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The Impact of Natural Gas Revenue on Economic Growth in Tanzania

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Abstract

This article investigates the linkage between natural gas revenue and economic growth in Tanzania from 2005q1 to 2017q2 periods. The study uses unit root analysis, Gregory Hansen (GH) cointegration test, autoregressive distributed lag (ARDL) bound cointegration test, and the error correction model (ECM). The Zivot and Andrews (ZA) and Clemente-Montares-Reyes (CMR) unit root tests reveal that the series had a mixed order of integration, i.e., I(0) and I(1) with a single structural break. The GH cointegration test suggests that the break date is 2012q1. Both GH and ARDL bound cointegration tests indicate that a long-run relationship exists. The empirical results show that natural gas revenues stimulate economic growth in Tanzania both in the long-run and short-run. Thus, it validates the non-existence of the resource curse hypothesis. Moreover, since the government's share of revenues increase with gas prices, the study recommends stimulating more economic growth by promoting more uses of natural gas in other sectors of the economy—i.e., industry, transport and households—where gas prices are high. Tanzania must also soon decide on an export-oriented liquefied natural gas (LNG) project to fetch a competitive gas price.

Keywords: *economic, growth, natural gas, revenue, ARDL-ECM*

1. Introduction

Every country is concerned with economic growth and how to sustain it. One of the stunning questions in economics is whether natural resource endowments promote or hamper economic growth. Natural gas revenues impact economic growth in many natural gas-producing countries through meeting various governmental needs, i.e., investment in infrastructure, human capital development, and social services improvement (Illyas & Siddiqi, 2010). However, this preconceived notion does not seem to hold in some countries due to the challenges experienced, for example, the resource curse and the Dutch disease. Tanzania is a petroleum economy in the making. It is almost seventeen (17) years now since commercial natural gas exploitation began in Tanzania, yet the natural gas industry has not shown a prominent role in the economic life of the people in terms of its contribution to their social well-being. The United Republic of Tanzania (URT) owns natural gas resources. As reported by Elinaza (2017, August 15) and Zacharia (2018, July 29), the use of natural gas

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domestically has helped Tanzania to increase the country's energy, generate revenue which finances non-gas fiscal deficits, provide public goods, and therefore facilitate economic growth.

Some resource-rich economies—such as Botswana and Norway—are very successful; while others, despite their immense natural resource wealth, have experienced a resource curse due to failure to benefit fully from their natural resource wealth, as a result of government's failure to respond effectively to public welfare needs (Van der Ploeg, 2011). Sachs and Warner (1995) report that, on average, some resource-rich countries have experienced slower economic growth and worse political outcomes than countries with little or no resource endowment since resources turn out to be a curse that causes various social and economic impacts, for example, social and political tensions, warfare, poor decision-making, and lower economic growth (Zubikova, 2019). In other countries, natural resource wealth has been well-used and has led to greater prosperity. This has further led to higher economic growth and income than in some countries. Tanzania belongs in the second group.

Figure 1 shows that before commercial natural gas exploitation in 2005, Tanzania's GDP per capita was the highest in the East African countries. However, from the outset of the natural gas commercial extraction in the mid-2000s, there has been a gradual increase in Tanzania's GDP per capita than in the other EAC countries, except Kenya. On most accounts, Kenya is similar to Tanzania except it lacks oil and natural gas resources. Kenya has had a GDP per capita higher than Tanzania since 2005, which brings suspicion for the resource curse problem. However, the Tanzania GDP per capita grew almost threefold from US$ 381.9 in 2001 to US$ 981.4 in 2016.

