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Does Energy Consumption Contribute to Economic Performance or Vice Versa?

An Economic Analysis of Energy Consumption and GDP in 9 Sub Saharan African Countries.

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I take full responsibility for any mistakes and omissions present within this thesis.

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Abstract

This study examines the relationship between energy consumption and economic growth in Rwanda, South Africa, Namibia, Kenya, Tanzania, Ghana, Ethiopia, Nigeria and the Democratic Republic of Congo. The period for the study spans the years 1996 to 2020. The independent variables in the study include capital, labour, energy consumption, financial development, foreign direct investment, regulatory quality, and voice and accountability. The presence of cross-sectional dependence in the data warrants the use of second-generation unit root and co-integration tests, alongside the augmented mean group estimator for parameter estimation. The findings of the study suggest that the impact of energy consumption on economic growth was mixed. It increases economic growth in Tanzania, Nigeria, and Ethiopia, but reduces economic growth in Congo DR, South Africa, Kenya, Ghana, Rwanda, and Tanzania. The causality results suggest a bidirectional causality between labour and economic growth, in the selected countries.

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Abbreviations

GDP	Gross Domestic Product
FDI	Foreign Direct Investment
Agric	Agricultural sector
Ind	Industrial sector
Man	Manufacturing sector
Ser	Services sector
(mt)	Metric Tonnes
OECD	Organization of Economic Cooperation and Development
UNFCC	United Nations Framework Convention on Climate Change
UN	United Nations
UNDP	United Nations Development Program
SSA	Sub Saharan Africa

Does Energy Consumption Contribute to Economic Performance Or Vice Versa?

An Economic Analysis of Energy Consumption & GDP In 9 Sub-Saharan African Countries

1. Introduction

The global economy has experienced remarkable growth over the past five decades, largely due to increased energy consumption leading to accelerated growth (Hassan, Mahmood, & Javaid, 2022). Furthermore, energy consumption is expected to soar by 80% between 2010 and 2050, while the over-reliance on non-renewable energy sources, particularly fossil fuels, is not expected to witness any significant change from its current value of 85% of the total energy consumption (OECD, 2022).

Therefore, it is crucial to prioritize promoting energy efficiency and transitioning to clean or alternative energy sources in energy policies. Energy efficiency has various advantages, including reducing carbon emissions, higher consumer welfare, savings in fuel cost, a decline in fossil fuel consumption, a cleaner environment, and environmental innovation (Wenlong, Tien, Sibghatullah, Asih, Soelton, & Ramli, 2022). Understanding the relationship between economic growth and energy consumption will ease the formulation and implementation of energy policies and the development of sustainable energy resources (Usman, Kousar, Makhdum, Yaseen, & Nadeem, 2022). Although the link between both variables has been well-studied, conflicting results abound for the same region by different researchers. The reasons for the conflicting results must have arisen from time variation, samples considered, empirical methodologies, and the choice of proxies.

Four main hypotheses underlying the relationship between economic growth and energy consumption exist. These hypotheses are built based on the perceived direction of causality between both variables (Ozcan, Tzeremes, & Tzeremes, 2020). The direction of causality is essential for economic growth and energy policy formulation. The four hypotheses associated with the link between economic growth and energy consumption include the *energy conservation hypothesis,* which suggests that economic growth triggers energy consumption and that energy conservation policies are not expected to negatively impact on economic growth. The *growth hypothesis* suggests the opposite direction of causality, stating that economic growth is a crucial factor in economic development. As such, inefficient policies and energy systems targeted at reducing energy use may undermine economic growth. The *feedback hypothesis* considers a two-way causality, suggesting that economic growth and energy consumption are complements, and that energy conservation policies will slow down the economic development process. Finally, the *neutrality hypothesis* shows no causal relationship between economic growth and energy consumption.

Africa is home to seven of the world's ten fastest-growing economies between 2000 and 2013 (Muhammad Al Amine, & Muhammad Al Amine, 2016) which provides interesting test cases to see the relationship between economic growth and energy use.

This thesis examines the nature of the relationship between energy and economic growth in Africa and contributes to the literature by hypothesizing that energy is a crucial factor contributing to rapid growth in Africa. As Poveda and Martinez (2011) note, energy use enhances economic opportunities, reduces travel costs, and modernizes the industrial sector, leading to economic modernization. Despite this, the continent still consumes relatively little energy compared to other parts of the world. Although Sub-Saharan Africa (SSA) has a larger population, electricity consumption in Europe was elevenfold higher in 2009 than in SSA (World Bank, 2011).

With Sub-Saharan Africa's economy modernizing, urbanization, and changing demographics, it is natural for its energy consumption to increase. In this light, it is imperative that both economists and policymakers understand how energy impacts economic growth in SSA. SSA economies have grown since the 2000s because energy use has facilitated human capital accumulation. It has been shown that energy use improves capital and labour productivity, promotes export potential (Narayan and Smith, 2009), decreases poverty, and improves socioeconomic development (Poveda and Martinez, 2011).

A key element of economic and sustainable development is the production and distribution of energy (UNDP, 2015). Due to this, two approaches can be used to link economic performance and energy consumption: the orthodox approach and the heterodox approach. In the orthodox approach, economic performance does not relate to energy consumption, and if there is a relationship, then economic performance explains energy consumption. The heterodox approach, however, suggests that energy consumption and economic growth are closely knitted, and it is possible that energy consumption will drive economic growth.

This thesis will test the hypothesis of the heterodox approach that suggests that energy consumption and economic performance are linked in a two-way fashion. It will also attempt to establish the effect of an increase in foreign direct investment on this two-way relationship.

According to Simon (2010), economic performance is affected by several economic factors. Considering the failure of conventional neoclassical growth models in SSA, (Kilishi et al. 2013) also propose that only institutional quality can explain the region's poor economic performance. The countries included in this study are Rwanda, South Africa, Namibia, Kenya, Tanzania, Ghana, Ethiopia, Nigeria and the Democratic Republic of Congo. The data set covers 1996 to 2020. The period for the study is constrained by data availability. For instance, the data for the selected governance indicators were first reported in 1996. Also, 2020 served as the end date for some of the selected variables, including energy consumption and FDI. For economic variables, the data is derived from the World Development Indicators (WDI) database.

The augmented mean group (AMG) estimator will be used to provide the basis of the nature of relationship between energy consumption and economic growth. GDP will be regressed on energy use and energy use on GDP to see whether there is causality, uni-directionality or bi-directionality. This thesis will attempt to answer if increased energy consumption leads to economic growth.

The first chapter of this study begins with the introduction. The second chapter addresses the background to the study, macroeconomic situation in the sampled countries, and the sources of energy in sub-Saharan Africa. The third chapter includes the theoretical framework and literature review. The fourth chapter contains a description of the data and methodology. Chapter five presents the results and discussion, while chapter six concludes.

2. Background

Energy is an essential component of economic growth in any country. Energy, which could either be non-renewable or renewable, is a production input required for attaining the United Nations (UN) Sustainable Development Goals (SDGs) (Aydin, Koc, & Sahpaz, 2023; Alper, Alper, Ozayturk, & Mike 2022). Energy plays a significant role in socioeconomic and human development and in improving life quality. Energy is needed for household consumption and production activities (Baltruszewicz, Steinberger, Paavola, Ivanova, Brand-Correa, & Owen, 2023; Alvarado, Ortiz, Jiménez, Ochoa-Jiménez, & Tillaguango, 2021). Energy resources are vital for personal and household needs and economic activities involving producing goods and services (Murshed, Rashid, Ulucak, Dagar, Rehman, Alvarado, & Nathaniel, 2022). Energy is consumed in a number of sectors, including industry (extraction of oil and gas, machinery and equipment, textiles, paper, non-ferrous metals, tobacco and food production, pharmaceuticals, fertilisers, steel, production of iron), transport (pipeline transportation of fuel and raw materials, railway sector, shipping, aviation, diesel and gasoline burning for transportation etc) and commercial and residential buildings (Nathaniel et al. 2022; Eregha et al. 2022; Liu et al. 2022; Akam et al. 2022).

The relationship between energy and economic growth is complementary (Fakher et al., 2023). For energy to be beneficial, energy efficiency should be encouraged. Energy efficiency is usually examined in relation to energy intensity, which shows the energy consumption to carry out production and perform specific activities. It is a sure way to examine the relationship between economic growth and energy consumption. Energy efficiency policy aimed at producing less energy (Makutėnienė, Staugaitis, Vaznonis, & Grīnberga-Zālīte, 2023).

Between 2000-2012, SSA's energy demand increased by nearly 45% (IEA, 2014). SSA had just two countries that exceeded the world average in 2017 (Sobrinho & Thakoor, 2019). As a result, SSA’s economic performance shows that a similar pattern exists for energy consumption and GDP growth. A country's social well-being and development are correlated with its per capita consumption. There is a correlation between improved living standards and energy consumption per capita in the UN Human Development Index, which combines health services, education, and poverty (Guterres, A. 2022). In addition to improving human welfare, increased energy consumption is directly correlated with economic growth. Almost all production and consumption activities require energy as an input. Economic growth, industrialization, and urbanization are driven by energy, which enhances capital, labour, and other production factors' productivity; economic growth, industrialization, and urbanization, in turn, increase the use of energy, mainly commercial energy (Paul and Bhattacharya, 2004).

Energy shortages or unaffordable energy cause severe economic disruptions and restrict growth (UNECA, 2007). Economic growth studies have examined the relationship between oil consumption and macroeconomic indicators, such as GDP, to understand how energy affects economic growth. Around 20 times more energy is consumed by the wealthiest 10% of people across 86 countries. A single kilowatt-hour can cost as much as 50 cents in many SSA countries, compared to around 10 cents in many other places worldwide (UNFCCC, 2022). Achieving universal access to electricity in SSA will require identifying constraints and policy levers that influence uptake, affordability, willingness to pay, and consumption.

Table 1 shows the contributions of different sectors to the GDP of the selected countries. From Table 1, the Service sector contributed the highest for all the selected countries across the years representing an average of 50% in single contributions except for Congo DR and Ethiopia where it was a close second at about 40% average. The agricultural and industrial sectors continued to be dominant in Nigeria, Congo DR, Ghana, Tanzania, Kenya and Rwanda with a combined contribution of 50-60% however continued to fall gradually and consistently across the review period albeit marginally.

Manufacturing is lowest in all the countries across the years at sub 10% for most except for South Africa, Congo DR and Namibia which still at an average of 15%. This could connect to the limited availability of energy in these countries.

South Africa and Namibia have similar performances with agriculture contributing 8% and 2% average respectively across the review period. Their dominant sectors continued to grow across the years.

Table 1: Sectoral Contributions to GDP by sector, %

	Nigeria				Congo DRC				Ghana			
	Agric	Ind	Man	Ser	Agric	Ind	Man	Ser	Agric	Ind	Man	Ser
1996-2000	25.78	32.92	17.19	40.29	42.32	23.03	7.19	33.45	36.36	25.07	8.94	27.92
2000-2005	29.72	26.78	11.74	42.48	26.19	31.01	18.67	39.63	36.47	25.11	8.88	29.01
2006-2010	25.06	24.27	7.96	49.84	22.11	32.97	16.50	40.11	28.94	19.04	7.81	47.18
2011-2015	21.10	25.18	8.58	52.81	19.52	41.43	15.76	32.69	21.15	30.02	9.16	42.39
2016-2020	21.82	24.36	10.25	52.74	19.50	41.49	18.89	34.45	18.94	29.96	10.44	44.28

	Ethiopia				Namibia				South Africa			
	Agric	Ind	Man	Ser	Agric	Ind	Man	Ser	Agric	Ind	Man	Ser
1996-2000	48.88	11.43	5.82	33.36	9.19	22.10	8.90	59.20	3.04	28.72	19.40	60.43
2000-2005	39.63	12.41	5.50	40.38	9.85	25.50	10.30	56.74	2.58	27.25	18.39	61.87
2006-2010	43.46	10.50	4.24	39.22	8.44	30.46	12.50	51.44	2.30	25.63	15.00	63.14
2011-2015	40.28	11.97	3.84	39.82	7.76	28.01	11.46	56.29	2.06	24.38	12.54	64.16
2016-2020	33.78	24.15	5.72	36.75	7.68	26.66	11.93	58.31	2.33	23.58	12.31	64.28

	Tanzania				Kenya				Rwanda			
	Agric	Ind	Man	Ser	Agric	Ind	Man	Ser	Agric	Ind	Man	Ser
1996-2000	33.16	17.02	8.82	43.10	28.08	15.56	10.96		40.29	18.10	10.94	38.43
2000-2005	25.24	22.03	9.29	46.57	25.73	15.92	9.97		32.56	15.31	9.05	43.30
2006-2010	24.66	23.00	8.74	44.54	19.43	18.85	12.05	53.22	26.12	16.15	8.25	48.42
2011-2015	26.17	25.37	9.01	40.80	18.83	19.19	10.82	56.01	24.45	17.79	7.42	49.10
2016-2020	27.47	26.85	8.11	37.53	20.95	17.46	8.40	55.64	25.26	17.79	7.82	48.52

World Development Indicator (WDI), 2023. **Note:** Table 1 is based on available data from the World Bank.

