Original Research Article

NON-RENEWABLE ENERGY CONSUMPTION AND ECONOMIC GROWTH: EVIDENCE FROM UGANDA

ABSTRACT

Back ground: This paper concerns itself with aninvestigation on non-renewable energy consumption and economic growth, the case of Uganda. The arguments of a causal relationship between non-renewable energy consumption and economic growth have dissenting view.

Methods: It used time series data econometric techniques to establish a causal link between variables of study. The Vector error correction and structural vector autoregression, Granger for causal linkage and Johansen co-integration test was carried out to ascertain if there exists a long run relationship between non-renewable energy consumption and real GDP.

Results: The results support the growth hypothesis between non-renewable energy consumption and economic growth in the long run as shown in the VECM. This SVAR shows that these results are not significant

Conclusion: The conclusion therefore is that non-renewable energy consumption in regard to economic growth is mainly attributed to imported fossil fuels particularly diesel that is used in thermal generators to run electricity hence unable to support the growth process over the long run.

Novelty: This paper provides insights on how energy drives economic growth and sustainable development. It also captures the impact of investment into overall economic growth that is in line with the contemporary global agenda.

Keywords: Key words: Non-renewable energy consumption, economic growth, causality, Vector error correction model, Cumulative impulse response, Uganda.

1.0 Introduction

1.1 Background and motivation

“Non-renewable energy consumption (NREC) and economic growth (GDP) is a critical issue in empirical research”(Mutumba et al., 2021, Alqaralleh& Hatemi-J2024). “For over fifty years, these studies world over are characterised with arguments”. (Mutumba et al., 2021).“The principal argument is that a risein non-renewable energy consumption promotes economic growth” (Zhang and Tan 2020; Mutumba et al. 2024).

“Other researchers disagree with that view. Theydo not find proof to back this finding” (Kasperowicz et al., 2020). The critical part of the debate is increased NREC also increases global warming that ultimately impacts climatic change. This study therefore goes ahead to establish whether NREC has a causal relationship on economic growth with evidence from Uganda.

Uganda’s energy mix has about 9% NREC, while 89 is from traditional biomass and 2% electricity. The first two dominant sources are climate sensitive and may not support sustainable transition. Furthermore, Uganda imoports about 2.5 billion litres of petroleum products (2022); with crude oil estimated at 6 billion barrel of which 1.4 billion is recoverable. And natural gas of 700 billion cubic feet (bcf) of which 173bcf is associated while 500 bcf is non associated gas. Further investment in NREC is likely to increase the carbon footprint (Twinomuhangi et al., 2022). It is therefore critical to examine and establish a causal relationship between NREC and Economic growth

The nexus between non-renewable energy consumption and GDP is necessary but not sufficient in answering the question ‘which energy drives growth?’ Modelling a bivariate analysis (Non-renewable energy consumption and economic growth) is likely to lead us into an omitted variables bias, and consequently a misspecification of the model. Further to overcome this challenge and establish that the model is correctly identified and specified, to minimise the omitted variables problem by adding control variables including domestic investment and foreign direct investments that were brought into the model. The justification of adding investment is that energy sector invests massively into energy generation, production and consumption with a hope to promote economic growth, thus domestic and foreign direct investments are sufficient drivers of the energy- growth nexus.

1.2 Antecedents

Initial results by de Janosi and Grayson(1972), Carter (1974), Nordhaus (1974), Jorgensen (1974), Odum and Odum (1976), Kraft and Kraft (1978), Tyner (1978), Akarca and Long (1979) were divergent in their findings. This controversy in findings calls for a re-examination using related variables to offer enough proof to guide policy making.

Non-renewable energy consumption may mean the use of fossil fuel energy sources shown in the rise in the use of coal, oil and gas (Stoddard et al., 2021).Government of Uganda (GOU) has considered investing in oil development following commercial discovery of oil and gas with a view of increasing non-renewable energy consumption in order to induce a reduction in poverty (Chingoiro and Mbulawa, 2017), however, there is already an rise of non-renewable energy consumption ahead of crude oil production. This calls for an interrogation as to whether crude oil a proxy of non-renewable energy and GDP are linked an aspect of interest to this study

1.3 Contribution of this paper

This paper will step up our intuition on theoretical. Econometric and practical perception of reality in the energy sector. This will therefore strengthen theoretical methodological and empirical work. Previous studies have focused on classical growth theories others have concentrated on either endogenous or exogenous growth theory. These do not fully explain the role of non-renewable energy consumption to the growth process. Linear exponential production function was used to evaluate energy consumption- economic growth nexus (Kummel 1982, Ayres et al., 2013, Kummel and Lindenberg 2014). This study makes a detailed discussion of linear exponential production theory and integrating knowledge within the theory of interest.

Methodologically,this study makes a contribution the theory of econometric methods in general and time series econometrics in particular. More specifically, the vector error correction mechanism (VECM), variance decomposition analysis (VDA) and cumulative impulse response (CIR) offered effective evidences for policy making. With econometric issues like endogeneitythese techniques from time series econometrics become useful (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, VDA and CIR. An analysis of the impact of non-renewable energy consumption on GDP was undertaken in order to guide policy (Tang et al., 2016, Mutumba et al., 2022c).

With this background, it is deemed appropriate to study the dynamic causal relationship of non-renewable energy consumption on Uganda's GDP, since it provides insight on the contribution of the energy sector to Uganda's economy at large. This study is significant in filling the gap of motivating policy makers to rethinking about the contributions of the Energy sector on Uganda's Economy.

1.5 Road Map

The rest of the write up is organised as theoretical literature and contemporary studies, methodology in section three, findings and discussion in section four and finally conclusions and policy recommendation.

2.0 Review of Literature

This part is about established theory and contemporary works as a way of internalising the leading debate to date.

2.1 Theoretical Literature

This study uses multiple theories to analyse the phenomenon because a single theory was not sufficient to explain the observable reality. The linear exponential growth theories have been used.

2.1.1 The Linear Exponential Production theory and Economic growth

The theoretical framework underpinning this study was theLINEX Production function theory. Kummel (1982) argued that energy makes a maiden contribution to overall production using mathematical expressions with output elasticities that have appropriate asymptotic behavior with the parameters having clear economic interpretations.

