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Natural Gas Consumption in Power Generation and Economic Growth in Tanzania

Gerald. J. Kondowe
Tanzania Public Service College. Box 2574 Dar Es Salaam
Author's email: kondowe@yahoo.com

Abstract: Natural gas is the domestic energy source in Tanzania that is primarily used in power generation. For this reason, changes in natural gas consumption in power generation affect economic growth, which is the most critical macroeconomic performance indicator. This paper investigates the existing relationships between natural gas consumption in power generation and economic growth in Tanzania, covering from 2005 to 2017. The study uses the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) Unit Root Tests, the Autoregressive Distributed Lag (ARDL) bound cointegration test, the Error Correction Model (ECM), and the Granger Causality Test. The results reveal that the variables in the Estimation Model have mixed order of integration which necessitated the choice of the ARDL. The variables were strongly cointegrated in the long run. The empirical estimation indicates a significant positive relationship between the real GDP per capita and explanatory variables in the model. The Granger Causality Test results indicate bi-directional causality between the real GDP per capita and natural gas consumed by the power sector. They also show bi-directional causality between the real GDP per capita and natural gas consumed by the industrial sector. The higher economic growth induced more demand for natural gas consumption in both power and industrial sectors, which significantly impacted the economy in terms of economic growth. The study recommends the joint implementation of policies promoting both natural gas consumption and economic growth in Tanzania.

Keywords: *Natural gas consumption, power generation, economic growth, Tanzania*

1.0 Introduction

For many years oil has been considered a leading source of energy. However, natural gas has become more attractive in replacing oil in recent years, especially in power generation and industrial production. Traditionally, electricity generation in Tanzania relied on hydroelectric sources. However, uncertain hydrology led the oil-fired power generation contracted from the Emergency Power Producers (EPPs) to supplement the deficiency. The domestic availability of natural gas drive the government toward an aggressive natural–gas led into power capacity expansion plan (Peng and Poudineh, 2016). Three companies that produce natural gas in Tanzania include the Songas, Maurel and Prom (MandP), and Tanzania Petroleum Development Corporation (TPDC). The Songas operates the Songo Songo gas field, Tanzania's first natural gas development that produces and processes natural gas from the four wells since 2004. The Maurel and Prom (MandP) produced and processed natural gas from Mnazi Bay Gas field since 2006. Moreover, the TPDC has been a new natural gas producer since 2015 at Mnazi Bay and

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2016 at Songo Songo Gas Fields. These producers supply natural gas to the Tanzania Electric Supply Company (TANESCO) and other Independent Power Producers (IPPs), industries, households and other domestic gas users. Natural gas production was primarily developed as part of the gas to power package and allows power generation to enjoy a discount on the price of natural gas used.

As of September 2020, total primary power generation mix in Tanzania was 1,876 MW including natural gas (45 percent), hydropower (42 percent) and liquid fuel (13 percent) (URT, 2016). The government of Tanzania expects future electricity capacity additions to come from domestically available fuels and primarily from hydro, gas, and coal power plants. Their choices take advantage of its availability, environmental implications, associated costs, and construction lead times. Tanzania works to expand gas to power projects to ensure a reliable power supply. Gas-fired power generators are more attractive since they are flexible, relatively cheaper, and quickly turned on and off (Amin-Naseri *et al.,* 2019). There is more expansion of several hydroelectric dams with the ongoing heavy investment in the Julius Nyerere Rufiji Hydro Electric Power Project. But this source of electricity remains unreliable due to climatic change. When rains fail, the water level at the dams drops significantly, causing an enormous shortage of electricity supply, as happened in 2010 when the country experienced severe power shortages. Tanzania considers domestic natural gas utilisation in meeting the domestic demand, and once fulfilled, export could follow. The development of gas to power projects in Tanzania targets ending long persisted power shortages in the country.

Since July 2004, when natural gas exploitation started in Tanzania, the power sector has been the major consumer of domestic natural gas, starting by consuming about 30MMscfd of natural gas to feed the Songas power generation facility Ubungo in 2004. In 2010, the total consumption reached almost 88*MMscfd*. In 2013, out of 103*MMscfd* average gas production, power generation consumed an average of 85*MMscfd*, to generate 358.5MW of electricity. Industries consumed the remaining 18*MMscfd*. Out of 131.91*MMscfd* average natural gas output in 2016, power generation consumed an average of 114.89*MMscfd* to generate 575MW of electricity. Industries located in Dar es Salaam finished the remaining 17*MMscfd* (EWURA, 2016). In recent years, The Tanzania's economy has registered an impressive growth rate of 6–7 percent, and tremendous improvements in real GDP per capita (at 2007 constant prices): Tshs 699, 127 in 2007, Tshs 856, 447 in 2013, and Tshs 990, 293 in 2017, respectively (BoT, 2020). However, the shortages of electricity hamper economic growth. Still, the priority in Tanzania natural gas utilisation is to use it domestically to alleviate severe power shortages in the country. Improving access to electricity is in line with the *Tanzania Development Vision 2025* of reaching high-quality livelihoods and a competitive and robust economy capable of producing sustainable growth and shared benefits. These created a need to study the association between natural gas consumption for power generation and the economic growth in Tanzania. The study aims at assessing whether changes in natural gas consumption for power generation enhance the predictability of changes in the aggregate output in the Tanzanian economy.