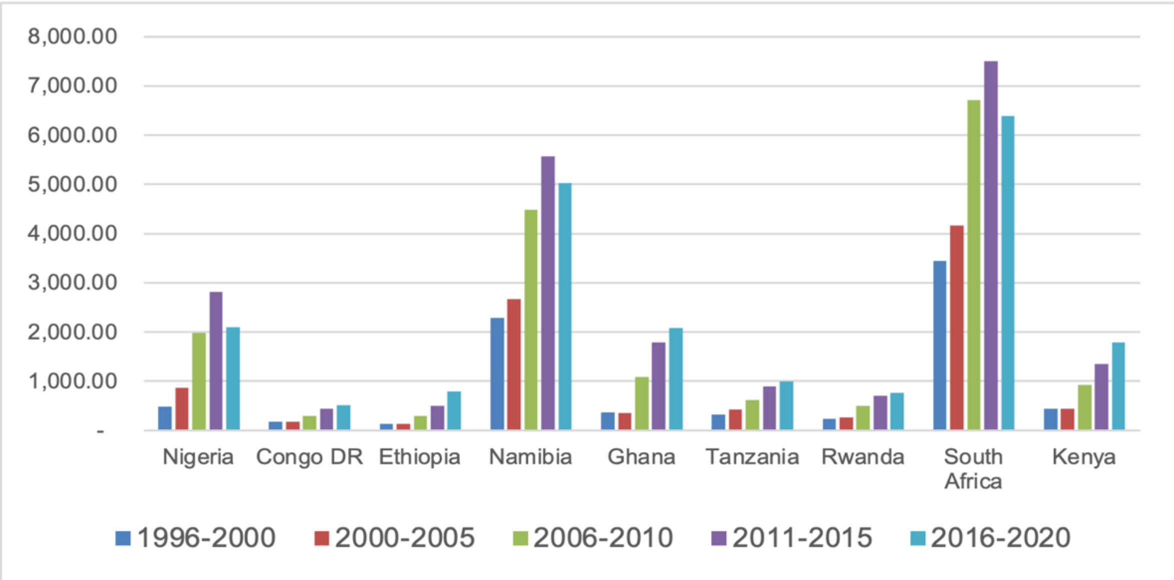
Agric- Agriculture, Ind – Industry, Man – Manufacturing, Ser - Services

2.1 Macroeconomic Situations in Sampled Countries

SSA had just two countries exceeding the world average in 2017 (Sobrinho & Thakoor, 2019). As a result, SSA's economic performance shows that a similar pattern exists for energy consumption and GDP growth. A country's social well-being and development correlate with per capita consumption. There is a correlation between improved living standards and energy consumption per capita in the UN Human Development Index, which combines health services, education, and poverty (Guterres, A. 2022). In addition to improving human welfare, increased energy consumption directly correlates with economic growth. Almost all production and consumption activities require energy as an input. Economic growth, industrialization, and urbanization are driven by energy, which enhances capital, labour, and other production factors' productivity; economic growth, industrialization, and urbanization, in turn, increase the use of energy, mainly commercial energy (Paul and Bhattacharya, 2004). Energy shortages or unaffordable energy cause severe economic disruptions and restrict growth in countries where energy is scarce or unaffordable (UNECA, 2007).

Economic growth studies have examined the relationship between oil consumption and macroeconomic indicators, such as GDP, to understand how energy affects economic growth around 20 times more energy is consumed by the wealthiest 10% of people across 86 countries.

Figure 1: GDP per Capita (US$) in Selected SSA Countries

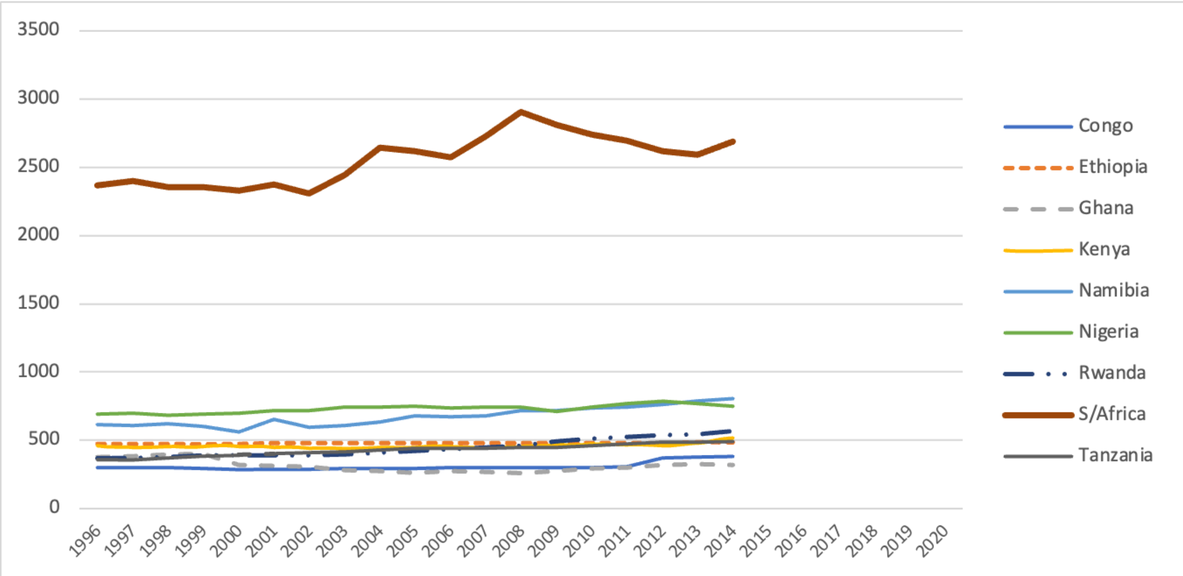


World Development Indicator (WDI, 2023).

Figure 1 below shows the GDP per capita for the 9 countries considered in the study. From the figure, the GDP per capital in Namibia and South Africa had significantly strong GDP per Capital of an average of US$4,000 and US$5,000 respectively. This is followed by Nigeria, Kenya and Ghana at the average of US$1,500 while the others Congo, Ethiopia, Tanzania and Rwanda are less than US$1,000 each.

South Africa has the highest GDP per capita of any of the countries. It almost doubled from 1996-2000 at about US$3,500 to US$6,800 in 2006-2010 and reaching further to its highest in 2011-2016 at about US$7,500 before taking a fall to about US$6,400 in the 2016-2020, lower than its position ten years prior. A similar trend is seen with Namibia but at a different scale.it reached its highest in 2011-2015 at US$5,500 then drops to the US$5,000 average in 2016-2020 period. Nigeria, Kenya and Ghana have consistently and gradually grown their GDP per capita across the years by an average of 50% year-on-year except for Nigeria which behaved like Namibia dropping from its highest in 2011-2016 at US$2,800 to about US$2,000 in 2016-2020, a similar position in 2006-2010, a ten-year reversal. Congo, Ethiopia, Tanzania and Rwanda with similar GDP per Capita grew from about US$250 in 1996-2000 consistently and doubling their GDP per Capita over the period until their highest at the end of the period reaching close US$500 (Congo), US$750 (Ethiopia and Rwanda) and almost US$1,000 (Tanzania). All the selected countries showed consistent position growth rate in GDP and even stronger in Ethiopia reaching doble digits growth (circa 10%) back-to-back in 10 years from 2006 to 2015. Furthermore, the 2000-2015, most of the countries enjoyed their best growth leading literarily doubling their GDP per Capital. The 2016-2020 period was tough for all the countries with growth slowing down and contraction experienced by Namibia and South Africa at 1.76% and 0.54% respectively.

Figure 2: Energy Consumption % in Selected SSA Countries



World Development Indicator (WDI, 2023).

Figure 2 shows the trend of energy consumption in the selected countries. Energy use here refers to use of primary energy before transformation to other use fuels including renewable energies; biomass, industrial and municipal waste which is a weighted average per capita. All the selected countries grew by a year-on-year average of 0.9%. South Africa towers about five times the other countries over the study period and grew by 13% over the same period. The other countries also showed positive growth albeit at their respective scales. Namibia and Nigeria are in a similar scale of consumption and year-on-year growth of 0.3% and 0.5% respectively. However, Namibia grew by 32% because of a 16% growth in 2001. Congo experienced a similar growth of 20% in 2012. The others have a flat growth average.

Table 2 shows the data on six selected macroeconomic variables in the selected countries. The macroeconomic data selected include GDP per capital US$, inflation rate, FDI, gross capital formation, labor force, and energy use.

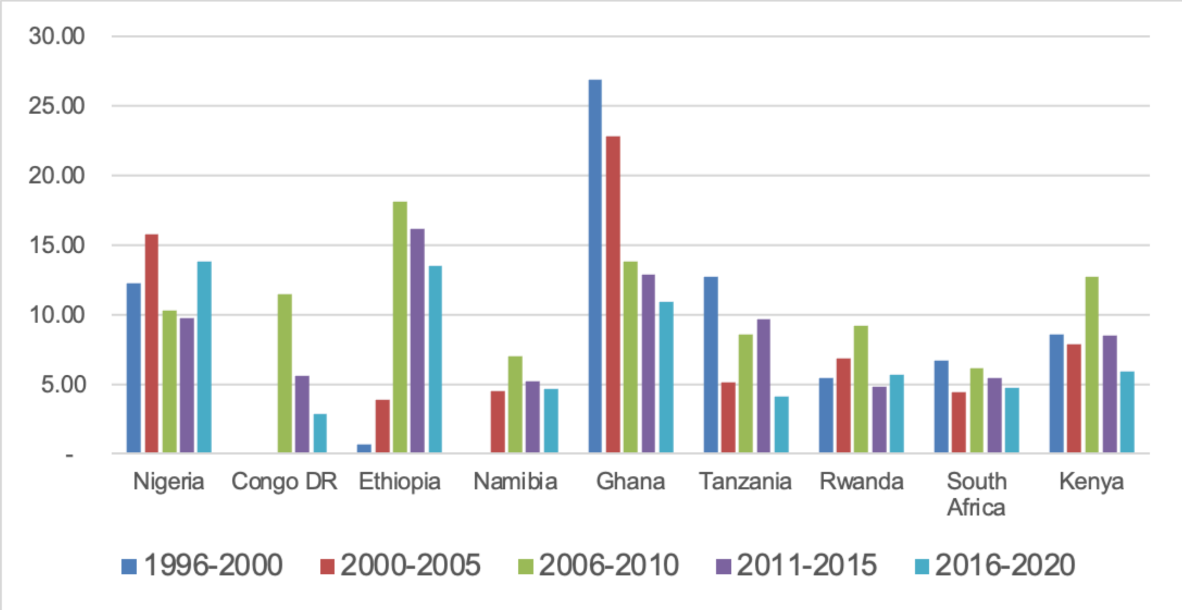
Figure 3 captures that Nigeria, Ethiopia and Ghana have high inflation rates of 12%, 15% and 20% respectively across the period. Congo DR was an outlier at an exponential 300% in 1996-2000 during the war but has slowed down drastically in the flowing ten years to about 50% before gaining a very low and indeed the lowest of the selected countries at 3% in 2016-2020. Namibia, Tanzania and South Africa has shown low and decreasing inflation figures across the period at 5, 7 and 5% respectively. Most of the countries experienced their peak Inflation figures in the 2006-2010 period all in double digits of: Nigeria 10%, Congo DR 11%, Ethiopia 18%, Ghana 14% and Kenya at 13%. Rwanda and Tanzania raged close to 10%.

Table 2: Macroeconomic Situations in Selected Countries

	Congo	Ethiopia	Ghana	Kenya	Nigeria	Rwanda	Tanzania	S/Africa	Namibia
GDP per Capital US$									
1996-2000	398.7	256.6	988.0	1,216.1	1,451.7	307.9	534.2	4,586.5	3,619.0
2001-2005	334.1	276.7	1,081.0	1,187.4	1,760.9	406.0	620.3	5,103.9	3,332.6
2006-2010	376.4	384.7	1,268.4	1,293.6	2,190.1	531.0	746.6	5,933.4	4,018.8
2011-2015	443.3	550.5	1,659.7	1,430.1	2,577.7	670.8	876.6	6,209.3	4,653.7
2016-2020	485.3	745.6	1,877.6	1,590.3	2,503.3	807.3	1,005.0	6,117.1	4,618.6
Gross Capital Formation % of GDP									
1996-2000	10.0	-	22.8	16.0	37.6	13.5	17.6	16.0	19.6
2001-2005	9.5	-	25.3	17.0	28.2	13.6	21.8	15.8	19.8
2006-2010	16.5	-	16.9	19.8	21.7	19.0	33.4	19.1	24.7
2011-2015	20.6	36.4	21.9	22.7	15.5	23.2	35.5	18.7	28.7
2016-2020	21.6	35.3	21.5	19.7	20.7	24.0	37.0	15.6	16.7
Labor Force '000,000									
1996-2000	18.1	26.4	8.0	11.3	39.8	2.5	15.6	17.8	0.5
2001-2005	20.8	31.5	9.3	13.6	45.3	3.0	18.1	19.7	0.6
2006-2010	23.4	37.4	10.6	16.3	51.5	3.4	20.6	20.8	0.7
2011-2015	26.2	44.5	11.7	19.1	55.5	3.9	23.0	21.8	0.8
2016-2020	30.8	52.7	13.2	22.2	64.7	4.3	26.9	23.6	0.9
Energy Use									
1996-2000	296.8	473.5	374.6	453.1	693.6	377.4	370.4	2,361.9	600.8
2001-2005	290.4	476.8	285.3	442.1	733.2	400.4	418.9	2,478.2	631.8
2006-2010	297.8	477.8	271.1	456.7	735.2	469.0	447.0	2,751.0	702.3
2011-2015	356.8	482.2	316.5	480.1	767.4	541.0	483.0	2,648.8	774.3
2016-2020	-	-	-	-	-	-	-	-	-
FDI US$ '000,000									
1996-2000	29.4	155.1	155.8	72.0	682.7	4.3	292.1	1,529.9	112.7
2001-2005	254.0	375.9	113.8	36.4	2,385.3	8.1	528.3	3,351.4	241.1
2006-2010	1,258.0	277.1	1,926.8	233.9	6,733.3	110.0	1,026.7	5,682.6	629.3
2011-2015	1,770.1	1,346.5	3,265.0	1,078.0	5,846.4	218.3	1,607.7	4,862.1	781.3
2016-2020	1,247.4	3,293.0	3,097.0	695.9	2,266.4	267.2	935.1	3,622.6	139.4
Inflation %									
1996-2000	303.8	0.7	26.8	8.5	12.3	5.4	12.7	6.7	-
2001-2005	85.9	3.9	22.8	7.9	15.7	6.8	5.1	4.4	4.5
2006-2010	11.4	18.1	13.8	12.7	10.3	9.2	8.6	6.2	7.0
2011-2015	5.6	16.2	12.8	8.5	9.7	4.8	9.7	5.4	5.2
2016-2020	2.9	13.5	10.9	5.9	13.8	5.7	4.1	4.7	4.6