It gives the greatest contribution energy makes as an input in the production process by expounding its usefulness when embedded with capital and labour. Capital effectiveness, energy consumption of the utilized capital stock and energy efficiency are reinforced with substantial energy consumption. It provides a production function explaining the nexus between GDP and non-renewable energy consumption as follows:

Output (***Y***) = f [Capital (*K*) Labour (***L***), Energy Consumption,***(E)*** Time ,(***t***)] (1)

These variable are thermodynamic variables in a conservation force field. Thus the growth equation can simply be given as:

$$\frac{dY}{Y} = \alpha\frac{dk}{k} + \beta\frac{dl}{l} + \gamma\frac{de}{e} + \delta\frac{dt}{t-to}\ , \ \delta \equiv \frac{t-to}{Y}\frac{\delta Y}{\delta t} \quad (2)$$

The Capital Labour Energy (KLE) explains incremental value added q by the linear exponential production function for KLE

$$\mathbf{Y_t = Y_0\ e\ exp\ [a(2 - \frac{l+e}{k}) + a(\frac{l}{e} - 1)]} \qquad (3)$$

Where the equation 3 is associated to energy e and ratios of capital k, labour l. Y and its theoretical representation Y_t are dimensionless units normalised to a base year. The technology parameters Y_o and α may depend on time ***t***. They are modelled on Taylor series and logistics.

The output elasticities of,

capital$\alpha \equiv (k/q)(\frac{\partial q}{\partial k})$, labour $\beta \equiv (l/q)(\frac{\partial q}{\partial l})$, energy $\gamma \equiv (e/q)(\frac{\partial q}{\partial q})$ (4)

Such that the linear exponential equation is set up as in equation 5 as

$$\alpha = a\frac{l+e}{k},\ \beta = al(\frac{1}{e} - \frac{1}{k}),\qquad \gamma = 1 - \alpha - \beta \quad (5)$$

The elasticity of capital α considers the principle of diminishing returns. Machines need energy to operate and human resource for management and repairs. Thus, L, Eand K are essential for modern production processes.

The elasticity of labourβconsidersthe degree of substitutability of E and K for L. Where K tends to the limit $k_m(Y)$ needed automated production of set output Y and time t, and if energy approaches the corresponding amount $e_m = k_m$, then output and corresponding labour approaches zero.

The elasticity of energy, γ shows constant returns to scale. Complementarity is limited by technological constraint that capacity utilisation cannot exceed 100% and substitutability is limited by the constraint that at a given time t, the degree of automation cannot exceed a technologically given limit $\rho T(t) \leq 1$. Output elasticities must bepositive.

The linex production function is fitted by minimising the sum of squared errors inlevenberg-Marquardt method, subject to the positive elasticities of k,l,e. Then the time averages of $\bar{\alpha}$, $\bar{\beta}$, $\bar{Y}$ are computed. Small changes of output, dY, capital dk, and labourlabour dl, energy de and time dt are related to one another by the growth equation [which is got from the total differential equation of the production function Y(k,l,e,t):

$$\frac{dq}{q} = \alpha\frac{dk}{k} + \beta\frac{dl}{l} + \gamma\frac{de}{e} + \delta\frac{dt}{t-to} \quad (6)$$

The output elasticities can be presented as

$$\alpha(k,l,e) \equiv \frac{k}{Y}\frac{\delta Y}{\delta k}, \quad \beta(k,l,e) \equiv \frac{l}{Y}\frac{\delta Y}{\delta l}, \; \gamma(k,l,e) \equiv \frac{e}{Y}\frac{\delta Y}{\delta e}, \quad \delta(k,l,e) \equiv \frac{t-to}{Y}\frac{\delta Y}{\delta t} \quad (7)$$

This gives the weights, with which relative changes of the inputscapital, labour, energy and of time t augment to the change of the product as the measure of their productive powers.

Production functions at time t at the second order are linearly homogeneous state functions of capital, labour, energyin factor space. Thus the elasticities of inputs should add up to one as indicated below,

$$\alpha + \beta + \gamma = 1 \qquad (8)$$

the sufficient order mixed derivatives of Y= Y(k, l, e, t) gives differential equations

$$k\frac{\partial \alpha}{\partial k} + l\frac{\partial \alpha}{\partial l} + e\frac{\partial \alpha}{\partial e} = 0,$$

$$k\frac{\partial \beta}{\partial k} + l\frac{\partial \beta}{\partial l} + e\frac{\partial \beta}{\partial e} = 0,$$

$$l\frac{\partial \alpha}{\partial l} = k\frac{\partial \beta}{\partial k} \quad (9)$$

This gives solutions such as

$$\alpha = A\left(\frac{l}{k}, \frac{e}{k}\right)\beta = \int \frac{l}{k}\frac{\partial A}{\partial l} + J\left(\frac{l}{e}\right), \quad (10)$$

Where $\boldsymbol{A}\,(\frac{l}{k}, \frac{e}{k})$ and $\boldsymbol{J}\left(\frac{l}{e}\right)$. Are differentiable functions of their arguments

So the limit $\boldsymbol{K = K_m (Y)}$ and $\boldsymbol{\eta=1}$. Thus the technological constraints on the combinations of capital, labour and energy are:

$$\eta(K,L,E)\leq 1, \quad \rho(K,L,E)\leq \quad \rho T(t) \ \leq 1 \qquad (11),$$

we identify $\boldsymbol{K, L, E}$ with components $\boldsymbol{X_1, X_2, X_3}$ of the vector

$$X=(X_1, X_2, X_3) \equiv (K, L, E) \qquad (12)$$

$\boldsymbol{X_\eta}$ and $\boldsymbol{X\rho}$ are slacks, the constraints in equation ***12***can be brought in the form of equations.

$$f_\eta\,(X, t) = 0, \quad f\rho(X, t) = 0 \qquad (13)$$

labour, capital and energy variables$\boldsymbol{l_\eta}$, $\boldsymbol{k\rho}$and$\boldsymbol{e_\eta}$***are slacks***, explained in a range of vector space within which the factors can vary independently at time ***t.*** $\boldsymbol{\rho_\rho}$

$$f_\eta\,(X, t)\equiv\eta_0{*}\,(\frac{L+L\eta}{K})^\lambda\,(\frac{E+E\eta}{K})^\nu\text{-}1 = 0, f\rho\,(X, t) \equiv \frac{K+K\rho}{Km(Y)})\text{-}\rho T(t)= 0 \quad (14)$$

Optimisationof profits with 3 inputs$\boldsymbol{(X_1, X_2, X_3)}$ have prices exogenously given prices per factor unit $\boldsymbol{p \equiv (p_1, p_2, p_3)}$ so that total factor cost $\boldsymbol{p\,(t).\ X\,(t) =\sum_{i=1}^{3} pi\,(t)\,Xi\,(t)}$

Then Economic equilibrium is defined as

$$G\,(X, p, t) \equiv Y(X, t) - p.X \qquad (15)$$

This is the maximum level of profits one can obtain in investing in the three inputs, capital, labour and energy.