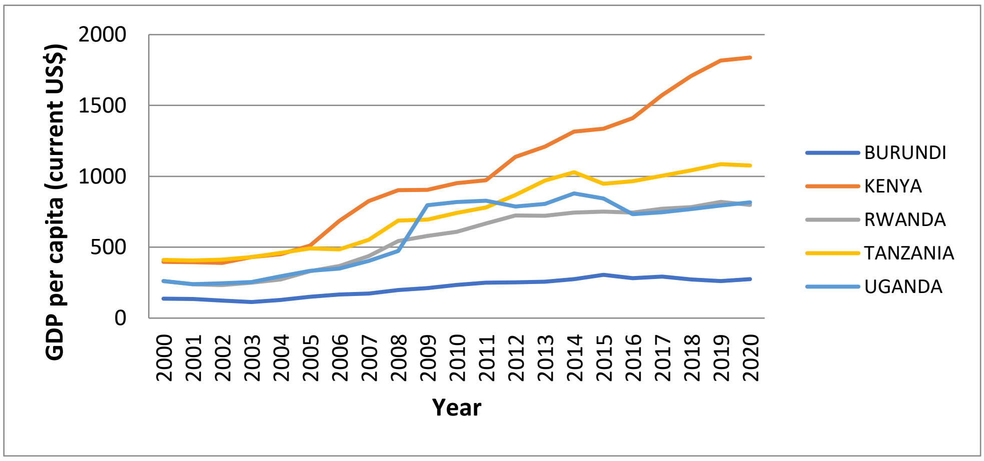

Figure 1: ***GDP per Capita of the East African Countries from 2000 to 2020***

Source: World Development Indicators

Moreover, the Dutch disease theory explains the adverse growth impacts due to a significant increase and overreliance on natural resources revenue, which hurts other sectors of the economy: mainly manufacturing and exports. The theory emerged from the harmful economic growth impacts experienced in the Netherlands after discovering natural gas in the North Sea in the 1960s (Bategeka & Matovu, 2011). Otaha (2012) and NRGI (2015) dwell sufficiently on the Dutch disease. When natural gas prices are high, they lead to high natural gas revenue. This increases public consumption due to higher domestic demand for imports and domestically produced non-tradable goods. The demand for non-tradable goods (mainly the services sector) increases, which pushes up prices for non-tradable goods. Such prices become higher than the prices for tradable goods. The real exchange rate rises to encourage a shift of resources, including labour, from the production of tradable goods to non-tradable goods. As the currency appreciates, the tradable goods sector contracts and the exports of all non-oil products become less competitive in the world market. The manufacturing sector eventually declines. Imports increase and promote an adverse balance of payments when prices fall. This reduces the incentive to risk investment in the tradable non-oil and non-gas sectors, e.g., agriculture and manufacturing. Symptoms of the Dutch disease include real exchange rate appreciation, faster service sector growth, higher overall wages, and a slow-down in manufacturing sector growth (Oomes & Kalcheva, 2007). The Dutch disease can also result from any significant increase in foreign currency due to heavy inflows of foreign direct investment, an increase in foreign aid or a substantial increase in the natural resource prices (Yang et al., 2006).

The existing literature on oil and natural gas revenue effects on economic growth presents a mixed verification of relationships. Some studies have showed negative impacts, while others have revealed positive impacts. Studies such as by Olayungbo and Adediran (2017), Nweze and Edamu (2016), and Olojede and Michael (2020) have found a negative long-run relationship between natural gas revenue and economic growth that result from the resource curse problem. It means that as oil and natural gas revenue increases, economic growth declines, causing economic stagnation (Sachs & Warner, 1995). However, Nwoba and Abah (2017), Asagunla (2018) and Ogbonna, and Ebimobowei (2012) disclose that oil revenue has a positive and significant long-run impact on economic growth. Olayungbo and Adediran (2017), Aregbeyen and Kolawole (2015), and Akinleye et al. (2021) have found that oil revenue promotes economic growth in the short-run. However, the present study focuses on the interaction between natural gas revenue earnings and the economic well-being of the people. Moreover, in most of the reviewed studies, oil/natural gas revenues were due to exports, and are considered as the main source of financing government expenditures and importation of goods. In our study, there is no gas export, therefore natural gas revenue is from the domestic market, and is considered a potential new source of government income that finances non-gas fiscal deficits.

Tanzania has been actively exploring oil and gas. By December 2018, its total gas reserves (both on-shore and off-shore) were around 57.548 trillion cubic feet (TCF) (TPDC, 2018). These reserves may result into significant revenues. However, if the resulting revenues from the reserves are not managed properly, they are likely to become a curse instead of a blessing (MoEM, 2013). Various policy reforms have taken place in Tanzania's energy industry since 2004. These include the Tanzania Electricity Act of 2008, Model Production Sharing Agreement (MPSA) updated four times (2004, 2008, 2010 and 2013), National Natural Gas Policy (NNGP) of 2013, Local Content Policy (LCP) of 2013, National Energy Policy (NEP) of 2012 and 2015, Petroleum Act, 2015, and the Oil and Gas Revenue Management Act, 2015.