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Theoretically, an increase in natural gas consumption in power generations increase quantity of electricity generated which tends to increase energy use. The energy use is either a cause or the facilitator of economic growth due improved productivity and reduced power outages (Sarker and Alam, 2010; Onyeisi *et al.*, 2016). The relationship between natural gas consumption and economic growth is now well documented in the literature. The direction of causation of this relationship, which has important policy implications, remains controversial. The findings suggest the existence of four hypotheses concerning the direction of causality, namely *Feedback Hypothesis*, *Growth Hypothesis*, *Conservational Hypothesis*, and *Neutral Hypothesis.* Shahbaz *et al.* (2016), Alam *et al.*(2017) and Li *et al.* (2019) found the prevalence of feedback hypothesis. The feedback hypothesis indicates that natural gas consumption and economic growth are complements. Natural gas consumption is a cause of economic growth and vice versa in the Granger sense. Hassan *et al. (*2018) and Amin *et al. (*2018) found unidirectional causality running from oil/gas consumption to economic growth, such as the growth hypothesis. Then the economy is considered to be oil/natural gas-dependent. Reducing oil/gas consumption could lead to a fall in economic growth, which implies that conservation policies could be harmful to economic growth; therefore, uninterrupted availability of natural gas is essential. The study by Sanches (2020) on natural gas consumption positively impacted economic growth in the short-run and long run. Fadiran *et al.* (2019) found a long-run impact of natural gas consumption on economic growth. However, Rahman *et al.* (2020) found a unidirectional relationship between economic growth and natural gas consumption. Any energy policy designed to reduce natural gas would not affect growth with significance. Changes in the GDP would directly influence natural gas consumptions trends. This relationship corresponds to the Conservation Hypothesis. Finally, the Neutrality Hypothesis if no relationship between natural gas consumption and economic growth is detected, then the variables are considered independent. This is congruent with the findings from Aydin (2018) that energy conservation policies do not affect growth.

Few studies have been undertaken in developing countries examining the nexus between industrial natural gas consumption and industrial output growth. Ifeakachukwu (2017) found short-run unidirectional causality from gas consumption to manufacturing, building, and construction, and the service sectors. Bernard and Oludare (2016) found that natural gas consumption contributed positively to the short-run industrial output growth in Nigeria. Makala and Zongmin (2019) conducted a study in Tanzania based on before and after commercial natural gas exploitation in Tanzania (1995 to 2018). They found evidence in favour of the Neutrality Hypothesis. Since the previous studies' findings are generally mixed, the direction of causality between natural gas consumption and economic growth remains controversial and inconclusive. Therefore, it is not easy to formulate a reliable hypothesis about the causal links between natural gas consumption and economic growth in a developing country like Tanzania. The previous study in Tanzania by Makala and Zongmin (2019) focused on analysing the relationship between aggregate natural gas consumption and economic growth. The present research focuses on the nexus between natural gas consumption in power generation and

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economic growth in Tanzania. To the best of my knowledge, no studies have focused on the empirical relationship between domestic natural gas consumption in power generation and economic growth in Tanzania. Hence, this paper investigates the relationships and direction of the relationship between the concerned variables in Tanzania mainland. The research question is as follows: what is the short-run causal relationship between natural gas consumption in power generation and economic growth in Tanzania?

2.0 Methodology

2.1 Study Location

The study was conducted in Tanzania mainland since oil and gas issues are among non-union matters in the United Republic of Tanzania (URT). The research focuses on natural gas consumption in bridging the gap of electricity deficits in Tanzania. The study includes natural gas produced from three sources: the Songo Songo gas field, the Mnazi Bay gas field, and the Kiliwani north gas field. The study focused on natural gas consumed by gas-fired generators owned by the TANESCO and IPPs in Dar es Salaam Gas Power Project, namely Ubungo II, Songas, Independent Power Tanzania Limited (IPTL), Symbion, Kinyerezi I, Kinyerezi II, Somanga Fungu Power Production, and Mtwara Power Production. Since the electricity generated has a multiplier effect on the economy. Hence, the study focused on the economic growth of the whole country.

2.2 Design

The present study used the longitudinal research design. The design allows observations of a given phenomenon over time based on the secondary data available in reports and websites collected by various institutions for other purposes but used to address the present study objectives and hypotheses testing. The analysis uses quarterly time-series data, covering the period of Q1:2005 to Q2 2017. The data were appropriately used to analyse essential parameters such as the Cointegration Test, Error Correction Model (ECM) and Granger Causality Test. The design helps to save time and overcome financial limitations.

2.3 Types and Sources of Data

The details of the variables of interest under investigation on the present study, measurements, and data sources are summarized in Table 1.

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Table 1: Variables Used and their Measurements

Variable Names	Variable Representation	Variable Proxy	Transformation of the Variable	*Data Source*
Economic growth	LnY_t	real GDP per capita	$Ln\left(\frac{real\ GDP}{total\ population}\right)$	BoT, NBS
Capital	LnK_t	Gross fixed capital formation per capita.	$Ln\left(\frac{Gross\ fixed\ capital\ formation}{total\ population}\right)$	BoT, NBS
Labour force	LnL_t	The proportion of labour force in the total population	$Ln\left(\frac{Labour\ force}{total\ population}\right)$	NBS
Natural gas consumed for power generation	$LnPNGCP_t$	The proportion of Natural gas consumed by the power sector	$Ln\left(\frac{Gas\ consumed\ by\ the\ power\ sector}{total\ natural\ gas\ consumption}\right)$	TPDC
Natural gas consumed by the industrial sector	$LnPNGCI_t$	The proportion of Natural gas consumed by the industrial sector	$Ln\left(\frac{Gas\ consumed\ by\ the\ industrial\ sector}{total\ natural\ gas\ consumption}\right)$	TPDC

The analysis used quarterly time series data on the real GDP per capita at constant 2007 prices (in $ per capita), real gross fixed capital formation per capita at constant 2007 prices (in $ per capita) as a proxy for physical capital formation. The proportion of the labour force in the population, such that the working-age population aged 15 to 64years over the total population, is a good proxy for labour since not every individual contributes to production. The proportion of natural gas consumed by the power and industrial sectors in the economy are the priority sectors in domestic natural gas utilisation. The data on the real GDP per capita and gross fixed capital formation per capita were collected from the Bank of Tanzania (BoT) and the National Bureau of Statistics (NBS). In the present study, the data on labour were collected from the NBS. At the same time, the data on aggregate natural gas consumption and consumption in both power generation and industrial end-users were collected from the TPDC.