The necessary condition for profit maximisation$\boldsymbol{G\equiv Y- p.X}$ subject to technological constraints in equation 15, is

$$\nabla \rightarrow [Y\ (X\ ,t)\text{-}\ \sum_{i=1}^{3} pi\,(t)\,Xi\,(t)\ +\ \mu_\eta\ f\ {}_\eta(X,T)\ +\mu_\rho\ f_\rho\ (X,\ t)]\ =0 \quad (16)$$

Where ∇→the gradient in factor space μη, μρare lag range multipliers.

The sufficient condition for profit maximisation involves a sum of sufficientorder derivatives yields three equilibrium conditions.

$$\frac{\partial y}{\partial x}\ \text{-}p + \mu_\eta \frac{\partial f\ \eta(X,t)}{\partial x\ t} + \mu_\rho \frac{\partial f\ \rho(X,t)}{\partial x\ t} \quad (17)$$

Multiplication of equation ***15*** with $\boldsymbol{X_i /Y}$ and given elasticities $\boldsymbol{\alpha, \beta, \gamma}$

$$\varepsilon i\equiv \frac{Xi}{Y}\frac{\partial y}{\partial xi}, \quad i= 1,2,3 \qquad (18)$$

This gives an equilibrium

$$\varepsilon_i\equiv \frac{Xi}{Y}\frac{\partial y}{\partial xi} = \frac{Xi}{Y}\,[p\text{-}\ \mu_\eta \frac{\partial f\ \eta}{\partial x\ t} + \mu_\rho \frac{\partial f\ \rho}{\partial x\ t}], \quad i= 1,2,3 \quad (19)$$

These equilibrium conditions can be rewritten as

$$\varepsilon i = \frac{Xi\,[p+si]}{\sum_{i=1}^{3} Xi[p+si]} \quad i = 1,2,3 \tag{20}$$

$$s_i \equiv -\frac{\partial f\eta}{\partial xi} + \mu_\rho \frac{\partial f\rho}{\partial xi} \tag{21}$$

Thes_i**'s** are generalised shadow prices help to explain why NRE is still demanded even at increasing prices of the energy good like the petrol prices. Where technological limitations on capital exist according to this theory they can be overcome by increasing the amount of energy as an input (Hall and Klitgaard, 2018).

A wealth is a stock of energy that has been preserved in thermodynamic systems (Hall and Klitgaard, 2018). A biophysical approach to studying economics is a reality whose time has come and finally, energy good can be commoditised and monetised to allow optimal use and reward for its contribution in the production process so shillings or dollars for each Kwh consumed can bring effective use of energy to promote GDP.

2.2 Empirical Literature

The growing body of Literature has been organised in subsection of energy consumption and economic growth in subsection 2.2.1 and Non-renewable energy consumption and economic growth in sub section 2.2.2

2.2.1 Literature on Energy consumption and Economic growth

Accordingly, Mutumba et al., (2021a) two way causality between energy and GDP in developing countries was confirmed. For instance, these included; Kasman and Duman, (2015), Danaraya and Hassan (2016), Dogan and Turkekul(2016),Hyes and Ryaz (2016), Rafindad and Ozturk (2017), Sekantsi and Motlokoa (2016), Riti et al., (2017), Mavikala and Khobai (2018), 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 Narayan et al. (2010), Odhiambo (2010a),Hartziorgioe et al.,(2011), Menegaki (2011), Li (2012),Tugcu et al., (2012), Ocal & Aslan (2013),Azlina et al. (2014),Bastoola&Sapkoota (2015), Salahuddin 2015, Omri et al., (2015), Alper & Oguz (2016), Bhattacharya et al., (2016), Cui (2016), Jing et al., (2016), Yoo & Kim (2016), Dogan and Ozturk (2017), Liu(2017), Ingletsi-Lots &Dogou (2017), Zhang et al., (2017), 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 norelationship established in these studies Dorgan 2016), Some of these studies include; Chedran and Tang (2013), Menegaki and Ozturk (2013), Yildirim et al., (2014), Chang et al. (2015), Jebli and Youssef (2015), Omri et al., (2015), Aper and Oguz (2016), Cetin et al. (2106), Fan and Hao (2016), Li et al., (2016), Lin and Liu (2016), Kocak and Sarkgunesi (2017), Tugcu and Topcu (2018), Chinedu et al., (2019), Ozcan and Ozturk (2019), Nepal and Paija (2019).

2.2.2 Literature on Non-Renewable energy consumption and Economic growth

3.0 Methodology

The study usedcausal relationship research design and quantitative approach (Chinedu et al., 2019). This enabled the researcher to subject data from time series analysis to unit root test statistic for establishing stationarity, cointegration test for establishing long run equilibrium among the variables of study. Error correction mechanism was done. A quantitative approach were numerical data was analysed using descriptive and inferential statistics, variables of quantitative nature wasanalysed using econometric techniques including the vector error correction mechanism (VECM), variance decomposition anlaysis (VDA) and cumulative impulse response (CIR) which was then be entered into the computer using Eviews

3.1 **Data Type and Sources**

Data time series econometrics from World Bank statistics, World Development Indicator andInternational Energy Agency (IEA)data base on non-renewable energy consumption as shown in table1.

Table 1: Variable description and expected signs

Variables	Symbol	Measure	Expected Sign	Data source
Gross Domestic Product Per capita	$PGDP_t$	Per capita GDP constant 2010 US$	+	World Bank: World development indicators(WDI)
Total Investment	INV_t	GDP constant 2010 US$	+	World Bank: World development indicators (WDI).
Foreign Direct Investment	FDI_t	GDP constant 2010 US$	+	World Bank: World development indicators (WDI).
Non-renewable Energy Consumption	$NREC_t$	% of TEC	+	International Energy Agency (IEA)

Source: Source: Author’s analysis based on data from World Bank, International Energy Agency

3.2 **Data Estimation Techniques**

These include a set of tools used to estimate the model variables in this study. They include a range of statistical and diagnostic tests. They also include structural set up of the models as explained.

3.2.1 Stationarity Test

The Augmented Dickey Fuller (ADF) test and Phillips Perron testwas handy. A unit root null hypothesis was tested against a stationary alternative. The justification for using ADF is to take care of serial corelationswhil PP is to take care of endogenity problems as in these notations;

$$Y_t = \alpha + \beta.t + \varepsilon_t \qquad \textbf{(22)}$$

$$dY_i = \alpha + \beta.t + \sum_{i=1}^{n} \lambda.dY_{t-i} + \delta.Y_{t-i} + \varepsilon_t \qquad \textbf{(23)}$$

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 technique used to deducelong run connection within variables is Maximum Likelihood (LM) test and unrestricted VAR. Cointegration order r (number of cointegrating vectors) established with aid of trace statistics and Maximum Eigen Statistics (MES). The trace statistics found anull hypothesis that there is at least 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

It answers a basic question “Is data 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 study will use the model presented by Baba (2013) to estimate the causal relationship between non-renewable energy consumption and Uganda’s GDP in the period under the review.

