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The Cointegration Between Energy Subsidy and Energy Accessibility in Eastern Africa Countries

Cornelius Kiprono Serem[1,2*], Richard Kiplangat Siele[1] and Muyiwa S Adaramola[2]

[1]*Department of Economics School of Business and Economics Moi University, Eldoret Kenya*

[2]*Faculty of Environmental Sciences and Natural Resource Management Norwegian University of Life Sciences, Ås, Norway*

[*]**Corresponding author**

Cornelius Kiprono Serem, Department of Economics School of Business and Economics Moi University, Eldoret Kenya, Faculty of Environmental Sciences and Natural Resource Management Norwegian University of Life Sciences, Ås, Norway.

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ABSTRACT

Despite the significant potential, the energy industry in East Africa remains largely underdeveloped, with minimal modern energy access, low per capita consumption, and heavy reliance on biomass energy, which makes up over 90% of the region's energy consumption. Less than 1% of rural areas have access to electricity. Introduction of subsidies on energy influences energy accessibility. The study found it clear that subsidies slightly improved energy accessibility in Eastern African countries in the long run. This can be explained by the fact that energy subsidies often result in lower prices for energy consumers. This makes energy more affordable for households, particularly those with lower incomes. Lower energy prices reduce the financial burden of meeting energy needs, making it easier for individuals and families to access essential energy services such as electricity, heating, and cooking. Lower energy prices due to subsidies can lead to increased energy consumption. It is therefore the responsibility of each member state to encourage the adoption of renewable energy sources by providing subsidies and incentives for renewable energy technologies such as solar panels, wind turbines, and energy-efficient appliances. Subsidizing renewable energy reduces reliance on fossil fuels, mitigates environmental impacts, and promotes sustainable energy practices.

Background Information

The International Energy Agency in 2022 stated that the attainment of widespread access to affordable electricity in Africa by 2030 necessitates the extension of connections to 90 million people annually, a threefold increase compared to recent years [1]. Numerous African nations continue to grapple with insufficient electricity generation capacity, often compounded by poorly maintained transmission and distribution networks. This situation results in an unreliable and frequently costly electricity supply, impeding crucial social and economic activities as highlighted by IRENA [2]. Moreover, there is a forecast suggesting that by 2040, the demand for energy in Africa will undergo a twofold increase, predominantly driven by the continent's expanding population and economic advancement, as outlined by IRENA [3]. Africa currently holds the position of having the world's most rapidly growing population, with almost 50% of the expected global population growth in the next decade projected to occur on the African continent. This demographic surge, coupled with rising economic activities and household incomes, is expected to substantially raise the need for energy services, as reported by the International Energy Agency in 2022 [1].

However, the annual growth rate of installed power capacity is a mere 0.1%, which stands in stark contrast to the 2% average observed in emerging economies [4]. This indicates a significant lag in Africa's electricity access, requiring substantial and urgent investments to align with global trends [5]. It is important to highlight that, despite its minimal contribution to global emissions, Africa is disproportionately impacted by extreme weather events linked to climate change, including rising temperatures, sea level changes, altered precipitation patterns, floods, wildfires, and droughts. These events pose severe threats to human health, food and water security, as well as the overall socioeconomic development of the continent [6]. Consequently, directing financial resources toward clean energy in the region becomes even more imperative to address climate change and promote sustainable development.

Recognized widely as a key driver of socio-economic progress, access to electricity holds the capacity to directly elevate various social aspects and enhance the overall quality of life [7,8]. Numerous studies have endeavored to evaluate the positive effects of electrification on households or small businesses. Both the grey and scientific literature consistently demonstrate significant impacts on social and economic well-being, indicating that access to electricity can contribute to income growth by creating new employment opportunities and fostering skills development [9,10]. Furthermore, it can enhance education and

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health outcomes and improve food security [11-14]. Additionally, indications from Kenya propose that the use of solar electricity plays a role in facilitating work- or income-related endeavors [15]. Nonetheless, the scientific evidence is inconclusive, and there is restricted understanding regarding the enduring social development outcomes linked to access to electricity [16].