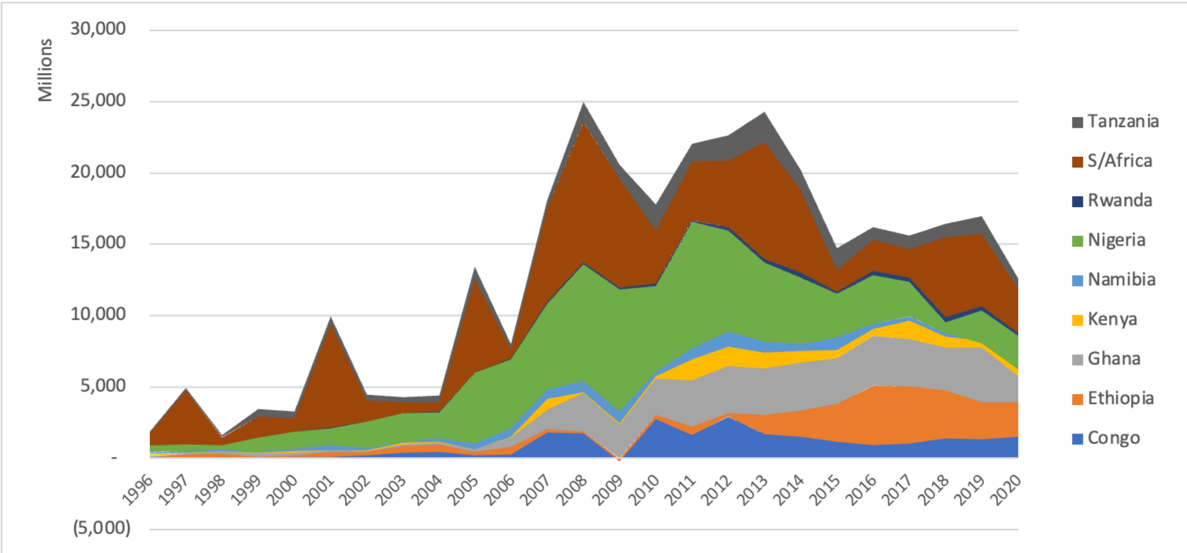
World Development Indicator (WDI), 2023.

Figure 3: Inflation % of the selected SSA Countries



World Development Indicator (WDI), 2023.

Figure 4: FDI in the Selected SSA countries

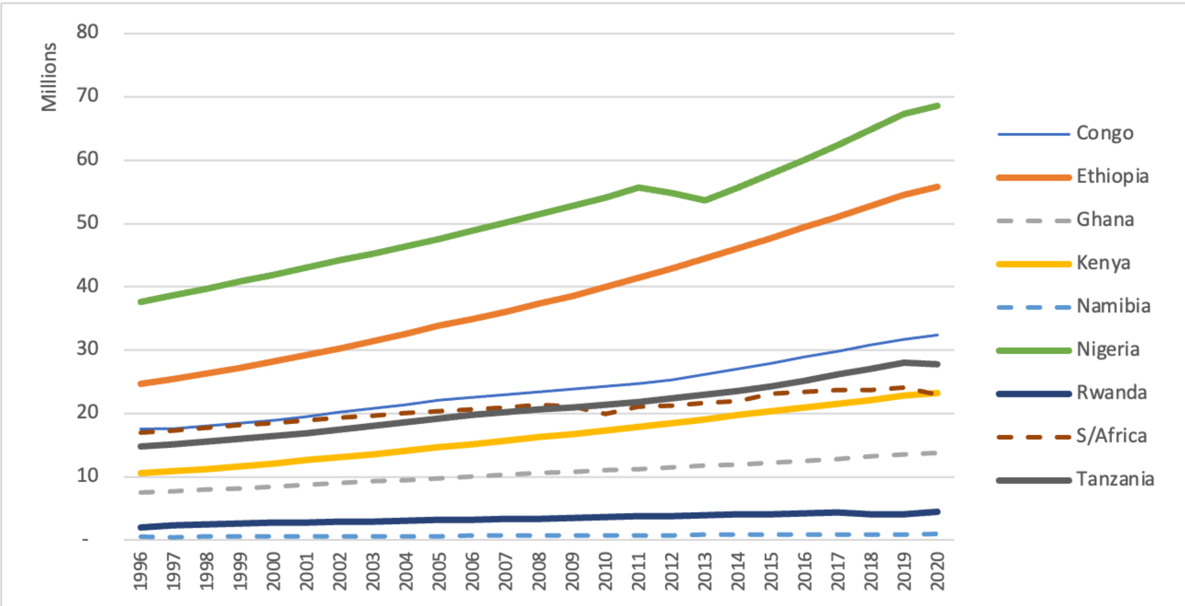


World Development Indicator (WDI), 2023.

Figure 4 shows the FDI inflows into these countries over the 25-year study period. South Africa US$95 billion and Nigeria US$89 billion represent 57% of the total FDI US$322 billion received in the countries followed by Ghana's US$42 billion (17%). The balance of 29% is shared by the rest. Ethiopia US$27 billion (8%), Conga US$23 billlion and Tanzania US$22 billion at 8%, 7% and 7% respectively with Rwanda and Namibia only received US$10 billion and US$3 billion represent the balance 4%.

From 1996 to 2004, an annual average of US$4b was injected in these but countries but for spikes in 1997 and 2001 into South Africa US$3b and US$7b respectively. From 2005, the FDIs moved to the US$10 billion annual average and in 2018 to astronomically to between US$20 billion and US$25 billion; South Africa and Nigeria being the biggest benefactors followed Ghana and Namibia while the others had very minimal benefits from the windfall. This trend is maintained but for a dip in 2010 which quickly recovers before another dip in 2015 to about US$15 billion until the end of the review period. Ethiopia joins the big benefactors even larger than Nigeria at this point it had reduced to about 20% of the FDI pie. From 2007, Congo has received a consistent average of US$1.5 billion until the end of the review period. Rwanda barely enjoyed FDI in its economy with an annual average of USD250million even during the astronomical investment period.

Figure 5: Total Labor in the selected SSA Countries



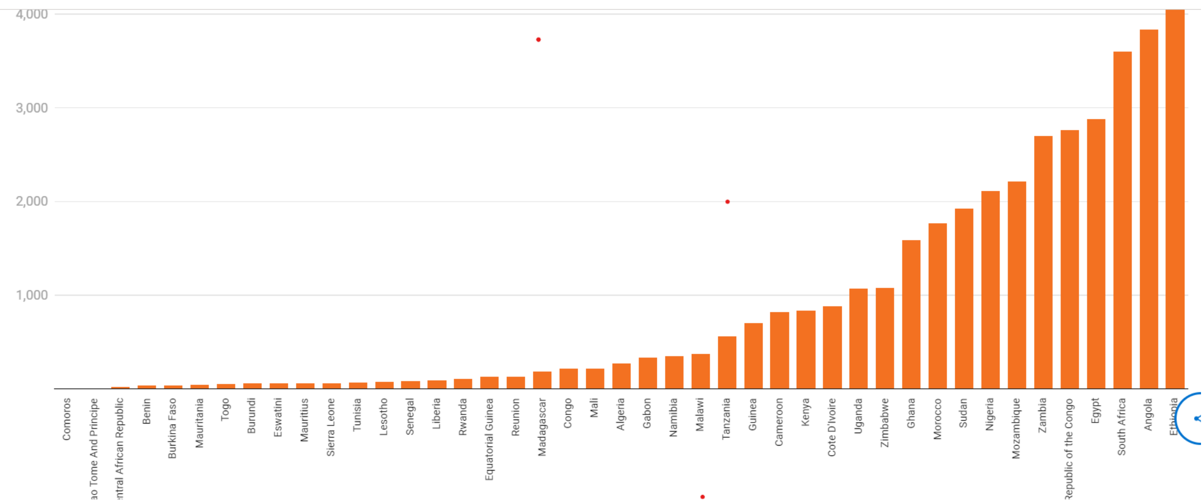
World Development Indicator (WDI), 2023.

Figure 5 shows the total labor force in the selected countries annualized over the study period. The total annual average labor force 250,000,000 has grown at an average of 2.7% year-on-year over the 25-year review period without any dip in the years similarly experienced in the individual countries except for Nigeria between 2011 and 2013 but quickly recovers and follows the trajectory. Nigeria and Ethiopia have the largest annual labor force of 64 and 52 million respectively both representing 48%. Congo, Tanzania, Kenya and South Africa follows closely representing 44% with a country average of 30, 22, 27 and 24 million labor force. The remaining countries Ghana, Namibia and Rwanda represent of 8% with 13, 1 and 5 million labor respectively. With regards growth, Ethiopia, Rwanda and Kenya experienced the highest year-on-year growth average of 3.5%, 3.3 and 3.5% respectively. Congo, Ghana, Namibia, Nigeria and Tanzania experienced an average of 2.5% with South Affrica trailing with 1.3%.

2.2 Sources of Energy in sub-Saharan Africa

Africa is rich in various energy sources with more than 70% renewable (da Silva, Cerqueira, & Ogbe, 2018). For solar energy, SSA enjoys at least 320 days of sunlight out of 365 days and 366 days which makes up a year and a leap year, respectively (IEA, 2022). However, hydroelectricity generation, wind generation, and biofuel production remain very low in Africa compared to other regions (e.g., North America, Asia Pacific, and Europe) of the world. Several of the world's largest river systems flow through Africa, including the Nile, Congo, Niger, Volta, and Zambezi, with a total hydropower generation of 147 TWh in 2021. (International Hydropower Association, 2022)

Figure 6: Hydropower generation in Africa



International Hydropower Association, 2022

The wind generating capacity in SSA is estimated at around 1,300GW, but the region can generate about 190 megawatts to meet its electricity needs (IEA, 2019). Geothermal energy is more concentrated in Kenya and Ethiopia. However, the region still generates between 10GW and 15GW of geothermal energy. Interestingly, Kenya has successfully installed about 250 megawatts of geothermal energy and further processed 280 megawatts. The country aimed to produce about 5,000 megawatts of geothermal energy by 2030 (IEA, 2019). Biomass energy is the most used renewable energy source in Africa. This energy source is mostly used for cooking. Although biomass energy is renewable, it is not clean. The hydropower generation capacity of Africa stands at 1,174TWh. However, the region has only succeeded in installing just 283GW as of 2020 (IEA, 2019). This suggests that only about 5% has been installed. Africa overwhelmingly depends on non-renewable energy sources which contributed about 69% to the region's total energy mix in 2020 (Guterres, A. 2022).

The Nigerian economy, and the economy of other oil producers in Africa, is prone to macroeconomic shocks because they are heavily dependent on crude oil. The oil sector vulnerability is deepened by widespread poverty, climate change, bad governance, and weak institutional quality. South Africa, for instance, receives large amount of solar radiation each year. Energy in South Africa is mostly generated from coal, solar, wind, tides, biomass, and geothermal heat (Ellabban, Omar; Abu-Rub, Haitham; Blaabjerg, Frede, 2014). The advancement and innovation in the energy sector of South Africa makes the country a vital component of global energy regime. Besides, the energy demand of the country is expected to rise and double in mid-2025 (Anna, 2010). On the other hand, the major energy sources in Nigeria include hydropower, tar sand, gas, oil, coal, and wood (biomass). Coal was the first non-renewable energy source to be discovered and used in Nigeria. Though some amount of renewable energy sources (like solar, wind, wood, hydropower, etc.) are consumed in Nigeria, the country relies overwhelmingly on fossil fuels, especially petroleum, coal, and natural gas (Ali, Nathaniel, Uzuner, Bekun, & Sarkodie 2020; Nathaniel & Bekun 2020; Nathaniel 2020).

In 2000, Ghana was able to produce about 6.2 million tonnes of oil equivalent (Nyasapoh, Elorm, & Derkyi, 2022), which rose to 6.8 million tons in 2004 (Addai, Tang, Twumasi, Asante, & Agyeman, 2022). This ranks Ghana among the top oil consumers in the continent. A large chunk of the total energy demand in Ghana is met by wood-fuels, that is, charcoal and firewood (Kipkoech, Takase, & Amankwa Afrifa, 2022). Wood-fuel accounts for about 60% and 71% of the final energy demand and total primary energy supply, respectively. However, the contribution of wood-fuel was 72% in 2018, of which the household and residential sector takes up and average of 50% of Ghana's energy consumption (Sarkodie, Ofosu, & Ampimah 2022; Appiah 2022).