Using log linear relationship, equation (25) can be written as follows;

$$log(GDP_t) = a_0 + a_1 log(NREC_t) + log(D.INV_t) + log(FDI\ t) + u_t \qquad \textbf{(24)}$$

Using equation (24), the model estimating the causality will be augmented by adding Non-Renewable Energy *(NREC)* and can thus be presented as follows;

$$log(GDP_t) = a_0 + a_1 log(NREC_t) + a_2\, log(D.INV_t) + a_3\, log(FD.I_t) + Vi_t \qquad \textbf{(25)}$$

Where:

GDP_t = Gross Domestic Product at time t

$NREC_t$= Non-Renewable Energy Consumption at time t

$DINVt$= 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 Non-Renewable 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.

3.3.1Granger Causality Test

The Granger pair wise deduced spectral connection between non-renewable energy consumption and GDP. Granger causal relationship to occur, thenX_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:

$$Yt+h\,|\Omega = Yt+h\,|\Omega/[Xt,s|x\leq t], h=1,2,3,4 \qquad \textbf{(26)}$$

3.3.2Vector Error Correction Model (VECM)

TheVECM establishes whether a long run connection within endogenous variables exists a primary requisite for estimating error correction model. The general form of the vector error correction model that will be estimated in this study is as follows;

$$\Delta X_t = \sum_{t=1}^{n}\beta_t \Delta X_{t-1} + \sum_{i=1}^{r}\gamma_i\, ECT_{t-1} + v_t \qquad \textbf{(27)}$$

Where X_t is an nx1 matrix and $n = 4$ vectors of dependent variables, ΔX_{t-1}, β and $\gamma$are parameters, whileV_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 $\gamma_i$associated with ECT_{t-1}measures proportion of adjustmentback towards equilibrium that can be completed within a single period.

If parameter $\gamma_i$is not significantly different from zero then there is no error correction process working within the model. Parameter $\beta_t$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.

3.3.3 Response of Uganda's Economic Growth to Shocks from Non-Renewable EnergyUse

Thestudyused Variance Decomposition Analysis (VDA) cumulated Impulse Response (CIR). Thus, the equation estimating the response of Uganda's Economic Growth to shocks from Non-Renewable Energy Consumption in the period under the review can be specified as follows:

$$y_t = c + \phi_i y_{t-1} \ldots\ldots\ldots\ldots\ldots\ldots + \phi_k y_{t-p} + \mu \textbf{(28)}$$

Where;

$y_t=(y_{1t},\ldots\ldots\ldots\ldots y_{kt})$representan*(nx1)* matrix ofvariablesand$\mu_t$is an*(nx1)* matrix with unobservable zeromean-whitenoisevector process(seriallyuncorrelated or independent)withtime invariantcovariancematrix. Following Osekhebhen, (2013) equation (29) canbe transformed as:

$$\boldsymbol{y_t = c + \sum_{t=1}^{n} \phi\, y_{t-1} + \mu_t} \quad \textbf{(29)}$$

Where;

$y_t$isa*(nx1)*vectorofobservationsattime*t*onthevariables.*C=(c1,……c2)*is the*(nx1)*interceptvectorof*VAR.*y_{t1}isasequenceof*(n×n)*matrixofautoregressivecoefficientsforI (identity matrix) =*1,2,...P*andμ_t =*(μ_{1t} ,....,μ_{3t})*isthe*(n×1)*generalizationofawhite noiseprocessorvectorofdisturbancestothesystem.

$$\boldsymbol{B\,(L) = y = c + \mu_t} \qquad \textbf{(30)}$$

Where;

*B (L)*issecond order matrixpolynomialsinthe lagoperator *L*suchthat:

$$\boldsymbol{B\,(L) = B_0 – B_1L – B_2L^2} \qquad \textbf{(31)}$$

B_0isa normalized non-singular matrixand i.

According to Mutumba et al. (2025), GDP reaction to shocks from Non-Renewable Energy Consumption can be deduced:

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

Where;

NREC = Non-Renewable Energy Consumption; D.*INV* = Domestic investments;

FDI = Foreign direct investments *GDP* = Gross Domestic Product;

$V_t$and $U_t$are assumed to be uncorrelated.

4.0 EmpiricalResults and Discussion

4.1 Empirical Results

4.1.1 Descriptive Statistics

The descriptive statistics are shown in table 2. The summary of the descriptive statistics indicate that the mean of all variables are positive values. The highest mean value being for

Domestic investment (Log DINV), while GDP has the lowest mean value, Economic growth (Log GDP) has negative value of skewness indicating that the distribution is skewed to the left, with more observations on the right. While the rest have positive skewness. There is evidence of variables being leptokurtic with a measure of kurtosis higher than 3 for all the variables. The normality test using the Jacque Bera is rejected in all the variables showing that data is normally distributed at the 5 percent level of significance.

Table 2 Summary of the Descriptive Statistics

	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(log(GDP))
Mean	0.131180	0.225670	0.131487	0.063932
Median	0.000000	0.192699	0.065053	0.062375
Maximum	3.536117	2.901422	2.781840	2.349342
Minimum	-0.559616	-0.436831	-0.496248	-2.252013
Std. Dev.	0.725437	0.607262	0.597656	0.651065
Skewness	4.175177	3.331165	3.431056	-0.071655
Kurtosis	20.24895	15.85521	16.22007	12.97667
Jarque-Bera	397.8594	227.1134	240.3471	107.8506
Probability	0.000000	0.000000	0.000000	0.000000
Sum	3.410676	5.867412	3.418661	1.662227
Sum Sq. Dev.	13.15649	9.219179	8.929811	10.59715
Observations	37	37	37	37

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

4.1.2Test for Stationarity

The stationarity test results issummarised in table 3 present the augmented Dickey Fuller (ADF) and Phillips Perron (PP) statistics for thevariables estimated. The ADF test is robust in overcoming serial correlations while the PP test handles the endogenity problem. The results indicate that all variables are not stationary at levels while they are stationary at first difference.

Table 3: Stationarity Test Results(Mutumba et al. 2024)

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(NREC)	0.819237	-0.157535	-12.13183**	-12.15760**

Source: Author's own analysis based on data from World Bank, International Energy Agency; **ADF and (PP) test statistics are significant at

**Significance at 5 Percent level of significance

4.1.3 Test for Cointegration

The results for the cointegration test are presented in table 4. 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.