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2.4 Sampling Procedures

The present study covers the period from Q1:2005 to Q2:2017 and it involved 50 quarterly time-series observations in each chosen variable. This sample size was reasonable for inferences. Commercial natural gas exploitation began in Tanzania in June 2004; so the selected period was a period of active natural gas exploitation. The data on natural gas utilisation were available for public consumption for only the chosen period.

2.5 Methods of Data Gathering

The data were collected from different official reports, publications, and websites of various public institutions such as BoT, NBS, and TPDC. Some data in annual time series data, such as real GDP per capita, real gross fixed capital formation per capita, and the proportion of labour force in the population were converted into quarterly time-series data by interpolation (temporal disaggregation) methods.

2.6 Analytical Framework

The model employed a modified Solow Model as Nadeem and Munir (2016) and Kim *et al.* (2019). The literature on applied energy economics shows that energy or natural gas, labour, and capital are essential inputs. The study used the Neoclassical Solow Model expressed as:

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \quad \text{...(1)}$$

where Y is total output to the economy, K is capital, L is labour force, and A is Total Factor Productivity (*TFP)* or effectiveness of labour. α and β are the elasticity of output with respect to capital and labour inputs, with a constant return to scale Cobb Douglas production function $\alpha + \beta = 1$.

Then natural gas consumption was added as energy input in the production function. The Aggregate Production Function (APF) was formulated as follows:

$$Y_t = f(K_t, L_t, E_t) \text{...(2)}$$

$$Y_t = f(K_t, L_t, P_t, I_t, C_t) \text{...(3)}$$

E is natural gas consumption input disaggregated into natural gas consumption by the power sector (*P*) and natural gas consumption by the industrial sector (*I*), which are likely to cause technological progress effects on economic growth. C_t is added representing other exogenous factors. The Cob-Douglas production function is employed and from equations (3), we get the following aggregate production function:

$$Y_t = C_t K_t^{\emptyset} L_t^{\varphi} P_t^{\delta} I_t^{\sigma} \text{...(4)}$$

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Where $\emptyset, \varphi, \delta,$ and σ, are the constant elasticity coefficients with respect to the K, L, P, and I in the AFP. Each coefficient is larger than zero and smaller than one. From equation 4, for simplicity with the subscript *"t"* omitted, and then taking natural logs of both sides, we obtain the linear logarithmic regression equations. The error term is assumed to be a Gaussian white noise error process with constant variances ε_t added and a constant term $Ln\,C = a$. We obtained the following equations (5):

$$Ln\,Y = a + \emptyset LnK + \varphi LnL + \delta LnP + \sigma LnI + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The signs of all constant coefficients, such that, $\emptyset, \varphi, \delta,$ and σ, were expected to be positive.

2.7 Data Analysis

The analysis involves four (4) steps: First, data exploration (preliminary testing) focusing on characteristics of the variables of interest such as descriptive statistics, visual observations, and unit root testing. The second are bound cointegration test and ARDL/ECM in the short- and long-run estimation model variables. The third are the post-diagnostic tests to check the efficiency and the consistency of the findings. The fourth is the causality test to examine the direction of causality.

2.7.1 Data Exploration

Preliminary testing performed includes visual analyses, descriptive statistics analyses, and unit root testing. The study undertakes visual examinations of the variables to visualise and communicate the behaviour or data changes over time. Descriptive statistics provide a historical background for the behaviour of our data to know whether the sample is normally distributed and detect the presence of outliers in the data. Common parameters examined in the descriptive analysis include measures of central tendency (mean, median, and mode); measures of dispersion (range, variance, and standard deviation); and measures of normality (kurtosis and skewness). The null hypothesis tested that the series under consideration is not normally distributed.

Unit root testing performed to ensure that none of the series (variables) is I(2) or higher as such will invalidate the methodology by complicating the F test and therefore cause the Autoregressive Distributed Lag (ARDL) model to crash (Nkoro and Uko, 2016). The study employed the most widely used unit root tests in the literature, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) methods. If both tests give the same results confirming the order of integration of the series, the data generating process was correctly undertaken considering pure random walk, random walk with drift, and random walk with adrift and time trend.

2.7.2 Bound Cointegration Test and Long-and Short-runs Analyses

The study adopts the ARDL bounds test methodology. In the ARDL model, the dependent variable is a function of its lagged value(s), the current and lagged values of regressors as explanatory variables. The long and short-run parameters are simultaneously estimated. Because of the appropriate lag selection, the study eliminates residual correlation and avoids the

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endogeneity problem. The ARDL is common in situation irrespective of whether the regressor variables are I(0) and I(1) or mixed order of integrations but not I(2). The ARDL model acts efficiently with small sample time-series data (Tursoy and Faisal, 2016).

The study uses the bound cointegration test to examine the long-run relationship between the variables. The bound test was performed using the F-statistics or Wald test to check the significance of the lagged coefficient in the unrestricted Error Correction Model (UECM). The null hypothesis of no cointegrating relationship exists tested. The decision rule is that if the computed F-statistic is greater than the value for the upper critical bound, I(1), there is cointegration, and one can reject the null hypothesis. If it is lower than the critical value for the lower bound I(0), then there is no long-run relationship, and one must accept the null hypothesis. If it is between the lower bound I(0) and the upper bound I(1), the test is inconclusive since no exact opinion can be made. The ARDL representation of the model is expressed as follows in equation (6).

$$\Delta Ln(GDPPC_t) = c_0 + \sum_{i=1}^{p} c_{1i}\Delta Ln(GDPPC_{t-i}) + \sum_{i=0}^{q} c_{2i}\Delta LnGFCFPC_{t-i} + \sum_{i=0}^{r} c_{3i}\Delta LnLFPC_{t-i} + \sum_{i=0}^{m} c_{4i}\Delta LnPNGCP_{t-i} + \sum_{i=0}^{n} c_{5i}\Delta LnPNGCI_{t-i} + d_{11}Ln(GDPPC_{t-1}) + d_{21}LnGFCFPC_{t-1} + d_{31}LnLFPC_{t-1} + d_{41}LnPNGCP_{t-1} + d_{51}LnPNGCI_{t-1} + \varepsilon_{2t}$$