Tanzania adopted the Norwegian style of management of petroleum resources, whereby the sizeable petroleum resources led to higher economic growth and a higher GDP per capita (Holden, 2013). The Tanzania Oil and Gas Revenue Management legislation codifies a fiscal rule, i.e., *3% of the GDP fiscal rule*, which guarantees a permanent and intergenerational income distribution in managing natural gas wealth (URT, 2019). The natural gas revenue of up to 3% of the GDP can be used annually to finance non-gas budget deficits. The remaining is saved and used in subsequent fiscal years. Natural gas revenue is now an essential source of government income in Tanzania. For 2012, Tanzania's total domestic revenue, excluding grants, was 11.3% of GDP, while the natural gas revenue was 1.01% of GDP. For 2016, Tanzania total domestic revenue, excluding grants, was 12.40% of GDP, while natural gas revenue was 1.4% of GDP (TPDC, 2018; WDI, 2021). However, up to the present, the annual gas revenue has never reached 3% of the country's GDP; hence, it has only been used to finance non-gas fiscal deficits. Therefore, there is an increased need to investigate the impact of natural gas revenue earnings on economic growth in Tanzania. This study aims to examine the extent to which natural gas revenue impacts economic growth in Tanzania.

2. Methodology

2.1 Research Design

This study sought to investigate the relationship between natural gas sales revenue earnings and economic growth in Tanzania Mainland. The study collected data from Tanzania Mainland covering the period from Q1:2005 to Q2:2017. Tanzania Mainland was chosen because it is a new natural gas producing country, with around 17 years of commercial natural gas exploitation. It is the third-largest natural gas producer in Sub-Saharan Africa after Mozambique and South Africa. Moreover, natural gas revenue is a potential new source of government revenue. The study chose the period due to the availability of data in this period, in line with the time of active commercial natural gas extraction in Tanzania.

The study collected the annual time series data of real GDP per capita, domestic general government health expenditure, and natural gas sales revenue earnings from various sources, as shown in Table A1 (in the Appendix). The data was converted to quarterly time series data using an interpolation (temporal disaggregation) method. This method is helpful in disaggregating low-frequency time series to higher frequency series (Sax et al., 2020). The Chow-Lin (1971) methods were also employed.

Quarterly time series data for nominal exchange rates was collected from the NBS and BoT. Real GDP per capita data was collected from the BoT; domestic general government health expenditure from the World Development Indicators (WDI), and natural gas revenue from the TPDC. The study used secondary data collected for some other purposes by these institutions and published in reports, data archives, or databases. The advantage of using secondary data is that there are no hassles of data collection and it is less expensive. The sample size chosen was 50 observations, as it is reasonable for the time series analysis to bring efficient results. The study analysed the collected quarterly time series data based on objectives and hypotheses using STATA statistical packages.

2.2 Theoretical Model

The theoretical model used in this study is the Augmented Solow Model, as explained in Mankiw et al. (1992). In brief, the model is known as Mankiw, Romer, and Weil (1992), henceforth the MRW model. It expanded the Solow model to include human capital and obtain the production function, popularly known as the Human Capital Augmented Solow Model, or MRW model. The model fits data better and yields an estimated capital share more than conventional wisdom (Bernanke & Gürkaynak, 2001).

The MRW's basic estimation framework is broadly consistent with any growth model that admits balanced growth paths. The MRW model, as adopted from Syed (2010), is expressed as:

$$Y_{ti} = A_t K_{ti}^{\alpha} H_t^{\beta} L_{ti}^{1-\alpha-\beta}, \quad \alpha + \beta < 1 \tag{1}$$

where Y is the flow of output of i^{th} sector, which is the function of physical capital investment in that sector (K_{ti}), labour in that sector (L_{ti}), human capital (H_t), and the level of technology (A_t), such as total factor productivity, which explains the output growth that is not accounted for by the growth in factors of production specified. α, β, and $1 - \alpha - \beta$ are output elasticities of the reproducible factors, such as physical capital, human capital and supply of labour. L and A are expected to grow exogenously at rates n and g:

$$L_{(t)} = L_{(0)} * e^{nt}$$
$$A_{(t)} = A_{(0)} * e^{gt}$$

Assuming that both types of capital depreciate at the same rate (δ) in capital depreciation equation (equations 2 and 3);

$$K_{t+1} = S_k Y_t + (1-\delta)K_t \qquad (2)$$

$$H_{t+1} = S_h Y_t + (1-\delta)H_t \qquad (3)$$

Thus, the physical and human capital can be expressed in the effective unit of labour as in equations (4) and (5):

