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Foreign Aid and Energy

Analyzing Energy Aid's Impact on sub-Saharan African Countries' Electrification Development

Master's thesis in Industrial Ecology

HANDAN ZHANG

DEPARTMENT OF SPACE, EARTH, AND ENVIRONMENT
ENERGY TECHNOLOGY DIVISION
CHALMERS UNIVERSITY OF TECHNOLOGY

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www.chalmers.se

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Supervisor:

Elias Hartvigsson, Department of Space, Earth, and Environment
Georgia Savvidou, Department of Space, Earth, and Environment

Examiner:

Erik Ahlgren, Department of Space, Earth, and Environment

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Abstract

Despite the continued flows of foreign aid on energy development to the sub-Saharan African region, more than half of the population lacks access to electricity. Achieving Sustainable Development Goal 7 and providing clean energy requires further development aid in the region. However, aid's role in development has so far been inconclusive. Research on the impact that finance flows in different energy sectors, such as energy generation and energy policy, hasn't gained much attention, mainly due to the lack of disaggregated data available until now. This research thus tries to look into energy aid's impact on electrification rate through energy sub-sectoral aid data.

This study uses two regression models to study aid's impact on energy development in sub-Saharan African regions. An ordinary least squares model was built to analyze energy aid's impact on the electrification rate with other macroeconomic factors such as economic growth, inflation, and trade openness, as well as countries' governance scores. An autoregressive distributed lag model is used to study sector-specific aid's impact on electrification rate in different country groups based on income.

Results from the ordinary least squares model confirm aid's inconclusive role in energy development but prove that an increase in inflation rate is correlated with higher electrification rate changes. Trade openness showed no significance, while governance changes indicate a positive relationship with changes in the electrification rate. The panel autoregressive distributed lag model found that aid's impact differs among country groups. The electrification rate in the two lower income groups correlated with different energy aid. In comparison, only the electrification rate in the past period correlated with electrification in higher-income country groups.

This study calls for future research to look into countries that receive large blocks of energy aid but shows little development, as well as countries that, despite receiving low amounts of energy aid, they have increased electrification rates, to understand what other factors influence the increase in electrification rate in SSA countries.

Acknowledgments

For most of us, access to reliable energy, especially for those who will read this text, access to clean, affordable, and reliable energy is taken for granted. However, its importance can only be felt when its absence is noticed. Energy and electricity are not only related to a healthy indoor environment and enhanced opportunities but also sources of life and safety in extreme weather conditions. Yet, in some areas of the world, access to electricity is still considered a luxury good. Has the energy aid donor countries provided assisted positively, and how macroeconomic factors and policies affect energy development are questions driving this research.

My interest related to energy was first triggered in the Energy, Environment, and Social Change course at the 2018 Summer School at the University of Oslo. It has led to me studying more about this topic and eventually taking a Master's degree in Industrial Ecology. The ideology behind the right to education allowed me to pursue what I am passionate about.

First and foremost, I would like to thank my supervisors – Elias Hartvigsson and Georgia Savvidou, as well as my examiner Erik Ahlgren. Thank you for giving me the opportunity to conduct research on an exciting and increasingly relevant topic. Your professional inputs not only helped directly with the study but also stimulated me to look into the topic from different perspectives. What goes beyond this work is that you taught me how to approach research and problem-solving in general.

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Last but not least, I'd like to thank my friends and family who supported me during these turbulent two years. Even though always from a distance, you gave me the courage to overcome hardships that would not be conquered alone. I am forever grateful for how lucky you make me feel.

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List of Abbreviations

SDG	Sustainable Development Goals
OLS	Ordinary Least Squares
ARDL	Autoregressive Distributed Lag
SSA	sub-Saharan Africa
ODA	Official Development Assistance
GDP	Gross Domestic Product
CPI	Consumer Price Index
OECD	Organization for Economic Co-operation and Development
CRS	Creditor Reporting System
DAC	Development Assistance Committee
UNCTAD	United Nations Conference on Trade and Development
FDI	Foreign Direct Investment
D-W	Durbin Watson
ADF	Augmented Dickey-Fuller
PP	Philips-Perron
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
IMF	International Monetary Fund

1 Introduction

Although progress toward many sustainable development indicators has been observed globally since the adoption of the Sustainable Development Goals (SDG) in 2015, progress in some SDGs has been slow or even negative during the past years. Technological advancement indicators such as increased access to mobile networks and enhanced access to technology by increasing internet use have shown the most progress in all regions globally (UN, 2021). At the same time, considerable disparity persists among regions. In general, Eastern and South-Eastern Asia and the developed countries in Europe, Northern America, Australia, and New Zealand have shown significant advancement in all areas except for goals 8, 9, and 15, mostly related to social and environmental resilience. They are closer to meeting the SDGs than Asia and Africa (UN, 2021). However, the impact of the COVID-19 pandemic has been perceived in the world's efforts to achieve SDGs. Food security (SDG 2), employment (SDG 8), and biodiversity protection (SDG 15) have backtracked in almost all regions (UN, 2021). Overall, wide gaps remain to meet the goals in 2030.

In Sub-Sahara Africa, foreign aid continues to play a vital role in achieving SDG goals such as poverty reduction and food security (Mahembe & Odhiambo, 2019; Petrikova, 2015). However, as countries focus on domestic economic recovery, the world is likely to see a reduction in foreign aid and the reposition of aid for basic needs such as poverty reduction, food, and health (UNEP, 2021). Therefore, continuing financing for SDGs in Sub-Saharan Africa (SSA) and effective use of foreign aid will affect the progress of SDGs in the future.

Between 2002 and 2019, $1 trillion in development finance was committed to SSA (Atteridge et al., 2019). Of this, 83% has been disbursed to recipient countries mainly through channels like Official Development Assistance (ODA) grants, ODA loans, and non-Export Credit. In the SSA region, aid support for basic needs is more prevalent. Emergency Response, Population policies/ programmes & reproductive health, and Health are the top three sectors, accounting for 26% of the total aid received by SSA. Energy comes in sixth place and makes up for 7% of the total aid received in the region.

In 2019, 47% of the region's population had electricity access (World Bank, 2022a). The number of those who live in rural areas is even less, reaching only 28%. On the contrary, the number of people with access to electricity in the urban population is 78%—great energy inequality is present between urban and rural areas. The population in SSA is expected to double in 2050 compared to its 2019 level (United Nations, 2019). Currently, in 2020, the majority of the population lives in rural areas (World Bank, 2022b). This trend will revise in the near future as urbanization continues and absorb the large majority of the population growth in the region (United Nations, 2019). Therefore, ensuring sufficient electricity access based on the current population and the expected growth is essential in fulfilling SDG 7.

Despite development aid's doubling in clean energy support in developing countries from 2010 to 2017 (the World Bank, 2020), energy poverty remains a challenging issue in SSA. Estimation states that in 2030, 85% of the 620 million people living without electricity will be in SSA. SDG 7 targets affordable and clean energy – "ensure access to affordable, reliable, sustainable and modern energy for all." The region demands not only electricity but also energy from clean and sustainable sources. From 2002 to 2019, foreign aid for renewable energy projects increased from 41 million USD to 1282 million USD. In relative terms, the share of aid for renewables has increased from 10% of total aid for energy projects to 29%, more than doubling in shares (Atteridge et al., 2019). At the same time, total energy aid to SSA has increased 11 times, from 399 million disbursed in 2002 to 4.5 billion in 2019. Transitioning to a clean energy system in Africa requires a further doubling of the current annual investment and an inflow of around $40-65 billion by 2030 (IRENA, 2021). Foreign aid for energy development thus remains crucial to achieving SDG 7 in SSA.

1.1 Aid’s impact

Despite the consensus on the need for energy investment in SSA to advance its position toward SDG 7 (African-EU Energy Partnership, 2021), researchers fail to provide robust results on foreign aid’s role in development (Berlin, 2015; Doucouliagos & Paldam, 2009). In general, research on foreign aid has been directed toward two areas: the effectiveness of aid and the determinants of aid (Alesina & Dollar, 2000; Bruck & Xu, 2012; Harford & Klein, 2004). The former studies whether foreign aid affects the recipients and what kind of influences they have. These studies have traditionally focused on aid’s effect on countries’ economic growth development (i.e. (Boone, 1996; Collier & Dollar, 2001; Doucouliagos & Paldam, 2009). With the introduction of Millennium Development Goals and Sustainable Development Goals, research has extended to different development goals, such as poverty reduction, health, and education. The latter asks why donors choose particular recipients’ countries and when they give aid (i.e. (Alesina & Dollar, 2000; Bruck & Xu, 2012)).

Among the economists, aid effectiveness research has studied aid’s effect on economic growth, development, savings, and investment. Such research are categorized as aid effectiveness literature within the field of economics. Three conclusions are often drawn through econometric analysis – lack of correlation between foreign aid and economic growth, good governance in recipient country as a determinant for aid effectiveness, and how real exchange rate undermines aid’s effect. Boone (1996) found aid has no significant impact on human development indicators. Ijaiya and Ijaiya (2004) used regression analysis on panel data to study the relationship between foreign aid and poverty reduction in SSA. They found a negative relationship between the two and argued that weak governance and political instability in recipient countries are two contributors to the results. Doucouliagos and Paldam (2009) applied meta-analysis on 97 econometric studies on aid effective literature. They found that aid has little effect with statistical significance on countries’ aggregated savings and economic growth. Burnside and Dollar (2000) found that aid only contributes to growth when countries have low inflation and budget deficits and high trade openness. Collier and Dollar (2001) argued the role of good governance – foreign aid must be accompanied by efficient policy to affect growth positively.

