent with the work of Murshed et al. (2021) and Cheng et al. (2021), who reported unidirectional causality from energy to growth. However, they differ from the studies of Azam (2020); Musah et al. (2020); Dinçer et al. (2017), which found bidirectional causality between energy consumption and economic growth. The observed two-way causality between capital and GDP aligns with the findings of Coskun and Vardar, (2016), as well as studies conducted in Europe, Asia, and Africa (Cevik et al., 2021; Zakari et al., 2022; Abdollahi, 2020; Rafindadi and Ozturk, 2017). In contrast, it contradicts the conclusions of Murshed et al. (2021); Keshavarzian and Tabatabaienasab (2021), who reported a one-way relationship between capital and economic growth in selected African and American contexts.

4.4. Effects of the Consumption of Energy on Economic Growth

Table 6 presents the results from different modeling techniques used to examine the effects of energy consumption on economic growth. The pooled OLS estimates show a positive coefficient for energy consumption (LnEnergy), which is statistically significant at the 10% level. As established in the literature, both pooled OLS and fixed effects (FE) models tend to suffer from biases,

Table 6: Results of robustness check

Variables	(1) Pooled OLS	(2) FE	(3) 2 step diff GMM	(4) 2 step syst GMM
L.GDP	0.580***	0.372***	0.752***	0.982***
	(0.076)	(0.082)	(0.023)	(0.093)
Capital	0.001	−0.072	−0.763***	−0.922**
	(0.061)	(0.087)	(0.140)	(0.453)
LnPrice	−6.159***	−10.018***	−8.487***	−7.269**
	(0.932)	(1.212)	(1.220)	(3.168)
LnLabor	0.195	18.849*	9.686	−0.252
	(0.531)	(10.880)	(7.623)	(1.486)
LnEnergy	1.363*	−1.772	−2.386	7.271***
	(0.703)	(4.956)	(2.707)	(1.946)
Constant	14.037**	−218.139		−16.628
	(6.173)	(139.075)		(14.579)
Observations	117	117	104	117
R-squared	0.825	0.699		
Number of countries		13	13	13
AR (1)			0.124	0.165
AR (2)			0.201	0.216
Hansen			0.455	0.146
Sargen			0.695	0.276
Number of Instruments			13.000	9.000

Standard errors in parentheses***P<0.001, **P<0.05, *P<0.1

with pooled OLS generally producing upward bias and fixed effects downward bias, particularly in the presence of a lagged dependent variable (Majeed and Luni, 2019; Ullah et al., 2018). For this reason, these models are used mainly as a reference for comparison rather than for drawing conclusions. The pooled OLS model shows that lagged GDP is statistically significant at the 1% level, capital is positive but not statistically significant, and labor is also not significant. In the FE model, lagged GDP remains positive and significant, labor becomes statistically significant at the 10% level, while energy shows a negative and statistically insignificant effect. These results highlight the limitations of using pooled OLS and FE estimators in dynamic panel settings, and their outputs are presented primarily for diagnostic comparison.

The difference GMM (DGMM) and system GMM (SGMM) estimators were then applied to address potential endogeneity and improve the consistency of the estimates. The lagged value of GDP is estimated at 0.752 under DGMM and 0.982 under SGMM, indicating that GDP is highly persistent over time. According to Blundell and Bond (1998), when the coefficient on the lagged dependent variable approaches one, the difference GMM estimator may produce downward-biased results, particularly in panels with a short time dimension. Therefore, the system GMM estimator is preferred, as it incorporates level moment conditions and helps reduce bias in estimating persistent dynamics. In the SGMM results, shown in Column 4 of Table 6, the coefficient on LnEnergy is statistically significant at the 1% level, with a value of 7.271 indicating a strong positive effect on economic growth. This implies that a 1% increase in energy consumption is associated with a 0.0727 unit increase in GDP per capita growth, holding other factors constant. This finding underscores the importance of energy in stimulating economic activity in the Eastern Africa region and aligns with previous studies such as Zaidi and Ferhi (2019) in Sub-Saharan Africa and Rahman et al. (2020) in China, both of which found a positive relationship between energy use and economic growth.

In contrast, energy price, with a coefficient value of −7.269, is statistically significant at the 5% level, indicating a negative relationship with economic growth. Rising energy prices are likely to increase production costs and reduce consumption, thereby constraining GDP growth. This finding suggests that stabilizing or reducing energy prices could serve as an important policy tool for promoting growth in regional economies. Capital, with a coefficient of ”. 0.922 and statistically significant at the 5% level, also shows a negative effect on GDP. This is counterintuitive, as theory generally suggests that capital accumulation fosters growth. However, this finding may reflect diminishing returns to capital investment, poor allocation of capital resources, or low efficiency in public investment, particularly where capital is directed toward non-productive sectors. These may suggest the need for deeper investigation and region-specific research to assess the quality and sectoral allocation of capital formation in Eastern Africa. Lastly, the labor, which have showed a statistically significant causal effect on GDP in the Dumitrescu and Hurlin causality test, appears statistically insignificant in the SGMM estimation. This disparity may arise from labor being captured only in terms of quantity rather than quality, or a potential time lag between workforce expansion and its effect on GDP. Therefore, while labor’s direct contribution may not be visible in the SGMM estimates, its role remains important and warrants future analysis. Therefore, the SGMM findings confirm that energy consumption is a statistically significant and positive driver of regional economic growth, while rising energy prices and inefficient or misallocated capital formation exert negative effects. These results highlight the need for policies focused on expanding energy access for increses consumption, stabilizing energy prices, improving the quality and efficiency of capital investments to support economic growth in Eastern Africa.