$$\dot{k}_t = s_k^* y_t - (n+g+\delta)k_t \qquad (4)$$

$$\dot{h}_t = s_h^* y_t - (n+g+\delta)h_t \qquad (5)$$

The small letters $k = {}^{K}/_{AL}$, $h = {}^{H}/_{AL}$ and $y = {}^{Y}/_{AL}$ denote quantities per an effective labour unit. s_k and s_h represent the rate of accumulation of physical and human capital, respectively. The existence of diminishing returns to capital implies that $\alpha + \beta$<1. Under these initial conditions, the capital follows a convergence path to the steady-state (k^*, h^*) given by the system equations (6) and (7):

$$k^* = \left(\frac{s_k^{1-\beta} * s_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta}} \qquad (6)$$

$$h^* = \left(\frac{s_k^{\alpha} * s_h^{1-\alpha}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta}} \qquad (7)$$

Substituting equations (6) and (7) into the production function (1) and taking logs, we could express the equilibrium level of income per capita (*y*) in two alternative ways depending on the available data; either as a function of investments in human capital s_h (eq. 6); or as a function of the human capital level h^* (eq. 7).

2.3 Estimation Model

Based on equation (1), the study develops the estimation model. The model includes the following variables: real GDP per capita as a proxy for economic growth, and government health expenditure as a proxy for human capital. Also, under TFP, natural gas revenue and exchange rate variables were added. Natural gas revenue is added to the model since it is one of the potential sources of government revenue. The output in the economy is expressed in GDP per capita terms showing the standard of living/well-being in Tanzania Mainland.

Therefore, when the variables are substituted, the model becomes as expressed in equation (8):

$$GDPPC_t = f(HE_t, GR_t, EXR_t) \qquad (8)$$

where:

$GDPPC_t$= the real GDP per capita in 2007 constant prices at time t, as a proxy for economic growth (in US$ per person).
HE_t= the domestic general government health expenditure at time t (in the percentage of government expenditure).
GR_t = the natural gas sales revenue earnings in the economy at time t (in US$).
EXR_t= the nominal exchange rate in the economy at time t (in US$ per TZS).

Equation (8) can be represented in a linear form to ensure the comparability of data. For ease of estimation, all the variables were transformed into a linear natural logarithm form by taking the natural logs on both sides. The error term is assumed to be a Gaussian white noise error process with a constant variance μ_t, and a constant term α_0 added. Equation (8) generates equation (9):

$$LnGDPPC_t = \alpha_0 + \alpha_1 LnHE_t + \alpha_2 LnGR_t + \alpha_3 LnEXR_t + \mu_t \qquad (9)$$

where α_1, α_2 and α_3 are the slopes of the coefficients, α_0 is a constant, and μ_t is the stochastic error term at time *t*. The signs of coefficients α_1 and α_2 are expected to be positive, while α_3 is expected to be negative.

2.4 Estimation Techniques

The study employed the Gregory Hansen (GH) cointegration test, ARDL bound cointegration analysis, and error correction model (ECM).

Given the possibility of a structural break in the cointegrating relationship, the study employed the residual-based cointegration tests, which consider the existence of one structural break proposed by Gregory and Hansen (1996) to obtain reliable inference on how the correlation between the variables with the observed break dates. This allows for the possibility of single regime shifts (structural breaks) at an unknown point in time. This is a natural extension of Perron (1989) and Zivot and Andrews (2002), who concentrated on the possibility of a shift in the trend in the context of a unit root testing. It uses the ADF, Z_α and Z_t types of tests. As Akinboyo et al. (2016) report, this test is robust to structural breaks in the cointegrating relationship among variables in an estimation model. They considered three cases: level shift, level shift with trend, and regime shift (both level shift and slope coefficients can change). The null hypothesis is that there is no cointegration at the breakpoint, against the alternative that there is cointegration at the breakpoint. The decision rule is to reject the null hypothesis and accept the alternative, implying the linear combination of the variables exhibits stable properties in the long-run, albeit with the presence of a structural break.