…………………………………………………………..(6)

where $GDPPC_t$ is real GDP per capita in 2007 US$, as a proxy for economic growth. $GFCFPC_t$ is gross fixed capital formation per capita in the economy (in US$) as the proxy for the contribution of capital stock in the economy at time t. $LFPC_t$ is proportion of labor force in the population at time t, such that, population of age between 15-64 years. $PNGCP_t$ is proportion of natural gas consumed by the power sector in the economy at time t. $PNGCI_t$ is proportion of natural gas consumed by the industrial sector in the economy at time t. $c_{1i} \ldots c_{5i}$ are the parameters short-run coefficients; $d_{11} \ldots d_{51}$ are the parameters long-run coefficients; c_0 is the constant coefficient. p, q, r, m and n are the optimal lag lengths of the variables.

Error correction specification is used to test for causality in two ways: short-run causality through the lagged differenced explanatory variables and long-run causality through the lagged ECM_{t-1} term. The ECM is specified as follows in equation (7):

$$\Delta Ln(GDPPC_t) = c_0 + \sum_{i=1}^{p} c_{1i}\Delta Ln(GDPPC_{t-i}) + \sum_{i=0}^{q} \alpha_{2i}\Delta LnGFCFPC_{t-i} + \sum_{i=0}^{r} \alpha_{3i}\Delta LnLFPC_{t-i} + \sum_{i=0}^{m} \alpha_{4i}\Delta LnPNGCP_{t-i} + \sum_{i=0}^{n} \alpha_{5i}\Delta LnPNGCI_{t-i} + \lambda ECT_{t-1} + \varepsilon_{2t}$$

…………………………………………………………......……(7)

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where λ is the parameter indicating the speed of adjustment to the equilibrium level after a shock. ECT_{t-1} is the error correction term. The error correction term must have a negative sign and be statistically significant to ensure convergence of the dynamics to the long-run equilibrium[1]. The coefficient of λ, ranges from -1 and 0. A -1 indicates perfect and instantaneous convergence, while 0 means no convergence after a shock in the process.

2.7.3 Causality Test

Cointegration also implies that there is Granger causality among the variables in at least one direction. It determines whether a one-time series helps forecast another and ascertain the direction of causal relationships between the variables. The Granger causality test is expressed as follows in equations (8 and 9):

$$X_t = \alpha_1 + \sum_{i=1}^{n} \lambda_{1i} Y_{t-i} + \sum_{i=1}^{n} \gamma_{1i} X_{t-i} + \delta_1 Z + \varepsilon_{1t} \qquad (8)$$

$$Y_t = \alpha_1 + \sum_{i=1}^{n} \gamma_{1i} X_{t-i} + \sum_{i=1}^{n} \lambda_{1i} Y_{t-i} + \delta_2 Z + \varepsilon_{2t} \qquad (9)$$

where (X_t) represents one variable, (Y_t) represents another variable, and (Z) is a set of seasonal dummies exogenously included to capture any seasonal effects. The examination of the joint significance of the lagged values helps to constitute the Granger causality. In equation 7, if $\lambda_{1i} \neq 0$, then Y is said to Granger cause X.

2.7.4 Post-diagnostic Tests

Post-diagnostic tests are performed to ensure that the estimates of the chosen multivariate model are reliable, efficient, consistent, and robust. The study uses numbers of post-diagnostic tests, such as the Durbin Watson's (DW) Statistic and the Breusch Godfrey (BG) test for serial correlation; the White test for heteroskedasticity. The study also uses non-normality tests, such as the Skewness test for normality, the Kurtosis test for normality, and the Joint test for normality. Moreover, the model structural stability test is performed to investigate the stability of the long-run coefficients used to form the error correction term(s) in conjunction with the short-run dynamics. The models' residuals were used to construct the plot of the cumulative sum (CUSUM) of squares to check whether the model is stable and consistent in both long-run and

[1] $\lambda = \left(1 - \sum_{i=1}^{p} \delta_t\right)$ is the speed of adjustment parameter with a negative sign

$ECT = \left(LnGDPPC_{t-i} - \theta X_t\right)$ is extracted residuals from the regression of the long-run equation commonly known as error correction term

$\theta = \frac{\sum_{i=0}^{q} \beta_i}{\alpha}$ is the long-run parameter

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short-run results. If the cumulative sum goes outside the two critical lines in CUSUM squares plot, then the model is not free from stability.

3.0 Results and Discussion

The variables of interest were well collected, edited, organised, and then entered into the Stata computer software for analysis and interpretation.

3.1 Data Exploration

Before estimating the model, the study performed data exploration on all the variables. It includes computation of descriptive statistics (Table 2), graphical description (Figure1 A-E), as well as analyses of unit root tests (Table 3). These preliminary tests guided the appropriate methodology for analysis. Table 2 shows the results for descriptive statistics.

Table 2: Descriptive Statistics Results for Variables Used

Variable	GDPPC	GFCFPC	LFPC	PNGCP	PNGCI
Mean	133.2941	45.34909	0.5053657	0.8365792	0.1634208
Std. Deviation	12.75364	3.765794	0.0075604	0.0746412	0.0746413
Min	106.9342	38.0205	0.4955723	0.645705	0.0426504
Max	158.168	51.66444	0.5174426	0.9573481	0.3542951
Variance	162.6554	14.18121	0.0000572	0.0055713	0.0055713
Skewness	-0.4103662	-0.5047465	0.1666414	-0.332971	0.3329746
Kurtosis	2.684141	2.533862	1.566341	2.562916	2.562895
Observation	50	50	50	50	50

Note: Normal Skew: 0, Mesokurtic : Kurtosis of 3[2]

Table 2 shows that the values of kurtosis and skewness statistic results for all the variables of the estimation model are not far from suggesting normality in the series. The kurtosis were about 3 (the mesokurtic value), and the skewness values were near zero. Therefore, the variables are assumed normally distributed such that they would lead to unbiased parameter estimates.