The imperative to enhance access to contemporary and environmentally friendly energy services, along with the availability of affordable energy, is recognized as essential for promoting poverty reduction, particularly in developing nations. This contributes to economic prosperity while considering social and environmental aspects. To achieve universal energy access in Sub-Saharan Africa, approximately 4 million additional energy-related jobs are required by 2030, as highlighted by the International Energy Agency in 2022 [1]. The 2030 Agenda for Sustainable Development, with its interconnected 17 Sustainable Development Goals (SDGs), notably SDG 7, underscores the pivotal role of energy in the pursuit of sustainable development. The subsequent sections offer insights into the interrelationships between energy and social development within the context of Sub-Saharan Africa.

Access to energy services and the critical role they play in poverty reduction and socio-economic development has been the subject of a growing body of energy for development literature over the past 30 years. The goal of expanding access to cutting-edge energy services has influenced policy deliberations on a global scale. Energy Access Year was announced in 2012, and universal access to modern energy services is to be achieved by 2030. It should also be noted that energy access is no longer the exclusive concern of donor agencies and international institutions but is instead becoming a central topic in national-level public policy discussions. Whether or not these debates can be incorporated into sectorial policy choices that enable the actual execution of expanding access to new energy sources remains unclear. One possible reason for this is that the old method of development planning does not mesh well with the fact that energy affects so many different areas. Not because they don't see energy as a key development issue, but because the energy access issue hasn't been presented in a way that resonates with national development goals, countries have yet to 'own' the agenda around energy.

Despite this immense potential, the energy industry in East Africa is still largely underdeveloped and is characterized by extremely scant levels of modern energy access, low per capita consumption, and a significant reliance on biomass energy, which accounts for more than 90% of the region's total energy consumption. Less than 1% of rural areas in the region have access to power. Wood fuel meets the traditional sector's energy demands, including those of rural and low-income urban homes and some cottage industries, while electricity and petroleum products meet a significant portion of the nation's commercial energy requirements. For instance, according to Karekezi and Kimani in Kenya and Uganda, just 1% of rural households have access to electricity, suggesting that a very small percentage of the impoverished are electrified. The two case studies highlight significant shortcomings in poor people's access to electricity. Firstly, the issue of the electrification of the poor is not adequately addressed by the amended Electricity Acts (e.g., by proposing new and innovative initiatives that would increase the electrification of the poor). Kenya produces nearly 80% of its energy from renewable sources, 36% of which comes from hydropower and another 36% from geothermal, which it intends to double by 2030. This provides it with a fairly strong baseload capacity to which variable energy can be added.

Energy's significance in the modern economy cannot be disputed, even if it is not considered an input in the conventional growth models. For instance, Hall and Klitgaard focused on the contribution of energy to economic growth and the cap on future growth as a result of our reliance on fossil fuels. This explains the industrial revolution as a release of the constraints on economic growth due to the development of methods of using coal and the discovery of new fossil fuel resources. Also, it was found that the elasticity of substitution between a capital-labor aggregate and energy is less than unity, which implies that when energy services are scarce, they strongly constrain output growth resulting in a low-income steady-state. When energy services are abundant the economy exhibits the behavior of the 'modern growth regime' with the Solow model as a limiting case.

The percentage of individuals adopting clean energy for cooking has shown a notable increase over the years, rising from 50% in 2010 to 66% in 2019, as reported by the United Nations. Renewable and nonrenewable energy sources are derived from the environment. Some examples of energy sources include coal, natural gas, petroleum, hydropower, solar, and wind. The global demand for energy sources, such as fossil fuels and renewables, is significant. Despite significant advancements in expanding access to power and increasing the utilization of renewable energy in the electrical sector, as well as improvements in energy efficiency over the past decade, it is evident that the world is still a long way from achieving affordable, reliable, sustainable, and modern energy for everyone. The global power access rate experienced a significant improvement from 83% in 2010 to 90% in 2019, with an average yearly electrification rate of 0.876 percentage points. The global access deficit has decreased from 1.22 billion in 2010 to 759 million in 2019. According to the United Nations, despite significant efforts, it is projected that approximately 660 million people will still lack access to electricity by 2030. Bioenergy is identified as the most prevalent form of renewable energy. According to the United Nations, around three billion individuals rely on energy sources like wood, coal, and animal waste.

