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Mercy T. Musakwa

Abstract

In this study, the impact of access to electricity on poverty reduction is examined using annual data from 1990 to 2021 for Botswana. The study was motivated by the need to establish if access to electricity could be a panacea on poverty reduction in Botswana. Given that the United National Sustainable Development Goal deadline is fast approaching, and Botswana being one of the signatories, is expected to end poverty in all its forms – Goal 1. Establishing the role that electrification plays in poverty alleviation helps in refocusing Botswana's poverty alleviation strategies on factors that have high impact on poverty. The main objective of this study, therefore, is to investigate the relationship between poverty alleviation and access to electricity in Botswana.

Approach: *The study uses the autoregressive distributed lag (ARDL) approach to investigate the nature of the relations. Two poverty proxies were used in this study namely, household consumption expenditure and life expectancy.*

Findings: *The study found access to electricity to reduce poverty in the long run and in the short run, regardless of the poverty measure used. Thus, access to electricity plays an important role in poverty alleviation and Botswana is recommended to continue with the rural and urban electrification initiatives.*

Originality: *The study explores the impact of access to electricity on poverty reduction in Botswana, a departure from current studies that examined the same relationship using energy consumption in general. This is on the back of increasing dependence of economic activities on electricity as a major source of energy.*

Key words: *electricity; Botswana; autoregressive distributed lag; poverty; life expectancy; household consumption expenditure*

JEL: I32, I38, P18

1. Introduction

According to the World Bank (2019) about 13% of the population live without electricity, while in Africa, one in three people do not have access to electricity. In sub-Saharan Africa (SSA), the proportion of the population without access to electricity has doubled between 1990 and 2016 (World Bank, 2019). Bazilian and Yumkella (2015) further projected 80% of the population without access to electricity to live in SSA. The proportion of the population without electricity resort to other energy sources like kerosine and firewood or stay in the dark. The figures are alarming when it comes to rural electrification in Africa that is still lagging with affordability to connect to the grid being a major hurdle (Independent Evaluation Group 'IEG', 2008). This is despite the importance of electricity access in reducing poverty through safe communities, provision of social services and boost in small businesses.

At household level, access to electricity increases household income through increased productivity (Asghar et al., 2022; Jimenez Mori, 2017) and improves access to social services by households (Alam et al., 2018). On the flip side, the lack of access to electricity threatens the achievement of universal access to electricity by 2030 – SDG 7 (access to affordable, reliable, sustainable energy for all).

For Botswana, electrification in urban areas reached 77%; while rural areas are still lagging, with 37% (Sustainable Energy for All, 2023), despite Government programmes to electrify Botswana through the Rural Electrification Program and National Electricity Standard Connection Cost Program. The progress made in electrification has been constrained, among

other factors, through reliance on imports from countries like South Africa and Zambia. Electricity challenges that South Africa has been experiencing is likely to negatively impact the electrification programmes in Botswana, given that Botswana generates 80% of its electricity from the Morupule and imports the short fall from South Africa and Zambia (UN Environment Programme, 2023).

The trends in poverty also point to high poverty levels in SSA post COVID-19 (Development Initiatives, 2023). According to Development Initiative (2023), extreme poverty is still concentrated in Sub-Saharan Africa with an estimated population of 62% living in extreme poverty, while other regions such as the Pacific and East Asia have experienced a reduction in extreme poverty. Although Botswana has recorded a gradual decline in poverty over the years, a lot of work still needs to be done to eradicate poverty in all its forms, including energy poverty. This makes a relook into the relationship between access to electricity and poverty reduction in this study country important.

The extant literature on the impact of access to electricity on poverty is still limited but growing. This is despite the importance of these measures among the SDGs that most countries are signatories including Botswana. Among the studies that investigated the relationship between access to electricity and poverty reduction, the results are inconclusive. Some studies found a positive impact of electrification on poverty reduction (Sokhanvar, 2023; Asghar et al., 2022; Ikhsan and Amri, 2022; Diallo and Moussa, 2020; Jimenez Mori, 2017; van de Walle et al., 2017), while other studies also found a negative impact of electrification on poverty reduction (see, Salmon and Tanguy, 2016; Willcox *et al*., 2015); and yet other studies found

no impact of access to electricity on poverty alleviation (for example, Tegene, Berhe and Teklemariam, 2015). The inconclusive results make another study on the impact of access to electricity on poverty on Botswana important as generalisation of results from other studies is inappropriate.

In this study, the impact of access to electricity on poverty reduction is investigated using two proxies, namely, household consumption expenditure and life expectancy, capturing income and health poverty, respectively. Economic growth is captured by the rate of change of gross domestic product (GDP). This study departs from previous studies by employing the ARDL approach to analyse the relationship between the two. The approach provides robust results in small samples and allows the interpretation of the results in the short and long run timeframes. This is important when policies have to be tied to time frames.