[2]GDPPC, GFCFPC and PNGCP are all negative skewness, have long left-tail, i.e., more lower values.
LFPC and PNGCI are all positive skewness, have long right-tail, i.e., more higher values.
Kurtosis results for all the variables are platykurtic as their values are more lower values, below the sample average (mesokurtic value), i.e., GDPPC(2.684141<3); GFCFPC(2.533862<3); LFPC(1.566341<3); PNGCP(2.562916<3) and PNGCI(2.562895<3)

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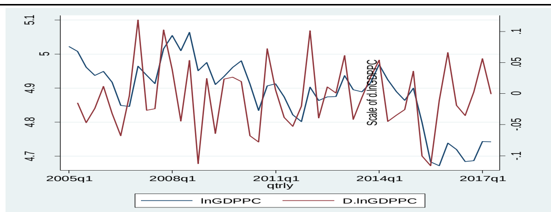
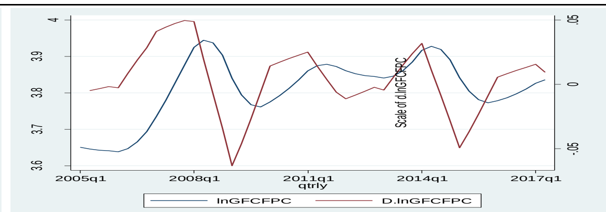
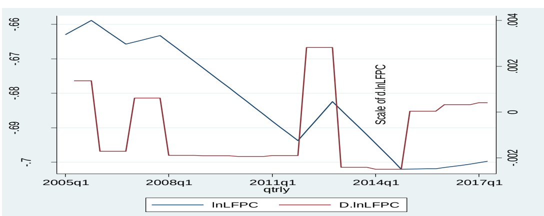
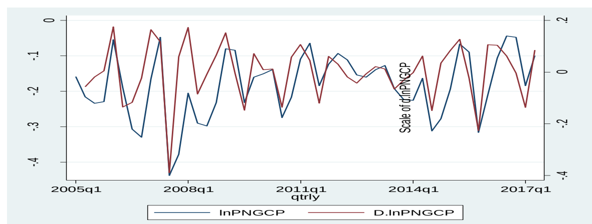
Figure 1 (A-E) represents a visual presentation of the variables used. The variables are visualised when in levels, then in their first difference. Both plots are in log form, plotted in the same figure.



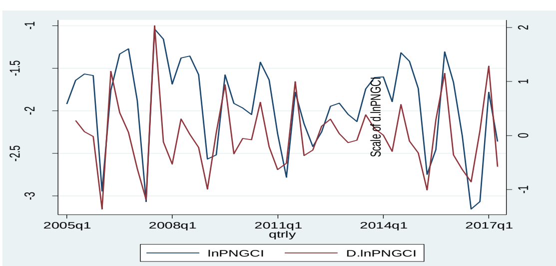


A: Log of level and first differenced series of GDPPC B: Log of level and first differenced series of GFCFPC





C: Log of level and first differenced series of LFPC D: Log of level and first differenced series of PNGCP



E:: Log of level and first differenced series of PNGCI

Figure 1: Graphic Representation of Variables Used in the Estimation Model

From Figure 1, none of the variables is stationary at level. However, the first difference series were all stationary.

Unit root testing was performed on each variable using the ADF and PP tests, in level and first difference, considering conditions like no constant, intercept, and constant and trend. Before performing unit root testing, the appropriate lag length for each variable was estimated and used for unit root testing. Table 3 reports the results.

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Table .3: Results for ADF and PP Unit root Tests for Variables of the Estimation Model

Variable (lags)	Test Formulation	At levels ADF	PP	At 1st difference ADF	PP	Order of integration
	test	Test stat	Test stat	Test stat	Test stat	
Log of real GDP per capita (1)	No Constant	-0.800	-0.819	-6.538*	-7.447*	I(1)
	Intercept	-1.769	-1.902	-6.594*	-7.455*	
	Trend	-2.781	-2.936	-6.546*	-7.374*	
Log of gross fixed capital formation per capita (3)	No Constant	0.761	0.565	-3.786*	-2.669*	I(1)
	Intercept	-3.005**	-2.211	-3.877*	-2.697	
	Trend	-2.387	-2.054	-4.505*	-2.752	
Log of proportion of labour force in the population(2)	No Constant	1.630	2.159**	-2.999*	-2.799*	I(0)
	Intercept	-1.462	-0.744	-3.753*	-3.170**	
	Trend	-2.743	-1.954	-3.826**	-3.152	
Log of proportion of natural gas consumed by the Power sector (4)	No Constant	-0.703	-1.504	-3.205*	-10.708*	I(1)
	Intercept	-1.449	-4.920*	-3.192**	-10.573 *	
	Trend	-2.173	-5.245*	-3.242	-10.441*	
Log of proportion of natural gas consumed by the Industrial sector (2)	No Constant	-0.177	-0.707	-8.421*	-9.035*	I(0)
	Intercept	-3.746*	-5.248*	-8.390*	-8.924*	
	Trend	-4.250*	-5.529 *	-8.320*	-8.803*	

Note *denotes rejection of the null hypothesis at the 1% significance level and** at the 5% significance level

From Table 3, the results suggest that the variables of the estimation model had a mixed order of integrations, such that some variables were stationary in levels (I(0)) and some were non-stationary in levels but became stationary in first difference (I(1)). These were examined under different conditions, first with no constant, then with intercept, and after that with constant and trend. Since the variables of the estimation model were of mixed order of integration, such that I(0) and I(1), and the dependent variable was I(1), the study recommends Pesaran *et al.* (2001) ARDL bound test procedure.

