Original Research Article

Box Jenkins for Forecasting Access to Clean Energy for Climate Mitigation in Tanzania: The Reality or a Myth?

Abstract

The effect of climate change is visibly spread with no boundaries all over the world. With multiple effects of climate change, its mitigation mechanisms vary. However, striving for universal access toaffordable, reliable, and sustainable clean energy is arguably one of the significant sought mitigation strategies, especially in the context of Africa. This raises concern about whether the road to clean energy in the work of mitigating the devastating climate change is eloquent or a myth. Using ARIMA, the paper forecasted access to electricity to calibrate the reduction of over-dependence on climate change-inducing energy sources such as firewood and charcoal. The paper used time series data from 1992 to 2022, with a forecast of 10 years. The results show that climate change mitigation through clean energy is far from the reality, the level of future access cannot be used to define progress in mitigating climate change.A large percentage of people will remain unconnected while few will be disconnected due to various reasons such as unaffordability and reliability of electricity supply. Along the energy ladder, consumers are likely to remain at the base where unclean energy sources dominate. People are likely to continue with the course of depending more on unclean energy sources thus, making climate change mitigation through access to electricity a less reality, a myth in such short. An equation of the available potential resources for producing more and more reliable modern energy shouldbe balanced by the utility supplier. Also, it should expand the production and distribution levels, it should change the monopoly system in the energy sector, and embrace innovation and collaboration at large.

Keywords: Energy access, ARIMA, Clean Energy, Electricity, Climate Change mitigation

Introduction

Today, than ever in time, the effect of climate change has increasingly become a global challenge leading to hastened deterioration of people's livelihoods and the life in particular. Due to climate change, the practice of agriculture for example which determine the quality of livelihood and life of human being faces a worrisome standpoint not only in the developing countries but at the global scale (Tomala et al., 2021). Unpredictable weather, dryness and catastrophic environmental occurrences endangers life on earth(Aklin, et al., 2018). Mega pollutions resulting from heavy industries and all other development activities that increases the emission of greenhouse gases and deforestation that deplete the carbon sinks have been cited as a critical contributor of climate change (Crippa et al., 2021)

The scale of the visible effects resulting from climate change has so far awakened the development planners and government authorities to launch for different mitigations approaches. Fostering, access to clean, affordable and reliable energy is pronounced a key strategy to reduce and mitigate the climate change(IPCC, 2019).With such phenomena and in the context of Tanzania, where the looming effects seem catastrophe due to less mitigation strategies coupled with terrifying poverty rates, thegrand question remain, is it the reality or a myth? Is the trend of access to clean energy offers a prime understanding of whether the long-time efforts of cultivating access to clean, affordable and reliable energy stand a promising reality?

In fact, clean energy is recognised as a quantum driver of not only climate change mitigation but also socio-economic development. The bundles of most renewable energies fall in the class of clean energy(Stiles& Murove, 2015). They include wind energy, solar energy, ocean energy, geothermal and bioenergy, liquid fuels, gaseous fuels including liquefied petroleum gas (LPG) and natural gas (Legros*et al*., 2009). The cleanest forms of energy are always on top of the energy ladder. Electricity is basically leading when efforts are explained to increase access to clean energy "*electricity is a superior energy carrier toppling the energy ladder*" (Okonkwo & Odularu, 2009) and thus, it forms a key focus of this study. Electricity being of multiple use at the domestic and industrial level is a powerful energy career which when well, can mitigate the risks and effects of climate by preventing or slowdown the increase of atmosphericgreenhouse gaseous concentrations by limiting currentand future emissions and enhancingpotential sinks for polluting gases (Luhunga et al.2018).

In the developing world including Sub-Saharan Africa and Tanzania in particular, electricity agenda has beenontop of development plans and manifesto of governments(Oseni & Pollit, 2015). Massive investment plans and search for new sources of clean energy has drained fiscal resources.This puts the efforts on test when information about the level of access to electricity is sought. However, access alone can hardly be used to judge a clear roadmap to clean energy in the work of mitigating climate by reducing overdependence on unclean sources of energy.In fact, people do not want access to "clean energy sources" but reliable and affordable clean energy sources(Mahongo and Francis, 2012).For that, it is crystal clearer that the work of ensuring access to clean form of energy sourcesis wretched if all components of quality energy are not gauged and entangled in the process.

The clear cuts towards achievement of the mitigation of climate change, it is palpable to note it is not clear energy sources that can make happenings, rather quality clean energy.The prevailing state of access to unreliable, unaffordable electricity can with challenges create a milestone towards mitigation of the climate change (Culver, 2017). Of all the quality issues, reliability and affordability mostly determine the level of access to clean energy (Deller&Waddams,2015). About 1.2 billion people (17% of the world's population) lack access to electricity(WB, 2019).Nearly, about 85% of those who lack access to electricity reside in low economically developing countries(LEDCs) including Sub-Saharan Africa.Forecasting the future trend of access to electricity is vital in order to regulate the speed of investment towards access to electricity which is a clean energy carrier(Carranza and Meeks, 2016)

Those with access to electricity which is a cleanest form of energy sources (83% globally) are troubled by low quality signalled by flickering supply and unaffordability. These problems are more pronounced not only inTanzania, but also in Developing Asia and Latin America Thus, succinctly, it is important to have access to quality electricity with expectation to stimulate a wider array of climate change mitigation(Bernad, 2012). While the struggle for electricity remains real in Sub-Saharan Africa, Western America, Europe and North Africa have achieved nearly a universal access to quality electricity by 97- 99%(World Bank, 2017)and so development gain and climate mitigation through dependence on clean energy especially in rural areas is discernible.