This study adds value to the body of knowledge in various ways. To the best knowledge of the author, this could be the first study that used time series analysis to investigate the relationship between access to electricity and poverty reduction in Botswana. In addition, the study examines the significance of electrification programmes on poverty in Botswana, an area that has not been fully explored, yet important. Most studies have focused on the impact of energy consumption in general on poverty, missing the relationship between electrification and poverty reduction. This study, therefore, adds value to policy formulation aimed at using electrification as a poverty reduction tool in Botswana.

Botswana has been selected for this study because of the strides it has made in poverty reduction and has consistently worked to alleviate poverty among Batswana. The country is a good case study on the impact of access to electricity on poverty given the work that has been done to electrify Botswana. Botswana is one of the few African countries that rank as upper-middle-income countries and other countries can learn from the results obtained from this study. The study provides an insight to Botswana policy makers on whether they should anchor poverty alleviation on electrification of the country.

The rest of the study is organised as follows; Section 2 reviews county-based and empirical literature, important in building a case for another study. Section 3 outlines the method that was used in the study and Section 4 presents and discusses the results of the study. Section 5 concludes the study.

2. Literature review

2.1 Dynamics of electricity access and poverty in Botswana

Electricity access dynamics

According to the UN Environment Programme (2023), in 2015, Botswana produced 278ktoe of power with the large percentage of this energy being produced from fossil fuels. The Morupule coal-fired station generates most of the power complemented by imports from South Africa and Zambia (UN Environment Programme, 2023). Botswana meets its demand for oil and gas through imports. The country is dependent on coal since it has large deposits, with the one at Morupule accounting for 80% of domestic production. Botswana opened the first solar power generating plant in 2012 (UN Environment Programme, 2023). Solar is used in households for heating and lighting including in rural areas where electricity connection is not

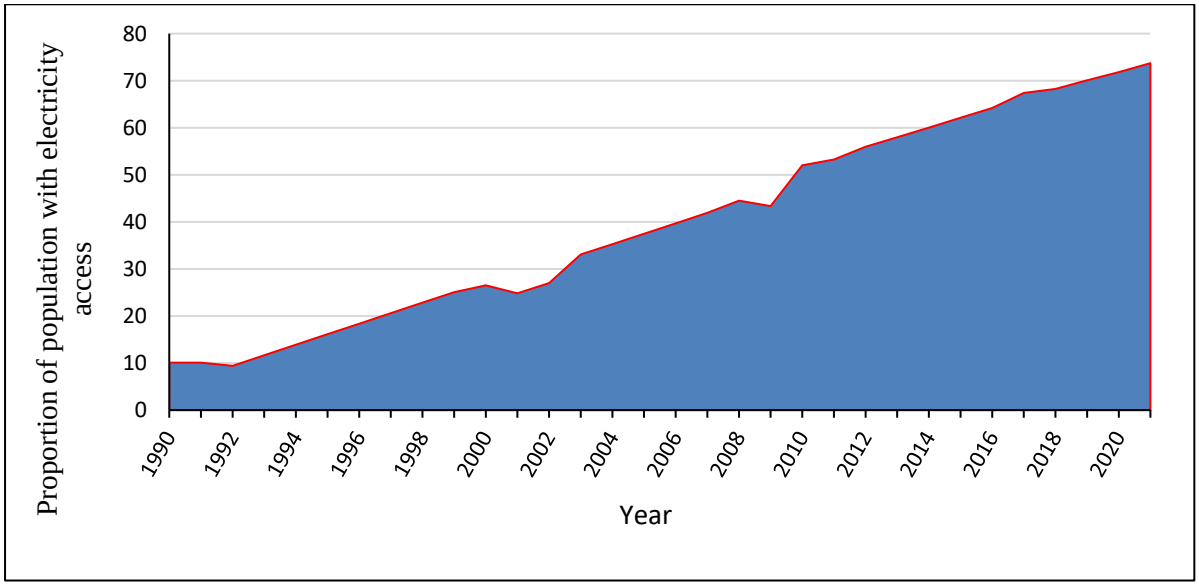
available. Access to electricity in Botswana is constrained in several ways, including reliance on imports and high connection costs, where the cost of connection from the grid is too expensive. In relation to standardisation of connection, Botswana rolled out the National Electricity Standard Connection (NESC) in 2010, that endeavours to make the cost of connection uniform across the country on new households (Botswana Corporation, 2023).