Just like SSA countries in this study, renewable energy sources are minimally consumed in Namibia. Because of energy poverty, about 45% Namibians still do not have access to electricity, particularly those living in informal settlements and rural areas (IRENA, 2021). The countries electricity access for urban and rural areas is 74.6% and 34.9%, respectively (World Bank, 2022). Although the government of the country has intensified efforts to electrify informal and rural settlements, via traditional grid extension, various factors have impeded the efforts, including large investment outlay and the rapid growth of the informal sector (Hoeck, Steurer, Dolunay, & Ileka 2022; Republic of Namibia 2020). Uranium production in Namibia and Niger is currently ranked among the top 7 in the world. As of 2021, about 12% of the world's secured supplies of uranium are found in Namibia while Niger has 4% (World Uranium Mining Production, 2023).

Table 3: World Leading Producers of Uranium

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Kazakhstan	21,317	22,451	23,127	23,607	24,689	23,321	21,705	22,808	19,477	21,819
Australia	6991	6350	5001	5654	6315	5882	6517	6613	6203	4192
Namibia	4495	4323	3255	2993	3654	4224	5525	5476	5413	5753
Canada	8999	9331	9134	13,325	14,039	13,116	7001	6938	3885	4693
Uzbekistan (est.)	2400	2400	2400	2385	3325	3400	3450	3500	3500	3500
Niger	4667	4518	4057	4116	3479	3449	2911	2983	2991	2248
Russia	2872	3135	2990	3055	3004	2917	2904	2911	2846	2635
China (est.)	1500	1500	1500	1616	1616	1692	1885	1885	1885	1885
Ukraine	960	922	926	1200	808	707	790	800	744	455
India (est.)	385	385	385	385	385	421	423	308	400	615
South Africa (est.)	465	531	573	393	490	308	346	346	250	385
Iran (est.)	0	0	0	38	0	40	71	71	71	71
Pakistan (est.)	45	45	45	45	45	45	45	45	45	45
Brazil	326	192	55	40	44	0	0	0	15	29
USA	1596	1792	1919	1256	1125	940	582	58	6	8

World Uranium Mining Production, 2023

In Kenya, energy supply is limited, but the demand for energy is constantly rising as a result of urbanization, industrialization, globalization, and economic growth (Omondi, Njoka, & Musonye, 2023). This has widened the supply-demand gap in Kenya's energy sector, coupled with the meagre energy supply emanating from hydro that made up a significant source of supply, has caused occasional power crisis in Kenya (Lukuyu, Shiran, Kennedy, Urpelainen, & Taneja, 2023). Besides, the country's energy crisis has also amplified the country's reliance on imported fuel (Moksnes, Korkovelos, Mentis, & Howells, 2017). In 2017, for instance, 79 million kWh out of 9 billion kWh of energy was imported (Sarkodie & Adom, 2018).

Ethiopia is endowed with lots of diversified renewable energy sources including biomass, geothermal, solar, wind, and hydro (Tiruye, Besha, Mekonnen, Benti, Gebreslase, & Tufa 2021; Kruger, Fezeka, Olakunle, 2019). The country has a hydropower exploitable potential of 45GW geothermal is 5GW, and wind is 10GW (Hailu & Kumsa, 2021). The solar radiation in Ethiopia ranges from 4.5kWh/m^2/days to 7.5kWh/m^2/days (Mondal, Bryan, Ringler, Mekonnen, & Rosegrant, 2018). Ethiopia also has significant reserve of fossil fuels. For instance, natural gas, one of the components of fossil fuels, is about 4 trillion cubic feet, whereas coal reserve is far over 300 million tons (Benti, Gurmesa, Argaw, Aneseyee, Gunta, Kassahun, & Asfaw, 2021). Despite all these renewable energy potentials, Ethiopia ranks among the countries with the lowest access to clean energy in the world (Getie 2020; Guta 2018). In Congo DR, the primary energy use is predominantly fossil fuels with meagre consumption of renewables, of which 2.4% is from nuclear energy (Mayala, Ngavouka, Douma, Hammerton, Ross, Brown, & Lovett, 2022). Only about 11.1% of the population currently have access to electricity, which is lower than what is obtainable to an average sub-Saharan developing country (İnal, Addi, Çakmak, Torusdağ, & Çalışkan, 2022). The electricity power consumption in Congo DR was approximately 100.9 kWh per capita in 2010, which was one of the lowest in continent at the time (Aquilas & Atemnkeng, 2022).

The major energy sources in Tanzania are hydropower, petroleum, and natural gas. Of the 1,264 megawatts installed power capacity in the country, 685.4 MW is from thermal power, 568 MW is from hydroelectric power, and 82.4 MW is from renewable sources. Only about 32.8% of the communities in Tanzania have access to electricity. People with access to electricity in the rural and urban areas are 16.9% and 65.3%, respectively. Besides, of the electrified households, 24.7% and 74.9% are electrified with solar power and national grid, respectively (Bonjour, Adair-Rohani, Wolf, Bruce, Mehta, Prüss-Ustün, & Smith, 2022). However, 0.3% are electrified from other sources like personal generators (Citizen Reporter, 2017). In Rwanda, electricity is mostly generated from renewable sources. The total installed electricity capacity is 160 MW, of which about 60% and 40% are derived from hydrological resources and diesel-powered generators, respectively (Namahoro, Wu, Xiao, & Zhou, 2021). Besides, the current on-grid access to electricity stands 23% of households, whereas off-grid is 1.5% in Rwanda (Niyonteze, Zou, Asemota, Bimenyimana, & Shyirambere, 2020). The energy sector scope extends far above electricity and include biogas, charcoal, wood fuel, including petroleum products like natural gas, liquid petroleum gas, kerosene, diesel, etc. (Mukeshimana, Zhao, & Nshimiyimana, 2021). Biomass contributes about 85% (charcoal 23%, crop residues 5%, and wood 57%) of the total primary energy consumed in Rwanda (de Dieu Uwisengeyimana, Teke, & Ibrikci, 2016).

The rate of energy poverty is still very high in Africa, including the oil-producing countries. The continent that has the lowest energy access rate in the world is Africa. About one-third of Africa countries have below 25% access, compared to just one in Asia (World Bank, 2022). In Africa, more than nine hundred million people do not have access to clean cooking solutions. Furthermore, more than eight hundred and ninety million people still cook with highly polluting energy sources that cause environmental degradation (IEA, 2022). The share of renewable energy in the region's was 1.20% compared to 25.4% in Europe, 21.2% in North America, 43.1% in Asia Pacific, and 8.40% in South and Central America in 2021 (BP Statistical Review of World Energy, 2022).

The 25 countries with the least electricity access in the world are in Sub-Saharan Africa (World Bank, 2020). The average rate of electricity in the region is 39%, which appears to be the lowest rate of any region in the world. The second region with low electricity access is South Asia, where 80% of the population still have access to electricity, compared to less than 40% in sub-Saharan Africa (World Bank, 2020). Furthermore, sub-Saharan Africa has the highest urbanization and population growth rate in the world. Aside from the recent worries associated with resources scarcity, the energy demand in the region is expected to triple in the nearest future because of the high rate of urbanization and population needing more access to energy. This expected surge in energy demand is guaranteed to create problems for many national governments considering the current electrification rate in the region (Ali M., 2021).

There will be demand for traditional and modern fuels. The rural population, having a higher population growth rate, will demand more traditional fuels, especially non-renewable energy sources like coal, petroleum, and natural gas. Living in the urban areas comes with lots of advantages like better health services compared to the rural areas, income opportunities, better education, and other welfare packages (Black, Adger, Arnell, Dercon, Geddes, & Thomas, 2011), and a higher likelihood of having access to energy, especially renewable energies like solar, wind, geothermal, hydropower, etc. (World Bank, 2020). The high rate of urbanization is caused mainly by two factors: natural growth of urban population and rural-urban migration (Fakher et al., 2023). The surge in the urban population will require more energy that should prompt the simultaneous increase in energy innovation and modern energy services (Ali et al., 2022).

Table 4: Access to Electricity (% of the population)

	Nigeria	Congo DR	Ethiopia	Namibia	Ghana	Tanzania	Rwanda	South Africa	Kenya
1996-2000	41.84	6.70	12.70	33.29	39.63	7.93	3.18	67.12	11.91
2000-2005	46.74	7.77	12.96	37.88	46.43	11.35	6.25	77.48	19.85
2006-2010	49.18	12.37	21.99	43.16	59.54	13.49	11.04	82.02	25.46
2011-2015	54.26	14.63	27.75	47.33	68.73	19.11	17.22	85.06	38.32
2016-2020	56.20	18.35	46.26	53.53	81.61	35.53	37.48	84.48	62.30

World Development Indicator (WDI), 2023.

Table 4 shows the degree of access to electricity in the selected countries. All countries showed a consistent increase in access to electricity. South Africa and Ghana are remarkably the highest with more than 80% of the population with access to electricity with Ghana doubling this position from 40% in 1996-2000 to 81% in 2016-2020. A similar pattern is experienced in Ethiopia, Rwanda, Kenya and Namibia but on different scales. Tanzania and Rwanda jumped from 8 and 3% in 1996-2000 to 36 and 37% respectively. Kenya 12 to 62% and Ethiopia 13 to 46%. At the end of the review period, less than 50% of the population in Congo, Tanzania, Ethiopia, and Rwanda still have access to electricity. Nigeria marginally beats this mark has only been able to improve its 1996-2000 position of 41% by only 15% across the 25 years of review. The same is recorded of Namibia.

3. Theory and Related Literature

3.1 Theoretical Framework

Economic growth and energy consumption can be explained by two different approaches, the Neoclassical and Ecological models. A key aspect of this methodology is its emphasis on energy as the primary factor of production, which is largely influenced by the development of intrinsic growth models, including public spending (Barro, 1990) and human capital (Lucas, 1988). The ecological perspective, however, suggests that the closed system underlying the neoclassical approach is unreal since the global economy involves an open system. The neoclassical growth model considers capital, labour, and land to be the primary factors of production, while energy is viewed as an intermediate input that eventually results in the primary factors of production. It has also been assumed by neoclassical economists that energy and capital are perfectly interchangeable (Solow, 1974). Therefore, under circumstances of economic efficiency, a decline in energy use does not reduce economic growth. This thesis will tend to lean towards the Neoclassical model, since the findings indicate that energy plays a significant role in GDP and economic growth.

Energy consumption and economic growth are discussed in four hypotheses in literature. Four factors (growth, conservation, feedback, and neutrality) can be used to categorise the findings that have emerged since Kraft & Kraft's seminal work in 1978. Percebois & Hansen (2011) state that changes in the economic actors' behaviour or adjustments to the economic structure cause the relationship between the two to arise. Kilishi et al. (2013) claim that this divergence is due to the neglect of institutional issues in this relationship. According to the latter, institutional quality is the only remaining explanation since traditional neoclassical growth models have failed to explain sub-Saharan Africa's poor economic performance.

According to the growth hypothesis, energy consumption plays a direct and indirect role in economic growth, complementing other growth factors. In this case, energy consumption leads to economic growth. As a result, any decision about energy consumption will also affect productivity. In the second hypothesis, the increase in production translates into an improvement in the standards of living throughout the population, which in turn increases the level of energy consumption. This second approach is a reversal of the first one. Growth in economic activity leads to an increase in energy consumption. Hypothesis conservation, which implies that energy conservation does not hinder growth, is the result of such a situation. It is unlikely that energy-saving policies will negatively affect production in such circumstances. In the third hypothesis, energy consumption affects economic growth, while economic growth influences energy consumption. In a world where energy consumption is limited, economic growth is slowed, while production is reduced. Finally, the neutrality hypothesis states that economic growth does not affect energy consumption. The rate of economic growth will not be affected by reducing energy consumption or other similar decisions (Ozcan, Tzeremes, & Tzeremes, 2020).

Due to the strong correlation between energy consumption and economic development, wealthier nations appear to consume more energy than the world's poorest nations. Energy distribution and production are crucial components of economic growth and sustainability, according to the United Nations Development Programme (UNDP, 2015).

As a result, the two methodologies used—the orthodox methodology and the heterodox methodology—can be used to divide the literature on the relationship between economic performance and energy consumption. The orthodox approach disregards the possibility of a connection between economic performance and energy use, and if one exists, economic performance will account for energy use. Conversely, the heterodox approach contends a reciprocal relationship exists between energy consumption and economic performance. If this relationship is one-way, then the link between economic performance and energy use is causal.

This thesis will test the hypothesis of the heterodox approach that suggests that energy consumption and economic performance are linked in a two-way fashion.

3.2 Literature Review

The state of the economy is influenced by a number of economic factors (Simon, 2010). This thesis takes GDP into account. Despite being deemed insufficient, Simon (2010) noted that this indicator is still the most important one because it has two benefits. The primary advantage of GDP, according to Simon (2010), is that it conforms to the internationally standardized framework for accounting and statistics, and the second advantage is that it is a synthesis that is widely accepted and used. Economic growth data for 2013 (International Energy Agency: IEA, 2014) show that sub-Saharan Africa's energy demand increased by nearly 45% between 2000 and 2012 and by a similar amount in 2013. However, only two SSA countries reported a level in 2017 that was higher than the global average, out of the 33 that did (Sobrinho & Thakoor, 2019). Therefore, analysis of the economic performance of sub-Saharan African

(SSA) nations reveals that the GDP appears to be changing in the same way as the rate of energy consumption.

According to several studies, including Lékana's (2018b), energy consumption and economic growth are unrelated. The lack of institutional variables in these studies can explain these results. This thesis asks, "Does increased energy consumption lead to economic growth? This thesis aims to analyse the two-way relationship between energy consumption and economic growth in select SSA countries.