Energy Subsidies

Energy subsidies represent intentional measures taken by the government to decrease the expenses associated with energy production, boost the earnings of energy producers, or lower the costs borne by energy consumers [17]. While the main objective of these subsidies is to ensure widespread access to essential energy services and promote the adoption of contemporary energy sources, governments face challenges due to the associated drawbacks, including adverse effects on efficient resource utilization and environmental expenses [18, 19]. Additionally, energy subsidies have the potential to create disruptions in markets, distort consumer perceptions of pricing, and worsen budget deficits in developing nations. Empirical data indicates that energy subsidies often fail to effectively assist low-income households and may contribute to reinforcing income disparities, as a significant share of the benefits is directed towards wealthier households [20].

Consequently, there has been a global decline in energy subsidies due to initiatives aimed at subsidy reform. For example, the total direct energy sector subsidies worldwide amounted to $634 billion in 2017 and are projected to decrease to $475 billion by 2050 [21]. In 2020, global fossil fuel subsidies were $180 billion, and total energy subsidies in 2021 reached $440 billion [22]. The reduction of energy subsidies leads to an increase in end-user energy prices, heightening the risk of energy poverty by affecting households' ability to afford essential energy services and negatively impacting social welfare in society [23]. However, the purpose of energy subsidies is to enhance energy accessibility by reducing end-user energy prices below market levels [24]. These subsidies are also anticipated to play a positive role in alleviating energy poverty. As subsidies lower costs for certain consumer goods, households may have additional resources, potentially resulting in increased welfare benefits.

The impact of energy subsidies on household welfare through mediating effects is extensively examined across various nations using diverse approaches in the literature [18]. Nevertheless, the existing literature lacks exploration of the welfare effects of energy subsidies at the household level, specifically considering the mediating effects of energy poverty in countries facing energy challenges. Consequently, this study aims to assess the mediating influence of energy subsidies on social well-being and the alleviation of energy poverty, utilizing household-level data from three consecutive waves of Bangladesh's national Household Income and Expenditure Survey (HIES) conducted in 2005, 2010, and 2016.

According to IEA 2022, globally, billions of dollars are annually spent on subsidies for fossil fuels. Energy subsidies are designed to shield competitive businesses from excessive energy prices as well as poor and vulnerable households. However, a lot of energy subsidies fall short of accomplishing this goal and waste scarce resources. Subsidies lead to economic distortions, which affect all areas of the economy, by artificially decreasing the cost of energy use. These subsidies also place a significant budgetary burden on governments and take funds away from other crucial objectives like spending money on green infrastructure, the response to the current worldwide pandemic, and providing health, education, and social protection services [25]. For developing nations, where there are more investment demands for infrastructure and human development and fewer budgetary resources, the opportunity costs of energy subsidies are particularly important.

It is commonly argued that energy subsidies safeguard impoverished and vulnerable households and businesses from high energy costs. Nonetheless, many subsidies rarely achieve this objective and squander scarce resources. In particular, broad-based energy price subsidies that keep energy prices low for all consumers tend to be regressive, with wealthy households benefiting more from these subsidies than impoverished households. This is because high-income households typically consume more energy than low-income households, and the greater a household's energy consumption, the greater its subsidy benefits [15].

Subsidies generate economic distortions throughout an economy by conveying inaccurate price signals, as they maintain artificially low energy prices [26]. The aforementioned phenomenon has the potential to result in excessive amounts of energy consumption, as well as heightened levels of regional atmospheric contaminants and emissions of greenhouse gases, particularly in instances where non-renewable resources play a significant role in a nation's energy portfolio. Subsidies have been observed to exert a significant fiscal strain on governments and cause a diversion of governmental resources from crucial developmental priorities such as health, education, social protection, and investments in green infrastructure. In developing nations, where fiscal resources are constrained and investment in human development and infrastructure is imperative, the opportunity costs associated with energy subsidies are particularly elevated. IAE and ESMP [1].