Some of the energy enabling policies include the National Energy Policy; Botswana Energy Master Plan 2004-2019; Renewable Energy Fund for off-grid solutions; 10th National Development Plan 2009-2016 (NDP 10); National Photovoltaic Rural Electrification Programme (UN Environment Programme, 2023). The rural Photovoltaic Rural Electrification Programme facilitates rural communities in Botswana to access the facility to purchase photovoltaic system and repay the loan over four years. This move allows rural households to use solar, a renewable energy, and complement other energy sources in water heating (IEG, 2023). The Ministry of Minerals, Energy and Water Resources (MMEWR) oversees the energy sector in Botswana and the Botswana Energy and Water Regulatory Agency is the regulator, while the Botswana Power Corporation oversees the electricity sector.

The percentage of the Batswana with access to clean energy for cooking has increased steadily since 1990, from 26.2% to 64.7% in 2020 (Ritchie, Roser and Rosado, 2022). Access to electricity in general, was at 10.1% of the population in 1990, increasing seven-fold in 2021 (World Bank, 2023). Average access to electricity over the study period was 39.6% of the population (World Bank, 2023). Although access to electricity has increased remarkably,

Botswana still has a long journey to ensure a large proportion of its population has access to electricity. Figure 1 reveals trends in electricity access in Botswana from 1990-2021.

Figure 1: Proportion of the Population with Access to Electricity in Botswana



Source: World Bank (2023)

(Figure by author)

Figure 1 reports access to electricity for Batswana for the period from 1990 to 2021 and there has been a consistent increase in households with access to electricity over the study period. This implies that despite electricity challenges the country has faced in the past, that has not deterred the country from electrification of Botswana.

Poverty dynamics

The government of Botswana has always desired to have a poverty and inequality free nation since attaining independent in 1966. This has found expression in the current vision – Vision 2036 - and the National Development Plans that have been drafted by the country since independence (United Nationals Development Programme 'UNDP', 2023a). Poverty reduction

in Botswana is also encapsulated in the Vision 2036 with the theme 'Prosperity for All'; and the National Development Plan 11 with the theme 'Inclusive Growth for the Realisation of Sustainable Employment Creation and Poverty Eradication,' that ended in March 2023.

The implementation of the National Development Plan 12 was deferred to 2025 and in the interim, a Transitional National Development Plan to 2025 has been rolled out. This was based on the need to strengthen among other reasons, the country's institutional and governance structures and build capacity to roll out the NDP12. The commitment of the Botswana government to eliminate poverty and inequality resulted in the government convening a conference in 2018 with a theme on not leaving anyone behind and fighting poverty, exclusion, and inequality. The main objective of the National Poverty Eradication Policy (NPEP) is to achieve poverty eradication and inequality by 2036 (UNDP, 2023a).

In 2011, the government came up with the Poverty Eradication Programme (PPE) with the objective of empowering beneficiaries who are graduates from extreme poverty. This was done through capacity and skills development, promotion of micro and small-scale entrepreneurship and employment generation (Republic of Botswana, 2023). Another economic empowerment programme is the Ipelegeng – a labour-intensive programme initially designed to cushion poor households from drought by working for a payment 'food-for-work' (Statistics Botswana, 2021). Thus, the Ipelegeng is one of the economic empowerment programmes aimed at integrating the poor into the economic development space.

Apart from the economic empowerment programmes, Botswana has social protection programmes targeted at the vulnerable in the society, such as, individuals with poor health and/or poor nutrition and those that lack access to social services, orphaned children, and the disabled and old aged persons. Some of the programmes include School Feeding Programme; Orphan Feeding Programme; Vulnerable Groups Feeding Program; Old Age Pension; Programme World War II Veterans; Community Home-Based Care; Livestock Management and Infrastructure Development; Destitute Persons Program; and Remote Area Development Plan, among other support programmes (Statistics Botswana, 2021). The most accessed programme is the School Feeding Programme followed by the Vulnerable Group Feeding and Ipelegeng (Statistics Botswana, 2021). Other programmes like the Poverty Eradication Programme only supported 1.3% of households that benefited from the social safety nets (Statistic Botswana, 2021).

Poverty levels in Botswana have decreased over the years when measured using metrics such as poverty headcount and poverty gap. Poverty headcount was at 41.8% in 1985 before it declined significantly to 15.4% in 2015 (World Bank, 2023). The same trend was recorded for poverty gap, which eased from 17.4% to 4.1% over the same period (World Bank, 2023). The trend in poverty has been decreasing when monetary measures of poverty are used. However, it is uncertain on other poverty dimensions like equality and energy. The decline in poverty metrics coincided with the gradual increase in Human Development Index (HDI) for Botswana over the study period (UNDP, 2023b). Poverty headcount, poverty gap and Human Development Index trends are presented in Table 1.