Two opposing approaches exist to the relationship between energy consumption and economic growth. There is an orthodox approach that refutes the contribution of energy consumption to economic growth and supports two hypotheses (the growth hypothesis and the neutrality hypothesis) as opposed to the heterodox approach, in which energy consumption is acknowledged as a contributor to economic growth. The conservation hypothesis and the feedback hypothesis are the foundation for these models.

Those who advocate the orthodox view (Stiglitz, 1974; Lucas, 1988; Barro, 1990; Mankiw et al., 1992) argue that energy is not a major factor in explaining growth. Conversely, energy is considered an important factor in explaining economic growth by heterodox economists who rely on biophysical theory and thermodynamics (Lékana, 2018a; Percebois & Hansen, 2011)

In the decades since North (1990), a few authors have proposed alternative explanations for the limitations of orthodox analysis (Acemoglu et al., 2008; Kilishi et al., 2013) argue that focusing solely on economic growth factors leaves out the issue of governance quality. As Acemoglu et al. (2008) have argued, institutions are the fundamental causes of economic growth, while capital stocks (physical and human), technological developments, and energy play only an intermediary role.

Mundial (2001) argues that strong institutions minimize market imperfections and are thus crucial for economic development. Effective and efficient regulations can contribute to economic development in countries with strong and developed institutions. He posits that economic growth is hindered by weak institutions, which are unable to regulate effectively.

Saidi et al. (2018) examines whether there are asymmetric effects in the relationship between energy demand and growth in 12 African countries over the period 1971–2008. Estimations show that conservation policies are likely to negatively affect growth rates in Gabon, Nigeria, and Côte d'Ivoire. However, for Benin, Kenya, and Sudan it is possible to grow more rapidly through conservation policies.

During the period 1995-2012, Streimikiene & Kasperowicz (2016) examine the long-term relationship between energy consumption and economic growth in 18 European Union countries. They find a positive relationship between energy consumption and economic growth.

According to Bhattacharya & Bhattacharya (2014), economic growth in India and China is influenced by energy consumption (electricity, coal and oil). Based on the estimation results, it appears that coal consumption in India has a two-way relationship with economic growth, while oil consumption has a one-way relationship with economic growth. Their findings for China indicate that oil consumption and coal consumption are unidirectionally related to economic growth.

Emmanuel & Ebi (2013) use a difference-of-difference approach to evaluate the relationship between institutional quality, oil resources and economic growth in Nigeria, Brazil and Canada during 2000-2010. According to the study conducted, there were noticeable variations in the economic growth rate of Nigeria and Canada versus Nigeria and Brazil. The primary reason for these differences in the observed economic growth rate is the level of corruption prevailing in the respective countries.

By using ordinary least squares analysis, Edame & Okoi (2015) examine the effect that energy consumption and institutional quality have on the manufacturing sector in Nigeria between 1999 and 2013. There were three measures of institutional quality used in the study: the Economic Freedom Index, the Corruption Perception Index, and the Monetary Intensive Contract Index. Meanwhile, total gas consumption (GCS), total oil consumption (PCN) and industrial sector electricity consumption (SLC) were used as energy consumption indicators. Study results indicate that the consumption of electricity, oil, and gas by the industrial sector does not significantly affect the manufacturing sector's performance.

According to Bass (2019), Russian manufacturing performance was influenced by institutional quality and global oil prices from 1996 to 2017. The study found long-term correlations between oil prices, institutional quality, and economic growth in Russia using Granger's causality technique. However, the short-term effects were found to be statistically insignificant. Also, both oil prices and institutional quality have a unidirectional causal relationship with economic growth, according to the Granger causality test.

The extended neoclassical model was used by Ogundipe et al. (2016) to analyze the correlation between electricity consumption and economic development in Nigeria from 1970 to 2013. The study accounted for the unique features of the Nigerian economy, such as the role of institutions, technology, emissions, and economic structure in the electricity consumption-development debate. The study discovered that electricity consumption is inversely linked to economic development in the long run, as evidenced by a long-term cointegration equation. Additionally, the vector error correction model did not reject the null hypothesis of long-term non-convergence. Lastly, the study provided evidence in support of a one-way relationship between economic development to electricity consumption.

Adams et al. (2016) analyzed the correlation between energy consumption, economic growth, and democracy in sixteen sub-Saharan African countries from 1971 to 2013. The study utilized two methods, namely the vector autoregressive panel (PVAR) and the generalized method of moments. The findings revealed that energy consumption and economic growth have a mutually beneficial relationship. Moreover, the study highlights that the interaction between energy consumption and democracy has a positive impact on economic growth.

Makutėnienė et al. (2023) assessed the effect of energy consumption and economic growth on the agricultural sector in the Baltic Countries, from 1995 to 2019, within a non-linear model framework. The non-linear autoregressive distributed lag (NARDL) model was used for data analysis. Selected energy consumption indicators were used as proxies for environmental degradation, pollution, and climate change. It is total energy use and electricity use in agriculture that emanate that is used to measure agriculture's gross added value.

László (2023) examined how energy consumption and economic growth have been related and interacted with each other over space and time in the European Union (EU) from 2010 to 2019. The purpose of the study was to analyse the link between energy and economic growth in the EU countries. Correlation calculations were used to display the relationship between both indicators per member state, whereas the hierarchical cluster analysis was applied to the findings. The results provided evidence of the fact there was no strong correlation, or robustness between energy consumption and economic growth in EU member states. Further findings suggest that energy consumption declined significantly. However, the decline in energy consumption did not have a negative effect on economic growth.

Odhiambo (2023) explored the asymmetric relationship between energy consumption and economic growth, using disaggregate data, from 1981 to 2020, for South Africa. The disaggregated energy sources include coal, electricity, oil, and gas. The findings show that positive and negative shocks in oil and electricity consumption affect economic growth in the short run. Besides, economic growth is mainly affected by negative and positive shocks in oil consumption, negative shocks in both gas and coal consumption and positive shocks in electricity consumption.

Alshami (2023) examined the effect of energy consumption on economic growth, while controlling for capital formation, in the United Arab Emirates, using a Vector Auto Regression approach to estimate the data because the time series of the variables were not cointegrated. The period for the study extends from 1996 to 2020. In this study, the author discovered a positive correlation between energy consumption and economic growth. However, a negative correlation ensued between capital formation and economic growth.

Mohammadi, Saghaian, & Zandi Dareh Gharibi (2023) investigated the long-run relationship between energy consumption and economic growth in selected developing and developed countries, via the Pedroni co-integration method. The data for the study spans from 1993 to 2019. The fully modified OLS (FMOLS) and the Dumitrescu and Hurlin causality method were the other two econometric procedures used for parameter estimation and causality test, respectively. Just like in previous study, energy consumption triggers economic growth in both developing and developed countries. The causality output showed the presence of a protection effect between energy consumption and economic growth only in developed countries, whereas the feedback effect exists in developing countries.

Soava & Mehedintu (2023) explored the relationship between energy consumption and economic growth in Romania and the EU from 1995 to 2020. Other variables in the model include final energy consumption by sectors, specifically household, commercial and public services, transport, and industry. The study controlled for the effects of the Russo-Ukrainian War and the Covid-19 pandemic, and also utilized the neural network and several regression models. The results revealed that energy consumption positively affects economic growth in the short run both in Romania and the EU. The structural analysis showed the direct and indirect effects of energy consumption with different intensities.

Azam, Ateeq, Shafique, Rafiq, & Yuan (2023) examined the energy-growth nexus for thirty developing countries from 1990 to 2017, while controlling for quality of government, natural resources, capital formation, and financial development. Data analysis was carried out via the random-and-fixed effect model. The findings confirmed that the quality of government, financial development, gross capital formation, and primary energy consumption increase economic growth in the selected developing countries. The causality outcome supports the feedback effect hypothesis between economic growth and primary energy consumption.

Hassan, Mahmood, & Javaid (2022) estimated the effect of electricity consumption on the economic growth of three European countries (Finland, France, and Portugal). The obtain reliable results, an effort was made to adjust the data for structural breaks in the cointegration analysis. The results of the analysis revealed that electric power consumption accelerates economic growth in France in the long run, and in Portugal and Finland in the short run. Besides, labour force also significantly triggers economic growth in Finland and France in the short and long run periods but impede growth in Portugal in the long run period. Capital plays a significantly role in boosting economic growth in the long run, only in Portugal, whereas it improves economic growth in all the countries in the short run.

4. Data and Methodology

4.1 Data Structure

This study applies a secondary quantitative research procedure because the dataset is mainly derived from secondary sources, e.g., data that are already collected and organized. The available data are then summarized and arranged to amplify the quality of the study. The dataset has been collected from the World Development Indicator (2023) of the World Bank. As mentioned earlier, the study considered selected Sub-Saharan Africa countries: Rwanda, South Africa, Namibia, Kenya, Tanzania, Ghana, Ethiopia, Nigeria, and Democratic Republic of Congo. The time period for the study extends from 1996 to 2020 and coincides with a period of increased energy consumption in SSA and the period when sustainable growth became a topical issue.

4.2 Data Description

The study examines the relationship between energy consumption and economic growth. The study mainly uses secondary data obtained from reliable and recognized sources. The data considered for the study include energy consumption, GDP per capita, foreign direct investment (FDI), gross fixed capital formation (proxy for capital), labour force, and inflation. In this study, GDP per capita is the proxy for economic growth, and the dependent variable, as well. On the other hand, energy consumption, FDI, capital, labour force, and inflation serve as the independent/explanatory variables. The aforementioned variables will be regressed on GDP per capita. GDP per capita is measured as GDP per capita (constant 2010 US$). Constant prices are a way of measuring the change in output in real terms. In this case, a particular year is chosen as the base year, and for every subsequent year, the output is measured in terms of the output level of the base year. This does not in any way include any nominal changes in output. This helps in discerning the actual change in goods and services produced.

Capital is measured as gross fixed capital formation per head (constant 2010 US$). It represents residents' producers' investments deducting disposals. Capital is a necessary factor that can promote economic growth in any country (Hayat, 2018). It is a macroeconomic variable used in the official national income account of a country. Capital formation is not a complete measure of total investment because only net addition to fixed assets is measured, with the exclusion of all kinds of financial assets, operating cost, and stock of inventories (Ali, 2015). It is nearly impossible to statistically differentiate between capital formation and intermediate consumption, as long as expenditure concerns alterations to fixed assets owned. In most cases, this expenditure can represent new fixed investment, in others it represents operating cost relating to the repair or maintenance of fixed assets (Kanu, Ozurumba, & Anyanwu, 2014). Gross fixed capital formation time series data is usually used to examine the trends in investment activities over a period of time, reflating or deflating the series using a price index. However, it is also sometimes used as an alternative measure of fixed capital stock (Trpeski & Cvetanoska 2019; McLaren & Murphy 2017).

Labour force is measured in (total), that is, in percentage of the total population. It includes all people able and willing to work. The labour force is made up of people ages 15 and older who supply their labour to produce goods and services at a particular period of time. It is made up of people who are currently employed and those who are not employed but searching for a job, including first-time seekers. However, not all workers are included in this case. Students, workers, and unpaid workers are often omitted, and in some cases, armed forces are excluded. The size of the labour force varies every year as workers enter and leave. Labour force is included in the study because labour is an important determinant of economic growth (Yakubu, Akanegbu, & Jelilov, 2020). Depending on the production techniques, labour force is of utmost importance if labour-intensive production technique is in operation (Ong, R., Wood, G. A., Whelan, S., Cigdem-Bayram, M., Atalay, K., & Dodson, J. (2017). Labour coordinates production activities and also contributes immensely to economic growth. In this study, we consider aggregate labour force encompassing both males and females. The choice of these variables was motivated from the theoretical framework of this study.

FDI is measured as foreign direct investment, net inflows (BoP, current US$), where BoP represents balance of payment. FDI is a cross-border investment where an investor residing in a particular country establishes a lasting interest in an enterprise resident in the economy of another country. It is the total sum of capital, reinvestment of earnings, and equity capital. FDI can promote economic growth indirectly through the financial development channel via backward linkages between domestic and foreign firms to turn into FDI spillovers (Popescu 2014; Almfraji & Almsafir 2014). Inflation is measured as inflation, consumer prices (annual %). That is, the annual percentage of consumer prices. It refers to the average price consumers pay for goods in a period of one year. It reflects annual percentages changes in the cost of a basket of goods and services, which may change or remain fixed at specified intervals.

Energy consumption NE in this study is measured as energy use (kg of oil equivalent per capita). It denotes the use of primary energy before it is transformed to other end-use fuels, which is equivalent to imports and stock changes plus indigenous production, minus exports and fuel supplied to aircraft and ships engaged in international transportation. Energy is needed for production. Without energy, production activities may not go smoothly. Energy performs different roles: for lighting, cooking, production, etc. (Akam, Owolabi, & Nathaniel 2021; Bilgili, Nathaniel, Kuşkaya, & Kassouri 2021; Adedoyin, Nathaniel, & Adeleye 2021).

