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Modelling Renewable Energy Consumption and Economic Growth in Uganda

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Abstract
Back ground: This study models renewable energy consumption and economic growth, with evidence from Uganda (1982-2018). The hypothesis that explains causality between renewable energy consumption and economic growth follows the growth, conservation, feedback and neutral.
Methods: The study uses vector error correction model (VECM) and structural vector auto regression (VAR), within a multivariate data framework. The Pairwise Granger test was specifically used to establish the direction of causality between variables of study. The Johansen co-integration test was carried out to ascertain if there exists a long run relationship between renewable, domestic investment, foreign direct investment and real GDP.
Results: The results support the neutral hypothesis between renewable energy consumption and economic growth.
Conclusion: The conclusion therefore is a unidirectional relationship running from of renewable energy consumption to economic growth
Implications/Relevance/Originality /Value: This paper provides insights into how renewable energy consumption drives economic growth and sustainable development.

Keywords: Renewable Energy consumption, economic growth, causality, Structural Vector autoregression, Vector error Correction Mechanism

1.0 Introduction

1.1 Background and motivation

Studies on renewable energy consumption and economic growth are important in contemporary research (Wang et al., 2020, Etokakpan et al., 2020, Mutumba et al., 2021). Studies are characterised with disagreements in their findings (Mutumba et al., 2021). The overriding view is that increase an energy consumption promotes economic growth (Zhang and Tan 2020). Other researchers, however, found little evidence in support of this (Kasperowicz et al., 2020).
Global economic growth increased by an average rate of 3.10 percent over the period of 2000-2018 while global renewable energy consumption increased at an average rate of 2 percent from 2000-2018. (Gielen et al., 2019). The nexus between renewable energy consumption and economic growth is not consistent with each other. This would cause an interrogation as to whether renewable energy consumption drives economic growth?

1.2 Studies and Antecedents

From the landmark studies of de Janosi and Grayson, Carter (1974), and Jorgensen (1974), Humphrey and Stanislaw (1975), Odum and Odum (1976), and Pachuri (1977), Kraft and Kraft (1978), Bergman (1978), Tyner (1978), Akarca and Long (1979), Hannon and Joyce (1980) gave dissenting views in their findings. The recent studies that followed were not any different. The results from the growing body of literature just will not converge. This controversy gives this study the mandate for a fresh investigation on modelling the variables of study with an eye on explaining the contradicting pieces of evidence.

Government of Uganda has invested in renewable energy generation, supply and consumption with a view that this will promote rapid economic growth (Chingoiro and Mbulawa, 2017), however, there has been a decline in the rate of increase of energy consumption as the rate of economic growth is increasing a paradox that is of interest to this study.

1.3 Hypothesis

The main arguments on causal relationship between renewable energy consumption and economic growth (GDP). The causal connection between the two variables of study is important in establishing which one would be a centre of focus by policy makers,

Mutumba et al., (2021a) expounded a nexus between energy consumption and GDP into four main arguments: growth, conservation, bi directional, and neutrality (Apergis 2009a, Alper & Oguz 2016, Dorgan 2016, Adewuyi and Awodumi, 2017a). The growth hypothesis contends that energy consumption influences economic growth explicitly and implicitly as an intermediate good that augments capital and labour. The growth hypothesis is supported if there is unidirectional causality from energy consumption to economic growth. Under the growth hypothesis, strategies that reduce energy consumption may affect economic growth negatively. While policies that increase energy consumption are an engine to increase GDP (Chandio et al., 2019, Sanu et al., 2019, Bekun and Agbola 2019, Belaid & Zreli 2019, Chen et al., 2020, Swu 2021, Yusui 2021).

Secondly, the conservation hypothesis postulates that causality runs from economic growth to energy consumption. The conservation hypothesis is confirmed if there is unidirectional causality from economic growth to energy consumption. Energy conservation policies designed to reduce energy consumption may not have an adverse impact on economic growth (Odhiambo 2020, Salari et al., 2021). This hypothesis presupposes that energy makes a small contribution to economic growth. Other factors explain the growth process more than energy consumption.

Third, the feedback hypothesis emphasizes the interdependent relationship between energy consumption and economic growth and their complementarity. There is bidirectional causality between energy consumption and economic growth (Zafar et al., 2019, Wang et al., 2021). Policies designed to increase energy consumption must be designed cautiously to attain optimum growth. For instance recommending energy efficiency must be done after careful consideration as it may promote growth in the short run and inhibit it in the long run.

Finally, the neutrality hypothesis considers energy consumption to be a small component of an economy's overall output and thus may have little or no impact on economic growth (Adewuyi and Awodumi 2017a, Zafar et al., 2019, Salahuddin and Gow 2019, Wang et al., 2019). Policies to boost energy consumption have minimal or no effect on economic growth.

What is clear about the hypothesis is that outcomes are still contested, there is no agreement on the direction of causality between energy consumption and economic growth. This study therefore, seeks to make an inquiry with a view of resolving the contradicting evidences.

1.4 Contribution of this paper

This study seeks to widen our understanding of growth theories. Previous studies have focused on classical growth theories. This study has focused on endogenous growth theory as useful in explaining that renewable energy consumption is primarily endogenous to economic growth. Furthermore that the renewable and non-renewable energy consumption is also endogenous to economic growth. This is in agreement with earlier studies (Ozturk *et al.*, 2010, Salahuddin and Gow 2019).

Methodologically, this study makes a contribution the theory of methods. More specifically, the vector error correction mechanism (VECM) was used to provide a suitable and valid basis for policy making. With endogenous variables being dominantly considered in the model the VECM model becomes suitable (Lütkepohl, 1999). It analysed the direction of causality on energy consumption a major driver of industrial growth and economic growth in Uganda. This study investigated the direction of causality using VECM. The Johansen cointegration test was be carried out and Granger causality test. The contribution energy consumption makes on GDP to the Ugandan economy is not clearly known.