Table 1: Trends in Poverty headcount, poverty gap and Human Development Index (HDI) 1985-2015

Year	Poverty Headcount (%)	Poverty Gap (%)	Human Development Index
1985	41.8	17.4	-
1993	34.1	13.1	0.588
2002	29.1	11.1	0.583
2009	17.7	5.5	0.647
2015	15.4	4.1	0.702

Source: World Bank (2023) and (UNDP, 2023b)

(Table by author)

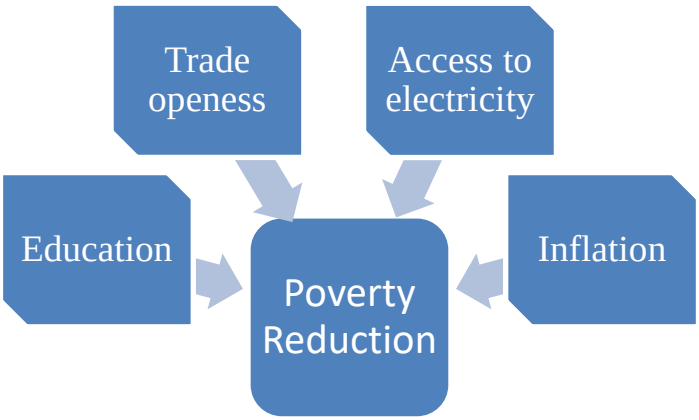
Poverty metrics reported in Table 1 confirm a decline in income poverty, measured by poverty headcount and poverty gap, and the multidimensional measure, captured by Human Development Index (usually used as a measure of living standards). The trend confirms the that steps taken by Botswana to reduce poverty have yielded the desired results, although more still has to be done to reduce poverty and to maintain it at lower levels. This was also reflected in the HDI that improved from 0.588 to 0.702 during the same period (UNDP, 2023b).

2.2 Theoretical and empirical literature review

The link between electrification and poverty can be traced to three channels opined by Diallo and Moussa (2020). The first channel is improvement in health through reduction in mortality, cleaner environment due to the use of electricity and improvement in the quality of health. The second channel is an improvement in education. Electrification makes it possible for children to learn for prolonged periods and use modern technologies that enhance their learning. In addition, availability of lighting allows adult education even during late hours (Wamukonya and Davis, 2001). Access to education leads to improvement in educational level which becomes a tool to getting out of poverty through securing high paying jobs and enhancing entrepreneurial abilities to run viable businesses.

The third channel is increased labour productivity (Diallo and Moussa, 2020; Willcox et al., 2015). Access and use of electricity leads to an increase in income from existing activities through efficient methods made possible with electricity, ability to innovate and have multiple sources of income, extended working time using lighting, and women employment. All these elements elevate household income earning abilities leading to poverty reduction. Theoretical literature reviewed points to the importance of education, health and income as key drivers in poverty reduction. This study includes education, trade openness and inflation as control variables. Botswana relies heavily on export of minerals, although efforts are being made to diversify to other sector, exports play a big role in the development of the country, where the country has managed to earn an upper-middle income country status. It is interesting to study the extent to which trade has contributed to poverty reduction in the country, apart from other control variables that have been included in the model. The conceptual framework is given in Figure 2.

Figure 2: Conceptual Framework



Source: Author's conceptualisation

(Figure by author)

Access to electricity is expected to lead to poverty reduction through increase in productivity, access to information, clean energy source and improved access to social services. Trade openness is expected to contribute positively to poverty reduction in several ways. Firstly, imports provide a wide variety of goods that can be consumed by households, thereby, removing local production limitations. Secondly, demand for exports cause expansion in the domestic economy to cater for the market needs. This consequently leads to an increase in demand for factors of production. Thirdly, exports provide export revenue to Botswana businesses and avails funds to government through tariffs, that can be used for poverty alleviation projects – social safety nets. Education increases the ability of the poor to secure better paying jobs or start new businesses, while inflation contribute negatively to poverty reduction. An increase in inflation erodes purchasing power of income, which consequently reduce consumption by households. Access to electricity, education, trade openness and inflation play an important role in poverty reduction in Botswana.

The next section reviews empirical studies on the impact of electrification on poverty reduction with a view to identify the gap in the literature. Studies on the impact of electrification on poverty are still limited; however, the reviewed studies highlight some insights into the relationship between the two variables of interest.

Sokhanvar (2023), using microdata at household level, examined the impact of access to electricity on energy poverty in Honduras. The study focused on quality, reliability, availability, affordability, formality, safety and capacity attributes on access to electricity. The study found households with better education, access to credit and bank loans to spend more

on energy. Grid access barriers were also found to negatively affect energy poverty. Asghar et al. (2022), in a study on the impact of access to electricity on total, rural and urban population for 82 developing countries, using data from 1990 to 2020, found an increase in access to electricity to initially worsen poverty, but in the long run, it was found to lead to poverty reduction. The study suggests that electrification and affordable access to power are drivers to poverty alleviation.