Moreover, the Bound cointegration test is performed based on the F-statistics or the Wald test. The $ARDL(p, q, m, n)$ representation for the model is expressed as follows:

$$\Delta LnGDPPC_t = b_0 + \sum_{i=1}^{p} b_{1i}\,\Delta LnGDPPC_{t-i} + \sum_{i=0}^{q} b_{2i}\,\Delta LnHE_{t-i} + \sum_{i=0}^{m} b_{3i}\,\Delta LnGR_{t-i} + \sum_{i=0}^{n} b_{4i}\,\Delta LnEXR_{t-i} + d_{11}LnGDPPC_{t-1} + d_{21}LnHE_{t-1} + d_{31}LnGR_{t-1} + d_{41}LnEXR_{t-1} + \varepsilon_{1t} \qquad (10)$$

where:

$b_{1i}\ldots b_{4i}$ are the coefficients of the short-run parameters
$d_{1i}\ldots d_{4i}$ are the coefficients of the long-run parameters
b_0 is the constant coefficient.
$p, q, m\ and\ n$ are the optimal lag lengths for the variables used in the ARDL model.

The study hypotheses are:

$H_0: b_{1i} = b_{2i} = b_{3i} = b_{4i} = 0$ indicates no cointegration
$H_A: b_{1i} \neq b_{2i} \neq b_{3i} \neq b_{4i} \neq 0$ indicates there is cointegration among variables

The decisions are the following: (i) if the computed F-statistic is greater than the upper critical bound I(1), reject the null hypothesis, hence a cointegrating relationship exists; (ii) if it is lower than the lower critical bound I(0), then do not reject the null hypothesis since no cointegrating relationship exists; and (iii) if it is between the lower and upper critical bounds, then the test is considered to be inconclusive.

The study employed the ECM derived from the ARDL model through a simple linear transformation. ECM integrates short-run adjustments with long-run equilibrium without losing long-run information frameworks. The ECM for the proposed model is specified (equation 12) as:

$$\Delta LnGDPPC_t = b_0 + \sum_{i=1}^{p} b_{1i}\,\Delta LnGDPPC_{t-i} + \sum_{i=0}^{q} b_{2i}\,\Delta LnHE_{t-i} + \sum_{i=0}^{m} b_{3i}\,\Delta LnGR_{t-i} + \sum_{i=0}^{n} b_{4i}\,\Delta LnEXR_{t-i} + \lambda ECT_{t-1} + \varepsilon_{1t} \qquad (11)$$

where ε_{1t} is the error term λ, indicating the speed of adjustment to the equilibrium level after a shock; ECT_{t-1} implies error correction term, the extracted residuals from the regression of the long-run equation. The error correction term must be statistically significant with a negative sign to ensure convergence of the dynamics to the long-run equilibrium.

3. Findings and Discussion

3.1 Exploratory Studies

The study conducted data exploration on all the variables of interest, i.e., computation of descriptive statistics, graphical description, and unit root tests such as conventional unit root test and unit root tests accounting for structural breaks. These inform about the appropriate methodology adopted for analysis.

Table 1 describes the variables used in the study. The descriptive results indicate an average of \$133.29 per capita over the period, with a maximum of \$158.16 per capita. Accordingly, the results show that Tanzania earns natural gas revenue at an average of \$8372981, quarterly. However, the maximum natural gas revenue recorded in 2014q2 was \$15700000. Also, analysis shows that Tanzania spent about 2.3% of its government budget on health expenditure, quarterly. Further, nominal exchange rate measured by Tanzanian shillings (TZS) required to purchase one US dollar estimated at an average of TZS1537.133 over the analysed period, with a minimum of TZS1104.5 and a maximum of TZS2228.4. Table 1 presents the descriptive statistics of the variables of interest of this study.

Table 1: Descriptive Statistics Results

Variable	GDPPC	GR	HE	EXR
Mean	133.2941	8372981	2.259	1537.133
Min	106.9342	1920000	1.486	1104.5
Max	158.168	1.57e+07	3.488	2228.4
Std. Deviation	12.75364	4115623	0.673	340.78
Variance	162.6554	1.69e+13	0.4526111	116131
Skewness	-0.4103662	0.138	0.473	0.778
Kurtosis	2.684141	1.713	1.617	2.533
Observation	50	50	50	50

Note: Normal Skew: 0, Mesokurtic[1]

Source: Computed by the authors

From Table 1, the values of Kurtosis and Skewness statistic results for all the variables of the estimation models are not far from suggesting normality in the series. The kurtosis is about 3 (the mesokurtic value), and the skewness values near zero. Therefore, the variables are about normally distributed such that they would lead to unbiased parameter estimates.