It further analysed the feedback effect of shocks from renewable energy consumption on Uganda's economic growth using the structural vector auto regression (SVAR). This model is robust in assessing the pass through effect of shocks say from Renewable energy consumption and Economic growth

1.5 Road Map

The remaining part of this paper is made up of empirical literature in section two mainly ladened with both theoretical and empirical literature, methods in section three, results and discussion in section four and finally conclusions and policy recommendation.

2.0 Review of Literature

The section on literature builds on theoretical as well as empirical literature as a way of setting the analytical stage.

2.1 Theoretical Literature

2.1.1 The endogenous growth theory and economic growth

Endogenous growth theory was first postulated by Schumpeter (1911). According to Schumpeter, endogenous growth occurs through creative destruction. Entrepreneurs take risks, try new ideas, innovate and embrace technical changes which ultimately lead to growth (Alcouffe and Kuhn, 2004). Schumpeter's growth theory takes on innovations as the source of long run growth. According to Schumpeter, monopoly rents motivate entrepreneurs to invest in creativity and innovations. In this case, new innovations replace old innovations ultimately leading to increased output and hence growth.

Accordingly, entrepreneurs would operate in a naturally self-regulating mechanism in which innovations create new economic order (Schumpeter 1911). In this case, entrepreneurs are rewarded profits that they use in wealth creation. The basic question here is how do such innovations in energy consumption affect economic growth? Dosi et al., (2010). This study, however, has a related question; which energy drives economic growth?

The endogenous growth theory was further popularised by Romer 1990, Grossman and Helpman 1991, Aghion and Howitt, 1992, 1998, Dinopolous, 1996. Most, if not all these authors argue that endogenous growth theory is predominantly determined by factors within the economy (Romer 1994). The theory presents investment in human capital (H), knowledge (K) and innovation as an important driver of economic growth in developing countries. The theory alluded to a technological component in the growth factor but in his a four variable model such as Y = f (H, L, K, A). Where H is Human capital, L is labour, K is capital and A is technology.

Nevertheless, investment in human capital, knowledge and innovation presented by Romer (1994) above may not adequately drive economic growth forward in developing countries, unless it is being complemented with rigorous investment in energy sector and such investment should be carried out in a reliable energy source.

It should, however, be realized that the major focus of this theory is on positive externalities and spill-over effect of knowledge based economy as the major driver of growth. This theory however, is completely silent on the role of energy consumption on economic growth in developing countries. Nonetheless, Lubumbe (2014) argued that energy sector is complementary in promoting economic growth in that it stimulates more output and growth in developing countries like Uganda.

Thus, endogenous growth theory confirms the notion that investment in energy sources in developing countries promotes creation of capital stock and also more means of production, which eventually contribute to economic growth in these countries. In this situation therefore, efficiency of capital can only be enhanced by investment in a more reliable energy sources (Manuel, 2005)**.** This justifies the use of both domestic and foreign direct investment as a way to establish which kind of investment has more linkages to economic growth of developing countries like Uganda.

Short comings of earlier classical growth theories viewed two factors of production namely land and labour as being important for production and growth like the Ricardian theory of distribution in which he postulated that land of uniform fertility would be cultivated, returns would be shared between labour and land and each would get its share indicated as 'the Ricardian rent'. This however, had clearly ignored capital as a key factor of production.

The endogenous growth models emphasized that it was capital not land which was important since land had zero supply price. So capital and labour were key determinants of growth. Harodd (1939) and Domar (1946) had included savings rate and investment as determinants of Growth. Standard economic theory regards capital and labour as main factors of production that satisfy the cost- share theorem. This is a neoclassical economics (NCE) growth paradigm, whose usefulness is being explored to the limit. These anchored on some growth models that treated all other materials under land, as Endogenous growth models. This, however, has left a missing link on energy's contribution to the production process.

Secondly, the conventional production process using labour and capital is embedded and fortified with energy. This does not mean energy cannot stand alone as input given the fundamental contribution to output. In fact this is better representation of the reality being studied.

Thirdly the composite energy good is both a flow and a stock of resources in a state of matter across time and space as in the Gibbs conservation force field. Finally, the production of small modern devices involves the use of embodied energy. A smaller device like mobile phone has a lot of energy used in folding, fitting and designing it. For instance in ratio of 4 phones to one car (Kulionis 2013).

2.2 Empirical Literature on Renewable Energy consumption and Economic growth

The growing body of Literature has been organised in this subsection of renewable energy consumption and economic growth.

Accordingly, Mutumba et al., (2021a) with over 1240 studies profiled the growth hypothesis is the most outstanding result. For instance this study found out that most of the papers reviewed in the literature support the growth hypothesis with over 43.8 percent of all country specific studies including; Al-Khawaldehand and Al- Qudah (2018), Benh- Salha et al., (2018), Bello et al., (2018), Elfaki et al., (2018) Elfaki and Aziz (2018), Ghoshray (2018), Gokmeglu and Kaakeh (2018), Gozgor (2018), Kotrizdis et al.,