Ikhsan and Amri (2022), in a study on the effects of electrification on rural and household non-food spending for Indonesia, using data from 2007 to 2017, VECM and Granger causality, found electrification to reduce poverty through a positive impact on non-food spending. However, in the long run, electrification was found to negatively influence poverty reduction.

A unidirectional causal flow was found from electrification to rural poverty, suggesting an important role of electrification on poverty reduction. In the same spirit, Diallo and Moussa (2020) found the same results as Ikhsan and Amri (2022), in a study on the effects of access to electricity on poverty using full information maximum likelihood framework using data from 2015, 2008, 2002 and 1998 Standard Measurement Surveys. Using household consumption per capita, the study found access to electricity to increases household consumption per capita by 5.2 to 23.3 percent.

Vernet et al. (2019) studied the impact of rural electrification on community development and entrepreneurship in Kenya. Like Asghar et al. (2022), the study found electrification to have positive impact on formation of micro-enterprises, household income and perception of social status and to increase opportunity for business development. Woman-led household were found

to benefit more than men-led households. van de Walle et al. (2017), in a study on the impact of electrification on consumption in rural India using data for 17 years, found electrification to bring consumption gains for those families with access to electricity compared to households without electricity. Labour was the main channel for consumption gains in households with electricity. Jimenez Mori (2017) in an evaluation of 50 studies concluded that electrification leads to 25% increase in employment, 7% increase in school enrolment and 30% increase in income.

Tegene et al. (2015) found rural electrification in Ethiopia to positively influence poverty reduction, however, the impact of electricity access on household income was insignificant. The results confirmed the findings by Wamukonya and Davis (2001). Wamukonya and Davis (2001), in a study on welfare impact of rural electrification using a sample of 400 households in Namibia, found that access to electricity was perceived to have improved the quality of life through lighting. Apart from lighting access to electricity was found to have a positive impact on security, health and education.

Although there is overwhelming evidence on access to electricity leading to poverty alleviation, there are studies that found conflicting results. For example, Salmon and Tanguy (2016), in a study on Nigeria, found energy poverty to negatively impact productivity on income generating opportunities important for lifting the poor out of poverty. Willcox *el al*. (2015) in a study that reviewed available literature found little evidence of a positive impact of electricity on poverty reduction unless it is complemented with other enabling measures. Wamukonya and Davis (2001) in a sample of 400 households for Namibia, found no evidence of improvement in income generating activities due to access to electricity. The study found that households on

the grid and off grid spend more on electricity which negatively impacted the household welfare.

The literature reviewed is inclined more towards access to electricity leading to poverty reduction. However, there are also conflicting results where electrification was found to have a negative impact on poverty reduction (Salmon and Tanguy, 2016) or have no significant impact on income (Tegene et al., 2015; Willcox *el al*., 2015). The inconclusive results make a relook on the impact of electrification on poverty reduction for Botswana important. The variation in the results could be as a result of study sample, methodology and measures of poverty. Based on these mixed results, this study seeks to close the gap by establishing the obtaining relationship in Botswana.

3.Methods

Autoregressive distributed lag (ARDL) approach, developed by Pesaran and Shin (1999) and extended by Pesaran, Shin and Smith (2001), was used to examine the impact of electrification on poverty reduction. The approach was selected because of several advantages it has over other approaches. For instance, the approach does not require all variable in the model to be integrated of the same order and results from the analysis can be interpreted in the short- and long-run time frames (Pesaran et al., 2001).

3.1 Variables

Access to electricity as a percentage of the population (ELEC) and poverty reduction (POV) captured by two proxies namely, household consumption expenditure (HCX) and life

expectancy (LE) are variables of interest in this study. Household consumption measures income poverty, while life expectancy captures health poverty. Household consumption expenditure is captured in Model 1 whereas life expectancy as a poverty proxy is captured in Model 2. The multidimensional nature of measuring poverty has motivated the selection of these two proxies. Electrification is expected to lead to a decrease in poverty, reflected by an increase in household consumption expenditure; while an increase in access to electricity is expected to lead to an improvement in life expectancy, thus reducing poverty. To fully specify the model, the following control variables were added into the model; education (EDU), captured by secondary school gross enrolment; inflation (INF), measured as the rate of change of the consumer price index; and trade openness (TOP), captured by the summation of exports and imports as a percentage of GDP.