[1] All variables, except GDPPC are positive skewness, i.e., have long right-tail. Kurtosis results for GDPPC, GR, HE and EXR are all platykurtic as the values are less than mesokurtic value (2.684141<3; 1.713<3; 1.617<3 and 2.533<3)

Figure 2 represents visual expressions of variables of the estimation model. The graphs show the visual presentation of variables in levels and their first difference in the same plot.

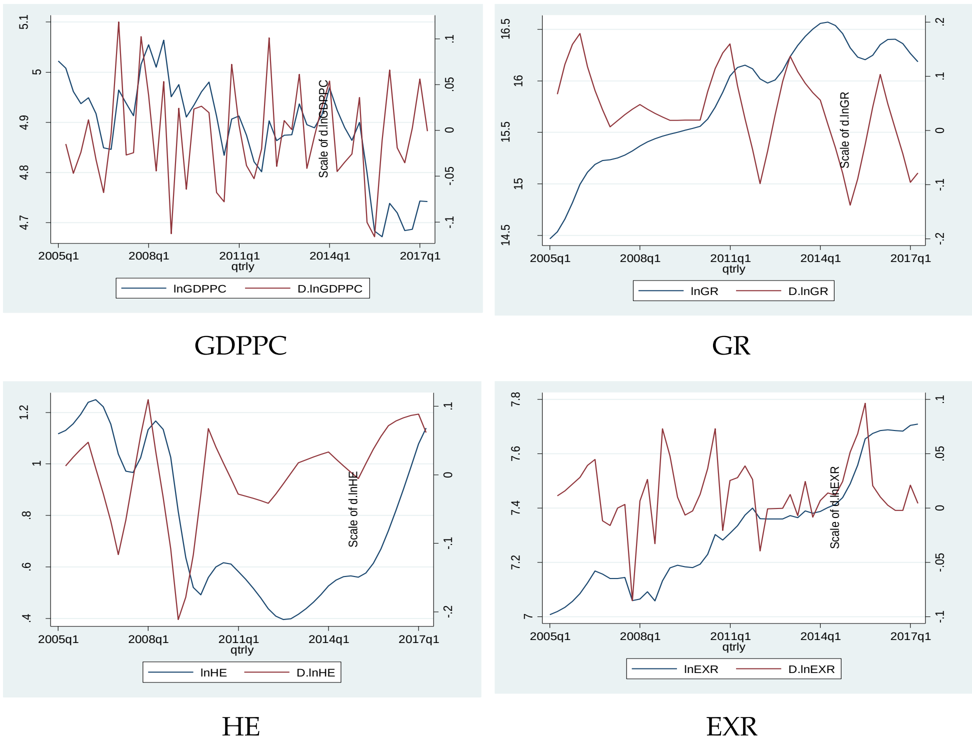

Figure 2: ***Visual Expressions of Variables Used in the Estimation Model in Level and First Differenced***

Source: Computed by the authors

In general, looking at the plots, the visual investigation of the graphs shows that the variables are non-stationary at levels since none of the variables oscillate around a zero mean. Natural gas sales revenue earnings seem to have an intercept and a stochastic trend. Figure 2 shows that the first differenced series of all the variables were stationary.

The study uses the conventional unit root tests, namely the ADF and PP tests, to test the null hypothesis of the unit root in all the variables of the estimation model. Table 2 summarizes the results. Based on Table 2, both ADF and PP indicate that the variables of the estimation model had a mixed order of integrations such that some variables were stationary in levels (I(0)); and others, together with the dependent variable, were non-stationary in levels but became stationary after the first difference (I(1)).

Table 2: ADF and PP Unit Root Tests Results

Variable	Test Formulation	At levels		At 1st difference		Order of integration
		ADF	*PP*	*ADF*	*PP*	
(lags)	*test*	*Test stat*	*Test stat*	*Test stat*	*Test stat*	
Log of GDPPC (1)	No Constant	-0.800	-0.819	-6.538***	-7.447***	I(1)
	Intercept	-1.769	-1.902	-6.594***	-7.455***	
Log of GR(4)	No Constant	1.777*	1.966**	-1.697*	-2.290**	I(0)
	Intercept	-2.178	-2.734*	-1.734	-2.375	
	Trend	0.300	-1.371	-2.326	-2.851	
Log of HE (3)	No Constant	-0.715	-0.410	-2.954***	-2.741***	I(1)
	Intercept	-1.386	-1.245	-2.932*	-2.723*	
Log of EXR(2)	No Constant	2.097**	2.855***	-2.578**	-4.609***	I(0)
	Intercept	-0.110	0.022	-3.170**	-5.347***	
	Trend	-2.580	-1.972	-5.001***	-2.657	