4.3 Methodology

This section of the study begins with model specification in line with the theoretical framework of the study. Thereafter, the study follows the procedure of panel data econometrics. As such, panel data preliminary tests would be carried out before parameter estimation. The first preliminary test will be the cross-sectional dependence test before the panel unit root and panel cointegration tests. Since the objective of the study focused on the relationship between energy consumption and economic growth, in line with the studies of Konyeaso et al. (2023) and Uwizeye (2021), the two primary models of the study are specified as follows:

$$GD_t = f(K_{it}, L_{it}, NE_{it}, FDI_{it}, INF_{it}, \mu_{it}) \quad (1)$$

$$NE_t = f(K_{it}, L_{it}, GD_{it}, FDI_{it}, INF_{it}, \mu_{it}) \quad (2)$$

Eq. (1) and (2) represent the functional form of the model to be estimated, where $GD_{it}, K_{it}, L_{it}, NE_{it}, FDI_{it}$, and INF_{it} GD represents GDP per capita (proxy for economic growth), K represents capital (proxy by gross fixed capital formation), L labour force, NE energy consumption (proxy by energy use (kg of oil equivalent per capita), FDI foreign direct investment, and INF inflation, respectively. μ_{it} is the error, also referred to as the white noise component. The model cannot be estimated in its current form. For ease of estimation, the natural logarithm of the variables is preferred to reduce skewness, especially for highly skewed variables. Also, it helps in the interpretation of parameters in terms of elasticities. Besides, log models assist in reducing data sharpness and the probabilities of heteroskedasticity (Fakher et al. 2023). Equation (2) shows the linear transformation of the variables in equation (1).

$$lngd_{it} = \psi_0 + \psi_1 lnk_{it} + \psi_2 lnl_{it} + \psi_3 lnne_{it} + \psi_4 lnfdi_{it} + \psi_5 lninf_{it} + \mu_t \quad (3)$$

$$lnne_{it} = \xi_0 + \xi_1 lnk_{it} + \xi_2 lnl_{it} + \xi_3 lngd_{it} + \xi_4 lnfdi_{it} + \xi_5 lninf_{it} + \mu_t \quad (4)$$

where lnk_{it}, lnl_{it}, $lnne_{it}$, $lnfdi_{it}$, $lninf_{it}$, and $lngd_{it}$ represent the natural logarithm of capital, labour force, energy consumption, foreign direct investment, inflation, and economic growth, respectively. $\psi_0 - \psi_5$ and $\xi_0 - \xi_5$ are the parameters to be estimated. Meanwhile, μ_t remains the white noise component. The variables in equation (3) and (4) have been selected in line empirical literature and economic theory. There is evidence in the extant literature that capital, labour force, and energy consumption trigger economic growth. As such, it is expected for

$\frac{\partial lngd_{it}}{\partial lnk_{it}} > 0, \frac{\partial lngd_{it}}{\partial lnl_{it}} > 0$, and $\frac{\partial lngd_{it}}{\partial lne_{it}} > 0$, However, the effect of FDI and inflation may vary. As such, $\frac{\partial lngd_{it}}{\partial lnfdi_{it}} >< 0$, and $\frac{\partial lngd_{it}}{\partial lninf_{it}} >< 0$.

After parameter estimation which will be done using the AMG estimator, the next step, based on the study objectives, will be to estimate the direction of causality among the variables. As such, the Dumitrescu and Hurlin (2012) (DH) panel Granger causality test was employed to assess the causal paths among the variables. The general equation of the DH test is given as

$$Y_{it} = w_i + \sum_{m=1}^{M} \alpha_i^{(m)} Y_{it-m} + \sum_{m=1}^{M} \delta_i^{(m)} X_{it-m} + \varepsilon_{it} \tag{5}$$

The regression coefficient, lag orders, and constant term are given as $\delta_i^{(m)}$, M, and w_i, respectively. The autoregressive coefficient of the equation is given as $\alpha_i^{(m)}$. The input and response variables of country i in period t are X_{it} and Y_{it}, respectively. In line with equation (5), equation (6) to (11) are developed to examine the direction of causality.

$$lngd_{it} = \gamma_1 + \sum_{m=1}^{M} \alpha_1^{(m)} lngd_{it-m} + \sum_{m=1}^{M} \delta_1^{(m)} lnk_{it-m} + \sum_{m=1}^{M} \delta_2^{(m)} lnl_{it-m} + \sum_{m=1}^{M} \delta_3^{(m)} lnne_{it-m} + \sum_{m=1}^{M} \delta_6^{(m)} lnfdi_{it-m} + \sum_{m=1}^{M} \delta_7^{(m)} lninf_{it-m} + \varepsilon_{it} \tag{6}$$

$$lnk_{it} = \gamma_2 + \sum_{m=1}^{M} \alpha_1^{(m)} lnk_{it-m} + \sum_{m=1}^{M} \delta_1^{(m)} lngd_{it-m} + \sum_{m=1}^{M} \delta_2^{(m)} lnl_{it-m} + \sum_{m=1}^{M} \delta_3^{(m)} lnne_{it-m} + \sum_{m=1}^{M} \delta_6^{(m)} lnfdi_{it-m} + \sum_{m=1}^{M} \delta_7^{(m)} lninf_{it-m} + \varepsilon_{it} \tag{7}$$

$$lnl_{it} = \gamma_3 + \sum_{m=1}^{M} \alpha_1{}^{(m)} lnl_{it-m} + \sum_{m=1}^{M} \delta_1{}^{(m)} lngd_{it-m} + \sum_{m=1}^{M} \delta_2{}^{(m)} lnk_{it-m} + \sum_{m=1}^{M} \delta_3{}^{(m)} lnne_{it-m} + \sum_{m=1}^{M} \delta_6{}^{(m)} lnfdi_{it-m} + \sum_{m=1}^{M} \delta_7{}^{(m)} lninf_{it-m} + \varepsilon_{it} \quad (8)$$

$$lnne_{it} = \gamma_4 + \sum_{m=1}^{M} \alpha_1{}^{(m)} lnne_{it-m} + \sum_{m=1}^{M} \delta_1{}^{(m)} lngd_{it-m} + \sum_{m=1}^{M} \delta_2{}^{(m)} lnk_{it-m} + \sum_{m=1}^{M} \delta_3{}^{(m)} lnl_{it-m} + \sum_{m=1}^{M} \delta_6{}^{(m)} lnfdi_{it-m} + \sum_{m=1}^{M} \delta_7{}^{(m)} lninf_{it-m} + \varepsilon_{it} \quad (9)$$

$$lnfdi_{it} = \gamma_5 + \sum_{m=1}^{M} \alpha_1{}^{(m)} lnfdi_{it-m} + \sum_{m=1}^{M} \delta_1{}^{(m)} lngd_{it-m} + \sum_{m=1}^{M} \delta_2{}^{(m)} lnk_{it-m} + \sum_{m=1}^{M} \delta_3{}^{(m)} lnl_{it-m} + \sum_{m=1}^{M} \delta_6{}^{(m)} lnne_{it-m} + \sum_{m=1}^{M} \delta_7{}^{(m)} lninf_{it-m} + \varepsilon_{it} \quad (10)$$

$$lninf_{it} = \gamma_6 + \sum_{m=1}^{M} \alpha_1{}^{(m)} lninf_{it-m} + \sum_{m=1}^{M} \delta_1{}^{(m)} lngd_{it-m} + \sum_{m=1}^{M} \delta_2{}^{(m)} lnk_{it-m} + \sum_{m=1}^{M} \delta_3{}^{(m)} lnl_{it-m} + \sum_{m=1}^{M} \delta_6{}^{(m)} lnne_{it-m} + \sum_{m=1}^{M} \delta_7{}^{(m)} lnfdi_{it-m} + \varepsilon_{it} \quad (11)$$

From the DH equations highlighted above, $\gamma_1 - \gamma_6$ represent the constant terms in the equations. Meanwhile, the autoregressive coefficients are represented by $\alpha_1 - \alpha_7$. The two test statistics suggested by the DH tests are;

$$W_{N,T}^{HNC} = N^{-1} \sum_{i=1}^{N} W_{i,t} \quad and \quad Z_{N,T}^{HNC} = \frac{\frac{1}{\sqrt{N}}[\sum_{i=1}^{N} W_{i,t} - \sum_{i=1}^{N} E(W_{i,t})]}{\sqrt{\frac{1}{N}\sum_{i=1}^{N} Var(W_{i,t})}} \quad (12)$$

The W-statistic and the Z-bar statistic are denoted by $W_{N,T}^{HNC}$ and $Z_{N,T}^{HNC}$, respectively. The expectation and variance of the W-statistic are $E(W_{i,t})$ and $Var(W_{i,t})$, respectively. The null hypothesis of the DH test is that of no causation. The rejection of the null hypothesis confirms evidence of causation.

The econometric procedure for parameter estimation involves some preliminary test, with the first being the cross-sectional dependence (CD) tests. The CD test is of necessity because of convergence of the internal (Sub-Saharan Africa) and external (world) economy. Many countries have cultural, social and economic ties and therefore depend on each other. As such, it is possible for macroeconomic factors that affect one country to have a spillover effect on others. The ignorance of CD could lead to bias inferences, estimates, and conclusion (Mesagan

& Vo 2023; Mamman, Zhanqin, & Iliyasu 2023; Carvelli 2023). To detect CD, Pesaran (2015) gave the following equation:

$$CD = \left[\frac{2T}{N(N-1)}\right]^{1/2} \sum_{i=1}^{N-1} \sum_{j=I+1}^{N} \hat{\rho}_{ij} \tag{13}$$

where the time dimension and cross section are T and N, respectively. The correlation coefficient of the residuals is given as $\hat{\rho}_{ij}$, which is represented as

$$\hat{\rho}_{ij} = \frac{\sum_{t=1}^{T} \varepsilon_{it}\varepsilon_{jt}}{(\sum_{t=1}^{T} \varepsilon_{it}^2)^{1/2} (\sum_{t=1}^{T} \varepsilon_{jt}^2)^{1/2}}$$

To confirm the integration level of the variables, the study applied two robust unit root tests CIPS and CADF. These tests will help provide the direction of subsequent econometric analysis. All the variables are expected to be integrated of the same order, say $I(1)$, to support the use of second-generation econometric procedures. Both tests are robust even in the presence of CD and are perfect for the characteristics of our dataset. The CADF equation is specified as:

$$\Delta y_{it} = \alpha_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + \sum_{j=0}^{p} d_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^{p} \delta_{ij} \Delta y_{i,t-j} + e_{it} \tag{14}$$

From equation (14), $\Delta\bar{y}_{t-j}$ and $\bar{y}_{t-j}$ are the cross-sectional averages. Besides, the simple average of the CADF statistic gives the equation of the CIPS as:

$$CIPS = N^{-1} \sum_{l=1}^{N} CADF_l \tag{15}$$

where the statistic of the CADF test is denoted by $CADF_l$. The two tests have the null hypothesis of no unit root. Though they are both robust to CD, they are not efficient amidst structural breaks in the dataset (Fakher et al., 2023). After confirming the integration level of the variables, the next step will be to check for the presence of long-run relationship. To assess long-run relationship, this study favours the Westerlund (2007) cointegration test. The Westerlund (2007) test is efficient in the presence of CD. The test has four statistics, the group mean statistics ($G_{\alpha} and\ G_{\tau}$) and the panel-mean statistics ($P_{\alpha} and\ P_{\tau}$). The equations of these statistics are listed below:

$$G_{\alpha} = \frac{1}{N}\sum_{i=1}^{N}\frac{T\theta_i}{\theta_i'(1)}\ \ and\ G_{\tau} = \frac{1}{N}\sum_{i=1}^{N}\frac{\theta_i}{SE(\theta_i)} \tag{16}$$

$$P_{\tau} = \frac{\hat{\theta}_i}{SE(\hat{\theta}_i)}\ \ and\ P_{\alpha} = T\hat{\theta}_i \tag{17}$$

In the presence of cointegration, the next procedure will be to investigate the elasticities of the explanatory variables. Conventional estimators such as the fixed effect, FMOLS, random effect, GMM, DOLS, and ARDL among others, are not efficient estimators in the presence of CD compared to second generation, and even third-generation econometric procedures. As such, this study applies the AMG technique popularized by Bond and Eberhardt (2013), which accounts for heterogeneity and CD in a dataset (Omojolaibi & Nathaniel 2022; Nathaniel & Adedoyin 2022; Nathaniel & Iheonu 2019). The method is robust for both non-stationary and stationary data (Ali, Jianguo, & Kirikkaleli 2022). The AMG technique is carried out in two stages. In the first stage, the $T-1$ dummies and the first difference form of the equation can be expressed as:

$$\Delta lngd_{it} = \alpha_i + \beta_1\Delta lnk_{it} + \beta_2\Delta lnl_{it} + \beta_3\Delta lnne_{it} + \beta_4\Delta lnfdi_{it} + \beta_5\Delta lnnf_{it} + \sum_{t=2}^{T}\emptyset_t(\Delta D_t) + \varepsilon_{it} \tag{18}$$

$$\Delta lnne_{it} = \alpha_i + \beta_1\Delta lnk_{it} + \beta_2\Delta lnl_{it} + \beta_3\Delta lngd_{it} + \beta_4\Delta lnfdi_{it} + \beta_5\Delta lnnf_{it} + \sum_{t=2}^{T}\emptyset_t(\Delta D_t) + \varepsilon_{it} \tag{19}$$

where ΔD_t and $\emptyset_t$ is the first difference order of $T-1$ dummies and is parameter. $\beta_1 - \beta_5$ are the difference form of the parameters, whereas α_i is the constant term. The second stage involves the transformation of $\emptyset_t$ to P_t ($\emptyset_t$=P_t) to form a common dynamic process as:

$$\Delta gd_{it} = \alpha_i + \beta_1\Delta k_{it} + \beta_2\Delta l_{it} + \beta_3\Delta ne_{it} + \beta_4\Delta fdi_{it} + \beta_5\Delta inf_{it} + P_t(d_t) + \varepsilon_{it} \tag{20}$$

$$\Delta gd_{it} - P_t(d_t) = \alpha_i + \beta_1\Delta k_{it} + \beta_2\Delta l_{it} + \beta_3\Delta ne_{it} + \beta_4\Delta fdi_{it} + \beta_5\Delta inf_{it} + \varepsilon_{it} \tag{21}$$

$$\Delta ne_{it} = \alpha_i + \beta_1\Delta k_{it} + \beta_2\Delta l_{it} + \beta_3\Delta gd_{it} + \beta_4\Delta fdi_{it} + \beta_5\Delta inf_{it} + P_t(d_t) + \varepsilon_{it} \tag{22}$$

$$\Delta ne_{it} - P_t(d_t) = \alpha_i + \beta_1\Delta k_{it} + \beta_2\Delta l_{it} + \beta_3\Delta gd_{it} + \beta_4\Delta fdi_{it} + \beta_5\Delta inf_{it} + \varepsilon_{it} \tag{23}$$

The estimated parameter of each dummy and the dynamic process is represented by d_t. The AMG equation will be estimated for the two models to ascertain, first, the influence of the variables on economic growth, and second, the influence of the variables on energy consumption.