3.2 Model Specification

Equation 1 provides the general model specification.

$$POV_m = \pi_0 + \pi_1 ELEC + \pi_2 EDU + \pi_3 INF + \pi_4 TOP\varepsilon_t \ldots\ldots\ldots\ldots\ldots (1)$$

Where: POV_m captures poverty reduction with two proxies; household consumption expenditure (HCX) - Model 1 and Life expectancy (LE)- Model 2, ELEC = access to electricity; EDU = education; INF = inflation; and TOP = trade openness.

$$\Delta POV_{mt} = \pi_0 + \sum_{i=1}^{p} \pi_{1i}\, \Delta POV_{nt-i} + \sum_{i=0}^{q} \pi_{2i} \Delta\, ELEC_{t-i} + \sum_{i=0}^{q} \pi_{3i} \Delta\, EDU_{t-i} + \sum_{i=0}^{q} \pi_{4i}\, \Delta INF_{t-i} + \sum_{i=0}^{q} \pi_{5i}\, \Delta TOP_{t-i} + \vartheta_1 POV_{nt-1} + \vartheta_2 ELEC_{t-1} + \vartheta_3 EDU + \vartheta_4 INF_{t-1} + \vartheta_5 TOP_{t-1} + \eta_{1t} \ldots\ldots\ldots\ldots\

Where π_0 is a constant, $\pi_{i1} - \pi_{5i}$ and $\vartheta_1 - \vartheta_5$ coefficients for short-run and long-run variables respectively, and η_{1t} is an error term. The rest of the variables remain the same as specified in Equation 1.

Error Correction Model (ECM) Specification

The ECM model specification is based on testing long-run relationship in variables in Equation 2. If a long-run relationship is established among the variables, an estimation of the long-run equation and saving the residuals is done in the first step. The second step involves including the residuals in the estimation of the short-run equation. The residuals are captured by the lagged error correction term in Equation 3. The ECM is expected to have a negative sign, showing a reversion to the equilibrium whenever there is a disequilibrium in the economy. However, a positive sign on the ECM shows an explosive behaviour, meaning whenever there is a disequilibrium instead of reverting to the equilibrium the model is unstable and moves away from the equilibrium.

The ECM model specification is given in Equation 3.

$$\Delta POV_{mt} = \pi_0 + \sum_{i=1}^{p} \pi_{1i}\, \Delta POV_{nt-i} + \sum_{i=0}^{q} \pi_{2i} \Delta\, ELEC_{t-i} + \sum_{i=0}^{q} \pi_{3i}\, \Delta EDU_{t-i} + \sum_{i=0}^{q} \pi_{4i}\, \Delta INF_{t-i} + \sum_{i=0}^{q} \pi_{5i}\, \Delta TOP_{t-i} + \gamma_1 ECM_{t-1} + \mu_{2t} \ldots\ldots\ldots\ldots\ldots (3)$$

Where ECM is the error correction term; γ_1 is the coefficient of the ECM and all other variables remain the same as specified in Equation 1.

Data Sources

The impact of access to electricity on poverty reduction was investigated for Botswana using data from 1990 to 2021. Household consumption expenditure (HCX); life expectancy (LE); Inflation (INF); and trade openness (TOP) were retrieved from World Bank Development Indicators. Access to electricity (ELEC) was extracted from Our World in Data (2023) database.

4. Empirical Results

Unit root test

Although unit root test is not a requirement when using the autoregressive distributed lag, in this study, Augmented Dickey-Fuller (GLS) and the Phillip and Perron (PP) tests were used to ascertain that all variables in the model are integrated of higher than order one. If there is any variable that is integrated of order two and higher, the approach falls away. Results on the unit root test are reported in Table 2.

Table 2: Unit Root Test Results

Augmented Dickey-Fuller (DLS) Test				
Variable	**Variables in Levels**		**Variables in First Difference**	
	Without Trend	With Trend	Without Trend	With Trend
LE	-1.678	-1.183	-4.386***	-3.999***
HCX	-1.830	-1.931	-6.264***	-4.297***
ELEC	-1.501	-2.275	-5.832***	-4.636***
EDU	-0.747	-2.111	-5.340***	-5.235***
INF	-1.282	-3.578**	-6.890***	-
TOP	-2.019	-2.240	-4.876***	-4.767***
Phillip-Perron (PP) Test				
Variable	**Variables in Levels**		**Vriables in First Difference**	
	Without Trend	With Trend	Without Trend	With Trend
LE	-1.119	-2.909	-5.645***	-7.660***
HCX	-2.139	-2.404	-8.127***	6.166***
ELEC	-0.944	-3.732	-7.454***	-
EDU	-0.651	-2.186	-5.354***	-5.235***
INF	-2.034	-2.315	-7.827***	-6.876***
TOP	-2.267	-2.236	-7.594***	-6.822***

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

(Table by author)

Table 2 confirms that all the variables included in Model 1, where household consumption expenditure is a proxy for poverty reduction; and Model 2, where life expectancy is used as a proxy for poverty) are stationary in levels or in first difference. The next step is a test for a long-run relationship among the variables included in the two models. Table 3 reports cointegration results.