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3.2 ARDL Bound Cointegration Test

First, the optimal lag structure for the ARDL model is determined. Among the information criteria, the AIC had the lowest score; therefore, the lag of 4 as suggested by the AIC was chosen. Second, the bound cointegration test was performed to test for the presence of long-run relationships. The model uses the *F*-test and the *t*-test to examine the existence of a long-run relationship between the variables. Table 4 shows the results.

Table 4: The ARDL Bound Test results for the Estimation Model

ARDL Bounds Test for Cointegration Results (ARDL (1, 0, 0, 1, 0) regression)

F Statistic	Significance Level	Lower Bound	Upper Bound	Decision
8.630	10%	2.45	3.52	**Cointegrated**
	5%	2.86	4.01	
	1%	3.74	5.06	
t-statistic	**Significance Level**	**Lower Bound**	**Upper Bound**	**Decision**
-5.801	10%	-2.57	-3.66	**Cointegrated**
	5%	-2.86	-3.99	
	1%	-3.43	-4.60	

From Table 4, the bound cointegration test when the real GDP per capita was a dependent variable shows that the calculated F- statistics is higher than the upper bound critical values in all significance levels. The study rejects the null hypothesis of no cointegration. It implies the cointegrating relationships among the dependent and independent variables. The presence of cointegration also suggests that the connection between the variables is permanent and recovered whenever disturbance arises.

3.3 Analysis of the Long-run and Short-run Relationship

Table 5 summarises the regression results for the Estimation Model, such as the long and short-run analyses (Panel A and B). Moreover, to ensure the robustness of the results, the model post diagnostic test results are presented (Panel C).

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Table 5: Regressions Results for the Variables in the Estimation Model Based on AIC (ARDL (1, 0, 0, 1, 0))

Panel A: Long-run coefficients- Dependent variable is Log of GDPPC				
Regressor	Coefficient	Standard Error	T -Ratio	T-Probability
Log of GFCFPC	0.583	0.143	4.080***	0.000
Log of LFPC	6.089	0.857	7.100***	0.000
Log of PNGCP	0.639	0.372	1.720*	0.093
Log of PNGCI	0.159	0.059	2.690**	0.010
Panel B: Short-run coefficients- Dependent variable is d (Log of GDPPC); d=first difference operator				
Regressor	Coefficient	Standard Error	T -Ratio	T Probability
d(log of Real GDPPC(-1))	0.439	0.097	4.54***	0.000
d(log of Real GFCFPC)	0.327	0.095	3.45***	0.001
d(log of LFPC)	3.415	0.763	4.47***	0.000
d(log of PNGCP)	0.540	0.203	2.66**	0.011
d(log of PNGCP (-1))	-0.181	0.069	-2.64**	0.012
d(log of PNGI)	0.089	0.034	2.59**	0.013
Constant	4.059	0.794	5.110***	0.000
ECM(-1)	-0.561	0.097	5.800***	0.000
Panel C: Diagnostic tests				
F-statistic			41.92; ***	
R-squared			0.5348	
Adjusted R-squared				0.4684
D-Watson-statistic				2.088061
Breusch-Godfrey LM Test of residual serial correlation *(p-value)*				0.337 (0.5614)
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity – dependent variable *(p-value)*				1.68 (0.1954)
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity – independent variables *(p-value)*				3.54 (0.7392)
Heteroskedasticity: *white test (p-value)*				24.15 (0.6221)
Skewness				5.65 (0.4632)

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Kurtosis	0.11 (0.7457)
Skewness test for Normality *(p-value)*	(0.02967)
Kurtosis test for Normality *(p-value)*	(0.0047)
Joint test for Normality *(p-value)*	3.67 (0.0026)
CUSUMSQ(Cumulative Sum of Square)	Stable

*, ** and *** show significance at 10%, 5% and 1% levels of significance, respectively. ECM is the error correction term generated from the long run model. Figures in brackets represent p-values. The AIC model lag selection criteria was used to generate these results, having been determined to be the most appropriate information criterion.

3.3.1Analysis of the Long-run Relationships

From Table 5 (Panel A), the estimated coefficients show that among the variables of interest, at the 1 percent significance level, the coefficients of labour force proxied by the proportion of Labour Force in the Population (LFPC) and capital investment proxied by the Gross Fixed Capital Formation Per Capita (GFCFPC), have a high positive effect on the real GDP per capita. A one percent increase in the proportion of labour force in the population leads to an approximately 6.089 percent increase in the real GDP per capita, all things being equal. A one percent increase in gross fixed capital formation per capita leads to an approximately 0.583 percent increase in the real GDP per capita when all things are equal.

The coefficient of the proportion of natural gas consumed for power generation is positive, such that 0.639 at 10 percent significant level; and the coefficient of the proportion of natural gas consumed by the industrial sector has a positive sign, such that, 0.159 at 5 percent significance level. A one percent increase in the proportion of natural gas consumed for power generation leads to approximately a 0.639 percent increase in the real GDP per capita, all things being equal. A one percent increase in the proportion of natural gas consumed by the industrial sector leads to approximately a 0.159 percent increase in real GDP per capita, all things being equal. Therefore, the results show that the proportions of natural gas consumed for power generation and of the industrial sector are statistically significant in the long run. Contrary to Makala and Zongmin (2019) in the findings, there was no long-run relationship between natural gas consumption and economic growth in Tanzania.

3.3.2 Short-run Analysis Results

Table 5 (Panel B) depicts the short-run relationship results. The presence of cointegration requires an Error Correction Model (ECM) to imprison the dynamics of the short-run relation with its coefficients, which measures the speed of adjustment.

The results show that the percentage change on the first lag of the GDPPC is associated with a 0.439 percent increase in the GDPPC, on average ceteris paribus at a 1 percent significance level. The coefficients of the current GFCFPC and current LFPC are both positive (i.e., 0.327 and

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3.415) and statistically significant at 1 percent levels. A unit increase in the GFCFPC will lead to a US$ 0.327 increase in the GDPPC. A unit increase in the LFPC will lead to a US$ 3.415 increase in the GDPPC.