While the current trend of access and future access are important in informing success towards climate change mitigation, the level of consumption needs also be disentangled. This is because of the fact access and consumption are two different parameters (URT, 2016). Sub- Saharan Africa (SSA) and Tanzania in that regard has per capita consumption estimated to be 488 kWh per annum. Similarly, it was reported that the 488 kWh is pushed up by the inclusion of South Africa with high electricity access rates in the region (Avila, Carvallo, & Shaw, 2017); if excluded, the average annual per capita consumption shrinks to 150 kWh (WB, 2014). Can this level of consumption be used to define climate change mitigation? This is important to understand.

Learning from other countries, the situation is worse and not welcoming to gauge mitigation of the climate change. For instance, until 2016, Eritrea had 51 kWh, Central African Republic

36 kWh, Liberia 69 kWh, Kenya 162 kWh, Uganda 70 kWh, Chad 16 kWh, Guinea-Bissau 17 kWh, while Tanzania had per capita consumption of electricity of 95 kWh per annum (Environmental Energy Service , 2018). In fact, if the level of consumption is not improved, it only brings to a simple interpretation that over dependence on greenhouse gases for domestic use will continue to challenge the efforts of climate change mitigation.Investment efforts in reducing electricity poverty have led to the decline of the population without electricity from 1.2 billion people in 2015 to 1.06 billion people (IEA & WB, 2017). Equally, the world's electrification rate has increased from 77.7% to 85.5%.

The increase in access to electricity is a real progress, it has also benefited rural access at the global scale which increased from 63% to 73% while urban centres had 97% (WB, 2017). In fact, improved access to electricity in urban areas is a milestone because since 2000 world's urban has received 1.6 billion people as new entrants, consequently, increasing the number of people with access to clean energy (WB, 2017).Sub-Saharan Africa (SSA) has moderate improvement from 26.5% to 37.5%, thus making 609 million (6 out of 10) people to remain off-electricity services compared to 620 million people in 2015 (WB, 2017). This means that, the number of people depending on climate change inducing energy sources is decreasing also.

Mechanism for increasing access to clean energy in Tanzania

Tanzania, in response to poor production and quality electricity, there are multiple tangible strategies put forth in the process of picking up. The strategies include the extension of National Grid, Micro Hydro Power (up to 1MW), Mini Hydro Power (up to 10 MW), Mini-grids (less than 10MW) and Photovoltaic (PV) which produce varying amount of electricity(Ordano, Sawe, Swai, Katyega, & Lee, 2018). The strategies represent the reliable means of ensuring access to electricity by the rural and sections of urban areas that are unlikely to be connected to the grid (Ordano *et al.*, 2018). Until recently, statistics indicate that in Tanzania, more than 109 mini-grids are registered to supply electricity in rural areas via the national grid and stand-alone mini-grids (Sarakikya, Ibrahim, & Kiplagat, 2015).

Additionally, Tanzania's energy utility has installed 29 solar power plants that produce 7MW (EWURA, 2018). In fact, the mini-grids will remain to be a key strategy in accelerating access to electricity in rural Tanzania and rest of Sub Saharan Africa. This is because of the reason that they are cost-effective than grid extension(Betraud, 2016).However, their cost in terms of operations and business return could have a huge mismatch. On the same, IRENA

(2018) confirmed that mini-grids are believed to have high reliability because they are manageable.In, Tanzania, electrification impetus increased from 2000s after stabilization of institutional and legal frameworks (Tomala et al., 2021).These include Rural Energy Board (REB) and Rural Energy Agency (REA) as manifested in the Rural Energy Act of 2005; Energy and Water Utility Regulatory Authority (EWURA), Electricity Act of 2008; National Energy Policy of 2003 (revised in 2015); and Public-Private Partnership Policy (PPP) of 2009 and PPP Act of 2010. The efforts have brought noticeable increase of rural electricity connection from only 1% in 2003 to 24% in 2020 and from 9% in 2003 to 40.2 in 2022. Further, the efforts have made Tanzania to be among the top ten countries with highest mini-grids developers in the world (Knuckles, 2019). Villages connected to electricity increased from 2,018 in 2015 to 9,112 in 2020 (Africa's Power Journal, 2020).

The Energy ladder model

The energy ladder model came into practice in 1980 as a result of new rethinking after the notable wood crisis of 1970s that extended up to 1980s (Kowsari and Zarriffi 2010; Taylor 2011). The energy ladder is rooted in economic view of consumers, basically at the household, but in the context of this paper it is viewed at the wider national level. It is a prominent model to explain theenergy choice (Kowseri and Zerriffi, 2011). It also describes the pattern of energy substitution as influenced byeconomic changes (Elias and Victor, 2005). The ladders consider income as one of the key determinants of energy switch from traditional biomass to clean energy fuels (Heltberg, 2003). In the context of the energy ladder, as income rises individuals consume energy that occupy higher rungs, ascending or climbing the energy ladder. A fuel’s rung is dictated primarily by its cost, a reflection of its cleanliness, reliability, efficiency and even affordability (Goldemberg 2000).In light of this paper, it will be exploring how the access to clean energy is influenced by GDP.The model is of the assumption that energy switching is linear (Heltberg, 2003) and envisions a three-stage energy switch, the first stage is the universal reliance on biomass, followed by transition fuels and finally to advanced fuel (Kroon et al., 2011).