Problem Statement

It's commonly believed that energy subsidies protect poor and vulnerable households and businesses from high energy costs. However, many of these subsidies often fail to achieve this goal and waste limited resources. Specifically, broad-based subsidies that lower energy prices for all consumers tend to benefit wealthy households more than poor ones, making them regressive. Despite the significant potential, the energy industry in East Africa remains largely underdeveloped, with minimal modern energy access, low per capita consumption, and heavy reliance on biomass energy, which makes up over 90% of the region's energy consumption [27]. Less than 1% of rural areas have access to electricity. Wood fuel satisfies the energy needs of traditional sectors, including rural and low-income urban homes, and some small industries, while electricity and petroleum products serve much of the nation's commercial energy needs. For example, research by Karekezi and Kimani (2004) in Kenya and Uganda shows that only 1% of rural households have electricity, indicating minimal electrification among the impoverished. These case studies underscore significant challenges in providing electricity access to the poor.

Objectives of the Research

The main objective was to examine the cointegrating relationship of how energy subsidies contributed to energy accessibility in Eastern African countries.

Research Methodology

Model: the study used the Engle-Granger two-step procedure to test for cointegration between energy subsidy and energy accessibility. This involved regressing energy subsidy on energy accessibility and testing the stationarity of the residuals using unit root tests like the Maddala-Wu Fisher Panel Unit Root Test. Since cointegration existed, an estimate a panel Vector Error Correction Model (VECM) was used to analyze short-term dynamics and long-term equilibrium relationships between energy subsidy and accessibility. Panel VECM allows the capture of both short-term deviations from equilibrium and the speed of adjustment towards the long-run equilibrium.

Control Variables

the relevant control variables that could affect energy subsidy and accessibility in East Africa included in the study were GDP per capita and population growth. The choice to control these two variables is that energy accessibility often correlates with income levels, as individuals with higher incomes can

afford better energy sources and technologies. Controlling for GDP per capita helps to isolate the effect of income on energy accessibility. It allows researchers to understand whether disparities in energy accessibility are due to income differences or other factors. Further, population size and density can influence energy accessibility through various channels. In densely populated areas, there may be higher demand for energy services, which could strain existing infrastructure or limit access to energy resources. Controlling for population helps to account for differences in demand for energy services across regions or countries.

Data Sources

Panel data was collected on energy subsidy, GDP per capita, population, and energy accessibility (e.g., percentage of the population with access to electricity or clean cooking fuels) from reliable sources such as the World Bank, International Energy Agency (IEA).

Data Preprocessing

Data was first checked for stationary through differencing to satisfy the assumptions of the cointegration tests.

Result and Discussions

The countries in Eastern Africa have different levels of access to electricity. In general, some nations have significantly improved access to electricity, while others continue to face difficulties. In Kenya, the region's efforts to electrify have been spearheaded by Kenya. By 2021, the nation had made significant strides toward expanding electricity access, with the majority of its citizens having access to grid-connected or off-grid electricity. Tanzania has made significant progress in increasing access to electricity. Uganda has improved the availability of electricity, especially in urban areas. However, a sizable portion of the rural population still does not have access to electricity, making rural electrification a challenge (see Figure 1 and Figure 2).