The real exchange rate is another reason mentioned in the literature. The real exchange rate is compared to the natural resource dilemma for the least developed countries (Rajan & Subramanian, 2011). When a country’s real exchange rate appreciates, its purchasing power decreases despite its increasing export revenue. In their meta-analysis, Doucouliagos and Paldam (2009) suggested that the re-evaluation of the real exchange rate due to the foreign aid inflow could explain why there is little relationship between aid and growth. Rajan and Subramanian (2011) used regression to test whether industries are affected by the exchange rate appreciation. They concluded that aid inflows cause the real exchange rate to appreciate, negatively affecting recipient countries’ competitiveness.

The same divergence is also present in research on whether foreign aid positively affects energy development in developing countries. Where aid effectiveness literature generally used econometrics to study aid's effect on the macro level, aid effectiveness on energy development often employs case studies as the preferred method to assess individual energy projects' effectiveness.

Munyanyi and Awaworyi Churchill (2022) studied the relationship between foreign aid and energy poverty in Senegal through geospatial impact evaluations. They found a positive relationship between aid projects and energy poverty reduction. Their analysis concluded the relationship between energy poverty and income poverty, education, and economic growth. Wang et al. (2021) showed ODA's positive impact on renewable energy development in 35 SSA using Panel Threshold Regression model, and Dornan and Shah (2016) found aid's similar contributions to renewable energy projects' sustainability for Small Island Developing States. Kretschmer et al. (2013) performed a dynamic panel Generalized Method of Moments and Least Squares Dummy Variable Corrected estimations using energy consumption, Gross Domestic Product (GDP), and industry value data from the World Bank. They found that foreign aid improves energy efficiency in developing countries. Sarpong and Bein (2021) used the Generalized Method of Moments method with different control variables across three models. They found that ODA projects negatively impact recipient countries' human development and quality of life for selected SSA countries. Monroy and Hernández's (2005) study of developing countries' rural areas concluded that NGOs' renewable energy projects tend to have the best performance against all other providers, while the private sector has the worst results. The inadequate institution has also been identified in other studies as a challenge to successful energy projects (Benecke, 2008; Sergi et al., 2018; Trotter & Abdullah, 2018). Simmet (2018) states that better social and political institutes stay essential drivers for energy development, more important than foreign aid itself.

Despite the abundant literature on aid effectiveness on economic growth and development, foreign aid's relation to energy is less studied. Research on the effectiveness of aid on energy is primarily based on country and project-specific research. To the best of my knowledge, there have been no studies using sub-section financial flows for the energy sector to research their impacts on electrification rates. And little research investigated the effect of foreign aid on the electrification rate in SSA on the macro level. There is a lack of studies on foreign aid's effect on energy development across countries in SSA. This study aims to bridge the gap between the prior research on energy projects' effect on electrification in specific regions and countries and conduct a macro-level analysis of how development-related factors interact with the success of energy development in SSA. The following two research questions will define the study.

1. Does sectoral aid impact the electrification rate for selected countries in sub-Saharan Africa?
2. Does sector-specific foreign aid's impact on electrification rates vary among selected countries?

2 Methodology

This chapter presents the overall research design that guided the study – exploring the impact of energy aid on SSA countries' electrification rate. After the research design is presented, the chapter concludes with the method and models used to analyze aid's impact on the electrification rate.

2.1 Research design

The study intends to use a quantitative framework to test the correlation between the electrification rate and energy aid and other macroeconomic factors. To analyze the impact of energy aid on SSA countries' electrification rate, the study plan to look at 35 countries in SSA regions based on electrification rate data availability from 2002 to 2019, regardless of their income levels. This allows the results to show whether there are significant differences among countries based on categorization. Due to data availabilities, a total of 35 countries were included in the final analysis. Four energy aid sub-sectors – Energy policy (shorten for Energy policy and administrative management), Energy distribution (shorten for Electric power transmission and distribution (centralized grids)), Energy generation from non-renewable sources, and Energy generation from renewable sources, are used in the study to understand different sectoral aid's impact on electrification rate in SSA countries. Including all countries in the region helps answer research question two (RQ 2): Does sector-specific foreign aid's impact on electrification rates vary among selected countries? In this research, countries were divided into three groups based on their income level.

Based on the literature and prior research review, the following hypotheses are developed to test the impact of foreign aid on the electrification rate in SSA countries. To test for the respective hypothesis (H) linked to RQ 1 and RQ 2, two regression methods - the Ordinary Least Squares (OLS) and the Autoregressive Distributed Lag model (ARDL) are used. The following table, Table 2-1 summarizes the different hypotheses used in this research.

H1s aim to answer RQ 1, looking at energy aid and different macroeconomic factors' impact on the electrification rate. Four sub-hypotheses are constructed within H1s to look at the effect of energy aid, economic development, macroeconomic factors, and the combination of all three related to the electrification rate respectively. OLS is adopted to answer research question one and the corresponding four H1s. The OLS model is adopted to study the relationship between the dependent and independent variables.

Table 2-1 illustrates the hypothesis and models produced to answer research question one. Four different H1s are generated to test for research question one; each hypothesis coincides with respective models using OLS with different variables, as listed in the figure. Which includes the independent variable – energy aid, as well as control variables – Consumer Price Index (CPI), GDP, governance, and trade openness, to control for energy aid's effect on the model.

Table 2-1 Summary of hypothesis

	Hypotheses
H1-0	***Energy aid has no impact on elefectrification rate for sub-Saharan African countries.***
H1a	***Energy aid impacts electrification rate for SSA countires.***
H1b	***Country's GDP level plays a bigger role in determining SSA countires' electrification rate than energy aid.***
H1c	***Trade openness and good governance impacts the electrification rate in SSA countries.***
H1d	***Energy aid together with macro-economic factors influence the eletrification rates in SSA countries***
H2-0	***Sector- specific aid for energy has same impact on all sub-Saharan African countries.***
H2a	***Different country categories react differently to individual sector-specific aid for energy.***

As Figure 2-1 shows, H1a tests for the sole impact of energy aid, H1b includes GDP to study the effect of economic conditions on the electrification rate. H1c then looks into other macroeconomic factors, H1d then brings all variables into one model to test for their combined effect on the electrification rate in SSA countries. These models and hypotheses are later applied to the panel data for the 35 SSA countries.

At the same time, H2s are constructed for RQ 2 to test for the differences among countries by dividing countries into income groups. ARDL model is used to answer RQ 2 and H2 due to its ability to handle non-stationary data as well as allow seeing the lagged effect on both dependent and independent variables.

Figure 2-2 gives an overview of the approach to answering RQ 2. One hypothesis is tested using the model produced by the Autoregressive Distributed Lag (ARDL) model. This model tests for different energy sectoral aid's impact on electrification rate; thus, four independent variables – aid for energy policy, aid for energy distribution, aid for energy generation from renewable sources, and aid for energy generation from non-renewable sources, are included. To identify the impact variation on different countries, SSA countries used in this study are divided into three country groups based on their income levels – low income, lower middle income, and upper-middle and high-income country groups based on the World Bank (2022)'s classification. The former two include 15 and 14 countries, while the last group with six countries. The list is presented in appendix 1.