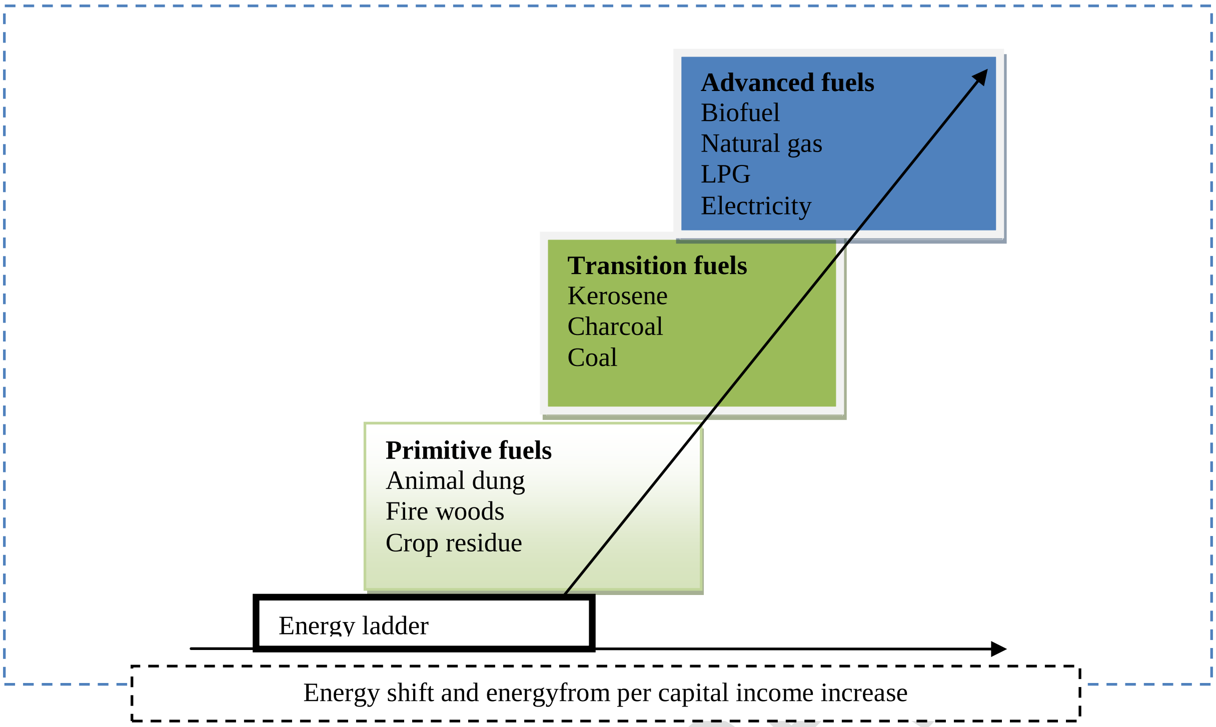

Chart 1 : The energy Ladder for Energy Transition
Source: Kowsari and Zerriffi (2011)

Overview of Tanzania energy profile, demand and supply

Tanzania is endowed with abundant energy resources of various nature and efficiency. The resources include natural gas, uranium, coal, hydro, and biomass, wind, solar and geothermal (URT, 2015). The domestic consumption of energy accounts for 75%, transport 6%, agriculture 4%, industry 14% while the rest accounted 1.2%. The current discovery shows that coal reserve is estimated to be 1.9bn tones, uranium deposits of about 2000million pounds (URT, 2015). Biomass is a dominant source of energy to both urban and rural dwellers by 85%, while 9.3% is a total energy from petroleum products, 4.5% is accounted by electricity while 1.25% is from coal and renewable energy (URT, 2016). Overdependence on biomass is creates a state of continued practices of inducing climate change activities. With development efforts in the sector, it is impeccable to gauge weather mitigating the climate change can be done by clean energy at large. In term of electricity, TANESCO is the sole vertical energy utility which dominate distribution through a central national grid and isolated mini-grids in remote areas (African Development Bank,2015). Tanzania had electricity fluctuation and erratic supply due to massive dependency on hydro power (Tanguy, 2012., and TANESCO, 2015). The annual demand growth for electricity is between 10-15 %, and the annual electricity consumption per capita was 105 kWh which is below acceptable global average per capita consumption of 500 kWh for urban and 250 for rural areas (Lusambo, 2009)

Methodology

This paper uses the time series data from Tanzania to analyse the current trend and forecast the future trend of access to electricity which could enlighten the success in mitigating climate change. Data comprised observations from 1992 to 2022 about the percentage of the population with access to electricity. The paper is based on the Box-Jenkins methodology (Box & Jenkins, 1976). The approach is suitable for short-runforecasts. It is an algebraic model that is commonly applied in forecasting and is known as an autoregressive integrated moving average (ARIMA). The Box Jenkins (BJ) methodology (Johnston & DiNardo, 1997) is an iterative process (Figure1) that follows a systematic flow in the estimation of time series data.