Cointegration

Table 3: Cointegration Results

Dependent variable	**Function**		**F-statistic**		**Cointegration Status**	
HCX	F(HCX|ELEC,EDU,INF,TOP)		6.237***		Cointegrated	
LE	F(LE|ELEC,EDU,INF, OP)		3.573*		Cointegrated	
Critical Values	**1%**		**5%**		**10%**	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	3.98	5.69	2.79	4.15	2.33	3.51

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

(Table by author)

Results reported in Table 3 confirm the presence of cointegration in Model 1 and Model 2. To proceed with the analysis, an estimation of long-run and short-run equations is done considering the non-linear ARDL estimation. Long-run and short-run results are presented in Table 4.

Table 4: Long-run and short-run Results

Regressors	**Poverty measured by Household consumption expenditure (HCX) (1,0,0,1,0)**		**Poverty measured by life expectancy expenditure (LE) (1, 0, 0, 1, 2)**	
	Coefficient	**T-ratio**	**Coefficient**	**T-ratio**
Panel A: Long-run Results				

C	50.576***	6.647	9.095	0.670
ELEC	0.259**	2.446	0.554**	1.897
EDU	0.975***	4.293	-0.105	-0.221
TOP	-0.142**	2.260	0.129	0.991
INFL	-0.199	0.903	0.881**	2.026
Panel B – Short-run Results				
ΔELEC	0.212***	2.913	0.118**	2.436
ΔEDU	0.795***	4.968	-0.023	0.227
ΔTOP	0.026	0.553	-0.062**	-2.459
ΔINFL	-0.1626	-0.933	-0.195*	-1.195
ECM (-1)	-0.816**	-5.564	-0.213***	-3.608
	R-squared - 0.667 S.E of Regression - 2.021 Akaike Info Criterion – -66.684 R-Bar Squared – 0.580 F-Stat (5, 24) – 9.220[0.000] Schwarz Bayesian Criterion – -71.588 DW-statistic – 2.164		R-squared - 0.635 S.E of Regression - 0.946 Akaike Info Criterion – -44.556 R-Bar Squared – 0.500 F-Stat (6, 23) – 6.100[0.001] Schwarz Bayesian Criterion – -50.861 DW-statistic – 1.688	

Note: *, ** and *** indicates significance of variables at 10%, 5% and 1% level of significance, respectively.

(Table by author)

Results reported in Table 4 show that access to electricity has a positive impact on poverty reduction in the short run and long run irrespective of the measure of poverty considered – household consumption expenditure or life expectancy. The results imply that access to electricity leads to an increase in household consumption and improvement in life expectancy.

This finding was expected as access to electricity allows households to use clean energy compared to other energy sources like firewood. Electricity allows poor households to use electronic gadgets like cellular phones, tablets and computers that allow access to information on economic opportunities and join the global community. The ability of households to use these gadgets allows them to access more opportunities in the economy and facilitate easy communication. Thus, access to electricity in Botswana plays a key role in reducing income poverty and health poverty. The findings of this study are not unique to Botswana alone, Asghar et al. (2022), Ikehsan and Amri (2022), Diallo and Moussa (2020) and Vernet et al. (2019), in separate studies on 82 developing countries, Indonesia, Cote d' Ivoire and Kenya, respectively, found the same results.

Other results reported in Table 4 for Model 1, where household consumption expenditure is used as a proxy for poverty reduction confirmed education has a positive impact on poverty reduction in the short run and in the long run. These results support the notion that when households invest in human capital, they can compete in the job market for better job opportunities that also have higher wages. This, consequently, allows the household to access better social services. In addition, education improves the ability of poor households to access economic opportunities, such as the ability to start small businesses. Trade openness was found to have a negative impact on poverty reduction in the long run but insignificant in the short run. This may be explained by the negative impact that reliance on imports has in reducing domestic expenditure, yet it is important to support domestic industries. Inflation was found to have a negative impact on poverty reduction in the short run. This confirms the theory on inflation where it erodes the purchasing power of households making them worse off as their income can only buy limited goods and services. To some, inflation may result in some goods

and services completely out of reach. The lagged error correction term was found to be -0.816 indicating that it takes slightly more than a year for the economy to return to equilibrium should there be a disequilibrium in the economy. The explanatory power of the model is 67%.

Other results presented in Table 4 for Model 2, where poverty reduction was measured by life expectancy, confirmed that education and trade openness have no significant impact on poverty reduction regardless of the timeframe considered, while inflation was found to reduce poverty in the long run and increase poverty in the short run. This finding confirms that inflation erodes purchasing power of households in the short run, thereby reducing their ability to access health services. In the long run, there is a certain level of inflation that gives an incentive for companies to continue providing goods and services. The lagged error correction term (ECM (-1)) for this model was found to be -0.213 and significant at 1% level. It takes slightly below five years for the economy to revert to the equilibrium when there is disequilibrium. The model is a good fit with an explanatory power of 64%. The diagnostic results for Model 1 and Model 2 are given in Table 5.