(2018), Lee and Jung (2018), Mukhtarov et al., (2018), Nadiamoha and Mansur (2018),Sulaiman and Abdul- Rahim (2018), Tang and Peng (2018), Zallé, 2018, Mbarek et al., (2018), Agbola and Bekun (2019a), Akadiri et al., (2019), Erdogan et al., (2019), Ketenci and Aydogan (2019), Khan et al., (2019), Latief and Lefen (2019), Lin and Wang (2019), Natalya and Touris (2019), Saudi et al., (2019), Samu et al., (2019), Shiba et al., (2019), Stamatiu and Dritsaki (2019),Thaker et al., (2019), Zhang et al., (2019), Ahmad et al., (2020), Bulukan et al., (2020), Bulut and Apergis (2020), Guris and Tiftikcigil (2020), Kirikkalelli et al., (2020), Parveen et al., (2020), Tao et al., (2020), Wang et al., (2020), Al- Rasasi et al., (2021), Alpdogan (2021), Fazal et al., (2021), Jayasinghe and Selvanathan (2021), Ha and Ngoch (2021), Kalimera (2021), Okoye et al., (2021), Soava et al., (2021), Yisui et al., (2021).
Feedback hypothesis in this study however, found out that 18.5 percent of literature reviewed. A two way causality between energy and GDPh in developing countries was confirmed. For instance, these included; Mavikala and Khobai (2018), Rathnayaka et al., (2018), Sunde (2018), Marcel (2019), Sultan and AlKhateeb (2019), Bui (2020), Cevik et al., (2020), Jiang and Che (2020), Koengken and Fuinhas (2020), Turan and Aksoy (2021). The bidirectional hypothesis suggests complementarity between energy consumption and economic growth.
Conservation hypothesis on the causality between variables of interest in this study constituted 27.2 percent. The conservation relationship in this study is supported by Bouznit et al., (2018), Brady and Magazzino (2018),Gobo et al., (2018), Naminse and Zuang (2018), Salahuddin et al., (2018), Xu et al., (2018), Akadiri et al. (2019), Bekun and Agbola (2019b), Chandio et al., (2019), Heun and Brockway (2019), Huang and Huang (2019),Gokmenoglu and Sadeghiel (2019), Gessesse and He (2020)Kumar et al., (2019), Li et al., (2019),Dat et al., (2020), Erkisi and Celik (2020), Etokapkan (2020) Fan et al., (2020) Salahuddin and Gow (2019), Magazzino and Schneidar (2020), Odhiambo (2020), Tiwari (2020), Wei et al., (2020), Zeraibi et al., (2020), Hassan and Kankanamge (2021), Salari et al., (2021).
While 10.5 percent of studies in this area can be categorized as neutral relationship. This is because they all found out that there was no relationship (Dorgan 2016). Some of these studies include; Bulut and Moratoglu (2018), Tugcu and Topcu (2018), Chinedu et al., (2019), Ozcan and Ozturk (2019), Nepal and Paija (2019).

3.0 Methods
The study used quantitative approach and a causal relationship and correlational research design (Chinedu et al., 2019). A quantitative approach where numerical data was analysed using descriptive and inferential statistics, variables of quantitative nature were analysed using the structural vector auto regression (VAR), vector error correction mechanism (VECM).

3.1 Data Type and Sources
Secondary data time series econometrics was adopted by this study. These include; Gross Domestic Product (GDP), Energy Consumption and Domestic Investment, (representing gross capital formation). The data was extracted from Current World Economic Statistics, World Bank data base, World Development Indicator and International Energy Agency (IEA) data base.

3.2 Data estimation techniques
3.2.1 Stationarity Test
The Stationarity was estimated in the study using Augmented Dickey Fuller (ADF) test and Phillips Perron test for each of the series. A unit root null hypothesis was tested against a stationary alternative. The

stationarity test in the study used regressions of a time series data analyzed against a constant. These can be expressed as follows;

$$Y_t = \alpha + \beta.t + \varepsilon_t \quad \textbf{(1)}$$

$$dY_i = \alpha + \beta.t + \sum_{i=1}^{n} \lambda.dY_{t-i} + \delta.Y_{t-i} + \varepsilon_t \quad \textbf{(2)}$$

The stationarity of residuals *(ε_t)* andLag length *(p)* of ADF *(dY_{t-i})* and Phillips Perron equations were chosen using Schwarz Information Criterion *(SIC)* and Bartlett Kernel respectively.

3.2.2 Cointegration Test

The procedure this study used to test for long run relationship within variables of interest included Maximum Likelihood (LM) test and unrestricted Vector Auto Regression (VAR) test. Cointegration rank r (number of cointegrating vectors) was tested using trace statistics and Maximum Eigen Statistics (MES). The trace statistics tested the null hypothesis that there is atleast one cointegrating vector against alternative ofmore cointegrating vectors, while the MES tested the null hypothesis of r cointegrating vectors against alternative of r+1 cointegrating vectors.

3.2.3 Normality test

Normality test was carried out in this study to determine whether the data series that was estimated in the study to establish whether they are normally distributed or not. If the residuals are normally distributed, the histogram is bell-shaped and the Jarque-Bera statistic should not be significant.

3.3 Models Specification

The model specified in the study is the structural vector autoregression (VAR) by Sims (1980) to assess the causal relationship between Energy Consumption and Uganda's GDP (1982 -2018). An extension to this is the Structural Vector Autoregressive (SVAR) model first presented by Sims (1980).