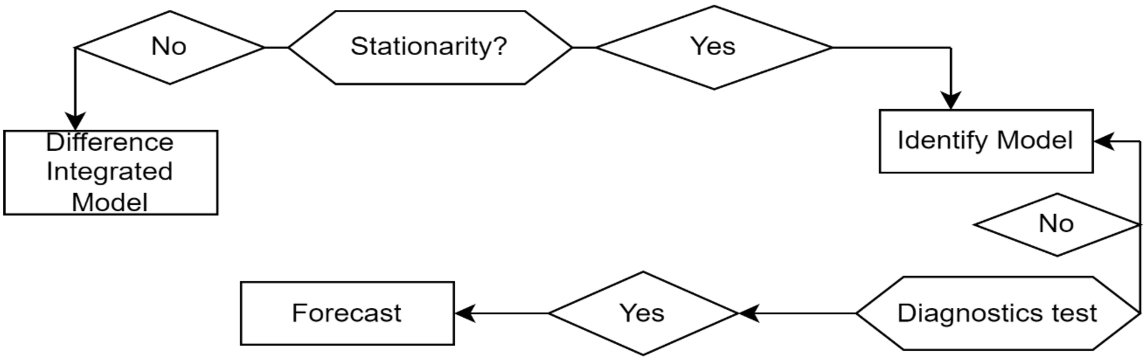

Figure 1: The Box Jenkins Approach for ARIMA

Source: Din(2016)

To use the Box-Jenkins methodology, it is important to have either a stationary time series or a time series that is stationary after one or more differencing. ARIMA consists of three parts, first is Autor Regression, AR(p), Moving Averages, MA(q) and Differencing in order to strip off the Integration (I) of the time series (d), this forms ARIMA (p, d, q).

Results

The Stationarity tests

This paper aimed at carrying out an estimation of clean energy (electricity) access in Tanzania by using time series data from the World Bank. With ARIMA estimation model, the first quality check includes stationaritychecks. Din (2016) suggests the check to be done by using graphs, correlogram and Augmented Dickey-Fuller Test. From the graph of Figure 2 and 3 the time the variable of interest is non-stationary because it has a trend as opposed to stationary. Its variation along the mean has no constant amplitude and is not consistent.

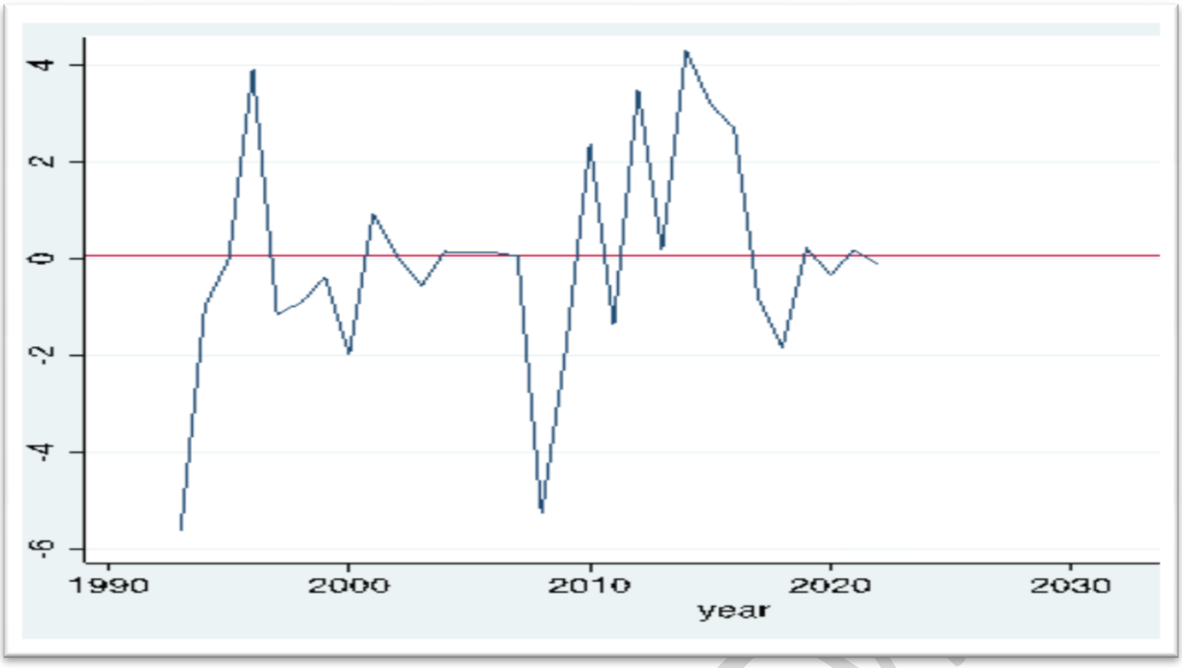

Figure 2: AR1 (Stationarity test for identification)