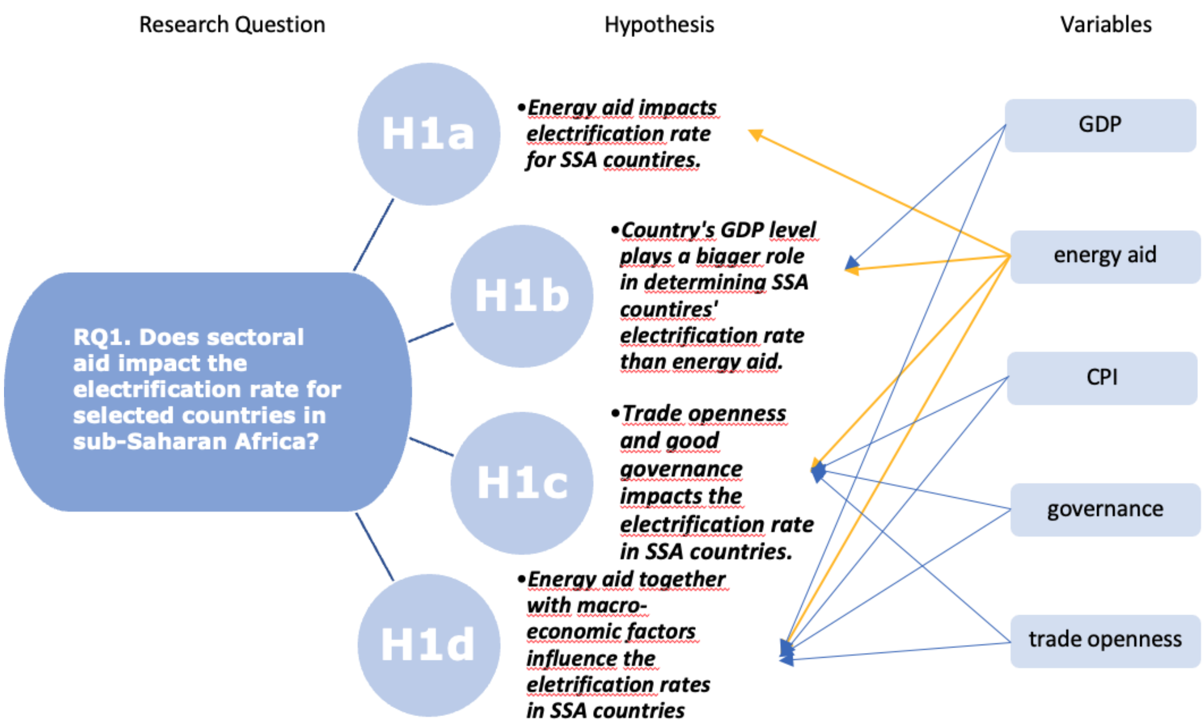

Figure 2-1 Method and data overview for RQ 1

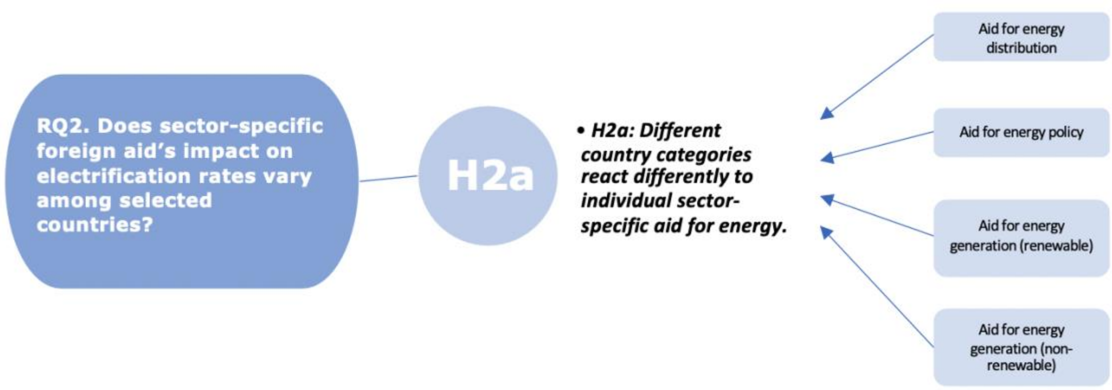

Figure 2-2 Method and data overview for RQ 2

2.2 regression analysis

This section presents the two models used in the study in detail. Regression analysis is a method used to test for independent variables' impact on the dependent variable. For RQ 1, four OLS models are constructed to test how energy aid and other macroeconomic variables' influence the electrification rate in the SSA region. Several macroeconomic factors, including inflation, economic growth, and trade openness, are included to test for foreign aid's effect on the electrification rate in selected SSA countries. The governance score is included in the independent variable to test for institutional quality's impact on the electrification rate.

2.2.1 Ordinary Least Squares

The linear regression model is widely used in empirical research to test correlations between variables. One of the subsets is the multiple linear regression model. It allows users to test the relationship between a dependent variable and one or more independent variables (Greene, 2018). The ordinary Least Squares (OLS) regression model as shown in *Equation **1*** is a sub-set of multiple linear regression model, it is used to estimate the unknown parameters in a linear model (Montgomery et al., 2006). It is useful in helping to find the correlation between the dependent variable y and the independent variables x. The general form of the OLS is expressed as following:

$$y_i = \alpha + \beta_i \cdot x_i + \varepsilon_i$$

Equation 1

where the left side y is the dependent variables, and the right side of the equation lists the independent variables used to explain the y. Parameter α represents the constant on the y-axis, β is the coefficient of the linear regression. ε is the error term in the model.

Multiple regression gives the advantage for the research to analyze the different independent and control variables' contribution to the electrification rate. However, as a disadvantage, impact variables beyond the model are not captured. This is a general critique of statistical models.

The following four OLS models are established to test hypotheses H1-0 to H1d. Model 1 is established to test for H1a – Energy aid impacts on electrification rate for SSA countries. Model 2 is used to test for H1b, which includes the GDP growth rate for each country and countries' GDP level in natural logarithm form to test for GDP's relative impact on electrification rate compared to energy aid. For H1c Model 3, it includes other macroeconomic factors including inflation and trade openness and country's governance score to test for the aspects mentioned in prior literature. Model 4 tries to include all the macroeconomic factors that are used in the models together with policy aspects and energy aid. Model 4 thus tests for H1d – for the combined effect of those variables on electrification rate in SSA.

Model 1:

$$\ln elec = \alpha_0 + \beta_1 \cdot \ln energy + \varepsilon_i$$

Model 2:

$$\ln elec = \alpha_0 + \beta_1 \cdot \ln energy + \beta_2 \cdot \ln gdp + \beta_3 \cdot dGDP + \varepsilon_i$$

Model 3:

$$\ln elec = \alpha_0 + \beta_1 \cdot \ln energy + \beta_2 \cdot \ln cpi + \beta_3 \cdot \ln govern + \beta_4 \cdot \ln trade + \varepsilon_i$$

Model 4:

$$\ln elec = \alpha_0 + \beta_1 \cdot \ln energy + \beta_2 \cdot \ln gdp + \beta_3 \cdot dGDP + \beta_4 \cdot \ln cpi + \beta_5 \cdot \ln govern + \beta_6 \cdot \ln trade + \varepsilon_i$$

2.2.2 Autoregressive distributed lag

RQ 1 is concerned of the combined effect of foreign aid and other macroeconomic factors, whereas RQ 2 only takes into accounts of the different energy sub-sector aids. Therefore, the lagged effects in RQ 2 takes a larger portion in determining the electrification rate than RQ 1, making it inappropriate to use OLS model.

To answer RQ 2, ARDL model is constructed to study the different effect energy aid have on various country groups.

ARDL is a standard least-squares regression type incorporating the lags in dependent and independent variables as regressors (Greene, 2018). It is the primary model used in the dynamic single-equation regressions (Hassler & Wolters, 2006). It allows the research to incorporate past period's impact in the model.

A problem related to foreign aid's effect on economic growth is aid's lagged effect. The same issue is also valid with energy projects. Large energy distribution projects and hydroelectric power plant construction take place over longer time horizons than projects like the distributed solar system. Therefore, it is necessary to consider the lag effect to determine energy aid's effect on the electrification rate. ARDL allows the study to understand the lag effect existing between aid and electrification by including the past period's foreign aid's impact in the model. This helps researchers to determine the effect of the change of certain variables.

ARDL follows a general form of the following as in *Equation **2***: the second part, $\sum_{i=1}^{p} \gamma_i y_{t-i}$, represents the autoregressive variables, and the third part, $\sum_{j=0}^{r} \beta_j x_{t-j}$, shows the distributed lag variables.

$$y_t = \mu + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=0}^{r} \beta_j x_{t-j} + \delta w_t + \varepsilon_t$$

Equation 2

The following model is constructed to test and compare energy sectoral aid's impact on the electrification rate across different country groups in the SSA region. For each variable, the model considers two time periods back to include the lag effects.

$$\begin{aligned} \ln elec = \mu &+ \gamma_1 \ln elec_{t-1} + \gamma_2 \ln elec_{t-2} + \beta_0 \ln AidErgDis_t + \beta_1 \ln AidErgDis_{t-1} + \beta_2 \ln AidErgDis_{t-2} \\ &+ \beta_4 \ln AidGenRe_t + \beta_5 \ln AidGenRe_{t-1} + \beta_6 \ln AidGenRe_{t-2} + \beta_7 \ln AidGenNr_t \\ &+ \beta_8 \ln AidGenNr_{t-1} + \beta_9 \ln AidGenNr_{t-2} + \beta_{10} \ln AidErgPoli_t + \beta_{11} \ln AidErgPoli_{t-1} \\ &+ \beta_{12} \ln AidErgPoli_{t-2} + \delta w_t + \varepsilon_t \end{aligned}$$

The assumption behind the model is that the error term, ε_t should be serially uncorrelated and homoscedastic. The conditions are thus tested for the models in the results section.

3 Data collection and processing

This chapter starts with data collection of dependent and independent variables used in the study, followed by the limitations of the data used. The second part of the chapter presents the procedures taken in data processing, and how the data are prepared and transferred are described.

3.1 Data collection

The following table, Table 3-1, gives an overview of the dependent, independent, and control variables used in the analysis. Data between the period of 2002 and 2019 were collected. Dependent variables were taken from the Organization for Economic Co-operation and Development (OECD) Creditor Reporting System (CRS) database; most control variables data were from the World Bank database, where the governance index is taken from the Notre Dame Global Adaptation Initiative.