The coefficients of the current PNGP and the current PNGI are both positive, 0.540 and 0.089, and statistically significant at 5 percent levels. A unit increase in the PNGP will lead to a US$ 0.540 increase in the GDPPC. A unit increase in the PNGI will lead to a rise of 0.089 US Dollars in the GDPPC. However, the coefficient of the first lag of the PNGP is negative contrary to the expectations of this study. This signals that the price of natural gas to the industrial sector is set based on alternative fuel prices determined by forces of demand and supply set above the average variable cost. While the government preferentially sets the price of natural gas to the power sector to protect price-sensitive customers in the power sector, it is always a regulated low, which does not cover the average variable cost. This resulted in an economic loss in terms of a decline in the GDPPC.

The equilibrium correction coefficient estimated as -0.561 is highly statistically significant at a 1 percent level. It has the correct sign and implies a good speed of adjustment to equilibrium after a shock. Approximately, 56.1 percent of disequilibrium from the previous quarter's shock back to the long-run equilibrium in the current quarter.

3.4 Diagnostic and Stability Tests for the Estimation Model

The regression for the underlying the ARDL equation (6) for the estimation model fits very well. Table 5 (Panel C) shows that the estimated value of R-squared for the estimation model was 0.5348 in the dynamics of the short-run relations, which demonstrate that about 53.48% of the variation in the real GDP per capita was described in the model by the independent variables. The value of adjusted R^2 was relatively high, such that, 0.4684 which exemplifies a good model fit.

The estimated model passes the diagnostic tests against serial correlation, heteroskedasticity, functional form misspecification, and non-normality errors. From Table 5 (Panel C), the D-Watson statistics were close to two such as 2.088061. The null hypothesis of no serial correlation is not rejected, indicating there was no problem of serial correlation between the residuals. This is confirmed by the Breusch Godfrey LM tests, which was 0.8609.

The results for the White's test for heteroskedasticity shows a p-value of 0.6221, greater than a 5 percent significance level. Thus, the null hypothesis of no problem of data heteroskedasticity was accepted. The heteroskedasticity test for the dependent variable carries a p-value of 0.1954; for independent variables, it was 0.7392. These suggest that the independent variables and the dependent variable do not suffer from a heteroskedasticity problem.

When testing for Normality, the study uses the Skewness test for Normality, Kurtosis test for Normality and Joint test for Normality. Table 5 (Panel C) summarises the results. The results

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show that the residuals are normally distributed since the p-values are not greater than 5 percent critical values.

Figure 2 summarises the model parameter stability test results using the CUSUM squares plot from recursive residuals.

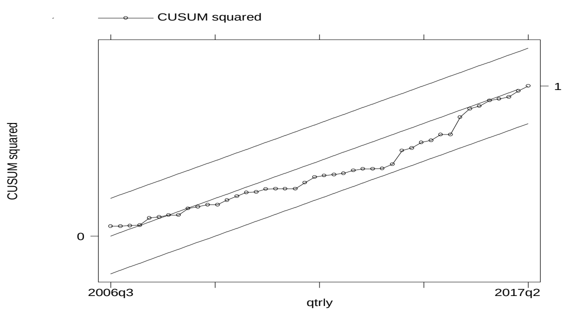

Figure 2: Plot of CUSUM Square for the Estimation Model

From Figure 2, the CUSUM squares plot shows that the model passes the parameter stability test. All the values fall within critical boundaries at the 5 percent statistical significance levels. Therefore, the null hypothesis cannot be rejected, confirming the model stability and consistent results in both long and short-term.

3.5 Analysis of the Direction of Causality

The Granger Causality Wald test examines the direction of causality between variables in the estimation model. Table 6 summarises the results.

From Table 6, the study observes the bi-directional causality relationship between the PNGCP and GDPPC; and between the PNGCI and GDPPC. The relationships were bi-directional as each variable caused the other. This implies the Feedback Hypothesis that an increase in the PNGCP and PNGCI influences economic growth. Economic growth stimulates further natural gas consumption in the power generation and industrial end uses. This observation is in consistency with the findings by Dincer *et al.* (2017) and Kao and Wan (2017).

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Table 6: Granger Causality Wald Test Results for Individual variables in the estimation model

S/NO.	Null Hypothesis	F Statistics (p-value)	Results	Conclusion
1.	GFCFPC does not cause GDPPC	31.425 (0.000)***	H_o Rejected	GFCFPC Granger causes GDPPC
	GDPPC does not cause GFCFPC	9.4156 (0.052) *	H_o Accepted	No Granger causes (very weak causality)
2.	LFPC does not cause GDPPC	26.735 (0.000) ***	H_o Rejected	LFPC Granger causes GDPPC
	GDPPC does not cause LFPC	4.2543 (0.373)	H_o Accepted	No Granger causes
3.	PNGCP does not cause GDPPC	17.246 (0.002) ***	H_o Rejected	PNGCP Granger causes GDPPC
	GDPPC does not cause PNGCP	16.128 (0.003) ***	H_o Rejected	GDPPC Granger causes PNGCP
4.	PNGCI does not cause GDPPC	11.268 (0.024)**	H_o Rejected	PNGCI Granger causes GDPPC
	GDPPC does not cause PNGCI	22.124 (0.000)***	H_o Rejected	GDPPC Granger causes PNGCI

Note ***, ** and * denotes rejection of null hypothesis at 1%, 5% and 10% significance levels, respectively.

A unidirectional causality relationship was revealed between the GFCFPC and real GDP per capita, running from the GFCFPC to the GDPPC. Moreover, unidirectional causality was between the LFPC and GDPPC, running from the LFPC to the GDPPC. Specifically, the results revealed that the GFCFPC Granger caused the GDPPC, and the LFPC Granger caused GDPPC, both at 1 percent levels of significance.