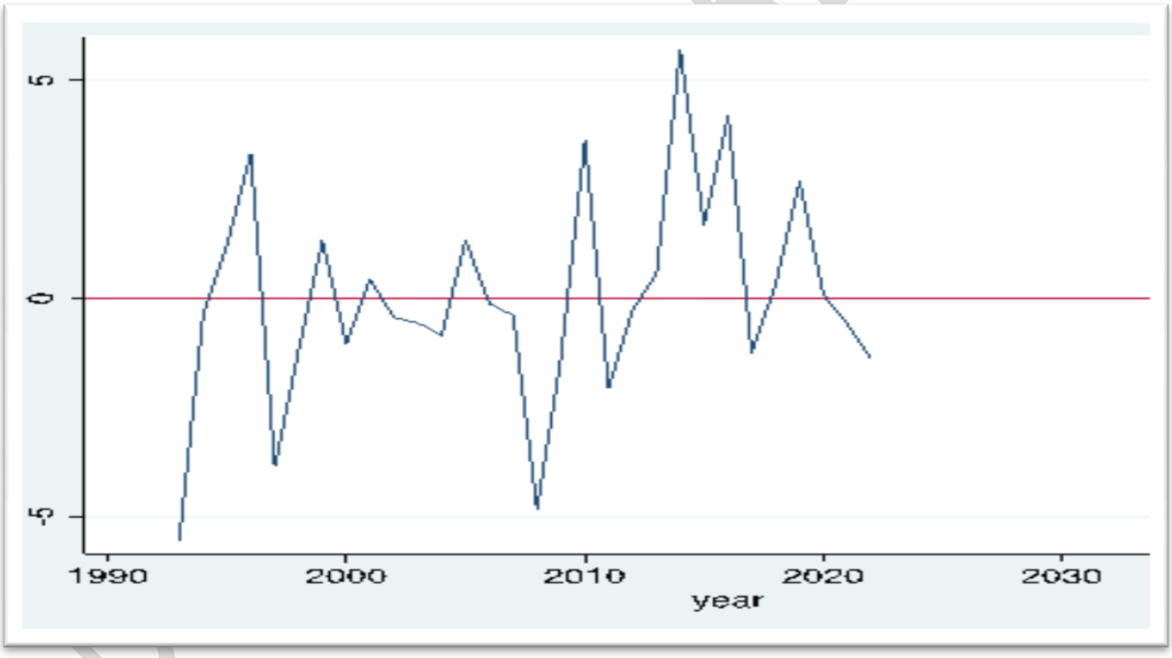

Figure 3: AR2 (Stationarity test for identification)

Correlogram analysis

Correlogram takes on board the parametric correlation of the variables of interest. Time series is commonly and linearly related to its lagged version of itself over successive time intervals. This is one of the analysis suggest by Petrevska (2013) in gauging the existing of the stationarity of the variable of interest. Thus, the analysis as in Figure 4 indicates that the decay is slow and constant along the diagonal path at 25 lags. This confirms that the variable lacks stationarity character.

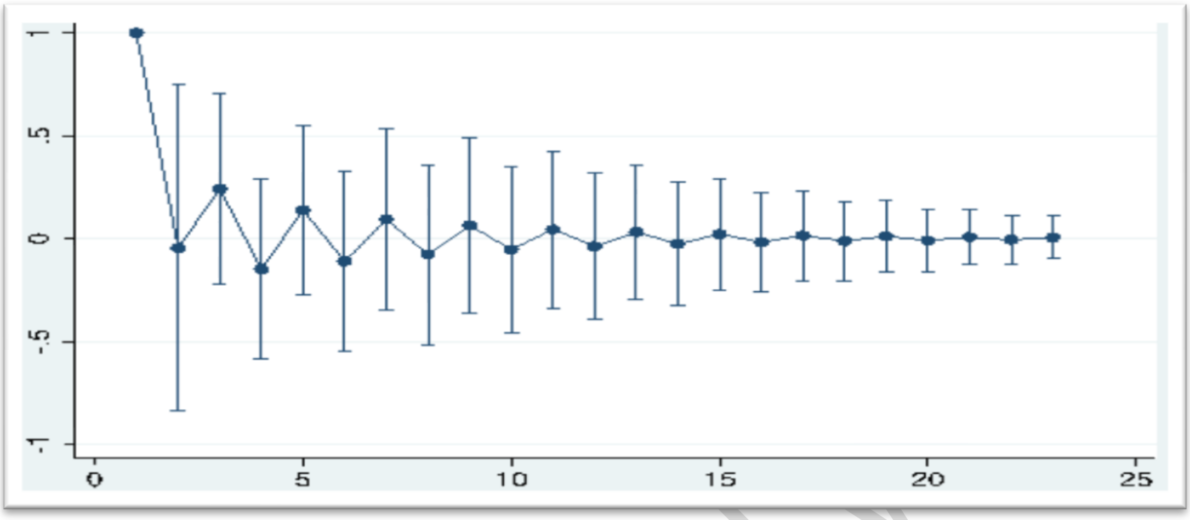

Figure 4: Parametric autocorrelation at 25 Lag
The x axis is lags in years while y axis is correlation coefficient

Figure 4 indicates that the correlation is constant in positive and negative side. There is strong correlation at Lag2. This indicates non-stationarity for general view of the time series because there are significantly non-zero correlations at the end.