Table 3-1 Definitions and sources of the variables

Variable in model	Full name	Definition	Sources	Data availability
AidErgPol	Energy policy	Foreign aid for energy policy as a % of GDP	OECD CRS[1]	2002 - 2019
AidErgDis	Energy distribution	Energy aid for energy distribution as a % of GDP	OECD CRS	2002 - 2019
AidGenRe	Energy generation, renewable sources	Foreign aid for energy generation from renewable sources as a % of GDP	OECD CRS	2002 - 2019
AidGenNr	Energy generation, non-renewable sources	Foreign aid for energy generation from non-renewable sources as a % of GDP	OECD CRS	2002 - 2019
energy	Total energy aid	Foreign aid for energy as a % of GDP	OECD CRS	2002 - 2019

[1] OECD CRS https://stats.oecd.org/Index.aspx?DataSetCode=crs1

govern	Governance index	Governance score for countries.	Notre Dame Global Adaptation Initiative[2]	2000 - 2019
cpi	Consumer price index	Consumer price index (2010 = 100)	World Bank, IMF[3]	1960 - 2020
gdp	Real GDP per capita, growth rate	The growth rate of GDP per capita	World Bank[4]	1961 - 2020
trade	Trade openness	The ratio of exports plus imports over GDP	World Bank[5]	1987 - 2021
elec	Electricity access rate	% of population that has electricity access	World Bank[6]	1990 - 2019

3.1.1 Dependent variable

The electrification rate for countries in the SSA region was thus collected to answer research question one. The period from 2002 and 2019 is used due to the limitation set by the available aid data. World Bank (2022a) provides comprehensive data on countries' access to electricity. World Bank's statistics on countries' percentage of the population with access to electricity are made by nationally representative household surveys such as the Demographic and Health Surveys (DHS), the Living Standards Measurement Surveys (LSMS), Multi-Indicator Cluster Surveys (MICS), and the World Health Survey (WHS) (World Bank, 2022a). Even though the access rate for urban areas is quite complete, the data on the electrification rate for rural areas is somewhat limited to only 15 countries. Thus, this study only uses the country's electricity rate without differentiating rural and urban areas. Countries with more than three consecutive missing values are excluded from this research. This excludes the Republic of the Congo, Guinea-Bissau, Equatorial Guinea, Liberia, Sierra Leone, and South Sudan, leaving 42 countries with available electrification rate data for analysis.

3.1.2 Independent variables

This section introduces the independent variables - energy aid and other macroeconomic factors, as well as how corresponding data are collected.

3.1.2.1 Energy aid

To study energy aid and energy sectoral aids' impact on electrification, financial flow data from donor countries that contributed to the SSA countries with a specific focus on energy are used as the independent variables for the OLS and ARDL models.

The research used the foreign aid data from Organization for Co-operation and Development (OECD) 's Creditor Reporting System (CRS). The CRS is a reporting system

[2] GAIN https://gain.nd.edu/our-work/country-index/
[3] CPI https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
[4] GDP https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
[5] Trade openness https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS
[6] Electrification rate https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS

established by the OECD to help classify foreign aid information in the DAC databases. CRS datasets are recorded per transaction with information on transaction amount, recipient country, donor, year, sector, and sub-sectors. OECD's CRS covers official aid through bilateral aid from Development Assistance Committee (DAC) countries, multilateral aid, and aid from some non-DAC countries, as well as private donors. The CRS uses pre-defined codes to categorize aid flows through donor, agency, recipient, major channels of delivery, whether the aid is bilateral or multilateral if the aid is through ODA, other official flows, or private flows, the type of finance, like grants or loans, sector of the foreign aid is targeting, and other categorizations that are related to the foreign aid flow (OECD, 2022). Through this protocol, donors report their aid flows to the DAC database. It is a comprehensive database that captures most foreign aid transactions reported to the OECD. The dataset captures the support provided as foreign aid disbursements that target development areas in 48 sub-Saharan countries. As an exception, China does not report its contribution to the committee.

For independent variables, total energy aid flow is used in the OLS to study aid's impact on electrification rate; energy sectoral aid flow is used for the ARDL model to test for different energy sector's impact on various country groups. The energy sector contains seven sub-sectors that further divide energy aid into energy distribution, energy generation from non-renewable sources, energy generation from renewable sources, energy policy, nuclear energy plants, hybrid energy plants, and unspecified energy projects. The first four categories account for 99% of the energy aid. Therefore, they are used as the independent variables in the regression analysis for ARDL.

3.1.2.2 Macroeconomic factors

Economic growth, good governance, and trade openness are used as the macroeconomic factors for the independent variables. Economic growth is represented by inflation through the CPI and countries' GDP per capita growth rate. This study thus includes the following as control variables: governance, economic growth, inflation, and trade openness, controlling the effect that other factors contribute to a country's electrification rate.

As prior research suggested, institution and governance strength are strong indicators for aid success and energy project success (Simmet, 2018; Trotter, 2016). The study has incorporated governance score to represent this aspect using data from the Notre Dame Global Adaptation Initiative (ND-GAIN) (GAIN, 2022). The governance score is calculated based on four indicators, "Political stability and non-violence", "Control of corruption", "Regulatory quality", and "Rule of law" (Chen et al., 2015).

Burnside and Dollar (2000)'s theory on low inflation and high trade openness's role in aid effectiveness is represented by including inflation and trade openness indicators as control variables. CPI and trade openness data used in the research is taken from the International Monetary Fund (IMF) and the World Bank database. Economic growth, as one of the most used variables to study aid effectiveness, is represented through countries' GDP per capita growth rate. Some countries lack the data observed in recent years; those are thus excluded from the analysis.

Even though electrification is a complex question and involves many social-economic factors, the research chooses to constrain the above variables to control the effect originating from the sectoral foreign aid. Condition testing are later conducted to validate the models' reliability through statistical tests.

3.1.3 Data limitation

The electrification rate data from World Bank is obtained through annual household surveys, major missing value is present for rural areas, where the majority of the population is located. This indicates that the reliability of certain population shares' electrification rate is low. At the same time, the study differentiates the aid energy generation from renewable and non-renewable sources. But it is impossible to know their impacts due to the lack of data on energy from renewable and non-renewable projects.

The OECD dataset captures the Official Development Aid flows, such as foreign aid from the traditional DAC countries and multilateral aid. But it excludes Foreign Direct Investment (FDI) and aid data from China. FDI data is partially available from the United Nations Conference on Trade and Development (UNCTAD) STAT database. However, data is gathered at a much-aggregated level and are categorized based on industry. This limits the possibility of testing private investment's role in controlling foreign aid's effect on the electrification rate. China does not report directly to OECD's CSR database, making it challenging to include China's contribution to the electrification in SSA countries. Together, the lack of complete energy aid data for SSA countries and private investment for energy projects data gives obstacles to investigating the total energy aid's impact on the electrification rate in curious countries.

The study also limits its scope to the period between 2002 and 2019, as OECD recommends using data after 2002 for completion issues. This prevents the possibility of analyzing the different countries' electrification development as countries evolve from different stages.

3.2 Data processing

This section briefly introduces how the data was prepared, how missing values were treated, and how data was normalized and transformed for the analysis.

3.2.1 Data preparation

Energy aid data are aggregated into country-year-sub-sector and country-year-sector data. In the end, 18 years for 39 countries across four sub-sector level aggregated data was obtained.

For dependent and control variables, the dataset comes with all countries and years; relevant countries and years are extracted from the original data. Missing data are recorded at the stage for further treatment.

3.2.2 Missing values

Based on the importance of the dependent variable on the model, missing values are handled from the dependent variable, then to the independent variables.

For the electrification rate, as it is the dependent variable, stricter data selection criteria were chosen. Countries with more than two years of data point loss are excluded. For missing data, when one year is missing in between two years, the average of the direct adjacent two data points is taken. An average growth rate is calculated based on past or future six years' data for data missing with two adjacent values. The growth rate is then applied to predict the electrification rate in the missing year. This excludes six countries from the data for analysis – the Republic of Congo, Guinea-Bissau, Equatorial Guinea, Liberia, Sierra Leone, and South Sudan.

South Sudan, Somalia, and Eritrea are excluded for incomplete GDP data, Congo, Dem. Rep. is taken away from the data for lack of governance points. For CPI, Sao Tome & Principle, Zimbabwe, Mozambique, Comoros, and Guinea showed missing data. Instead of mean value and growth rate, missing data related to CPI are calculated based on countries' GDP deflator (annual %). This is because the GDP deflator and CPI are commonly used as inflation indicators. Therefore, there is a close correlation between the two variables.

For trade openness, Ethiopia misses the period from 2002-2010, Lesotho 2002-2006, Malawi whole period, and Sao Tome & Principle whole period. Unlike CPI, there are no direct correlating indicators that can be used. A total of 50 missing values were found. Due to the fluctuation in the trend, the growth rate is also difficult to apply here. Missing values are therefore left as 0, causing irregularity in the dataset. Therefore, all countries with missing data are excluded from the analysis. This leaves the panel data 35 countries from the initial 47, with a final sample size of 630. As the sample size is still ten times bigger than the independent variables used in the analysis, the sample size is considered large enough (Barlett et al., 2001). Therefore, it is valid to use for further data analysis.

3.2.3 Data normalization and transformation

As OLS generally does not cope with missing values well, a data normalization procedure was done to help smooth the data and make the data more reliable for the regression analysis. Due to frequent missing data points and yearly differences, sector-specific energy aid are transformed into accumulated values. This is then normalized by taking the percentage per GDP of that country on a yearly basis. Because GDP is recorded as millions USD annually, sector-specific energy aid thus is also divided by one million to have a uniform unit. To reduce the fluctuations presented in data, especially for independent variables, year-to-year fluctuation can lead up to millions.
Aid data is transformed first by taking the cumulative value for each year, which helps reduce the number of missing values in the dataset. GDP scores are divided by population to gain each country's GDP per capita value.

Log transformation is done on all variables to reduce the skew in distributions. Since both dependent and independent as well as the control variables, are transformed into logarithmic values, the interpretation of the results should also be modified accordingly. Therefore, the results should be read as how much percentage the dependent variable changes when the independent variables are increased by one percent.