Table 4: Cointegration Test Results(Mutumba et al. 2024)

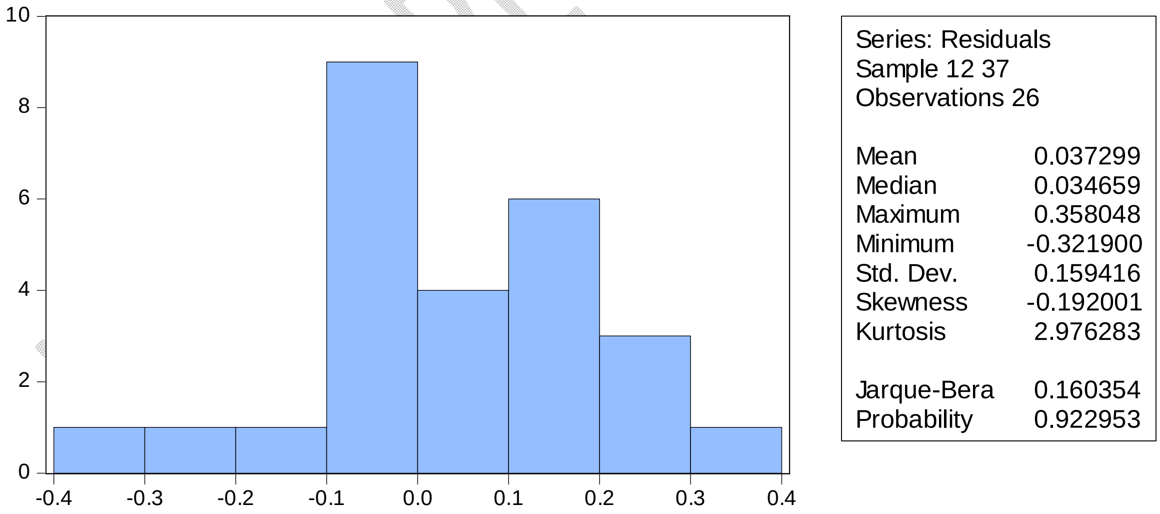
Trace test of:	Trace Statistics	Critical Values
r ≤ 4	4.468502	3.841466
r ≤ 3	20.2380815.49471	
r ≤ 2	50.25429**	29.79707**
r ≤ 1	90.56138**	47.85613**
r ≤ 0	210.9315**	69.81889**
Maximum Eigen value	**Max-Eigen Statistics**	**Critical Values**
Test of:		
r ≤ 4	4.4685023.841466	
r ≤ 3	15.7695714.26460	
r ≤ 2	30.01621**	21.13162
r ≤ 1	40.30709**	27.58434
r ≤ 0	120.3701**	33.87687

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

4.1.4 Test for Normality

AJacque Bera test, to determine whether the data estimatedis linearly distributed or not. This condition 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 1.

The histogram and the descriptive statisticsprovides the results. The reported probability in the figure 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 1 below.



```
Series: Residuals
Sample 12 37
Observations 26

Mean         0.037299
Median       0.034659
Maximum      0.358048
Minimum     -0.321900
Std. Dev.    0.159416
Skewness    -0.192001
Kurtosis     2.976283

Jarque-Bera  0.160354
Probability  0.922953
```

Figure 1: The Jacque Bera normality test(Mutumba et al. 2024)

4.1.5 The Lagrange Multiplier (LM) test for Serial correlation

The results from the LM test under this study is indicate in the table 5.

Table 5: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

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.Table 6: Heteroskedasticity Test: ARCH(Mutumba et al. 2024)

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,

From table 6 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.

4.2Causal relationship between non-renewable energy consumption and economic growth in Uganda.

The dynamic causal relationship between non-renewable energy consumption and economic growth in Uganda is done using a pairwise Granger as shown in table 7.

Table 7: **Granger Pair-Wise Test Results**

Null Hypothesis:	**Obs*F-Statistic***		**Prob.**
Null Hypothesis:	***Obs***	***F-Statistic***	***Prob.***
d(log(DINV)) does not Granger Cause d(log(NREC))	37	0.07318	0.9297
d(log(NREC)) does not Granger Cause d(log(DINV))		0.72823	0.4958
d(log(FDI)) does not Granger Cause d(log(NREC))	37	0.02451	0.9758
d(log(NREC)) does not Granger Cause d(log(FDI))		1.24570	0.3091
d(log(GDP)) does not Granger Cause d(log(NREC))	37	0.00402	0.9960
d(log(NREC)) does not Granger Cause d(log(GDP))		0.07359	0.9292
d(log(FDI)) does not Granger Cause d(log(DINV))	37	5.69002	0.0116***
d(log(DINV)) does not Granger Cause d(log(FDI))		7.61921	0.0037***
d(log(GDP)) does not Granger Cause d(log(DINV))	37	0.76494	0.4792

d(log(DINV)) does not Granger Cause d(log(GDP))		0.03212	0.9684
d(log(GDP)) does not Granger Cause d(log(FDI))	37	0.18024	0.8364
d(log(FDI)) does not Granger Cause D(log(GDP))		0.00672	0.9933

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

*** Granger test results are significant at 1 percent level of significance

The summary results presented in this table 7 indicate that Non-renewable energy consumption has no causal relationship to economic growth at a 5 percent level of significance. There exists a bidirectional causality between domestic investment and FDI. The remaining variables show no systematic causal relationship in the long run.

4.1.3.1 Estimates of Vector Error Correction Model (VECM)

The results in this table 8 indicate 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 8: Vector Error Correction Estimates

Error Correction:	d(log(GDP),2)	d(log(NREC),2	d(log(DINV),2)	d(log(FDI),2)
CointEq1	-0.193603	0.165901	0.082396	0.335289
	(0.50916)	(0.62468)	(0.17069)	(0.11499)
	[-0.38024]	[0.26558]	[0.48273]	[2.91572]
d(log(GDP(-1)),2)	-0.945422	-0.294642	-0.017801	-0.227052
	(0.42355)	(0.51964)	(0.14199)	(0.09566)
	[-2.23215]	[-0.56701]	[-0.12537]	[-2.37360]
d(log(NREC(-1)),2)	0.016490	-0.426970	-0.025534	0.088028
	(0.31053)	(0.38098)	(0.10410)	(0.07013)
	[0.05310]	[-1.12072]	[-0.24529]	[1.25518]
d(log(DINV(-1)),2)	-0.779540	1.703008	-1.379353	-0.929215
	(1.21692)	(1.49302)	(0.40795)	(0.27484)
	[-0.64058]	[1.14065]	[-3.38118]	[-3.38094]
d(log(FDI(-1)),2)	1.057272	-0.006555	1.575261	1.421437
	(1.15378)	(1.41554)	(0.38678)	(0.26058)
	[0.91636]	[-0.00463]	[4.07275]	[5.45495]
C	0.031796	0.109384	-0.014753	0.009540
	(0.16480)	(0.20219)	(0.05524)	(0.03722)
	[0.19294]	[0.54101]	[-0.26704]	[0.25633]