Thus the equation estimating the causal relationship between Energy Consumption *(ENC)* and Uganda's Economic Growth *(GDP)* in the period under the review can be presented and augmented with domestic investment *(D.INV)* and Foreign Direct Investment (FDI) as follows;

$$GDP_t = f(ENC_t .D.INV_t, FDI_{t,}) \quad \textbf{(3)}$$

Using log linear relationship, equation (32) can be rewritten as follows;

$$log(GDP_t) = a_0 + a_1 \, log(ENC_t) + log(D.INV_t) + log(FDI\ t) + u_t \quad \textbf{(4)}$$

Using equation (3), the model estimating the causality will be augmented by adding in Renewable Energy *(ENCR)* and can thus be presented as follows;

$$log(GDP_t) = a_0 + a_1 \, log(ENCR_t) + a_2 \, log(D.INV_t) + a_3 \, log(F\,D.I_t) + Vi_t \quad \textbf{(5)}$$

Where:

GDP_t = Gross Domestic Product at time t

$ENCR_t$ = Renewable Energy Consumption at time t

DINV_t = Domestic Investment at time t

FDIt = Foreign Direct Investment at time t

V_{it} = Error Term

$a_0, a_1, a_2, a_3 > 0$

Thus the causal relationship between Energy Consumption and Uganda's economic growth in the period between 1982 and 2018 will be estimated using Granger Causality Test and Vector Error Correction Model.

3.3.1 Granger Causality Test

The Granger pair wise test wase carried out in this study to estimate the causal relationship between Energy Consumption and Uganda's economic growth in the period, 1982-2018. Granger causal relationship is said to exist if variable X_t helps to improve forecast of another variable, say Y_t. The forecast of Y_t can be denoted as $Yt+h|\Omega$ for optimum h–step at origin t, based on set of all relevant information in the universe (Ωt). Xt is said to be Granger non-causal for Y_t if and only if $Yt+h \ |\Omega = Yt+h \ |\Omega/[Xt,s|x \leq t], h=1,2,3,4$ **(6)**

3.3.2 Vector Error Correction Model (VECM)

The vector error correction model (VECM) was determine presence of cointegrating relationship within endogenous variables is an essential step for estimating vector error correction model. The general form of the vector error correction model that will be estimated in this study is as follows;

$$\Delta X_t = \sum_{t=1}^{n} \beta_t \Delta X_{t-1} + \sum_{i=1}^{r} \gamma_i \, ECT_{t-1} + v_t \quad \textbf{(7)}$$

Where X_t is an nx1 matrix and $n = 4$ vectors of dependent variables, ΔX_{t-1}, β and γ are parameters, while V_t is a residual. Error correction mechanism is evidence in the Error Correction Term (ECT_{t-1}). There are as many error correction terms as there are cointegrating vectors (r). Parameter γ_i associated with ECT_{t-1} measures proportion of adjustment back towards equilibrium that can be completed within a single period. If parameter γ_i is not significantly different from zero then there is no error correction process working within the model. Parameter β_t on the other hand, indicates the presence of a short term lag from one variable to another and it measures short term adjustment back towards equilibrium.

Therefore the justification for use of the VECM is due to existence of a long run relationship among variables of study. Secondly was to take care of the endogeneity problem. This made VECM a suitable method of analysis.

3.3.3 Response of Uganda's Economic Growth to Shocks from Renewable Energy Use

This used Structural Vector Auto Regression (SVAR) model to investigate the response of Uganda's economic growth to shocks from renewable energy consumption. It was operationalized as Variance Decomposition Analysis (VDA) and Cumulative Impulse Response (CIR) function pioneered by Sims in 1980 to investigate the response of Uganda's Economic Growth to shocks from renewable energy consumption.

Thus, the equation estimating the response of Uganda's Economic Growth to shocks from renewable energy consumption in the period under the review can be specified as follows:

$$y_t \ \square\, c \,\square\square_i\, y_{t \,\square 1} \ldots\ldots\ldots\ldots \square\square_k\, y_{t \,\square\, p} \ \square\ \mu_t \quad \textbf{(8)}$$

Where;

$yt = (y_{1t} \ldots\ldots\ldots\ldots y_{kt})$ represent an $(n \times 1)$ matrix of time series variables and μ_t is an $(n \times 1)$. Following Osekhebhen, (2013) equation (9) can be transformed as:

$$y_t = c + \sum_{t=1}^{n} \square \ y_{t-1} + \mu_t \quad \textbf{(9)}$$

Where;

y_t is a *(n x 1)* vector of observations at time t on the economic variables under consideration. $C = (c_1,\ldots\ldots c_2)$ is the (nx1) intercept vector of *VAR*. y_{t_1} is a sequence of $(n\times n)$ matrix of autoregressive coefficients for I (identity matrix) = *1, 2,...P* and $\mu_t = (\mu_{1t}, \ldots, \mu_{3t})$ is the $(n\times 1)$ generalization of a white noise process or vector of disturbances to the system.

The structural model:

$$B(L) = y = c + \mu_t \qquad \textbf{(10)}$$

Where;

B (L) is second order matrix polynomials in the lag operator *L* such that:

$$B(L) = B_0 - B_1 L - B_2 L^2 \qquad \textbf{(11)}$$

B_0 is a normalized non-singular matrix and it summarizes the contemporaneous relationship between the variables contained in the vector *y*. But μ_t is a vector of structural disturbances which is serially uncorrelated.

3.3.4 Structural Vector Autoregression

The Structural Vector Autoregression (SVAR) as postulated by Sims (1980) who argued that "it should be feasible to estimate large macro models as unrestricted reduced forms, treating all variables as endogenous". Today, SVARs are regarded as easy and having gained technological success to use models for the time series econometrics Wang and Zivot (2006). In this study SVAR lend themselves to use in multivariate framework, they are simplistic and yet easy without specifying which variables are endogenous or exogenous. The SVAR is handy when feedback mechanism exists. Three tests are used in order to choose the optimal lag length p in the SVAR model, the Akaike (AIC), Schwarz (SBIC) and the Hanna-Quinn (HQIC) criterions. If the conflicting results are obtained, then we choose a lag length suggested by majority of criterion tests. Post-estimation tests for skewness, kurtosis and normality of residuals are carried out after estimating each VAR model. In addition we also test for the serial autocorrelation in the residual if we find any evidence of autocorrelations we try to fix it buy adding or removing lags of our variables.