4 Results

This chapter presents results from the Ordinary Least Squares (OLS) and the Autoregressive Distributed Lag (ARDL) models. It starts with OLS' results in testing energy aid's impact on electrification rate in SSA countries. This is followed by the results generated through the ARDL model, where the energy aid sub-sectors are tested for three different income groups in SSA countries. The overarching results are summarized in Table 4-1.

The following table summarizes the findings from the OLS and ARDL models. For both H1 and H2, the null hypotheses are rejected, indicating that energy aid indeed has an influence on the electrification rate in SSA countries. All hypotheses were supported or partially supported by the analysis. Energy aid and macroeconomic factors' influence on the electrification rates in SSA countries is concluded positively in H1d. H2a supports the hypothesis that different country groups indicate different reactions to sector-specific energy aid.

Table 4-1 Summary for hypothesis results

Hypotheses	Conclusion	Findings Summary
H1-0	Rejected	***Energy aid impacts electrification rate in SSA countries.***
H1a	Partial Support	***Energy aid partially explains for the electrification rate changes in SSA countries.***
H1b	Support	***The country's GDP level significantly determines SSA countries' electrification rate than energy aid.***
H1c	Partial Support	***Trade openness and good governance impact the electrification rate in SSA countries.***
H1d	Support	***Energy aid, together with macroeconomic factors, influence the electrification rates in SSA countries***
H2-0	Rejected	***Sector-specific aid for energy's impact differs for SSA country groups***
H2a	Support	***The electrification rate in lower-income country groups reacts to sector-specific aid for energy.***

4.1 Ordinary Least Squares

As shown in Table 4-2, this section presents the summary of the results from the OLS for the four models. The number for each variable represents the coefficient; it is interpreted as when there is a 1% increase in the independent variable, the dependent variable will increase by coefficient/100 unit. The r squared value, as shown in the same table, in a model explains the fraction of variance an independent variable in a regression model explains for the dependent variable.

In the results presented in Table 4-2, Model 1 has the lowest fitting; changes in energy aid show significance to the changes in electrification, but a shallow degree. The best-fitting model has further minimized energy aid's impact on the electrification rate. In the results for the four models from the OLS, model 4 shows the highest r-square adjusted value of 0.68. This means that the model explains 68% of the variance in the dependent variable.

Percentage changes in GDP in combination with the GDP change rate bring the model fitting to an r-squared adjusted of 0.67. The effect of inflation, governance, and trade changes shows positive relationships to changes in electrification rate in model 3 in Table 4-2. The same impact persists in model 4, whereas the effect of trade fade in model 4. As shown from model 4 in Table 4-2, changes in inflation measured by CPI, changes in GDP, and changes in governance dominance in their roles explain changes in electrification rate in SSA panel data in the model. All significant results show a positive relationship to the changes in electrification rate except for the energy aid variable.

Table 4-2 Results for the OLS

	Model 1	Model 2	Model 3	Model 4
R-squared	0.07433397	0.67160810	0.34131620	0.68586283
R-squared Adj.	0.07285997	0.67003434	0.33710062	0.68283743
const	50.84865008***	-146.06938739***	-200.34135577***	-193.06424382***
	(1.63134378)	(5.91920934)	(15.94352513)	(11.04942729)
dGDP		-0.32158740**		-0.21415649
		(0.14618837)		(0.14838612)
log_cpi			51.53990992***	16.61349604***
			(5.14224368)	(3.87182791)
log_energy	-5.89148526***	-0.33232377	-6.67424080***	-1.51455034***
	(0.82961862)	(0.52256315)	(0.77989765)	(0.58108407)
log_gdp		23.55472781***		21.44885797***
		(0.69809150)		(0.82072239)
log_govern			58.74555409***	16.36566557***
			(6.08584740)	(4.51472539)
log_trade			13.82263399***	1.58591272
			(1.76644561)	(1.31585210)
N	630	630	630	630
R2	0.07	0.67	0.34	0.69
R2-adjusted	0.0729	0.6700	0.3371	0.6828

Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01

Model 1 tests the simple correlation between the change in electrification rate and the percentage change in energy aid. The coefficient for energy aid shows a p-value of well below 0.1 percent. Thus, it can be concluded that changes in energy aid correlate with the electrification rate in SSA countries. The negative coefficient indicates that the relationship between the dependent variable aid for energy and the independent variable electrification rate is negative. This negative relationship between changes in energy aid and electrification rate persists under all models. As shown in Table 4-2, in model 1, for every 1% decrease in energy aid, the electrification rate will increase by 0.06 units. Due to the low R-squared adjusted value of 0.07, energy aid's impact only accounts for 7% of the development in electrification rate in SSA countries.

Model 2 incorporates economic growth variables to test the combined effect of GDP and energy aid on electrification rate development in SSA countries. As shown in Table 4-2, incorporating GDP into the OLS increases the R-squared adjusted from 7% to 67%. This indicates the dominant position economic growth has on the electrification rate in the variables considered. GDP has a positive coefficient of 23.55, which means that for every $554 million increase in GDP, the electrification rate will increase by 1%.

Model 3 tests for different macroeconomic variables' combined impact on electrification with energy aid. All control variables showed significant p-values and a positive relationship with the dependent variable. When CPI increases by 5%, governance score increases by 0.59 unit, trade openness increase by 2%, and energy aid decrease by 0.06%, the total impact combined by all the variables tend to explain 34% of the reason why the electrification rate increase by 1%. However, the combined effect is not as strong as the economic condition as tested in model 2, suggesting that in the SSA region, GDP has a dominant relationship with the electrification rate. Thus, it shows as a better indicator in the model.

As more variables are added, as per model 4, the model's explanatory power reached the highest among the four, but only slightly higher than model 2, to an R-squared adjusted of 0.68. Similar trends in models 2 and 3 continue in this model. Only trade openness' significance drops down to smaller than 0.1, making trade's role irrelevant concerning the electrification rate in this model.

From the results, the model concludes that the relationship between energy aid and electrification rate is complex; there is a controversial conclusion on whether the change in energy aid also led to a change in electrification rate in SSA countries.

4.1.1 Conditions for OLS

As regression models are built on limitations, several requirements must be met to interpret the results from the regression model correctly. In the following sections, three conditions, linearity, autocorrelation, and heteroscedasticity are tested to ensure the requirements are met for the statistical test.

4.1.1.1 Linearity

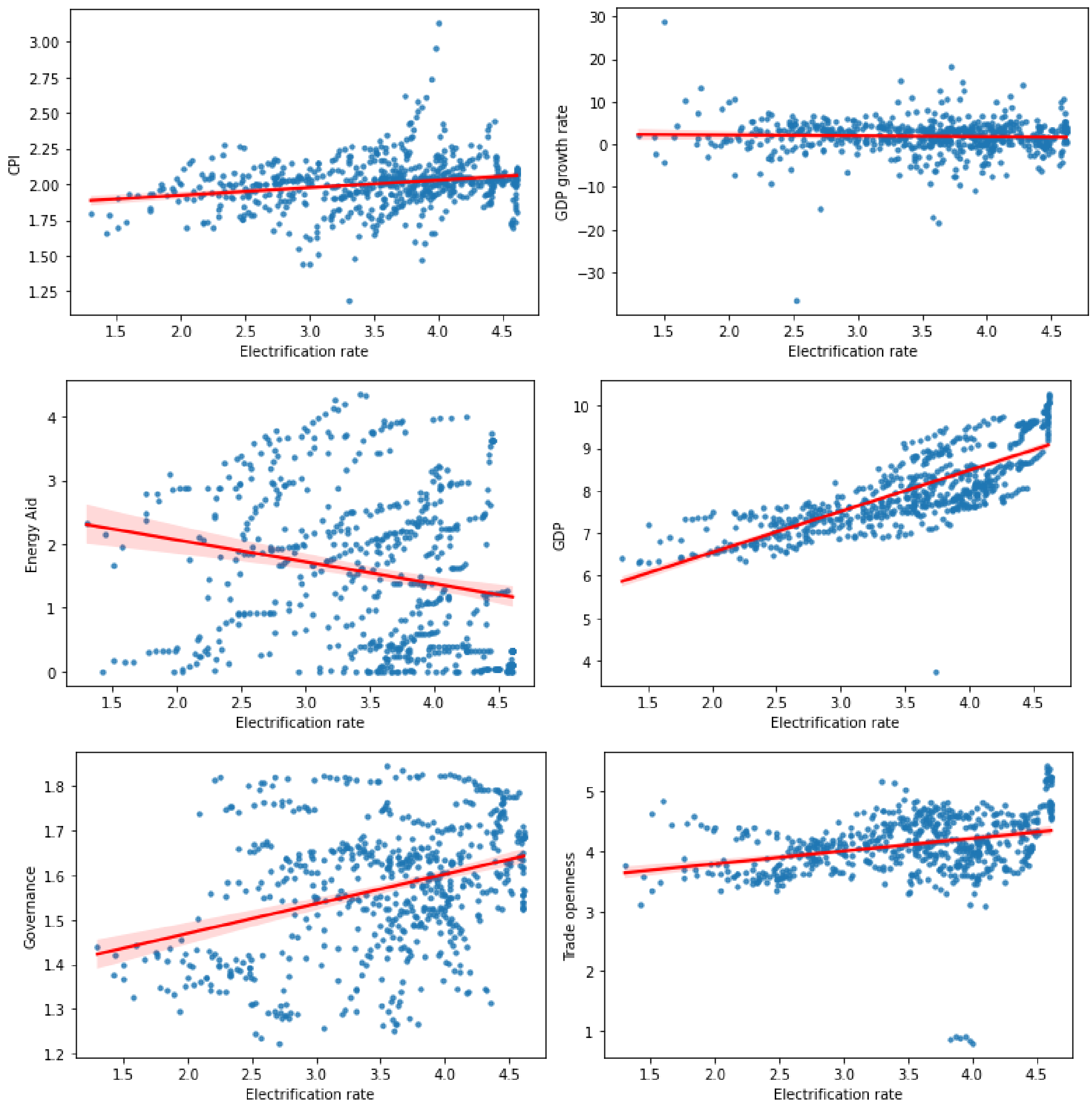

Figure 4-1 Electrification against different independent and control variables. From the top left, CPI, GDP growth rate, Energy aid, GDP, Governance, and Trade openness.