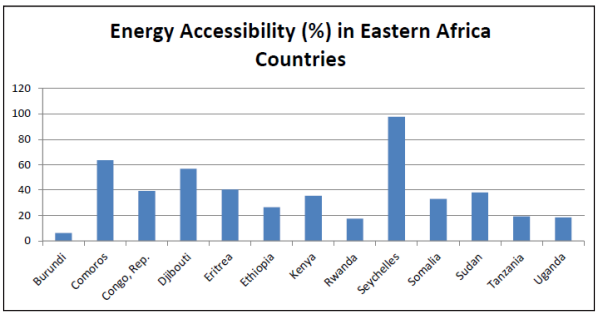

Figure 1: Energy Accessibility (%) in Eastern African Countries

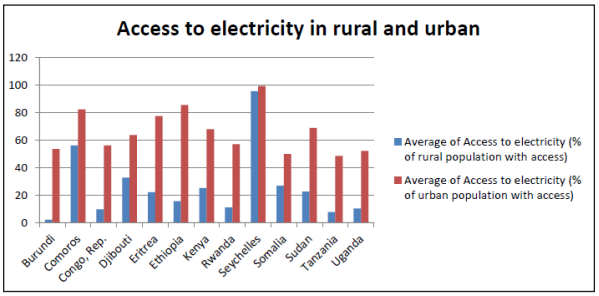

Figure2: Access to Electricity in Rural and Urban in East Africa

In Rwanda, the country has improved access to electricity significantly over time. The government has put forward cutting-edge strategies, such as off-grid options, to increase access to electricity, particularly in rural areas. Ethiopia has been working to increase the number of people who have access to electricity, primarily through sizable hydropower projects. Despite this achievement in improving electricity access, rural areas of most of East African nations, still lacked access to electricity as of 2021. EA Countries with improved access in rural areas include Comoros, Djibouti, Kenya, Seychelles Somali, and Sudan. Other nations like Burundi, have encountered significant difficulties in achieving widespread access to electricity. Progress in these nations has been hampered by inadequate infrastructure, unstable political environments, and financial constraints.

Figure 3 provides comparison how energy accessibility varies from the introduction of energy subsidies (measured as a dummy variable). It is clear that subsidies slightly improved energy accessibility in Eastern African countries. This can be explained by the fact that energy subsidies often result in lower prices for energy consumers. This makes energy more affordable for households, particularly those with lower incomes. Lower energy prices reduce the financial burden of meeting energy needs, making it easier for individuals and families to access essential energy services such as electricity, heating, and cooking [28]. Lower energy prices due to subsidies can lead to increased energy consumption. When energy is cheaper, households may use more energy intensive appliances or adopt energy-intensive behaviors, such as keeping lights on for longer periods or using inefficient heating systems. This increased consumption can improve energy accessibility by allowing households to meet their energy needs more comfortably.

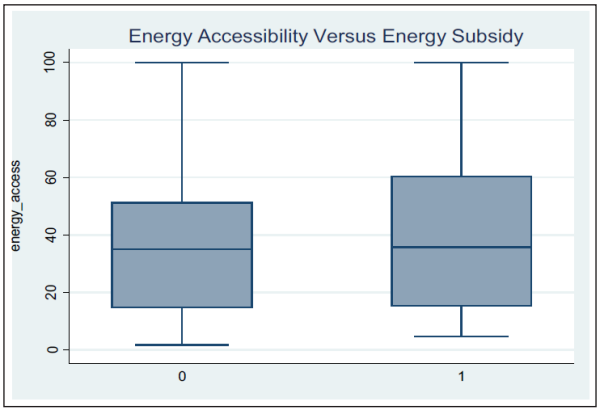

Figure 3: Energy Accessibility versus Energy Subsidy

Table 1 provides results for the unit root test for four Fisher-type statistics (P, Z, L*, and Pm. Each of the Fisher-type statistics is compared against their corresponding p-values at a 5% level of significance. Since these corresponding p-values were greater than 0.005, it was concluded that there is not sufficient statistical evidence to reject the null hypothesis (that all panels contain a unit root, and the alternative hypothesis is that at least one panel is stationary) at 5% level of statistical significance; hence need for differencing. Taking the first difference of the variables helped eliminate the unit root and make the data stationary [29]. By differencing the data, the common time-invariant component is removed, allowing for the estimation of meaningful relationships among variables [30]. The Fisher Type

unit root indicated that all the variables were stationary after the first difference. Similar to the unit test for variables at levels, the Fisher-type unit root test output also includes the results of the test statistic, p-and p-value. Since they are all p-values were less than 0.05, overwhelming evidence against the null hypothesis of a unit root. Hence, this led to the rejection of the null (all panels contain unit root). This means there are no unit roots in panels under the given test conditions and therefore it was concluded that at least one panel is stationary.

Table 1: Fisher Test for Unit Roots

All variables at Levels								
	Energy Access		Energy Subsidy		Pop. growth		GDP per capita	
	t	p	t	p	t	p	t	p
(P)	34.046	.013	1.854	1.00	44.379	.014	27.673	.375
(Z)	-.132	.450	3.353	.999	-.740	.230	1.655	.951
(L*)	-.356	.361	3.257	.999	-1.444	.077	1.935	.971
(Pm)	1.114	.133	-3.349	.999	2.549	.005	.232	.408
Remark	Unit root		Unit root		Unit root		Unit root	
Variables at First Difference								
	t	p	t	p	t	p	t	p
(P)	295.06	.000	99.69	.000	85.408	.000	83.898	.000
(Z)	-14.740	.000	-4.666	.000	-5.412	.000	-7.404	.000
(L*)	-22.725	.000	-7.000	.000	-6.164	.000	-8.354	.000
(Pm)	37.312	.000	10.219	.000	8.238	.000	8.029	.000
Remark	Stationary		Stationary		Stationary		Stationary	