The Augmented Dickey-Fuller Test (ADF)

Augmented Dickey Fuller test (ADF Test) is a common statistical test used to test whether a given Time series is stationary or otherwise. The test is mostly and commonly applied in statistical test when it comes to analyses of the stationarity of a series. The ADF test belongs to a category of tests called 'Unit Root Test', which is the proper method for testing the stationarity of a time series. This means that, a Dickey-Fuller, test null hypothesis that assumes the presence of unit root, thus the p-value obtained should be less than the significance level of 0.05. The results of the ADF is presented in Table 1

Table 1: The ADF for Unit Root

	ADF for Unit Root	**Number of observations =30, p value, *z(t)= 0.9916***		
		Interpolated Dickey-Fuller		
	Test Statistic	1% Critical value	5% Critical value	10% Critical value
Z(t)	-5.0904	-3.716	-2.986	-2.624
	ADF for Unit Root	**Number of observations =29**		
		Interpolated Dickey-Fuller		
	Test Statistic	1% Critical value	5% Critical value	10% Critical value
Z(t)	-5.0904	-3.723	-2.989	-2.625

Mackinnon approximate P-value is z(t)= 0.000

The results show that the time series is stationary at first difference since the Test statistic in absolute value is greater than the critical values. Since the null hypothesis of the ADF test is that the variable has a unit root (a causative of non-stationarity). The test statistic −5.905 is in absolute value greater than all of the critical values at $p<0.05$. Hence, the null hypothesis is rejected, signifying the presence of stationarity (unit root).

Model identification and Diagnosis

To identify whether ARIMA (111) or ARIMA (211), an estimation was done by identifying the value of *p* and p and *q*. The inspection of the correlogram was done to obtain the q (Figure 4). Notably, the autocorrelation function determines the value of q and partial correlation function is for p value. From the correlogram, the partial autocorrelation was having 2lags which are significant. Thus, the value of p is 2, leading to a selection of ARIMA (211) model. ARIMA (111) was estimated but sounded with less fits while also sufferingfrom autocorrelationand the residuals were not white noise. Thus, ARIMA (211), autocorrelations, partial autocorrelations were diagnosed through the Portmanteau white noise test on the residuals, and the model had the favourable results as indicate in Table 2. Portmanteau, tests that the null hypothesis that the white residual are noise,

Table 2: The Portmanteau test for white noise

Portmanteau test for white noise	25 Lags
Portmanteau (Q) statistic	12.2480
Prob > chi2(13)	0.5074

The Portmanteau test for the white noise suggests that the model does not suffer from autocorrelation because the Portmanteau statistic is not significant ($p>0.05$). The plot for the autocorrelations and partial autocorrelations thus can show the same results. This is a good sign for the analysis, indicating that the model is performing well. Further diagnosticobservation was done by inspecting the inverse roots of the ARMA polynomials in Figure 5. The estimated ARMA process was checked for covariance (stationarity) and it was found that the AR roots lie inside the circle. Further, the MA root lies within the unit circle, all the assured that the model met the conditions.

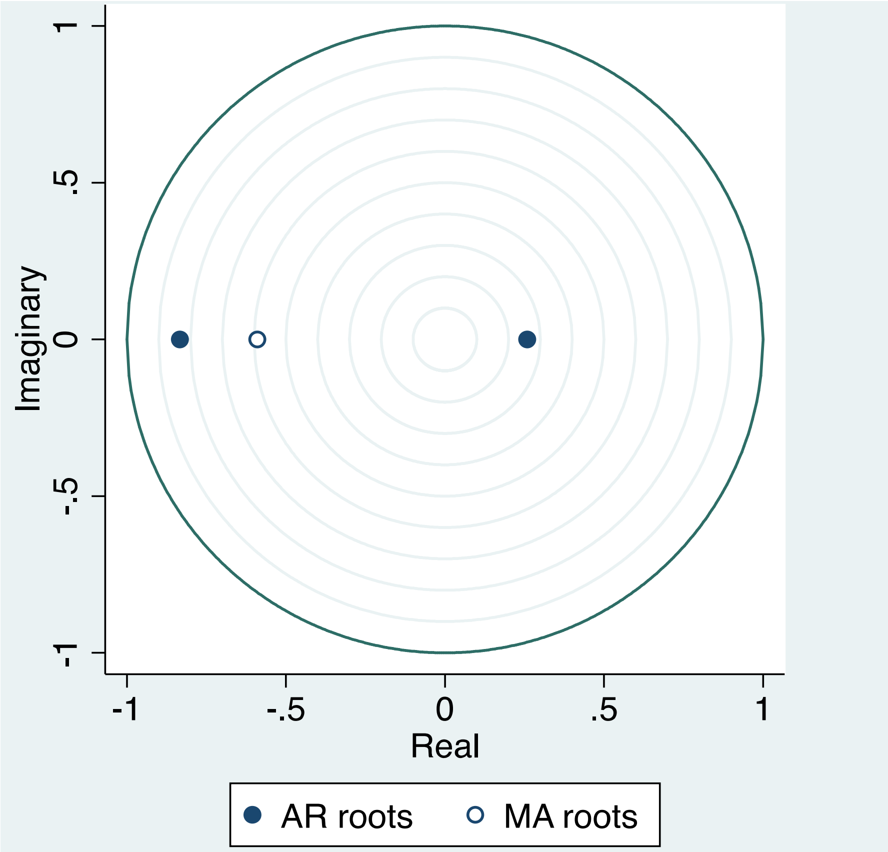

Figure 5: Inverse roots of ARMA Polynomials

Forecasting

The purpose of the paper is to forecast the percentage of people with access to electricity in Tanzania for a period of 10 years from 2023-2032 in order to shed light on whether dependency on climate change induced energy is mitigated. The forecast uses access data from 1992 to 2022 using ARIMA (211) Model. Therefore, after model identification and diagnostic evaluation,the forecast results are presented in Figure 6.