Figure 4-1 plots the relationship between each dependent variable and independent and control variables used in the multiple regression model. As Figure 4-1 shows, GDP growth rate, GDP changes, and changes in trade openness have a quite strong linear relationship with the dependent variable, changes in electrification rate. CPI shows mild linearity with the dependent variable. Changes in energy aid and governance have a somewhat volatile distribution against the changes in the electrification rate.

4.1.1.2 Autocorrelation

The Durbin Watson (D-W) statistic tests for autocorrelation in the model. A D-W statistic always tests for autocorrelation in the residuals in a regression model. It always has a value range between 0 and 4. It is commonly accepted to have a value between 1.5 to 2.5. A value smaller than 2.0 indicates a positive correlation, and a value above the level means negative autocorrelation among the variable. All four models show a D-W statistic lower than 0.25, meaning there is a significant autocorrelation between the variables. P values are suggested to be close to zero; the null hypothesis can be rejected and conclude that the time series used in all four are autocorrelated. One crucial component is that electrification rate as a time series with a clear up-ward trend corrupts the data and causes autocorrelation for the variables.

Table 4-3 Durbin Watson Statistic

	Autocorrelation	D-W Statistic	lag	p-value
Model 1	0.8928	0.2139	1	0
Model 2	0.8416	0.2503	1	0
Model 3	0.9001	0.1935	1	0
Model 4	0.8651	0.2240	1	0

4.1.1.3 Heteroscedasticity

Heteroscedasticity is the unequal distribution of residuals in a statistical model; in other words, the error terms are distributed without a clear linear pattern. OLS regression model considers its variance to be constant, meaning it is homoscedastic. Homoscedasity in the dataset will interfere with the correlation results, thus producing unreliable results.

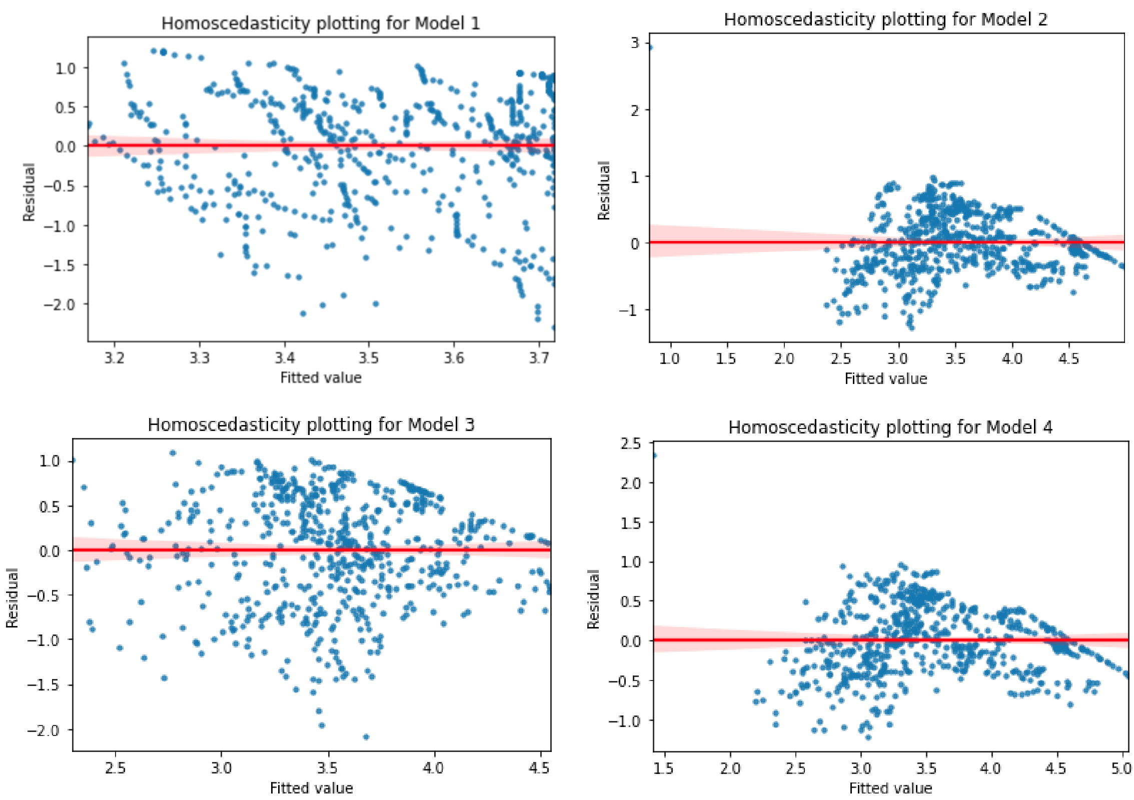

Figure 4-2 Homescedasticity plotting of fitted values against residuals in different models

As Figure 4-2 shows, there is no consistent relationship between the fitted value against the residuals in all models. This relationship from the initial plotting is further tested using the statistical tool Breusch Pagan test. The results are shown in Table 4-4.

Table 4-4 Breusch-Pagan test results for SSA panel data OLS models

	Model 1	Model 2	Model 3	Model 4
Lagrange multiplier statistic	3.35E+00	1.01E+02	2.40E+01	1.42E+02
p-value	6.73E-02	1.16E-21	7.85E-05	4.48E-28
f-value	3.36E+00	3.96E+01	6.20E+00	3.01E+01
f p-value	6.75E-02	1.82E-23	6.79E-05	8.86E-32

The null hypothesis indicates that homoscedasticity is present in the regression model. The alternative hypothesis indicates an unequal distribution of residuals. The null hypothesis is rejected when the p-value is smaller than 0.05, and heteroscedasticity is detected in the model.

As shown in Table 4-4, model 2 to model 4 all have a p-value significantly smaller than 0.05. It is concluded that heteroscedasticity exists in these three models. Whereas model 1 lands in the null hypothesis, concluding for homoscedasticity.

Approaches were taken to try to correct heteroscedasticity. In the initial attempt, the dependent variable is transformed through log transformation. As electrification rate, the dependent variable in this dataset has already been transformed into natural logarithm forms. Therefore, moving to the second solution, redefining the dependent variable by using its growth rate. Similar results have been obtained through this approach. Heteroscedasticity persists after transformation, encouraging careful interpretation of the results from the models.

4.2 Autoregressive distributed lag model

This section presents the results from the autoregressive distributed lag for three income groups in the SSA. For all three income groups, past year's changes in electrification rate have a positive relationship with the current changes in electrification rate. All three cases have a p-value small enough to validate the relationship between the two variables.

As shown in Table 4-5, for the low-income group, in the past two periods, in this case, the past two years, electrification rate changes seem to influence the current period's electrification rate. But two periods before have less impact on the current period than the direct adjunct year. Energy generation from both renewable and non-renewable generation also contributes a slight change to the changes in electrification rate. Changes in the current period energy aid show a positive relationship to the changes in the current period electrification rate. Still, for renewable and non-renewable generation, the changes in the last period negatively impact the changes in the current electrification rate. Similar results can be observed for lower-middle-income countries, as shown in Table 4-6. However, the results are very different in higher middle and high-income countries. Table 4-7 shows that only the changes in the past period electrification rate are relevant to the changes in the current period electrification rate in the country group with a higher income level. Energy aid does not explain the changes in the current period's electrification rate.