Following Odongo and Muwanga (2014), response of Uganda's Economic Growth to shocks from Renewable Energy Consumption in the period between 1982 and 2018 can be presented as follows:

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ -\alpha_{21} & 1 & 0 & 0 \\ -\alpha_{31} & -\alpha_{32} & 1 & -\alpha_{34} \\ -\alpha_{41} & -\alpha_{42} & -\alpha_{43} & 1 \end{pmatrix} \begin{pmatrix} V_t^{ENCR} \\ V_t^{DINV} \\ V_t^{FDI} \\ V_t^{GDP} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ \beta_{21} & 1 & 0 & 0 \\ \beta_{31} & \beta_{32} & 1 & 0 \\ \beta_{41} & \beta_{42} & \beta_{43} & 1 \end{pmatrix} \begin{pmatrix} U_t^{ENCR} \\ U_t^{DINV} \\ U_t^{FDI} \\ U_t^{GDP} \end{pmatrix} \qquad \textbf{(12)}$$

Where;

ENCR = Renewable Energy Consumption;

D.*INV* = Domestic investments;

GDP = Gross Domestic Product;

V_t and U_t are assumed to be uncorrelated.

4.0 Results and Discussion

4.1 Results

4.1.1 Test Results for Stationarity

The stationarity test results is summarised in table 4.1 present the ADF and PP statistics for the variables estimated. The results indicate that all variables are not stationary at levels while they are stationary at first difference.

Table 4.1: Stationarity Test Results

Estimation period (1982 - 2018)				
Variables	ADF(level)	PP(level)	ADF(Difference)	PP(Difference)
Log(GDP)	-0.498588	-1.264296	-9.915456**	-23.72136**
Log(DINV)	-0.974207	-0.965360	-10.35787**	-10.35841**
	-	-		
Log(FDI)	1.772290	2.408257	-11.17349**	-11.27732**
Log(REC)	0.819237	1.953711	-12.37050**	-12.89455**

Source: Author's analysis based on data from World Bank, International Energy Agency, Bank of Uganda; **ADF and (PP) test statistics are significant at **Significance at 5 Percent level of significance

4.1.2 Test for Cointegration

The results for the cointegration test are presented in table 4.2.

Table 4.2: Cointegration Test Results

Trace test of:	Trace Statistics	Critical Values
r ≤ 4	4.468502**	3.841466**
r ≤ 3	20.23808**	15.49471**
r ≤ 2	50.25429**	29.79707**
r ≤ 1	90.56138**	47.85613**
r ≤ 0	210.9315**	69.81889**
Maximum Eigen value Test of:	Max-Eigen Statistics	Critical Values
r ≤ 4	4.468502**	3.841466**
r ≤ 3	15.76957**	14.26460**
r ≤ 2	30.01621**	21.13162**
r ≤ 1	40.30709**	27.58434**
r ≤ 0	120.3701**	33.87687**

Source: Author's analysis based on data from World Bank, International Energy Agency, Bank of Uganda; ** Critical values and Max Eigen statistics are significant at 5 percent.

The Unrestricted Trace Statistics (UTS) indicate three cointegrating vectors at 5 percent level of significance; while Maximum Eigen Statistics (MES) indicate three cointegrating vectors at 5 percent level of significance. Thus; there exists long run relationship within variables in the model specified.

4.1.3 Test for Normality

A normality test was carried out using the Jacque Bera test, to determine whether the data series estimated in the study are normally distributed or not. The condition for normality is that probability must not be less than 5 percent, and the probability from the Jacque Bera in this study is 92 percent as shown in Figure 4.1. The results in this figure displays histogram and the descriptive statistics of the residuals including the Jacque Bera statistics that test for normality. If the residuals are normally distributed, the histogram should be bell shaped and the Jacque Bera should be significant. The reported probability in the table below exceeds the value under the null hypothesis. The study therefore does not reject the null hypothesis of a normal distribution. Therefore this data has a normal distribution as shown in figure 41 below.

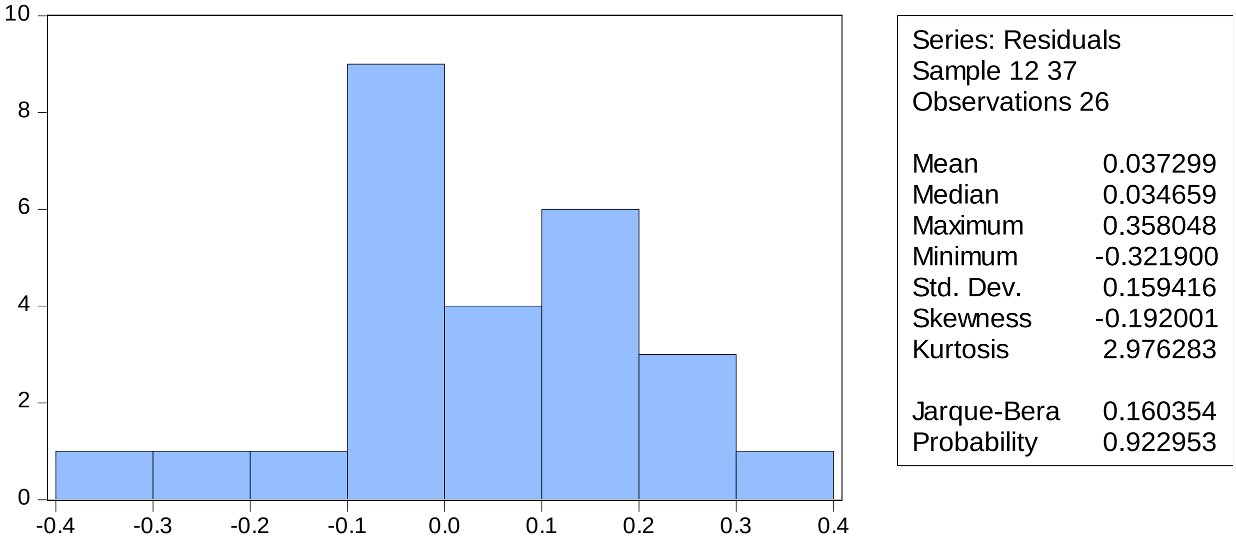

Figure 4.1: The Jacque Bera normality test

4.1.4 The Lagrange Multiplier (LM) test for Serial correlation

The results from the LM test under this study is indicate in the table 4.3.