R-squared	0.813626	0.674842	0.792799	0.873535
Adj. R-squared	0.627252	0.349683	0.585599	0.747070
Sum sq. resids	5.931853	8.928795	0.666618	0.302567
S.E. equation	0.734343	0.900949	0.246174	0.165850
F-statistic	4.365561	2.075426	3.826237	6.907336
Log likelihood	-17.05127	-21.75414	8.086291	17.17030
Akaike AIC	2.526198	2.935143	0.340322	-0.449592
Schwarz SC	3.118630	3.527574	0.932754	0.142840
Mean dependent	-0.002173	-5.94E-17	-0.001675	0.011023
S.D. dependent	1.202794	1.117217	0.382412	0.329773
Determinant resid covariance (dof adj.)		4.05E-08		
Determinant resid covariance		1.01E-09		
Log likelihood		74.99813		
Akaike information criterion		-0.869402		
Schwarz criterion		2.339603		

Source: Author’s own analysis based on data from World Bank, International Energy Agency

It uses VECM to impute if any short run or long run connection between NREC and Uganda’s GDP performance exists. 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 8.

The results in this table indicate the estimated parameters in each of the three 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.

The short run results that 1 percent increase in Non-renewable Energy Consumption (NREC) causes 2 percent increase in GDP. A 1 percent increase in Domestic Investment (DINV) causes 78 percent increase in GDP, while 1 percent increase in Foreign Direct Investment (FDI) causes a 105 percent increase in GDP.The summary of the results for the short run relationship in the VECM estimates are shown by equation 33 below.

$$\Delta GDP_{(t)} = 0.02\Delta NREC_{(t)} - 0.78\Delta DINV_{(t)} + 1.05\Delta FDI_{(t)} \qquad 33$$

The Results for the long run relationship in VECM in this study, however, indicate that 1 percent increase in Non-renewable Energy Consumption increases Uganda’s Economic Growth by 17percent.The result in the long run relationship indicate that 1 percent increase in domestic investment inflows increases Uganda’s Economic Growth by 8 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 34 percent.The summary of the results for the long run relationship in this study is indicated in equation 34 below.

$$\Delta GDP_{(t)} = 0.17\Delta NREC_{(t)} - 0.08\Delta DINV_{(t)} + 0.34\Delta FDI_{(t)} \qquad 34$$

4.2.2Pass through effect Using Variance decomposition

4.2.2.1 Estimates of Variance Decomposition

The estimated results are presented in table 9.

Table 9: Variance Decomposition of Non-Renewable Energy Consumption

Variance Decomposition of d(log(NREC)):

Period	S.E.	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(lg(GDP))
1	4.121346	100.0000	0.000000	0.000000	0.000000
2	5.761527	99.79628	0.072164	0.068801	0.062755
3	6.990131	99.45766	0.203631	0.182059	0.156646
4	8.088087	99.15245	0.186550	0.217348	0.443647
5	9.088031	98.79864	0.155213	0.231667	0.814475
6	10.00727	98.43573	0.129821	0.240691	1.193761
7	10.86385	98.08504	0.110277	0.245874	1.558812
8	11.66877	97.75855	0.095692	0.248712	1.897042
9	12.42935	97.46215	0.084879	0.250325	2.202648
10	13.15145	97.19671	0.076799	0.251234	2.475261

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

Following parametric estimates presented in table 9, 97 percent of total variations in NREC are by itself over the whole sample, while 0.8 percent of total variations in Domestic investments during this period are explained by shocks from the exchange rate and 0.25 percent of total variations in Economic growth are explained by shocks from FDI. Therefore, the big percentage of variations of data on non-renewable energy consumption is explained by itself and not GDP.

The variance decomposition of non-renewable energy consumption has been carried out in this study to determine the relative importance of Domestic Investment to shocks from Economic growth. The estimated results are presented in table 10.

Table 10: Variance Decomposition of Domestic Investment

Period	S.E.	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(lg(GDP))
1	20455588	1.062514	98.93749	0.000000	0.000000
2	28247942	1.553504	97.96017	0.224718	0.261603
3	33990869	2.055357	96.65068	0.605610	0.688353
4	39560716	1.901315	95.49276	0.725035	1.880888
5	44901523	1.653326	94.21578	0.764798	3.366099
6	49965137	1.434605	92.93920	0.781514	4.844679
7	54789062	1.250936	91.74617	0.784430	6.218469
8	59389629	1.100200	90.67223	0.780351	7.447216
9	63776665	0.977570	89.72610	0.773581	8.522748
10	67964295	0.877368	88.90128	0.765966	9.455387

Cholesky Ordering: d(log(NREC)) 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;

Table 10 shows, 89 percent of total variations in domestic investment is explained by itself, while 0.7 percent of total variations in GDP are explained by shocks from FDI and 0.9 percent of total variations in economic growth are explained by shocks from non–renewable energy consumption.

The variance decomposition of FDI has been carried out in this study to determine the relative importance of FDI to shocks from GDP. The estimates are presented in table 11.

Table 11: Variance Decomposition of Foreign Direct Investment

Variance Decomposition of d(log(FDI)):

Period	S.E.	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(log(GDP))
1	0.122244	0.037413	52.58310	47.37948	0.000000
2	0.172246	0.033168	53.16134	46.77937	0.026130
3	0.210260	0.028011	53.57300	46.32555	0.073430
4	0.241919	0.021268	53.50559	46.28013	0.193008
5	0.269636	0.017833	53.28591	46.34320	0.353061
6	0.294614	0.017327	53.01526	46.43655	0.530858
7	0.317548	0.018810	52.73655	46.53408	0.710559
8	0.338881	0.021462	52.46957	46.62590	0.883074
9	0.358915	0.024697	52.22293	46.70864	1.043729
10	0.377868	0.028145	51.99919	46.78197	1.190697

Cholesky Ordering: d(log(NREC) d(log(DINV)) d(log(FD))I d(log(GDP))

According to estimated results presented in table 11, 47 percent of total variations in domestic investment is explained by itself over the whole sample period, while 51 percent of total variations in economic growth during this period are explained by shocks from Domestic Investment and 0.3 percent of total variations in economic growth are explained by shocks from non –renewable energy consumption.

The variance decomposition of Economic growth has been carried out in this study to determine the relative importance of GDP to shocks from NREC. The estimated results are presented in table 12.