Table 4-5 ARDL Model Results for low income group

Dep. Varibale:	ln(elec)		No. Observations:		241
Model:	ARDL(2, 1, 1)		Residual SD:		0.2519
F-statistic:	178.7				
Adj. R-squared:	0.851		p-value:		<2.20E-16
Residuals:					
Min	1Q	Median	3Q	Max	
-1.4562	-0.0521	0.0292	0.1059	1.4592	

Coefficients:					
	Estimate	Std. Error	t-value	Pr(>|t|)	
Intercept	0.1236	0.0927	1.3340	0.1836	
ln(elec).L1	0.8207	0.0574	14.2950	<2.20E-16	***
ln(elec).L2	0.1167	0.0569	2.0520	0.0412	*
ln(dis).L0	-0.0260	0.0370	-0.7030	0.4829	
ln(nrgen).L0	0.2817	0.0740	3.8090	0.0002	***
ln(nrgen).L1	-0.2463	0.0741	-3.3240	0.0010	**
ln(policy).L0	0.0989	0.0471	2.0980	0.0370	*
ln(rgen).L0	0.2289	0.0747	3.0650	0.0024	**
ln(rgen).L1	-0.2344	0.0680	-3.4490	0.0007	***

Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 4-6 ARDL Model Results for lower-middle income group

Dep. Varibale:	ln(elec)		No. Observations:		260
Model:	ARDL(1, 1, 1, 1)		Residual SD:		0.1684
F-statistic:	194.7				
Adj. R-squared:	0.8525		p-value:		<2.20E-16
Residuals:					
Min	1Q	Median	3Q	Max	
-1.0070	-0.0366	0.0182	0.0652	0.7683	

Coefficients:					
	Estimate	Std. Error	t-value	Pr(>|t|)	
Intercept	0.2682	0.1200	2.2350	0.0263	*
ln(elec).L1	0.9283	0.0308	30.1170	<2.20E-16	***
ln(dis).L0	-0.0055	0.0242	-0.2290	0.8193	
ln(nrgen).L0	0.1399	0.0598	2.3390	0.0201	*

ln(nrgen).L1	-0.1406	0.0586	-2.4000	0.0171	*
ln(policy).L0	0.3035	0.0721	4.2110	0.0000	***
ln(policy).L1	-0.2811	0.0701	-4.0070	0.0001	***
ln(rgen).L0	0.1017	0.0524	1.9430	0.0531	.
ln(rgen).L1	-0.1037	0.0488	-2.1260	0.0344	*

Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 4-7 ARDL Model Results for higher-middle and high income group

Dep. Varibale:	ln(elec)		No. Observations:		101
Model:	ARDL(1)		Residual SD:		0.1153
F-statistic:	147.8				
Adj. R-squared:	0.8738		p-value:		<2.20E-16
Residuals:					
Min	1Q	Median	3Q	Max	
-0.9579	-0.0103	0.0108	0.0209	0.5152	

Coefficients:

	Estimate	Std. Error	t-value	Pr(>|t|)	
Intercept	0.3835	0.1597	2.4020	0.0182	*
ln(elec).L1	0.9127	0.0362	25.1800	<2e-16	***
ln(dis).L0	0.0445	0.0882	0.5040	0.6151	
ln(nrgen).L0	-0.0151	0.0637	-0.2370	0.8133	
ln(policy).L0	-0.0038	0.0533	-0.0720	0.9430	
ln(rgen).L0	-0.0104	0.0886	-0.1180	0.9066	

Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

For all country income groups, percentage changes in the past period contribute to 1% increase in electrification rate change in the current period. All groups show an intercept of close to 90%, indicating that the electrification rate changes are almost linear. For the high-income group, aid shows zero significance in predicting the current period's electrification rate. One of the reasons is that the majority of these countries already have close to full electricity access. Thus, energy aid does not show an impact on electrification. What research could consider studying is the relationship between the electrification rate and energy aid for South Africa. South Africa receives by far the largest share of energy aid. However, it has the lowest electrification rate among the higher middle and high-income country group.

For all country groups, the current period distribution showed no correlation with the electrification rate. One reason would be the long-time horizon transmission projects take, including planning, legislation, investment, and construction phase. As for both country groups, the optimal lagged period was a maximum of 2; the lagged effect from the energy aid for transmission could be challenging to capture in the model.

For all the other energy sectoral aid, energy generation from non-renewable sources, energy generation from renewable sources, and energy policy all showed a positive correlation to the percentage change in electrification rate based on their percentage change in the current period. At the same time, the lagged value of those variables in the period before shows a negative correlation with the percentage change in the current electrification rate. The possible explanation is that all the sectoral energy aid is transformed to cumulative value. Therefore, whenever a value is captured, the next year is guaranteed to have an increased value. And as energy aid is divided into four sub-sectors, the segregation between missing values becomes more vivid here. Due to the cumulative and missing values, the sectoral energy aid has a flat or upward trend. Therefore, when lagged values are used, the past period will always be a negative change compared to the current period. This could potentially explain why the past period negatively correlated with the percentage change in electrification rate in both the low and middle-income country groups.

4.2.1 Conditions for ARDL

This section presents the results of several key conditions for the ARDL model; this includes stationarity and co-integration.

4.2.2 Stationarity

Stationarity is a common issue in time series data. The unit root test is the typical statistical procedure used to determine a series' stationery. Standard methods are Augmented Dickey-Fuller (ADF), Philips-Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests.

This research uses the ADF together with PP and KPSS test to test the unit root in the transformed panel data because of its higher reliability than the PP test. However, issues around size distortion and low power testing are discussed as the weaknesses of both tests (Shrestha & Bhatta, 2018). Table 4-8 shows ADF results for the seven variables used in the ordinary least squared multiple regression model. All variables show a p-value significantly smaller than 0.001, which means that the hypothesis can be rejected and conclude that the panel data series are stationary. Similar results, as shown in Table 4-10 are obtained from the PP test, showing that the panel data series are stationary. However, KPSS shows a different result in Table 4-9, suggesting non-stationary in the panel data.

Table 4-8 ADF test results for SSA panel data

	log elec	log trade	log cpi	log energy	log gdp	log govern	dGDP
Test Statistic	-5.0546	-5.1206	-6.1954	-4.4322	-4.1554	-4.6742	-7.9483
p-value	1.70E-05	1.30E-05	5.98E-08	2.60E-04	7.83E-04	9.40E-05	3.18E-12
#Lags Used	3	6	18	20	0	0	9
Critical Value (5%)	-2.8662	-2.8662	-2.8663	-2.8663	-2.8661	-2.8661	-2.8662
Number of Obsservations Used	626	623	611	609	629	629	620

Table 4-9 KPSS test results for SSA panel data

	log elec	log trade	log cpi	log energy	log gdp	log govern	dGDP
Test Statistic	0.1160	0.1270	0.1440	0.7320	0.0620	0.1420	0.1200
p-value	0.5110	0.4670	0.4080	0.0110	0.8030	0.4140	0.4940
#Lags Used	15	15	12	15	16	16	8
Critical Value (5%)	0.4600	0.4600	0.4600	0.4600	0.4600	0.4600	0.4600

Table 4-10 PP test results for SSA panel data

	log elec	log trade	log cpi	log energy	log gdp	log govern	dGDP
Test Statistic	-5.3630	-5.5870	-7.8910	-6.2050	-4.3500	-4.9150	-18.2400
p-value	4.04E-06	1.36E-06	4.44E-12	5.67E-08	3.64E-04	3.26E-05	2.36E-30
#Lags Used	20	20	20	20	20	20	20
Critical Value (5%)	-2.8700	-2.8700	-2.8700	-2.8700	-2.8700	-2.8700	-2.8700

4.2.3 Cointegration for ARDL model

Because the ADF test reports that non-stationary variables are included in the model for high-income countries, the bounds test is used to test for cointegration. The bound F-test tests for all coefficients of the error correction terms are not zero. The bound t-test test that the coefficient on the lagged dependent variable, in this case, the electrification rate, is zero.

From Table 4-11, for the higher-middle and high-income group, the bounds t-test shows a t = -2.409, p-value = 0.5382, suggesting the alternative hypothesis, which means there is possible co-integration in the model. Similar results can be seen for the bound F-test. In the F-test, the same group showed a F = 1.4681, p-value = 0.7618, suggesting possible co-integration in the model. The same possible co-integration results are shown for the other two country groups. This result calls for caution when interpreting the results from the ARDL model.

Table 4-11 Co-integration results for ARDL model

	Bound t-test		Bound F-test	
	t	p-value	F	p-value
Low-income group	-2.0464	0.6823	2.4486	0.3556
Lower-middle income group	-2.3273	0.5728	-2.3273	0.5728
Higher-middle and high income group	-2.409	0.5382	1.4681	0.7618

5 Discussion

5.1 Energy aid and other macroeconomic variables' impact on electrification rate in SSA

The results from the OLS models confirm prior research (Berlin, 2015; Doucouliagos & Paldam, 2009) on the ambiguity of aid's role in achieving its objectives. Although in some models, energy aid indicated a negative correlation with the percentage change in electrification rate for SSA countries. The relationship's significance changes across models. All make it challenging to conclude the definite impact of energy aid on the electrification rate in SSA.

The negative correlation and changing significance as measured in p values could be originated from several aspects. The first is the time effect in the dataset, the second is the non-linear relationship between the two variables, third is the interdependence between the variables. Lastly, a bidirectional causal relationship could exist between the different dependent variables and independent variables. Thus, making it difficult to conclude the exact correlation between the dependent and independent variables. Even though two of the three unit root tests came back as stationary, unit root could exist in some variables. Such non-stationary data can cause the results from OLS to be unreliable. The lagged effect is not detected through the OLS, which leads to contradicting results between models. In 4.1.1.2, the DW statistics tested for autocorrelation in the four OLS models. DW statistic tests for autocorrelation and concluded that variables are not independent of each other. OLS does not capture relationships between independent variables and how they influence each other. The codependent interlinks among the variables are thus ignored in the model. Beyond modeling, what influences the development of electricity capacity is complex; such factors are not captured in the regression models. Their role must be considered when answering what drives the change in the electrification rate.