Table 4.3: Breusch-Godfrey Serial Correlation LM Test:

F-statistic	120.9339	Prob. F(2,102)	0.0000***
Obs*R-squared	75.85634	Prob. Chi-Square(2)	0.0000***

***Significance at 1 Percent level of significance

Using the Lag range (LM) + n*R- squared, which is equal to 75.85634 under the null hypothesis of no serial correlation, the probability of rejecting the null hypothesis is 0.00. Thus we do not reject the null hypothesis of no serial correlation.

4.1.5 Heteroskedasticity Test

The Heteroskedasticity test was done using the Breusch-Pagan-Godfrey test. Results indicate no heteroskedasticity as shown in table 4.4.

Table 4. 4: Heteroskedasticity Test: Breusch-Pagan-Godfrey test

F-statistic	1.875311	Prob. F(5,16)	0.1550
Obs*R-squared	8.128929	Prob. Chi-Square(5)	0.1493

Source: Author's analysis based on data from World Bank, International Energy Agency, Bank of Uganda;

Using the lag range observation *R square which is equal to 8.128929 under the null hypothesis of no Heteroskedasticity. The probability of rejecting the null hypothesis is 0.1493. Thus we do not reject the null hypothesis of no Heteroskedasticity.

4.1.6 Causal relationship between energy consumption and economic growth in Uganda.

The dynamic causal relationship between energy consumption and economic growth in Uganda is done using a pairwise Granger as shown in table 4.5.

Table 4.5: Granger Pair-Wise Test Results

Null Hypothesis:	Obs	F-Statistic	Prob.
d(log(FDI)) does not Granger Cause d(log(DINV))	37	0.712	0.503
d(log (DINV)) does not Granger Cause d(log(FDI))		0.230	0.797
d(GDP) does not Granger Cause d(log(DINV))	37	3.268	0.059*
d(log (DINV) does not Granger Cause d(GDP))		0.911	0.418
d(log(REC)) does not Granger Cause d(log(DINV))	37	2.299	0.126
d(log(DINV)) does not Granger Cause d(log(REC))		6.002	0.009***
d(GDP)) does not Granger Cause d(log(FDI))	37	0.222	0.803
d(log(FDI)) does not Granger Cause d(GDP))		0.100	0.905
d(log (REC)) does not Granger Cause d(log(FDI))	37	1.385	0.270
d(log(FDI)) does not Granger Cause d(log(REC))		1.543	0.234
d(log (REC)) does not Granger Cause d(GDP))	37	4.96	0.014**
d(GDP)) does not Granger Cause d(log (REC))		1.160	0.327
d(log (REC) does not Granger Cause d(log (NREC))	37	3.961	0.023**
d(log (NREC)) does not Granger Cause d(log (REC))		1.581	0.222

*Granger test results significant at 10% ** Granger test results significant at 5 percent, *** Granger test results are significant at 1 percent

Source: Author's analysis based on data from World Bank, International Energy Agency, Bank of Uganda;

The summary results presented in this table 5 indicate that a causal relationship exists between renewable energy consumption and economic growth.

4.1.7 **Estimates of Vector Error Correction Model (VECM)**

The VECM results in this study are presented in table 4.6. The results in this table indicate the estimated parameters in each of the five versions of the VECM equations that are drawn from each column. The first row contains Error Correction Term (ECT) for each equation. The estimated parameters on ECT are presented in the first row and their standard errors are presented in the second row, while *t* ratios are presented in the third row.

Table 4.6: Vector Error Correction Estimates

Error Correction:	d(GDP,2)	d(log(DINV),2)	d(log(FDI),2)	d(log(NREC),2)	d(log(REC),2)
CointEq1	-0.016	0.0701	0.041	0.0408	0.018
	(0.025)	(0.021)	(0.021)	(0.025)	(0.060)
	[-0.640]	[3.342]	[1.992]	[1.639]	[3.009]
D(GDP(-1),2)	-0.656	-0.047	-0.027	-0.027	-0.012
	(0.103)	(0.0874)	(0.086)	(0.104)	(0.025)
	[-6.376]	[-0.535]	[-0.319]	[-0.262]	[-0.482]
D(LOG(DINV(-1)),2)	-0.338	0.831	0.873	0.871	0.379
	(0.690)	(0.58598)	(0.573)	(0.695)	(0.165)
	[-0.489]	[1.418]	[1.523]	[1.253]	[2.301]
D(LOG(FDI(-1)),2)	0.299	-1.323	-1.438	-0.770	-0.335
	(0.665)	(0.565)	(0.552)	(0.670)	(0.159)
	[0.449]	[-2.343]	[-2.603]	[-1.149]	[-2.110]
D(LOG(REC(-1)),2)	-0.1742	0.772	0.450	0.449	-0.479
	(0.503)	(0.427)	(0.418)	(0.506)	(0.120)
	[-0.346]	[1.808]	[1.077]	[0.887]	[-3.930]
C	-1.48E-17	-7.40E-17	4.67E-17	1.08E-16	3.05E-16
	(0.043)	(0.036)	(0.035)	(0.043)	(0.010)
	[-3.5e-16]	[-2.0e-15]	[1.3e-15]	[2.5e-15]	[3.0e-14]
R-squared	0.336	0.410	0.361	0.352	0.393
Adj. R-squared	0.257	0.334	0.284	0.275	0.321