4.5. Robustness Checks

To assess the validity of the instrumental variables and detect possible serial correlation in the error term, the researcher conducted robustness checks on the SGMM model. Two key tests were employed to ensure the reliability of the analysis: the Hansen test of over-identifying restrictions and the Autoregressive test for second-order serial correlation (AR (2)). The Hansen test evaluates the null hypothesis that the instruments used in the model are valid and not correlated with the error term. According to Roodman (2009, p. 129), caution should be exercised when interpreting Hansen test results. While a significant P-value (typically below 0.05 or 0.1) may suggest that the instruments are invalid, an excessively high P-value may indicate problems such as instrument proliferation or weak identification. Ideally, the Hansen test P-value should be insignificant but not excessively large. In this case, the P = 0.146 falls within an acceptable range, meaning we do not reject the null hypothesis, and thus the instruments used are considered valid. Also there is no evidence of second-order autocorrelation as the AR(2) fall with P = 0.216, overall both the Hansen and serial correlation tests support the validity of the instruments (P = 0.146 and 0.276, respectively), therefore, these robustness checks confirm that the SGMM model satisfies key diagnostic requirements, reinforcing the reliability of the estimated results.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The Eastern Africa region is projected to experience sustained economic growth; however, energy access and availability remain persistent challenges, with consumption levels still lower than in other regions. As energy is a fundamental input for production, resolving these challenges is critical for unlocking the region’s growth potential. Despite ongoing efforts to expand energy infrastructure, it has remained unclear whether energy consumption serves as a driver or an outcome of economic growth in this regional context. This study addressed that gap and revealed a unidirectional causal relationship from energy consumption to economic growth, supporting the growth hypothesis and confirming that energy acts as a driver rather than a consequence of economic expansion. In addition, bidirectional causality was found between capital and GDP, indicating mutual reinforcement, while energy prices and labor were also found to Granger-cause GDP. The robust estimation results reinforced these findings by confirming that energy consumption has a strong and statistically significant positive effect on GDP, while capital formation and energy price stability significantly influence economic growth in Eastern Africa, though the negative sign on capital highlights potential inefficiencies that must be addressed. These findings have clear policy implications, indicating that the region must prioritize expanding energy access, ensuring stable energy prices, and improving the efficiency of capital investment. Consequently, the study affirms that total energy consumption, capital formation, and energy price stability are central to regional economic growth and that the role of labor requires further exploration in future research.

5.2. Policy Implications and Recommendations

The findings of this study carry clear policy relevance for Eastern Africa economies. Most notably, the empirical evidence suggests that a comprehensive strategy linking increased energy use, price stability, and capital efficiency, and investing in labor productivity to support long-term growth. Policymakers should adopt coordinated, multi-sectoral approaches informed by these findings to ensure resilient and inclusive growth across Eastern Africa. Specifically, the identification of a unidirectional causal relationship from energy consumption to economic growth confirms that energy is not merely a consequence of regional economic growth, but a primary driver of it. This reinforces the need for increased investment in energy infrastructure and expanded access, particularly in underserved areas.

Ongoing infrastructure projects such as the Stiegler's Gorge Dam in Tanzania, the Uganda–Tanzania crude oil pipeline, and the Tanzania–Kenya gas pipeline should continue to receive high-level support. These projects should also be complemented by policies that ensure affordability, efficiency, and equitable access. In this context, regional collaboration is essential, harmonized investment strategies, shared technologies, and cross-border energy markets will ensure control over generation costs, optimize resource utilization, and strengthen energy security across the region. The study also finds that energy prices exert a statistically significant and negative effect on economic growth, highlighting the risk that rising costs pose to regional competitiveness. Policymakers should prioritize stabilizing and managing energy pricing structures. This may include targeted subsidies for low-income households or productive sectors, tariff reforms that reflect cost and efficiency, and reduced pricing distortions. Ensuring that energy remains affordable and predictable will support macroeconomic stability and inclusive growth.

In addition, capital found to be significantly associated with economic growth, while labor was not statistically significant in the SGMM model, it showed a meaningful causal direction in the panel causality analysis. This underscores the importance of investing in human capital, particularly through education and training systems aligned with labor market needs. Expanding access to vocational and technical training, specially in energy-dependent sectors can enhance productivity and labor market participation. The study also confirms a bidirectional relationship between capital and GDP, indicating that investment and economic growth reinforce one another. To unlock this cycle, policies should aim to foster an enabling investment environment. This includes improving access to finance for public and private sector actors, promoting domestic savings, and strengthening institutional frameworks to reduce the risk of capital misallocation. Supporting capital accumulation in infrastructure, manufacturing, and services will amplify the growth effects identified in this study.

5.3. Area for Further Research

To further elucidate the relationship between energy consumption and economic growth in Eastern Africa, future research should delve into sector-specific analyses, particularly within agriculture, manufacturing, and services. These sectors are pivotal to the region's GDP and are likely to exhibit distinct energy consumption patterns and sensitivities to energy availability and pricing. For instance, agriculture, accounting for a significant portion of GDP in countries like Kenya, relies heavily on energy for irrigation, mechanization, and processing. Understanding how energy consumption impacts productivity and output in these sectors can provide more granular insights into the energy-growth nexus.

Additionally, examining the economic implications of major energy infrastructure projects is crucial. Projects such as the Stiegler's Gorge Hydropower Dam in Tanzania, the Uganda-Tanzania crude oil pipeline, and the Tanzania-Kenya gas pipeline have the potential to significantly alter the energy landscape of the region. However, these projects also raise concerns regarding environmental impacts and displacement of communities. Comprehensive assessments of these projects should consider not only their contributions to energy quantity and economic growth but also their social and environmental ramifications. Therefore, a more nuanced understanding of energy consumption patterns, sectoral impacts, and the implications of large-scale energy projects will be instrumental in formulating policies that effectively harness energy as a driver of economic growth in East Africa.

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