Table 5: Diagnostic Results

LM Test Statistic	**Model 1 – Household consumption expenditure as a measure of poverty reduction**	**Model 2- Life expectancy as a measure of poverty reduction**
Serial Correlation	0.511 [0.475]	0.298[0.585]
Normality	1.269 [0.530]	1.246[0.529]
Functional Form	0.219 [0.640]	1.536[0.215]

Heteroscedasticity	1.012 [0.912]	1.662[0.197]

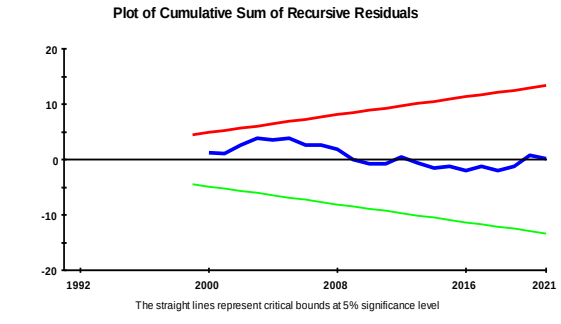
Note: *, ** and *** indicates significance of variables at 10%, 5% and 1% level of significance, respectively.

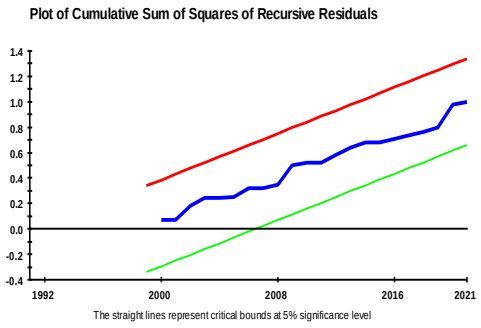
(Table by author)

Table 5 reports the diagnostic results for Models 1 and 2. The two models passed heteroscedasticity, normality test, serial correlation and functional form. A test of the stability of the models was done at 5% level of significance. Both models passed the stability tests – Cumulative Sum of Recursive (CUSUM) and the Cumulative Sum of Square Recursive (CUSUMQ). The results are presented in Figure 2.

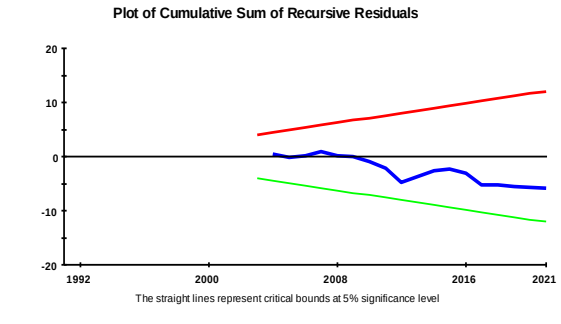
Figure 3: Stability Test

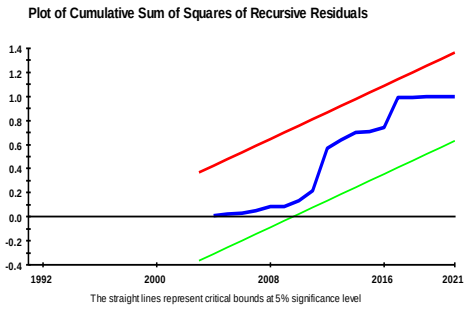
Household Consumption Expenditure as A Measure of Poverty Reduction





Life Expectancy as A Measure of Poverty Reduction





Note: Stability of the models at 5% level of significance

(Figure courtesy of EViews 13)

Conclusion

The impact of access to electricity on poverty reduction for Botswana was studied employing data from 1990 to 2021. The study was motivated by the need to find out if access to electricity can be a panacea to poverty reduction in Botswana. Botswana is a signatory to the Sustainable Development Goals (SGD) where reduction of poverty is among one of the goals the country is expected to work on, making this study important to policy makers in the study country. Two poverty measures were used namely, household consumption expenditure and life expectancy, covering income poverty and health poverty, respectively. Employing the autoregressive distributed lag approach, the study found access to electricity to reduce poverty irrespective of the poverty measure used in both the long and the short run. Based on these findings, it can be concluded that electrification plays a positive significant role in poverty reduction in Botswana. It is recommended that Botswana speeds up electrification in both rural and urban areas as a strategy to reduce poverty. Given the current challenges with electricity generation, Botswana can complement electricity from the grid with off-grid sources, such as solar and wind to fast tract access to electricity.

Although all efforts were made to ensure that the results from this study are robust, there are limitations that were encountered, such as unavailability of data on access to electricity for a larger sample period. Although the sample size is reasonable for a scientific study, future studies can benefit from the use of a large sample period. In addition, empirical literature on the impact of electrification, though showing signs of growth, is still limited, hence future studies may benefit from the expansion in the literature with time.

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