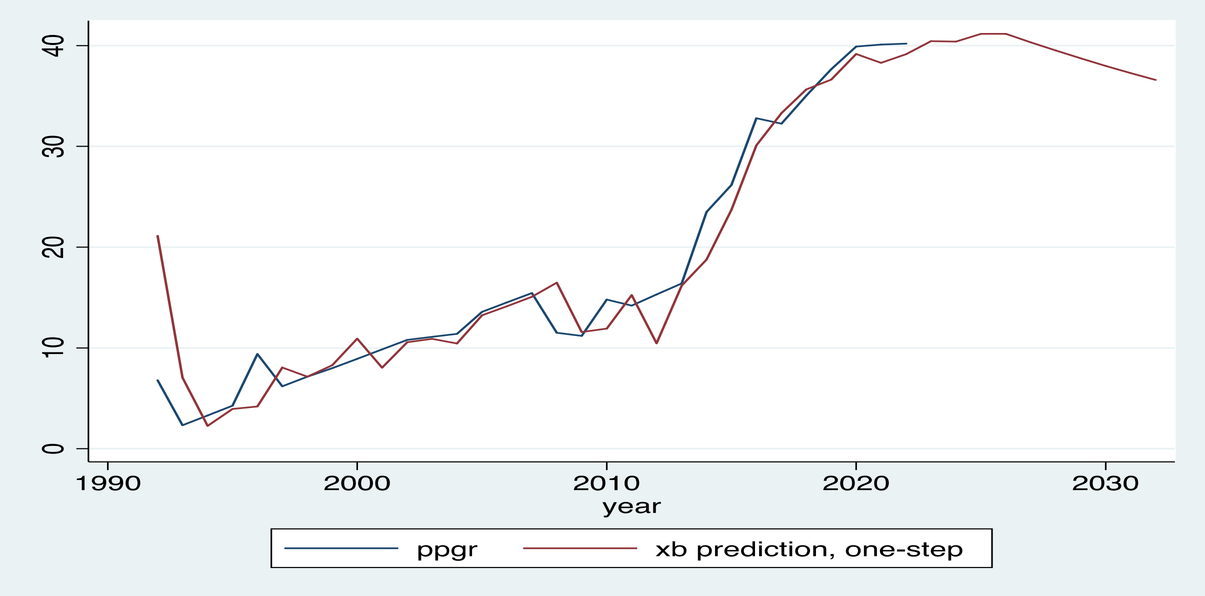

Figure 6: Forecast for electricity access (x-axis is % of population with access, y-axis is years)

The results show thatfor next ten (10) years from 2023 through to 2032, there will be variation of percentage of access to electricity. The highest percentage of access is revealed in 2023 with 40.44 percent. In the rest of the years do not show high profile and remain low. For example, year 2032 shows that the access rate is expected to shrink to 36.58%, this means that it will decline form the current rate of 40.2% (for year 2022). The key question is how it is possible to have such a decline of access? The reality is, due to unaffordability of consumption some people connected to electricity might disconnect, especially in the rural areas.

Discussion

Access to clean form of energy such as electricity is one of the most visible strategies for climate change mitigation. It reduces over dependence on climate change inducing sources of energy. From the forecast results, it is viable that the rate and trend of access to electricity by most of the population is negatively alarming not to be better in the work of climate change mitigation. The results show that the trend will continue to shrink, this means that the population in Tanzania will continue to rely on wood, charcoal and other solid biomass for cooking energy. With reference to energy ladder, although climbing it is associated with best economic status of energy consumers, but the certainty is that energy itself must be available and accessible in the first place. The population cannot climb the energy ladder such that from charcoal to electricity while the latter is not available in adequacy.

To increase the rate of access electricity, the economy of the state needs to grow first to allow investment in the energy sector to expand production, transmission and distribution of electricity to consumers whose economy needs to change status to better alsoin order toclimb and affordelectricity along the ladder. Failure to increase production would meant that the population that keeps growing, the industries that need to be fed with electricity will likely suffer and thus affects income and employees at the end. This felt effect has direct repercussion on access to electricity through reduced purchase power.

The forecast results for next ten (10) years raises a worrisome trend of less improvement in electricity access. The decline from 40.2 to 36.58 in 2032 offers new insight to look into. Either there is a possibility of many connected customers to shy away from electricity due to such issues related to unaffordability of its consumption which is again stand as one of the most compelling reasons for poor consumption of electricity in Sub-Saharan Africa and Tanzania in particular. This means that, attaining a level of good access to electricity as a means of climate change mitigation is still far and it is really a myth. Moreover, the decline and failure to increase access to electricity is looked at in the name of reliability of supply. The incidence of electricity outages gives no attraction for most consumers to delve into connection. This creates a negative booming loss of interest in state utility, hence leading to reliance on green house inducing sources of energy especially for domestic use.