5. Results and Discussion

The first point of call for this analysis section is the descriptive statistics of the variables. The descriptive statistics show the properties of each of the variables used in the model. From the Table, the variable with the highest average value is economic growth with 1845.026, closely followed by labour with 2.07E+07. These go to show that the level of economic growth is relatively higher than some of the selected variables in the study. Beyond economic growth figures, it is also evident that these countries are relatively safe to attract FDI inflows. The variables also have their minimum values. The minimum value for capital is 0.0000. This did not come as a surprise, considering the fact that the level of capital development is still very low in sub-Saharan Africa countries (SSA).

Table 5: Descriptive Statistics

Variables	Mean	Std. Deviation	Minimum	Maximum
GD	1845.026	1760.826	246.3873	6263.104
K	20.2302	9.206195	0.000000	41.01825
L	2.07E+07	1.61E+07	516621	6.86E+07
NE	708.9791	672.2616	257.7809	2904.276
FDI	1.43E+09	1.96E+09	-2.43E+08	9.89E+09
INF	18.0221	58.11502	-8.484250	513.9069

Capital needs to be developed in SSA for the countries to witness any significant level of economic growth. Besides, compared to other regions of the world, SSA remains the least developed region, which may be as a result of low level of capital (proxy by gross fixed capital formation) in the region. The minimum values of FDI and inflation are negative. They are respectively -2.43E+08 and -8.484250. The other variables in the study have positive minimum values. Still, labour has the highest value of any of the selected variables, closely followed by economic growth with 246.3873. The standard deviation values reveal the variables that are volatile and less volatile. From the results, inflation is the least volatile of all the values. However, labour force is among the variables that are higher volatile. Besides, economic growth and FDI are also highly volatile.

Table 6: Cross-sectional Dependence (Pesaran (2004) CD test)

Variables	CD-test	P-value	Corr	Abs (corr)
LOG(GD)	24.99	0.000***	0.833	0.833
LOG(K)	2.26	0.024***	0.080	0.479
LOG(L)	29.52	0.000***	0.982	0.982
LOG(NE)	12.65	0.000***	0.484	0.644
LOG(FDI)	14.70	0.000***	0.496	0.505
LOG(INF)	4.90	0.000***	0.179	0.256

Note: **** and ** represent 0.01 and 0.05 levels of significance, respectively. Under the H_0 of cross-section independence CD ~ N (0,1)*

The need and benefits of the CD test have earlier been mentioned in the preceding chapter. The CD test suggests the direction of econometric analysis. Once CD test is ignored, regression results become bias and meaningless. Table 6 shows the Pesaran (2004) CD test results. The CD test results contain the CD-test estimates, p-values, correlation, and Abs correlation. From Table 6, the probability values are all significant, suggesting the presence of CD in the dataset. For this reason, we applied the second-generation unit root tests, as well as second-generation cointegration test for dealing with the issues of CD. Table 6 presents two-unit root tests carried out in this study. The tests are the CADF and the CIPS test. The two tests are robust in the presence of heterogeneity and CD. The results of the two tests are presented in Table 7 below.

Table 7: Unit root Test

Variables	CADF		CIPS	
	Levels I(0)	First Difference	Levels I(0)	First Difference
LOG(GD)	-1.891	-2.638***	-1.891	-3.715***
LOG(K)	-0.996	-6.012***	-1.917	-3.867**
LOG(L)	-2.109	-2.464**	-2.225	-2.274**
LOG(NE)	-1.214	-3.096***	-1.238	-3.531***
LOG(FDI)	-1.055	-3.807***	-1.533	-4.284***
LOG(INF)	-0.603	-4.421***	-2.173	-5.275***

Note: **** and ** represent 0.01 and 0.05 levels of significance, respectively.*

For the CADF test, all the variables have a unit root. However, the variables became stationary after the first difference. For the CIPS results are similar to the CADF findings. The CIPS test also suggests unit root at levels, and stationarity at first difference for all the variables. These outcomes are favourable considering the fact that there is no I(2) variable in the study. Since all the variables are I(1), there is a need to investigate the presence, or otherwise, of long-run relationship in the dataset. For this reason, Table 8 presents the long-run relationship test.

Table 8: Cointegration Test (Westerlund, 2007)

Statistic	Value	Z-value	P-value	Statistic
Gt	-3.139	-2.922	0.002***	Gt
Ga	-9.999	-2.946	0.001***	Ga
Pt	-7.921	-1.613	0.043***	Pt
Pa	-3.591	1.766	0.961***	Pa

*Note: *** denotes significance at 0.01%.*

There are different long-run relationship tests. However, most are first-generation tests that are not robust to some panel data issues, including CD. Table 8 shows the results of the Westerlund (2007) cointegration test. From the results, three of the four statistics are significant, which confirms the presence of long-run relationship among the variables. Table 9 shows the country-wise AMG results.

Table 9: Augmented Mean Group (AMG) Results

VARIABLES	Coef.	Std. Err	Z	P > |z|
LOG(K)	0.004	0.0019	2.10	0.036
LOG(L)	0.800	0.2443	3.27	0.001
LOG(NE)	0.002	0.0010	1.88	0.060
LOG(FDI)	-2.090	3.5900	-0.58	0.560
LOG(INF)	0.000	0.0011	0.02	0.981

Note: **** and ** represent 0.01 and 0.05 levels of significance, respectively.*

From table 9, the key variable, energy consumption, is significant and positive. However, in all, three of the variables (capital, labour, and energy consumption) are significant, whereas the other two variables (FDI and inflation) are not significant. A 1% increase in capital accelerates economic growth by 0.800%, holding the influence of other variables constant. The relationship between labour force and economic growth is positive and significant. The implication here is that labour force drives economic growth in the selected countries. This finding is intuitive because countries in the SSA region are among the most populated countries in the world, and as such, it is expected that labour contributes to economic growth in the country. This outcome is similar to the earlier findings of Somoye, Ozdeser, & Seraj (2022) and Uzokwe & Onyije (2020).

Similar to the effect of labour force on economic growth in the selected countries, capital also increases economic growth, but with a lower impact compared to the effect of labour force. A 1% increase in capital accelerates economic growth by 0.004%, holding the influence of other variables constant. Capital is an important component in the production function of any country. Besides, capital comes in different forms like human skills, machines, etc. Capital, like labour force, is available in every country and is used to make the production process efficient and robust. Similar findings were discovered by Azam, Ateeq, Shafique, Rafiq, & Yuan (2023)

The results show that energy use also exacts a positive and significant impact on economic growth in the selected countries. A 1% increase in energy consumption leads to about 0.002% increase in economic growth. From this result, labour force is the highest contributor to economic growth than any of the selected variables in the study. However, the reason for the significant impact of energy consumption on economic growth cannot be overemphasized because energy is an important component of production and consumption by firms and households, respectively. Energy, in any form, is consumed in the selected countries, and there is evidence that energy is a great contributor to economic growth as discovered in the findings. A study with similar findings is Dahmani, Mabrouki, & Ben Youssef (2023).

Further results from the study suggest that FDI is not an important contributor to economic growth in the selected countries. SSA countries are among the largest exporters of commodities in the world, especially commodities where they have a comparative advantage. Some of the commodities imported by these countries promote the decline of infant industries and also the growth of the existing ones. It has been argued by different scholars in the literature that SSA countries should do away with FDI because it hurts their economy rather than developing it. SSA remains a large market for investors all over the world because of the region's large population and available market for imported products. The outcome of the effect of FDI on economic growth in this study contradicts the findings of Appiah, Gyamfi, Adebayo, & Bekun (2023)

Finally, from Table 9, inflation has no significant impact on economic growth. Over the years, inflation has continued to increase in SSA countries mainly due to weak policies and over-reliance on imported goods. Sometimes, inflation in SSA is imported because of the high degree of importation. However, there are studies in the literature that have shown a positive relationship between inflation and economic growth, such as Kasidi & Mwakanemela (2013).

Table 10: Augmented Mean Group (AMG) Results

VARIABLES	Coef.	Std. Err	Z	P > |z|
LOG(K)	0.05894	0.06439	0.92	0.360
LOG(L)	0.00816	0.38437	0.02	0.983
LOG(GD)	0.00038	0.00019	1.96	0.050
LOG(FDI)	-0.00761	0.00373	2.04	0.041
LOG(INF)	-0.00192	0.00082	-2.32	0.020

Table 10 shows the results of the model with energy consumption as the dependent variable. From the results, labour force and capital are not significant contributors to energy consumption. On the other hand, economic growth drives energy consumption in the selected countries. From the result, a 1% increase in economic growth leads to about 0.00038% increase in energy consumption. The intuition here is that energy consumption is not the only variable that drives economic growth in the selected countries, economic growth also drives energy consumption. There are arguments in the literature that more growth comes with an increase in energy consumption. Energy consumption increases with more economic growth because it is energy that facilitates the growth process. Besides, it is energy that is used in the growth process of any country. This outcome suggests that economic growth and energy consumption are closely knitted. There are studies in the literature with similar findings, that economic growth increases energy consumption, they include Saidi & Hammami (2015) for 58 countries, Komal & Abbas (2015) for Pakistan, Farhani& Ben Rejeb (2012) for ninety countries, Nasreen & Anwar (2014) for Asian countries, Bayar & Özel (2014) for emerging countries, and Khoshnevis Yazdi & Shakouri (2017) for Iran.

Furthermore, FDI is significant, but the impact of FDI on energy consumption is negative. This means that FDI reduces energy consumption in the selected countries. Similar to the effect of FDI, is the negative impact of inflation on energy consumption. This suggests that when inflation is high, the demand for energy consumption declines. This could be true because inflation reduces the value of money, making too much money to chase few goods. During inflationary period, people may prefer to keep money hoping that its value will increase over time.

Table 11: Dumitrescu & Hurlin (DH) Granger Causality Results

Null Hypotheses	**W-Stat.**	**Z-bar Stat.**	**Probability**	**Conclusion**
LogK → LogGD	5.4244	3.73281	0.0001	Bidirectional
LogGD → LogK	4.8149	3.01609	0.0025	
LogL → LogGD	8.6505	7.52632	5.2180	Unidirectional
LogGD → LogL	5.2813	3.56451	0.000	
LogNE → LogGD	2.6875	0.29346	0.7691	No causality
LogGD → LogNE	8.5240	6.25036	0.0873	
LogFDI → LogGD	3.7036	1.70938	0.7480	Unidirectional
LogINF → LogGD	2.5631	0.32121	0.0001	

Finally, Table 11 displays the causality results, especially for the variables that are of interest. From the results, a bidirectional causality is witnessed between capital and economic growth in the selected countries. However, the relationship between labour force and economic growth is unidirectional. In this case, it is economic growth that causes labour force. Furthermore, no directional causality exists between energy consumption and economic growth. The nature of the causality between energy consumption and economic growth buttresses the point that impact does not suggest causation. Finally, a unidirectional causality flows from inflation to economic growth. That is, inflation causes economic growth in the selected countries.

6. Conclusion

This study was carried out to examine the relationship between energy consumption and economic growth in selected nine SSA countries. The countries selected in the study include Rwanda, South Africa, Namibia, Kenya, Tanzania, Ghana, Ethiopia, Nigeria and the Democratic Republic of Congo. The study period extends from 1996 to 2020. The data for the study was ultimately determined by data availability. In the study, capital, labour, energy consumption, FDI, and inflation were the explanatory variables in the study, whereas GDP per capita served as the dependent and the proxy for economic growth in the first model. For the second model, capital, labour, economic growth, FDI, and inflation were the explanatory variables whereas energy consumption was the dependent variable in the first model. The choice of the variables used in the study was informed by existing theories and empirical literature.

The first step embarked upon was the descriptive statistics of the variables of interest. Thereafter, the cross-sectional dependence (CD) test was carried out. The results of the CD test confirmed the presence of the CD in the dataset. With the presence of CD, further analysis should concentrate on second-generation techniques because they are robust in the presence of CD. As such, the study proceeded with the CIPS and CADF unit root tests. These unit root tests suggest that the variables have a unit root in their level forms. The conclusion was derived in line with the probability values of the variables. However, after first differencing, all the variables became stable. With stable variables, the need to conduct a cointegration test arises. The Westerlund (2007) cointegration test was carried out. Of the four statistics associated with the Westerlund (2007) test, three of the statistics were significant. therefore, confirming the presence of long-run relationship among the variables. The augmented mean group (AMG) estimator was used for parameter estimation. The AMG estimator provided some interesting results.