Sum sq. resids	17.380	12.524	11.989	17.624	0.989
S.E. equation	0.435	0.369	0.361	0.438	0.104
F-statistic	4.238	5.705	4.730	4.548	5.416
Log likelihood	-54.537	-37.499	-35.228	-55.263	94.540
Akaike AIC	1.280	0.952	0.908	1.295	-1.587
Schwarz SC	1.585	1.257	1.213	1.600	-1.282
Mean dependent	2.14E-18	-6.37E-17	3.42E-18	4.21E-17	1.42E-16
S.D. dependent	0.504	0.452	0.427	0.514	0.126

Determinant resid covariance (dof adj.)	3.12E-07
Determinant resid covariance	1.69E-07
Log likelihood	72.92469
Akaike information criterion	-0.152398
Schwarz criterion	1.500346

The presence of cointegrating vectors in the model specified implies that there exists long run error correction process working within the model such that any deviation from the long run equilibrium path would be restored by correction of equilibrium error back towards its long run relationship. The VECM results in this study are presented in the table 6.

The short run results indicate that a 1 percent increase in Renewable Energy Consumption (REC) causes 0.17 percent reduction in Economic growth.

$$\Delta GDP\ growth_{(t)} = -0.17\Delta REC_{(t)} - 0.34\Delta DINV_{(t)} + 0.30\Delta FDI_{(t)} \qquad (13)$$

The results for the long run relationship in VECM in this study, however, indicate that a 1 percent increase in Renewable Energy Consumption reduces Uganda's Economic Growth by 0.02 percent.
A 1 percent increase in Domestic Investment causes increase in Uganda's Economic Growth by 0.07 percent. Finally, the result for the long run relationship in this study indicate that 1 percent increase in FDI inflows increases Uganda's Economic Growth by 0.04 percent.

$$\Delta GDP\ growth_{(t)} = 0.02\Delta REC_{(t)} + 0.07\Delta DINV_{(t)} + 0.04\Delta FDI_{(t)} \qquad (14)$$

4.2 Pass through effect Using Variance decomposition

The results in this section are obtained from estimates of variance decomposition and accumulated impulse responses.

4.2.1 Estimates of Variance Decomposition

According to estimated results presented in table 4.7, 87 percent of total variations in renewable energy consumption are explained by itself over the whole sample period, while 5 percent of total variations in Domestic investments during this period are explained by shocks from the exchange rate and 8 percent of total variations in economic growth are explained by shocks from Foreign Direct Investments.

Therefore for the sample period, the big percentage of variations of data on renewable energy consumption is explained by itself.

Table 4.7: Variance Decomposition of Renewable Energy Consumption

Variance Decomposition of d(log(REC)):

Period	S.E.	d(log(REC))	d(log(DINV))	d(log(FDI))	d(log(GDP))
1	0.102428	100.0000	0.000000	0.000000	0.000000
2	0.107186	96.89931	1.285153	1.814514	0.001027
3	0.114974	93.51209	2.689062	3.796701	0.002149
4	0.127530	90.08017	4.111497	5.805043	0.003286
5	0.134411	89.69473	4.271254	6.030606	0.003414
6	0.142135	89.08122	4.525537	6.389630	0.003617
7	0.149975	88.39269	4.810913	6.792552	0.003845
8	0.156721	87.78134	5.064302	7.150314	0.004048
9	0.163478	87.30373	5.262257	7.429808	0.004206
10	0.169995	86.91849	5.421930	7.655251	0.004333

Cholesky Ordering: d(log(REC)) d(log(DINV)) d(log(FDI)) d(log(GDP))

Source: Author's own analysis based on data from World Bank, International Energy Agency, Bank of Uganda;

4.3 Estimates of Cumulative Impulse Responses

Table 4.8 presents the results from the estimates of cumulative impulse response function of economic growth due to shocks from other endogenous variables. The responses are from contemporaneous shocks and on-word through the whole sample period. The magnitudes of shocks are in the first row, while their standard errors are in parenthesis in the second row.

Although some significant responses are observed in Economic growth due to shocks from renewable energy consumption, such responses are conveyed throughout the whole sample period. The estimated results for the accumulated impulse response function of economic growth in this study therefore indicate a significant pass through effect of economic growth to renewable energy consumption in the period under review.

Table 4.8: **Cumulative Impulse Response of Renewable Energy Consumption**

Period	d(log(DINV))	d(log(FDI))	d(log(GDP))
1	0.000000	0.000000	0.000000
	(0.00000)	(0.00000)	(0.00000)
2	-0.00333***	0.00349***	7.76E-05
	(0.00758)	(0.00816)	(0.01171)
3	-0.0062***	0.00655***	0.00015
	(0.01265)	(0.01332)	(0.01496)
4	-0.00545***	0.00572***	0.00013

	(0.01200)	(0.01278)	(0.01463)
5	-0.00518***	0.00544***	0.00012
	(0.01197)	(0.01273)	(0.01460)
6	-0.005311***	0.0056***	0.000124
	(0.01230)	(0.01307)	(0.01471)
7	-0.005328***	0.00559***	0.000124
	(0.01239)	(0.01326)	(0.01481)
8	-0.00531***	0.00557***	0.000124
	(0.01248)	(0.01328)	(0.01482)
9	-0.00531***	0.005574***	0.000124
	(0.01252)	(0.01330)	(0.01484)
10	-0.005312***	0.005576***	0.000124
	(0.01251)	(0.01332)	(0.01486)

Cholesky Ordering: d(log(REC)) d(log(DINV)) d(log(FDI)) d(log(GDP))
Standard Errors: Monte Carlo (100 repetitions)

Source: Author's own analysis based on data from World Bank, International Energy Agency, Bank of Uganda;

An assumption has been made in this study that internal shocks on the performance of economic growth; such that a positive shock on economic growth during this period encourages an increases in renewable energy consumption. A negative shock on economic growth on the other hand, encourages increase in renewable energy consumption.