The linear regression model assumes a linear relationship between the dependent and independent variables. As the plotting for the different independent variables against the dependent variable shows, there lacks a clear linear relationship between the dependent variable and the explanatory variables. This encourages future research to explore the non-linear relationship between energy aid and electrification rate in the SSA region. The non-linear ARDL model has been used in other studies on energy consumption about its impacts on different variables. Several researchers have studied the non-linear relationship between energy use and economic growth (Kouton, 2019; Luqman et al., 2019; Wu, 2020), human capital, and Carbon Dioxide emissions (Li & Ullah, 2022) through the non-linear panel ARDL models. This method allows for integration and co-integration, which relaxes the requirement for the conventional ARDL and produces more reliable results (Luqman et al., 2019).

From the OLS results, inflation, as measured in CPI, reported a positive correlation with the percentage change in the electrification rate. Because the OLS assumes a linear relationship, it is hard to test for what Burnside and Dollar (2000) suggested in their study; low inflation is one of the conditions for aid to impact a country's growth. The OLS results suggest a positive relationship between CPI and the electrification rate. The definite relationship between the two variables needs to be tested using a non-linear model to analyze the threshold to maximize the electrification rate. At the same time, the low adjusted r-squared indicates a low explanation power of CPI over electrification. Compared to model 2 in OLS models, economic growth shows a more significant share in explaining the growth of the electrification rate. Their hypothesis (Burnside & Dollar, 2000) on high trade openness's impact on aid is also unclear from the OLS results. Models 3 and 4 show a positive relationship between trade openness and electrification rate. But the relationship showed a p-value of bigger than 0.1, indicating there is no correlation between the electrification rate and trade openness when economic growth is included in the model. This could be due to the complicated relationship between economic growth and trade openness. Research has found a bidirectional causal relationship between the two variables (Sakyi et al., 2015). Kim et al. (2011) found that whether trade openness leads to economic development depends on a country's income levels. This complex relationship between the two variables can explain the different results in models 3 and 4. As indicated by the governance score, the good governance has reported a positive correlation, which proves Collier and Dollar (2001) 's theory of good governance as well as other prior research suggesting the importance of institutions (Benecke, 2008; Sergi et al., 2018; Simmet, 2018; Trotter, 2016; Trotter & Abdullah, 2018; Young et al., 2007). The coefficient decreases in model 4 compared to model 3; this indicates that better economic development is more important than the governance aspect for electrification development. The natural logarithm of GDP shows a positive correlation with the electrification rate. The coefficient decreases from model 3 to model 4. However, the adjusted r-squared rarely increased by 2%. This indicates that other macroeconomic factors substitute part of the effect of economic development.

From the OLS results, it is clear that energy aid and different macroeconomic variables correlate with the electrification rate. However, their exact relationship with the OLS is inconclusive. Further research should take the time lag effect and consider adopting a model that allows the use of absolute values for each variable to observe their real impact on the electrification rate.

5.2 Energy sectoral foreign aid and electrification rate in different country groups

For the second research question, ARDL was employed to test for the sectoral energy aid and its impact on the electrification rate in different country groups. ARDL considers the time lag effect and gives more reliable results than the OLS used for research question one.

Country groups with lower income differ from those in the higher middle and high-income country categories. For lower-income and lower-middle-income countries, both groups showed a correlation between the percentage change in electrification rate and the percentage change in different energy sectoral aid. Energy sectoral aid shows no impact on the percentage change in electrification rate for higher middle and high-income countries. One of the differences between the low-income and lower-middle-income country groups is their relatively larger sample compared to the higher-middle and high-income groups. The first two consist of 252 samples each, while the high-income group has 108, less than half of the other two groups. As the Central Limit Theorem states, the sample approaches a normal distribution as the sample sizes get larger (Ross, 2017). The effect of the large number could be one of the reasons why such a distinct difference exists between the groups.

As mentioned in the data limitation section, because the progress in electrification takes place under different periods, limited time-series data between 2002 and 2019 makes it difficult to compare countries of the energy aid's impact on electrification. Another possible explanation for the difference between the three groups is the varied growth rate for the electrification rate in the three country categories. For low-income country groups, the average growth rate for electrification between 2002 and 2019 is 2.87, with the highest for Rwanda with an astonishing 5.64 growth rate, surging from 6.70 to 37.78% in 2019 and the lowest being Sudan with 1.67. The average growth rate for the lower-middle-income countries is 2.04, and 1.34 for higher middle and high-income country groups, Mauritius with the lowest growth rate of 1.006. The minimal growth for the higher income countries means that energy aid would have a marginal explanation power to the electrification rate growth.

As previously mentioned, South Africa is a country within the higher middle and high-income countries. The country receives the most energy aid support with a minimal increase in electrification rate, 1.04, seen in the concerned years. On the contrary, over the concerned years, Gabon recorded a 1.16 increase in electrification. However, its cumulative energy aid in the 18 years is less than 5% of its GDP. The most recent large power generation-related projects are all involving the collaboration between the national power company and foreign private investment (i.e. 30MW Kinguélé Aval Hydropower project, 120 MW solar project in Ayémé Plaine, and 120 MW gas power plant in Owendo) (IPPJournal, 2022). 3.1.3 Data limitation talks about the limitation of the energy aid data, that private investment and China's energy aid are not included in the dataset. Therefore, their impacts are unknown. Case studies looking into the specific country case will help understand the unincluded variables affecting the country's electrification rate.

5.3 Research quality

Variables used in the model can have a multi-directional relationship with the electrification rate. The changes in the electrification rate can impact macroeconomic variables. It is essential to be aware of the possible relationship between the variables and make a rational conclusion. Another caution is using theories to interpret the results concluded from the statistical models. Theories provide the background that explains the possible causal relationship between the variables. However, this study doesn't aim to predict the electrification development rate based on the variables used in the model. The goal is to understand the sectoral foreign aid's influence on electrification.

In this research, I want to understand is the construct of the electrification rate in selected SSA countries. The indicator used here is the percentage of the population with access to electricity. Whether the research measures what it's supposed to measure relies purely on the quality of the electrification data used in this research. During the course of analysis, the data has been transformed by taking the change rate to the base year 2002, which changes the nature of the indicator for the construct. By transforming the dataset, I thus infer what affects the changes in electrification rate in the interested countries.

Data quality also plays a role in this. As will be mentioned in the data chapter's dependent variable section, the electrification rate is measured based on the household survey conducted annually to a fraction of the population to approximate the access to electricity rate. Despite the majority of the people living in rural areas, poor data quality for rural areas is recorded. This creates obstacles for the indicator to work as a proper representation for the construct the study wishes to measure. Potential issues related to construct validity are using CPI and import-export value as measurements for inflation and trade openness.

Due to the complexity of different SDG indicators, it is difficult to conclude the transferability of this research’s results to other sectoral aid. Since the research uses panel data analysis for the continent, similar results are likely to be seen using a similar method for other continents. However, due to the aggregate results, it’s not hard to conclude that such results will be hard to reproduce for individual countries.

6 Conclusion

The study tried to answer how energy aid impacts the electrification rate in SSA countries through two regression models using financial flows and other macroeconomic data.

For RQ 1 – Does sectoral aid impact the electrification rate for selected countries in SSA? Based on the results from the four OLS models, it is hard to conclude changes in foreign aid's definite contribution to electrification rate changes in combination with other macroeconomic factors in selected SSA countries. Energy aid shows a limited contribution to the electrification rate. The results confirm prior research on the ambiguous role aid has in development. The inflation rate correlates with a positive change in electrification. However, as a linear model cannot capture the non-linear relationship between variables, it is hard to validate earlier hypotheses from other research. Good governance and high trade openness levels confirm earlier research, suggesting a positive relationship with electrification development.

ARDL model used for RQ2 shows a clear distinction between the low and lower-middle-income country group with the higher middle and high-income countries appeared. Energy aid shows a more significant impact on countries with lower income level than the countries with higher incomes. Several energy sub-sector aids showed correlations with electrification rate in lower-income country groups; the correlation only exists in past year's electrification for higher-income country groups. One explanation of the differences between these is that the higher income group starts with a rather high electrification rate and has a relatively low increase in electrification rate than the countries with lower income. Another reason is that the higher-income group has a sample size of about half compared to the other groups.

Overall, the research cannot conclude the impact of energy aid on the electrification rate in SSA countries. However, the impact of energy sub-sector aid on different income groups calls for further research. Countries that receive high energy aid with minimal advances in electrification rate and the opposite require case studies. Such qualitative studies will help to investigate the role of energy aid and the other factors not included in the study, and how they influence electrification development in the SSA region.

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Appendix

Appendix 1. Countries by income level

Country Name	Income Level
Angola	lower middle income
Benin	lower middle income
Botswana	upper middle income
Burkina Faso	low income
Burundi	low income
Cameroon	lower middle income
Central African Republic	low income
Chad	low income
Comoros	lower middle income
Cote d'Ivoire	lower middle income
Eswatini	lower middle income
Ethiopia	low income
Gabon	upper middle income
Gambia, The	low income
Ghana	lower middle income
Guinea	low income
Kenya	lower middle income
Lesotho	lower middle income
Madagascar	low income
Malawi	low income
Mali	low income
Mauritania	lower middle income
Mauritius	upper middle income
Mozambique	low income
Namibia	upper middle income
Niger	low income
Nigeria	lower middle income
Rwanda	low income
Sao Tome and Principe	lower middle income
Senegal	lower middle income
Seychelles	high income
South Africa	upper middle income
Sudan	low income
Tanzania	lower middle income
Togo	low income
Uganda	low income
Zambia	lower middle income
Zimbabwe	lower middle income

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