4.0 Conclusions

Natural gas consumption in both power generation and industrial applications influence economic growth in Tanzania. Any limitation in natural gas consumption will restrict economic growth in Tanzania. A feedback hypothesis indicates the simultaneous relationship between natural gas consumption in both power generation and industrial applications and economic growth in the country. Natural gas consumption influences economic improvement for Tanzania; also, the level of economic growth affects natural gas consumption in both sectors. That is to say, countries that are more developed, such that with higher economic growth, tend to have more

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natural gas consumption in both sectors. Labour has the highest contribution towards economic growth in Tanzania.

5.0 Recommendations

i. A country should advocate an appropriate energy policy framework to curb the constraints regarding natural gas consumption to electricity generation and industrial end users. Moreover, to support stable economic growth for the present and future generations, Tanzania should increase gas distribution in other regions.
ii. There is a need to carry out joint implementation of policies promoting both natural gas consumption and economic growth. The higher economic growth induced more demand for natural gas consumption in both power and industrial sectors, which significantly impacted the economy in terms of economic growth.
iii. Further investment in human capital development increases the quality of labour and productivity and therefore speeds up economic growth in Tanzania.

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References

Alam, M. S., Paramati, S. R., Shahbaz, M. and Bhattacharya, M. (2017). Natural gas, trade and sustainable growth: empirical evidence from the top gas consumers of the developing world. *Applied Economics*, 49(7): 635-649.

Amin, S., Khan, F. and Rahman, S. (2018). The relationship between oil consumption and economic growth in Bangladesh: an empirical analysis. *World Review of Business Research*, 8(3): 24-36.

Amin-Naseri, M.R., Asali, M., Daneshzand, F. and Dourandish, M. (2019). Studying the Dynamic Effects of Natural Gas Prices on Supply Security: a Systems Approach. In *International Conference on Modern Research in Engineering Technology and Science*. 10-21.

Aydin, M. 2018. Natural gas consumption and economic growth nexus for top 10 natural Gas–Consuming countries: A granger causality analysis in the frequency domain. *Energy*, 165: 179-186.

Bernard, O. A. and A. Oludare. (2016). Is energy consumption relevant to industrial output in Nigeria? *European Journal of Research in Social Sciences*, 4(4): 1-14.

BoT. (2020). Tanzania Mainland GDP Series (1966-2017). Gross Domestic Product by kind of economic activity at 2007 constant prices (2007 series).

Dinçer, H., Yüksel, S. and Adalı, Z. (2017). Identifying causality relationship between energy consumption and economic growth in developed countries. *International Business and Accounting Research Journal*, 1(2): 71-81.

EWURA. (2016). Annual Report for the year ended 30th June, 2016. The United Republic of Tanzania, Energy and Water Utilities Regulatory Authority.

Fadiran, G., Adebusuyi, A. T and Fadiran, D. (2019). Natural gas consumption and economic growth: Evidence from selected natural gas vehicle markets in Europe. *Energy,* 169**:** 467-477.

Hassan, M. S., Tahir, M. N., Wajid, A., Mahmood, H. and Farooq, A. (2018). Natural gas consumption and economic growth in Pakistan: production function approach. *Global Business Review*, *19*(2), 297-310.

Ifeakachukwu, N. P. (2017). Disaggregate energy consumption and sectoral output in Nigeria. *Science Journal of Energy Engineering, 5*(6): 136-145.

Kao, C. W. and Wan, J. Y. (2017). Energy consumption and economic growth: Further evidence from Taiwan. *International Journal of Economics Finance, 9*(7): 165-178.

Kim, G.S., Kim, H. J. and Yoo, S. H.. (2019). Optimal Share of Natural Gas in the Electric Power Generation of South Korea: A Note. *Sustainability*, 11(13): 1-6.

Received March 2021
Accepted August 2021
Available online 15 December 2021

Li, Z.G., Cheng, H and Gu, T.Y. (2019). Research on dynamic relationship between natural gas consumption and economic growth in China. *Structural Change and Economic Dynamics, 49*: 334-339.

Makala, D. and Zongmin, L. (2019). Natural Gas Consumption and Economic Growth in Tanzania. *European Journal of Sustainable Development Research, 4*(2): 1-9.

Nadeem, S. and Munir, K. (2016). Energy consumption and economic growth in Pakistan: A Sectoral analysis. Available from: https://mpra.ub.uni-muenchen.de/74569/. [29 May 2021].

Nkoro, E. and A.K. Uko. (2016). Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation. *Journal of Statistical and Econometric Methods*, *5*(4), 63-91.

Onyeisi, O.S., Odo, S. I. and Attamah, N. (2016). Power Generation Capacity and Economic Growth in Nigeria: A Causality Approach. *European Journal of Business and Management*, 8(32): 74-90.

Peng, D. and Poudineh, R. (2016). *Sustainable Electricity Pricing for Tanzania*. Oxford Institute for Energy Studies.

Rahman, Z.U., S.I. Khattak., Ahmad, M. and A. Khan. (2020). A disaggregated-level analysis of the relationship among energy production, energy consumption and economic growth: Evidence from China. *Energy*, 194: 116-136.

Sarker, A.R. and Alam, K. (2010). Nexus between electricity generation and economic growth in Bangladesh. *Asian Social Science,* 6(12): 16-22.

Sanches, R.R.S. 2020. Relationship between Natural Gas Consumption and Economic Growth. Doctoral dissertation. Universidade Beira Interior.

Shahbaz, M., H. Mallick., M.K. Mahalik and P. Sadorsky. (2016). The role of globalization on the recent evolution of energy demand in India: Implications for sustainable development. *Energy Economics*, 55**:** 52-68.

Tursoy, T. and F. Faisal. (2016). Causality between stock price and GDP in Turkey: an ARDL bounds testing approach. *Romanian Statistical Review*, 64(4)**:** 3-19.

URT. (2016). Power System Master Plan 2016 Update. The United Republic of Tanzania, Ministry of Energy and Minerals.

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