While mitigating climate change is based on reducingan increasing flow of heat-trapping greenhouse gases into the atmosphere. This involves cutting and or reducing greenhouse gases from main sources such as power plants, factories, cars, and farms. While these measures are invisibly practical especially due to high level of industrial development in the world. It is important to venture into reduction of forest depletion by exploiting the available sources of energy in the country. With such forecast results in Figure 6, the efforts of reducing greenhouse gaseous which constituents of the atmosphere, both natural or anthropogenic, that absorb and re-emit infrared radiation becomes a myth towards climate change mitigation. To eradicate the myth of mitigating the effect of climate change in Tanzania and to increase the access along the forecast line as in Figure 6. Tanzania should intensively extract energy form the vast and readily available potentials such as hydropower, natural gas, coal, uranium, wind, geothermal, solar, tidal, and waves.

Conclusion and Recommendation

The paper aimed at forecasting percentage of people or population with access to electricity for ten years from 2023-2032 in the work of mitigation climate change. The supposition is that, Tanzania is still far from reaching the reality of mitigating the climate change through access to clean form of energy. This is because of the fact that, the forecast results showed that the rate of increase of people with access to electricity is less encouraging, stagnating and does not prove the reality. There is a danger of continued dependence on unclean sources of energy due to poor access, this will negatively affect the actions based on mitigating climate change. This is to say that attaining climate change mitigation through access to clean energy like electricity is still a myth. It is the responsibility of energy utility and development partners and planners to extract the available resources to increase the rate of access to electricity. This, in the end, will move a large population from depending on unclean energy sources which induce climate change. The poor forecast results are happening amid the potential of clean energy sources in the country. There is also a need to increase the use of energy-efficient technologies,especially at the domestic level where up to 85% of energy produced is consumed.

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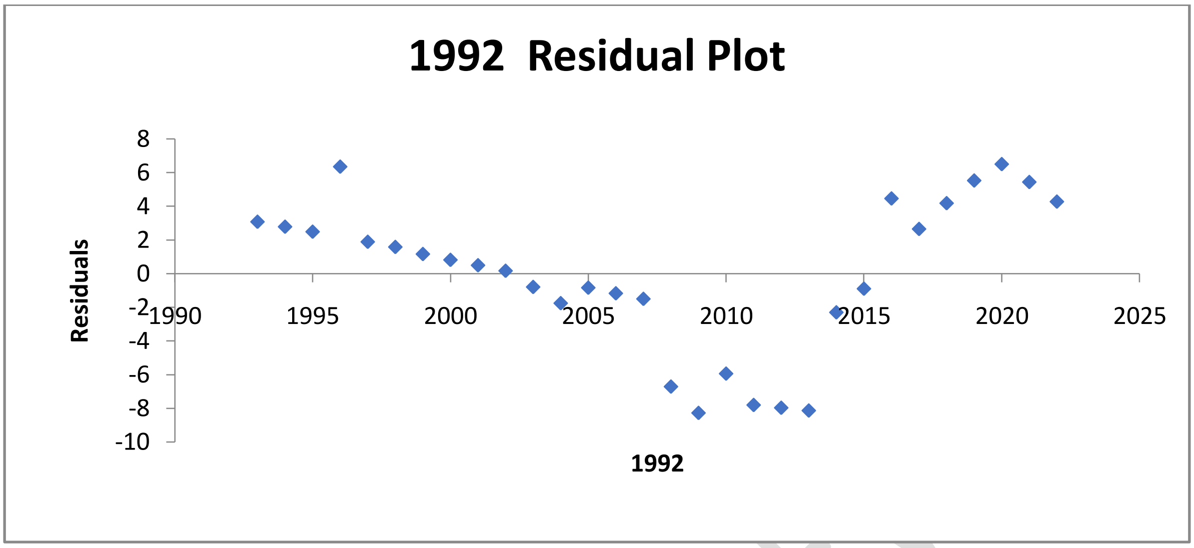
Appendix: Data used

YEAR	PPGR	P
1992	6.8	21.11724
1993	2.3302	7.057416
1994	3.3006	2.270059
1995	4.2691	3.944964
1996	9.4	4.18872
1997	6.1971	8.060953
1998	7.1553	7.140966
1999	8	8.278741
2000	8.9167	10.9102
2001	9.861	8.037768
2002	10.7977	10.56006
2003	11.1	10.90533
2004	11.4	10.44799
2005	13.5858	13.24251
2006	14.5157	14.13754
2007	15.4501	15.0754
2008	11.5	16.46984
2009	11.2	11.58338
2010	14.8	11.91144
2011	14.2	15.2451
2012	15.3	10.45287
2013	16.4	16.18901
2014	23.5	18.7606
2015	26.1706	23.71782
2016	32.8	30.09676
2017	32.2512	33.30633
2018	35.048	35.66054
2019	37.6597	36.62049
2020	39.9	39.1698
2021	40.1	38.28015
2022	40.2	39.15431
2023		40.44001
2024		40.39742
2025		41.17014
2026		41.17291
2027		40.32392
2028		39.51087
2029		38.73224
2030		37.98657
2031		37.27246
2032		36.58858

Picture 1 :Residual Plot



Picture 2 :The fit line for the plot