The results on economic growth due to renewable energy consumption are not significant, however, the shocks of domestic investment and FDI are significant on economic growth.

4.3.1 Pass through effect of using accumulated impulse response

This section presents and discusses the results for the second objective that investigates pass through effect of renewable energy consumption Shocks to Economic growth in the period under review. Despite having cointegrating relationship within endogenous variables, the structural VAR model has been selected for this study because it best explains feedback effect among set of variables. The results in this section are obtained from estimates of variance decomposition and accumulated impulse responses.

4.4 Discussion of Results

4.4.1 Renewable Energy consumption and Uganda's economic growth.

The results that investigates the causal relationship between renewable energy consumption and economic growth. Domestic investment and Foreign Direct investments are controls of the model. Having exhibited at least one cointegrating relationship made VECM a suitable model for analysing this model. With pairwise Granger specifically answering the causality question from first principles as explained below.

4.4.2 Causal relationship between renewable energy consumption and economic growth Using Granger and VECM

The growth hypothesis alludes to the fact that renewable energy consumption Granger causes economic growth, while the VECM results indicate a long run causal relationship running from renewable energy consumption to economic growth. The renewable energy indicate a long run relationship running from renewable energy consumption to economic growth. This relationship from renewable energy is attributed to the electric power that has high efficiency in converting heat into useful energy to drive economic growth.

4.5 Pass through effect using Variance decomposition

Following the estimated results in table 7, quite a huge percentage (86%) of total variations in renewable energy consumption in the period under study are explained by itself throughout the whole sample period, while only 8 percent of total variations in economic growth during this period are explained by shocks from domestic investments. The results in this table therefore indicate insignificant pass through effect of renewable energy consumption shocks to economic growth in the period under study. This is because most of the renewable energy sources are intermittent. So relying on them to drive economic growth has not yielded results for Uganda.

Secondly, the estimated results presented in this table indicate that the response of GDP to total variations in renewable energy consumption in the period is explained by 14 percent in the model.

Following the estimated results in table 8, quite a huge percentage (88%) of total variations in Domestic investment in the period under study are explained by itself throughout the whole sample period, while only 9 percent of total variations in economic growth during this period are explained by shocks from GDP itself. Domestic investment has positive multiplier to growth as it is critical for local investors to undertake investments in to the energy sector, those that do bring positive a returns hence the growth hypothesis.

4.6 Pass through effect using cumulative Impulsive Responses

Cumulative impulse response explains the shock from economic growth to the endogenous variables. The responses are from contemporaneous shocks and on-word through the whole sample period. The magnitudes of shocks are in the first row, while their standard errors are in parenthesis in the second row.

The estimated responses do not exceed the two standard error criteria of significance throughout the whole sample period. Shocks on economic growth during this period insignificant responses from Renewable energy consumption, throughout the whole sample period.

5.0 Conclusion and Policy Recommendation

5.1 Conclusions

The investigation of causality between renewable energy consumption and economic growth in Uganda in the period between 1982 and 2018 has been carried out using Granger causality test and vector error correction model. The results from Granger causality test in this study indicate a causal relationship exists between renewable energy consumption and economic growth in the long run.

The results from vector error correction model in the study indicate that a causal relationship exist between renewable energy consumption and economic growth hence growth hypothesis. This study is in agreement with earlier studies Wang et al., (2020), Al- Rasasi et al., (2021), Alpdogan (2021), Fazal et al., (2021), Jayasinghe and Selvanathan (2021), Ha and Ngoch (2021), Kalimera (2021), Okoye et al., (2021), Soava et al., (2021), Yisui et al., (2021).

5.2 Policy Implications

Renewable energy policy that advocates for a transition from traditional biomass consumption to modern bioenergy and electricity. This will foster clean energy consumption that has better health and environmental consequences (Buyiza and Kappeler 2018, Mutumba et al., 2021b). This will also promote sustainable rates of economic growth.

Solar electrification to provide cheaper and more readily available (Alinda et al 2021). Sources of energy will ensure that the solar energy potential is optimally utilized. One of the issues with current electricity supply in Uganda is high tariff. Solar energy is only 4 % of the country's energy mix, yet the cost of solar is falling and has falling by 60 % in the last decade. This means that Uganda will be opening its gates to affordable and yet readily available power for commercial and residential use to supplement the existing hydro electricity

To streamline the development of crude oil resources through developing local capacity by training locals with relevant skill sin development of oil value chain. It is also important that the environmental and social impact assessment is reviewed and done for the East African Oil pipeline (EACOP) and the Refinery.

5.3 Areas for further Research

This study concentrated on renewable energy consumption and Uganda's Economic growth. It intended to establish whether renewable energy consumption drives growth in the context of Uganda. It used GDP as a measure of economic growth, however, the contribution of energy consumption to different sectors of the economy where not investigated. This therefore follows that future studies can investigate the relation of energy consumption to sectoral GDP with a view to inform macroeconomic policy

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