Source: Research Data Analysis, 2024

Having confirmed the presence of unit roots, it implies energy subsidy and energy access have a long-run relationship. Table 2 indicates energy subsidies enhanced the accessibility of energy among the member states of Eastern Africa. GDP per capita indicates positive significant effects while population growth did not show a significant effect even though it has a negative association with energy accessibility.

Table 2: Long run Effects

Energy access	Coef.	Std.Err.	t	p	Sig
Energy subsidy	4.186	1.778	2.35	.019	**
GDP per capita	.003	.001	2.79	.006	***
Population growth	-1.09	1.182	-0.92	.357	
Constant	35.455	3.62	9.80	.000	***
R-squared	0.59				
F-test	4.601 Prob > F				0.000
Akaike crit. (AIC)	1771.822 Bayesian crit. (BIC)				1785.694

*** p<.01, ** p<.05, * p<.1

The findings show that government energy subsidies achieved the goal of cutting energy production costs, increasing earnings for energy producers, or lowering costs for energy consumers. The major purpose of these subsidies is to ensure widespread access to critical energy services while also encouraging the use of advanced energy sources. However, governments face hurdles as a result of linked disadvantages, such as negative effects on efficient resource utilization and environmental costs. While not necessarily environmentally beneficial, energy subsidies can increase energy consumption, potentially improving energy access for individuals who were previously neglected. Increased consumption can boost economic activity, raise living conditions, and enhance access to modern energy services. Energy subsidies can boost economic growth by lowering corporate production costs, boosting investment in energy-intensive industries, and fostering entrepreneurship. This can lead to more employment, higher household incomes, and general economic welfare, all of which improve energy accessibility. Subsidies for energy access initiatives, such as electrification and renewable energy projects, can encourage investment in energy infrastructure. This helps with the extension and enhancement of energy networks. particularly in rural and remote areas where access is limited, thereby enhancing energy accessibility.

Conclusions

Evaluating co-integrating relationship between energy subsidy and energy accessibility in international economics aids energy policymaking. Understanding co-integrating interactions allows researchers and practitioners to make policies that promote clean energy production, enhance clean energy availability, and boost energy affordability. Knowledge may be utilized to create legislation and policies that improve energy production, distribution, and consumption. Cointegration analysis on energy can help to optimize resource allocation and understand the long-term linkages between energy in rural and urban populations and energy poverty, as well as economic growth, allowing policymakers to spend resources in ways that promote sustainable development and overall well-being.

Policy Recommendations

To improve energy accessibility through energy subsidies, governments can implement various policies tailored to the specific needs and circumstances of their population. These include;

Implementation of targeted subsidy programs that focus on providing financial assistance to low-income households and marginalized communities. Targeting subsidies to those most in

need ensures that energy accessibility is improved for vulnerable populations without incurring unnecessary costs.

Establish transparent and efficient mechanisms for delivering energy subsidies to beneficiaries. This may involve using digital platforms, smart meters, and electronic payment systems to accurately identify eligible households, distribute subsidies, and monitor their effectiveness.

Gradually phase out universal energy subsidies that disproportionately benefit higher-income households. Redirecting resources from universal subsidies towards targeted programs can improve the effectiveness and equity of subsidy schemes while minimizing fiscal burdens.

Encourage the adoption of renewable energy sources by providing subsidies and incentives for renewable energy technologies such as solar panels, wind turbines, and energy-efficient appliances. Subsidizing renewable energy reduces reliance on fossil fuels, mitigates environmental impacts, and promotes sustainable energy practices.

Government needs to allocate subsidies towards the development and maintenance of energy infrastructure, including grid expansion, rural electrification, and off-grid solutions. Investing in energy infrastructure improves energy accessibility by extending energy networks to underserved areas and enhancing reliability and quality of service.

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