Table 12: Variance Decomposition of GDP

Variance Decomposition of d(log(GDP)):

Period	S.E.	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(log(GDP)

1	840.4756	0.089870	12.46088	3.991355	83.45790
2	1162.175	0.133362	14.24740	5.574359	80.04487
3	1398.298	0.165030	15.72653	7.093231	77.01521
4	1552.395	0.133983	16.37491	8.303248	75.18786
5	1665.271	0.135267	16.77508	9.403803	73.68585
6	1754.649	0.171307	17.07266	10.43553	72.32051
7	1829.077	0.237130	17.29832	11.40194	71.06261
8	1893.625	0.324942	17.47414	12.30690	69.89402
9	1951.452	0.426756	17.61589	13.15439	68.80297
10	2004.515	0.536507	17.73307	13.94761	67.78281

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

Source: Author's analysis based on data from Bank of Uganda;*** the responses exceed twice asymptotic standard errors in parenthesis.

According to table 13, 67 percent of total variations in domestic investment is explained by itself over the whole sample period, 17% of the variations are explained by domestic investments, while 14 percent of total variations in economic growth during this period are explained by shocks from FDI and 0.5 percent of total variations in economic growth are explained by shocks from NREC.

The results from the estimates of variance decomposition and cumulative impulse responses are consistent with each other. The above results indicate significant pass through effect of non-renewable energy consumption shocks to economic growth.

4.3 **Estimates of Cumulative Impulse Responses(CIR)**

Table 13 presents the results from the estimates of CIR function of GDP due to shocks from other endogenous variables. Effect of shocks are in the first row, while their standard errors are in parenthesis in the second row.

Table 13:Cumulative Impulse Response of Non-Renewable Energy Consumption

Period	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(log(GDP))
1	0.374560	0.000000	0.000000	0.000000
	(0.02808)	(0.00000)	(0.00000)	(0.00000)
2	0.371212	-0.006276	0.009389	-0.001148
	(0.04594)	(0.04184)	(0.04023)	(0.04140)
3	0.368238	-0.011851	0.017730	-0.002167
	(0.06326)	(0.05999)	(0.05762)	(0.05891)
4	0.368944	-0.010527	0.015750	-0.001925
	(0.06615)	(0.06204)	(0.05499)	(0.05907)
5	0.369197	-0.010053	0.015039	-0.001838
	(0.06575)	(0.06292)	(0.05445)	(0.05962)
6	0.369090	-0.010253	0.015340	-0.001875
	(0.06737)	(0.06407)	(0.05536)	(0.06052)
7	0.369074	-0.010284	0.015386	-0.001881

	(0.06877)	(0.06430)	(0.05491)	(0.06132)
8	0.369087	-0.010258	0.015347	-0.001876
	(0.06887)	(0.06463)	(0.05533)	(0.06148)
9	0.369088	-0.010258	0.015346	-0.001876
	(0.06922)	(0.06479)	(0.05546)	(0.06158)
10	0.369086	-0.010261	0.015351	-0.001876
	(0.06933)	(0.06488)	(0.05534)	(0.06158)

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

Source: Author's analysis based on data from Bank of Uganda;*** the responses exceed twice asymptotic standard errors in parenthesis.

The cumulative impulse response function of economic growth with respect to other endogenous variables has been estimated in line with the above options and the estimated results are presented in table 13. The results are insignificant for non-renewable energy consumption as doubling the standard errors are in parenthesis does not exceed the magnitude of the shock. Further significant result are obtained with domestic investment and FDI.

In table 14, significant responses are observed in GDP due to shocks from Domestic Investments and FDI, such responses are conveyed throughout the whole sample period. The estimated results for the cumulative impulse response function of economic growth in this study therefore indicate an insignificant effect on economic growth due to shocks in domestic investment. However, significant pass through effect of economic growth to GDP is observed in the period under review.

Table 14:Cumulative Impulse Response of Domestic Investment

Period	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(log(GDP))
1	0.039406	0.322489	0.000000	0.000000
	(0.03161)	(0.02029)	(0.00000)	(0.00000)
2	0.033650	0.311700	0.016140	-0.001973
	(0.04737)	(0.04115)	(0.03492)	(0.03415)
3	0.028537	0.302116	0.030478	-0.003725
	(0.05336)	(0.05904)	(0.04915)	(0.04937)
4	0.029751	0.304392	0.027074	-0.003309
	(0.05367)	(0.05694)	(0.04626)	(0.04797)
5	0.030187	0.305208	0.025853	-0.003160
	(0.05415)	(0.05659)	(0.04486)	(0.04806)
6	0.030003	0.304863	0.026369	-0.003223
	(0.05455)	(0.05829)	(0.04530)	(0.04803)
7	0.029975	0.304810	0.026448	-0.003233
	(0.05454)	(0.05968)	(0.04580)	(0.04850)
8	0.029998	0.304855	0.026382	-0.003225
	(0.05473)	(0.05962)	(0.04588)	(0.04880)
9	0.029999	0.304855	0.026380	-0.003224

	(0.05478)	(0.05968)	(0.04591)	(0.04883)
10	0.029996	0.304850	0.026388	-0.003225
	(0.05477)	(0.05987)	(0.04598)	(0.04885)

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

Source: Author's analysis based on data from Bank of Uganda;*** the responses exceed twice asymptotic standard errors in parenthesis.

The cumulative impulse response function of economic growth with respect to other endogenous variables has been estimated in line with the above options and the estimated results are presented in table 14

In table 15, significant responses are observed in Economic growth due to shocks from non-renewable energy consumption, Foreign Direct Investments, domestic investment such responses are conveyed throughout the whole sample period. The estimated results for the cumulative impulse response function of economic growth in this study therefore indicate a significant pass through effect of economic growth to Foreign Direct Investments in the period under review.

Table 15:Cumulative Impulse Response of Foreign Direct Investment

Period	d(log(NREC))	d(log(DINV))	d(log(FDI))	d(log(GDP))
1	0.032385	0.298748	0.077355	0.000000
	(0.03002)	(0.02017)	(0.00522)	(0.00000)
2	0.029029	0.292457	0.086766	-0.001150
	(0.04522)	(0.04025)	(0.03393)	(0.03247)
3	0.026047	0.286869	0.095126	-0.002172
	(0.05297)	(0.05223)	(0.04838)	(0.04643)
4	0.026755	0.288196	0.093141	-0.001930
	(0.05358)	(0.05044)	(0.04625)	(0.04597)
5	0.027009	0.288672	0.092429	-0.001843
	(0.05426)	(0.05112)	(0.04477)	(0.04622)
6	0.026902	0.288470	0.092730	-0.001879
	(0.05445)	(0.05241)	(0.04558)	(0.04600)
7	0.026885	0.288440	0.092776	-0.001885
	(0.05481)	(0.05347)	(0.04618)	(0.04642)
8	0.026899	0.288466	0.092737	-0.001880
	(0.05497)	(0.05349)	(0.04623)	(0.04674)
9	0.026899	0.288466	0.092737	-0.001880
	(0.05500)	(0.05358)	(0.04625)	(0.04681)
10	0.026898	0.288463	0.092741	-0.001881
	(0.05502)	(0.05373)	(0.04632)	(0.04682)

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

Standard Errors: Monte Carlo (100 repetitions)

Source: Author's analysis based on data from Bank of Uganda;*** the responses exceed twice asymptotic standard errors in parenthesis.