From the findings of the study, labour, capital, and energy consumption drives economic growth in the first model, whereas the coefficient of inflation and FDI was not significant. In the second model, capital and labour force were not significant drivers of energy consumption in the selected countries, rather economic growth showed a positive and significant impact on energy consumption. Though FDI and inflation reduce energy consumption, they were not significant. The causality results showed different directions of causality. For instance, a unidirectional causality flows from labour to economic growth, a bidirectional causality is witnessed between capital and economic growth in the selected countries. However, there was no direction of causality between energy consumption and economic growth.

6.1 Limitations and Suggestions for Future Research

This thesis endeavored to examine the nature of the relationship between energy and economic growth in Africa and to contribute to the literature by hypothesizing that energy is a crucial factor contributing to rapid growth in Africa. As mentioned above, labour, capital, and energy consumption drive economic growth. It is therefore imperative that policies be put in place to ensure energy efficiency.

Limitations encountered were access to comprehensive data to cover each year for all the 9 sampled countries.

Future research can be on the effect of the voice and accountability to ensure energy efficiency.

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APPENDICES REVISED

Descriptive Statistics

sum	gd k l ne	fdi	inf			
	Variable	Obs	Mean	Std. Dev.	Min	Max
gd	225	1845.026	1760.826	246.3873	6263.104	
k	225	20.23902	9.206195	0	41.01825	
l	225	2.07E+07	1.61E+07	516621	6.86E+07	
ne	171	708.9791	672.2616	257.7809	2904.276	
fdi	225	1.43E+09	1.96E+09	-2.43E+08	9.89E+09	
inf	214	18.0221	58.11502	-8.48425	513.9069	

CIPS Unit Root

For log GD

```
xtcips loggd, maxlag(2) bglags(2) q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for loggd
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS =    -1.891       N,T = (9,25)
----------------------------------------------------
               |      10%       5%       1%
-------------------+-------------------------------
Critical values at |    -2.21     -2.33     -2.57
----------------------------------------------------
xtcips d.loggd, maxlag(2) bglags(2) q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for D.loggd
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white noise
Individual ti were truncated during the aggregation process
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS* =    -3.715       N,T = (9,24)
----------------------------------------------------
               |      10%       5%       1%
-------------------+-------------------------------
Critical values at |    -2.21     -2.33     -2.57
----------------------------------------------------
```

FOR LOGK

xtcips logk, maxlag(2) bglags(2) q

Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for loggd logk

Deterministics chosen: constant

Dynamics: lags criterion decision Portmanteau (Q) test for white noise

H0 (homogeneous non-stationary): bi = 0 for all i

CIPS = -1.917 N,T = (9,25)

```
---------------------------------------------------
                  |   10%     5%     1%
------------------+--------------------------------
Critical values at |  -2.21   -2.33   -2.57
---------------------------------------------------
------------------+--------------------------------
Critical values at |  -2.21   -2.33   -2.57
---------------------------------------------------
```

xtcips d.logk, maxlag(2) bglags(2) q

Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for D.loggd d.logk

Deterministics chosen: constant

Dynamics: lags criterion decision Portmanteau (Q) test for white noise

Individual ti were truncated during the aggregation process

H0 (homogeneous non-stationary): bi = 0 for all i

CIPS* = -3.867 N,T = (9,24)

```
---------------------------------------------------
                  |   10%     5%     1%
------------------+--------------------------------
Critical values at |  -2.21   -2.33   -2.57
---------------------------------------------------
```

FORLOGL

xtcips logl, maxlag(2) bglags(2) q

Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for logl

Deterministics chosen: constant

Dynamics: lags criterion decision Portmanteau (Q) test for white noise

H0 (homogeneous non-stationary): bi = 0 for all i

CIPS = -2.225 N,T = (9,25)

```
---------------------------------------------------
                  |   10%     5%     1%
------------------+--------------------------------
```

Critical values at | -2.21 -2.33 -2.57

. xtcips d.logl, maxlag(2) bglags(2) q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for D.logl
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS = -2.274 N,T = (9,24)

| 10% 5% 1%
-------------------+-------------------------------
Critical values at | -2.21 -2.33 -2.57

FOR LOGFDI
xtcips logfdi, maxlag(2) bglags(2) q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for logl
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS = -1.5334 N,T = (9,25)

| 10% 5% 1%
-------------------+-------------------------------
Critical values at | -2.21 -2.33 -2.57
----
xtcips d.logfdi, maxlag(2) bglags(2) q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for D.logl
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS = -4.284 N,T = (9,24)

| 10% 5% 1%
-------------------+-------------------------------
Critical values at | -2.21 -2.33 -2.57
----

xtcips loginf, maxlag(2) bglags(2)
q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for logl loginf
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white
noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS = -2.173 N,T = (9,25)

| 10% 5%
1%
-------------------+-------------------------------
Critical values at | -2.21 -2.33 -2.57
----
xtcips d.loginf, maxlag(2) bglags(2) q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for
D.logl loginf
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white
noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS = -5.275 N,T = (9,24)

| 10% 5%
1%
-------------------+-------------------------------
Critical values at | -2.21 -2.33 -2.57

FOR LOGNE
xtcips logne, maxlag(2) bglags(1)
q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for
logne
Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white
noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS = -1.238 N,T = (9,19)

| 10% 5%
1%
-------------------+-------------------------------
Critical values at | -2.21 -2.34 -2.6

. xtcips d.logne, maxlag(2) bglags(1) q
Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for D.logne

Deterministics chosen: constant
Dynamics: lags criterion decision Portmanteau (Q) test for white noise
H0 (homogeneous non-stationary): bi = 0 for all i
CIPS =   -3.531   N,T = (9,18)

```
-------------------------------------------------
                 |      10%       5%
1%
-------------------+-------------------------------
Critical values at |     -2.21     -2.34      -2.6
-------------------------------------------------
```

CD TEST

xtcd loggd

```
 Average correlation coefficients & Pesaran (2004) CD test
 Variables series tested: loggd
                    Group variable: code
                  Number of groups: 9
          Average # of observations: 28.13
                       Panel is: unbalanced
------------------------------------------------------
   Variable |    CD-test  p-value     corr  abs(corr)
-------------+------------------------------------------
      loggd |     24.99    0.000    0.833    0.833
------------------------------------------------------
 Notes: Under the null hypothesis of cross-section
       independence CD ~ N(0,1)
```

xtcd logk

```
 Average correlation coefficients & Pesaran (2004) CD test
 Variables series tested: logk
                    Group variable: code
                  Number of groups: 9
          Average # of observations: 24.58
                       Panel is: unbalanced
------------------------------------------------------
   Variable |    CD-test  p-value     corr  abs(corr)
-------------+------------------------------------------
       logk |      2.26    0.024    0.080    0.479
------------------------------------------------------
 Notes: Under the null hypothesis of cross-section
       independence CD ~ N(0,1)
```

xtcd logl

```
Average correlation coefficients & Pesaran (2004) CD test
 Variables series tested: logl
```

```
                    Group variable: code
                  Number of groups: 9
        Average # of observations: 28.13
                       Panel is: unbalanced
---------------------------------------------------------
   Variable |    CD-test  p-value     corr  abs(corr)
-------------+-------------------------------------------
       logl |      29.52    0.000    0.984    0.984
---------------------------------------------------------
 Notes: Under the null hypothesis of cross-section
       independence CD ~ N(0,1)
xtcd logne

Average correlation coefficients & Pesaran (2004) CD test
                    Group variable: code
                  Number of groups: 9
        Average # of observations: 21.38
                       Panel is: unbalanced
---------------------------------------------------------
   Variable |    CD-test  p-value     corr  abs(corr)
-------------+-------------------------------------------
      logne |      12.65    0.000    0.484    0.644
---------------------------------------------------------
 Notes: Under the null hypothesis of cross-section
       independence CD ~ N(0,1)
xtcd logfdi

Average correlation coefficients & Pesaran (2004) CD test
 Variables series tested: logfdi
                    Group variable: code
                  Number of groups: 9
        Average # of observations: 27.42
                       Panel is: unbalanced
---------------------------------------------------------
   Variable |    CD-test  p-value     corr  abs(corr)
-------------+-------------------------------------------
     logfdi |      14.70    0.000    0.496    0.505
---------------------------------------------------------
 Notes: Under the null hypothesis of cross-section
       independence CD ~ N(0,1)

Average correlation coefficients & Pesaran (2004) CD test
 Variables series tested: loginf
                    Group variable: code
                  Number of groups: 9
        Average # of observations: 24.22
                       Panel is: unbalanced
```

Variable	CD-test	p-value	corr	abs(corr)
loginf	4.90	0.000	0.179	0.256

Notes: Under the null hypothesis of cross-section independence CD ~ N(0,1)

COINTEGRATION RESULT

xtwest loggd logk logl logne logfdi loginf lags(0) leads (0) lrwindow(0)

Calculating Westerlund ECM panel cointegration tests..........

Results for H0: no cointegration

Statistic	Value	Z-value	P-value
Gt	-3.139	-2.922	0.002
Ga	-9.999	-2.946	0.001
Pt	-7.921	-1.613	0.043
Pa	-3.591	1.766	0.961

AMG RESULT

xtmg loggd logk logl logne logfdi loginf

Pesaran & Smith (1995) Mean Group estimator

All coefficients present represent averages across groups (code)

Coefficient averages computed as unweighted means

Mean Group type estimation Number of obs = 164

Group variable: code Number of groups = 9

Obs per group:

min = 12

avg = 18.2

max = 19

Wald chi2(4) = 25.65

Prob > chi2 = 0.0000

loggd	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
logk	.0040363	.0019221	2.10	0.036	.0002691	.0078036
logl	.8001307	.2443636	3.27	0.001	.3211868	1.279075
logne	.0020382	.0010836	1.88	0.060	-.0000855	.004162
logfdi	-2.09e-11	3.59e-11	-0.58	0.560	-9.12e-11	4.94e-11
loginf	.0000277	.0011937	0.02	0.981	-.0023119	.0023674
_cons	-7.087211	4.113493	-1.72	0.085	-15.14951	.9750868

Root Mean Squared Error (sigma): 0.0399

Pairwise Dumitrescu Hurlin Panel Causality Tests
Date: 05/13/23 Time: 16:49
Sample: 1996 2020
Lags: 2

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
K does not homogeneously cause GD	5.42446	3.73281	0.0002
GD does not homogeneously cause K	4.81495	3.0161	0.0026
L does not homogeneously cause GD	8.65053	7.52632	5.00E-14
GD does not homogeneously cause L	5.28133	3.56451	0.0004
NE does not homogeneously cause GD	2.68753	0.29346	0.7692
GD does not homogeneously cause NE	8.52408	6.25037	4.00E-10
FDI does not homogeneously cause GD	3.7037	1.70939	0.0874
GD does not homogeneously cause FDI	3.43951	1.39874	0.1619
INF does not homogeneously cause GD	2.56319	0.32122	0.748
GD does not homogeneously cause INF	5.66863	3.8544	0.0001
L does not homogeneously cause K	4.38994	2.51634	0.0119
K does not homogeneously cause L	3.0827	0.97917	0.3275
NE does not homogeneously cause K	5.26065	2.91964	0.0035
K does not homogeneously cause NE	4.48003	2.12292	0.0338
FDI does not homogeneously cause K	2.85834	0.71534	0.4744
K does not homogeneously cause FDI	7.74093	6.45673	1.00E-10
INF does not homogeneously cause K	1.43106	-0.96686	0.3336
K does not homogeneously cause INF	1.9651	-0.35926	0.7194
NE does not homogeneously cause L	6.0642	3.73976	0.0002
L does not homogeneously cause NE	6.71269	4.40162	1.00E-05
FDI does not homogeneously cause L	4.61507	2.78107	0.0054
L does not homogeneously cause FDI	5.71756	4.07747	5.00E-05
INF does not homogeneously cause L	0.91302	-1.55625	0.1196
L does not homogeneously cause INF	3.76398	1.68741	0.0915
FDI does not homogeneously cause NE	5.85038	3.52153	0.0004
NE does not homogeneously cause FDI	4.25457	1.89281	0.0584
INF does not homogeneously cause NE	1.44369	-0.85441	0.3929
NE does not homogeneously cause INF	3.77053	1.0211	0.3072

INF does not homogeneously cause FDI 1.78371 -0.56563 0.5716

FDI does not homogeneously cause INF 2.29692 0.01827 0.9854

xtmg logne logk logl logfdi loginf loggd

Note: 4 obs. dropped (panels too small)

Pesaran & Smith (1995) Mean Group estimator

All coefficients present represent averages across groups (code)

Coefficient averages computed as unweighted means

```
Mean Group type estimation                Number of obs    =      143
Group variable: code                      Number of groups  =       8
                                Obs per group:
                                           min =       12
                                           avg =      17.9
                                           max =       19
                                Wald chi2(5)     =     30.62
                                Prob > chi2      =    0.0000
------------------------------------------------------------------------------
       logne |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        logk |   .0589485   .0643902     0.92   0.360     -.067254    .1851509
        logl |    .008168   .3843739     0.02   0.983    -.7451909     .761527
      logfdi |   .0076163   .0037308     2.04   0.041     .0003042    .0149285
      loginf -.0019258   .0008292    -2.32   0.020     -.003551   -.0003007
          gd |   .0003849   .0001962     1.96   0.050     2.74e-07    .0007695
       _cons |   5.656192   5.967254     0.95   0.343    -6.039412     17.3518
------------------------------------------------------------------------------
Root Mean Squared Error (sigma): 0.0227
```

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