The cumulative impulse response function of economic growth with respect to other endogenous variables has been estimated in line with the above options and the estimated results are presented in table 15. The results are not significant on economic growth due to shocks from FDI.

4.4 Discussion

4.4.1Causal relationship between Non-renewable energy consumption and economic growth Using VECM

The results from VECM indicate a long run causal relationship running from non-renewable energy consumption to GDP being positive. The non-renewable energy is used in mainly in industry and transport sector. Non-renewable energy mainly crude oil is used in running generators for the commercial sector, especially those not connected to the main grid and during load shedding. It therefore becomes an important driver of economic growth. This supports the growth hypothesis.

There is a positive relationship from domestic investment to GDP, domestic investment shows a positive multiplier due to a small threshold of domestic investment into the energy sector. It therefore follows that those that undertake these investments support economic growth. FDI also supports the growth hypothesis, as many foreign investment are done in strategic areas of electricity generation, transmission and distribution that facilitate power to the end user in the value chain.

4.4.2 Conclusion

The causality test in this study has been carried out using Granger causality test and vector error correction model. The results from Granger causality test in the study indicate that non-renewable energy consumption do not cause a shift in economic growth. This is mainly due to the use of traditional biomass which is not very productive, the electricity reserve that increases the cost of electricity and hence higher tariff and the use of imported crude oil whose price volatilities affect growth adversely. The results from vector error correction model indicate that non-renewable energy consumption is negatively related to economic growth in the long run.

4.5 **Pass through effect using Variance decomposition**

This sub chapter discusses results for the second objective to deduce the pass through effect of renewable energy consumption shocks to Economic growth. Despite having cointegrating relationship within endogenous variables, the structural VAR model has been selected for this study to explain feedback effect among set of variables. The estimates of variance decomposition and cumulative impulse responses were used.

4.5.1 Discussion of Variance decomposition

Following the estimated results,quite a huge percentage (97%) of total variations in non-renewable energy consumption in the period under study are explained by itself throughout the whole sample period, while only 2 percent of total variations in economic growth during this period are explained by shocks from GDP itself. The results in this table therefore indicate insignificant pass through effect of non-renewable energy consumption shocks to economic growth in the period under study. This performance is possible because nom-renewable energy consumption shocks according to the Environmental Kuznet curve hypothesis, in transition economies would positively impact on GDP up to some threshold. Uganda as a developing country is still in transition with most of its energy mix being renewable energy consumption. Transiting to incremental consumption in non-renewable energy consumption would hence result into positive effects to GDP.

Following the estimated results in table 10, 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.

Following the estimated results in table 10, quite a small percentage (46%) of total variations in FDI in the period under study are explained by itself throughout the whole sample period, while 51 percent of total variations in economic growth during this period are explained by shocks from domestic investment. These results therefore indicate significant pass through effect of FDI shocks to economic growth in the period under study FDI has positive and significant multiplier to growth as it is critical for energy investments in a developing country like Uganda, FDI brings a positive returns in 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.

4.6.1 Cumulative impulse response of economic growth due to Non-renewable energy consumption shocks

According to estimated results presented, there exist significant responses from economic growth due to shocks from other endogenous variables. The estimated responses do not exceed the two standard error criteria of significance throughout the whole sample period. The estimated responses in this table therefore indicate that the response of economic growth due to total variations in non-renewable energy consumption in the period under study is significant.

Shocks on economic growth during this period inspired significant responses from domestic investment and FDI, throughout the whole sample period. Following the estimated results presented, the responses from domestic investment during this period are determined by shocks from non-renewable energy; such shocks are conveyed to FDI and GDP. And whereas the responses from FDI and domestic investment during this period are determined by shocks from non-renewable energy; such shocks are conveyed to GDP.

The results from the estimates of variance decomposition and cumulative impulse responses are consistent with each other. The above results indicate insignificant pass through effect of non-renewable energy consumption shocks to economic growth in the period of study.

Although some significant responses are observed in economic growth rate due to shocks from non-renewable energy consumption, it has rather been determined by other co-operating factors in the economy. Such factors may include domestic as well as foreign direct investment and consequently resulting into economic growth.

5.0 Conclusion and Policy Recommendation

5.1 Conclusions

The investigation of causality between non-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 no causality exists between energy consumption and economic growth. The, no causal relationship between non-renewable energy consumption and economic growth in the short run.

Secondly, the results from vector error correction model in the study indicate a positive causal relationship exist between non-renewable energy consumption and economic growth exists in the long run. A 1 percent increase in NREC increases Uganda's Economic Growth by 17percent.This result, however, is not significant as in the long run several other factors come into play to explain this positive result.

Many earlier studies have investigated the effect of non-renewable energy consumption and economic growth Some of these studies confirmed a neutrality hypothesisChedran and Tang (2013), Menegaki and Ozturk (2013), Yildirim et al., (2014), Chang et al. (2015), Jebli and Youssef (2015), Omri et al., (2015), Aper and Oguz (2016), Cetin et al. (2106), Fan and Hao (2016), Li et al., (2016), Lin and Liu (2016), Kocak and Sarkgunesi (2017), Tugcu and Topcu (2018), Chinedu et al., (2019), Ozcan and Ozturk (2019), Nepal and Paija (2019).

The results from VDA and CIR analysis further confirmed the earlier findings from vector error correction model that indicate no significant relationship between non-renewable energy consumption and economic growth. The estimated results from variance decomposition and cumulative impulse responses in this study indicate that there is a no significant pass through effect of non-renewable energy consumption shocks to economic growth in the period of study. Therefore no significant pass through effect on economic growth due to shocks in non-renewable energy consumption.

5.2 Policy Implications

The policy implications is 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. This will ensure steady growth of the oil sector to provide a steady and local non-renewable resource that can promote economic growth.

5.3 Area of Further Research

Furthermore, studies can still focus on the institutional and governance variables in energy consumption and how they impact on the growth process in Uganda. The institutional and governance aspect of Energy sector is important in fostering Economic growth.

While this study is relevant for a given context and period of study. The methods and variables have been carefully selected, however, there is no guarantee that when these are varied will give the same results.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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