Note: *, **, and *** denote rejections of the null hypothesis at *10%*, *5%* and *1%* significance levels

Source: Computed by the authors

The visual expressions of some variables like GR and EXR show the trends, indicating that they are not stationary. However, the ADF and PP suggest that these variables are stationary at levels that bring suspicion of the existence of structural breaks. Moreover, the ADF and PP do not accommodate information about unknown break dates in the series, thus weakens the stationarity hypothesis. Failure to address a structural break can lead to the unreliability of a model and general forecasting errors (Majune, 2018). Therefore, the study employed the Zivot and Andrews (ZA) unit root test to test for a unit root against the alternative trend stationary process with a structural break both in slope and intercept. The hypothesis is that the breakpoints should coincide with periods when an innovation is introduced in the economy. AIC chose the lag length. Table 3 presents the ZA unit root test results.

The ZA unit root test results for the variables in Table 3 show a mixed order of integration, i.e., I(0) and I(1). There is a strong evidence against the unit root hypothesis for the GR. The null hypothesis is rejected at a 5% significance level when the model is with the trend. The ZA test results indicate the breakpoint occurs in 2014q2 for GDPPC and 2008q2 for HE. Moreover, in 2008q4 for the EXR and 2010q2, 2014q2 and 2010q2 for GR series testing, the trend indicated both the interception character during analysis. These periods are associated with significant events in the economy. The Tanzania Electricity Act of 2008 improves the environment for private operators in the electricity industry. The PSRS of 2010 restructured the electricity supply industry in Tanzania and attracted private operators in electricity generation, who engaged more gas-fired power generators: the MPSA addendum for natural gas 2010. The NNGP of Tanzania enacted in 2013 had its primary objective to provide guidance for a sustainable development and utilization of the natural gas resource to maximize its benefits.

Table 3: ZA Unit Root Test Results

Variables	Allowing for break in:	Levels (lags)	Structural break time	First differences (lags)	Structural break time	Order of integration
		Minimum t- statistics		*Minimum t- statistics*		
Log of GDPPC	Intercept	-4.533 (0)	2015q2	-6.811*** (1)	2014q2	I(1)
	Trend	-3.601 (0)	2014q2	-6.738 *** (1)	2007q2	
	Intercept and trend	-4.103 (0)	2015q2	-7.495*** (1)	2015q2	
Log of GR	Intercept	-2.725 (2)	2014q4	-6.780*** (2)	2010q2	I(0)
	Trend	-4.911** (2)	2014q2	-5.911 *** (2)	2013q4	
	Intercept and trend	-4.894 *(2)	2013q4	-6.637*** (2)	2010q2	
Log of HE	Intercept	-1.452 (2)	2008q2	-8.168*** (2)	2008q2	I(1)
	Trend	-3.215 (2)	2013q1	-7.233*** (2)	2009q2	
	Intercept and trend	-3.041 (2)	2013q1	-7.609*** (2)	2008q2	
Log of EXR	Intercept	-3.700 (1)	2015q1	-5.533*** (0)	2008q4	I(1)
	Trend	-3.016 (1)	2014q1	-5.463*** (0)	2007q2	
	Intercept and trend	-3.134 (1)	2007q4	-6.062*** (0)	2015q1	

Note: *, **, and *** denote rejection of the null hypothesis at 10%, 5% and 1% significance levels.

Source: Computed by the authors

After understanding that a structural break exists, the study used Clemente-Montares-Reyes (CMR) to test unit root, allowing for two structural breaks. Tables A2 and A3 in the Appendix show the CMR test results for the variables accounting for a single and double endogenous break(s). The CMR test results show that only GDPPC, the dependent variable, had two structural breaks. However, all regressors had a single structural break; the additive outliers, i.e., considering a sudden change. Therefore, the study recommends the existence of a single structural break, and bases on the ZA unit root test results.

3.2 *Cointegration Tests*

The cointegration test concept as initially suggested by Granger (1981), and later formulated by Engle and Granger (1987), is that, over the long-run, a special time-invariant linear combination of non-stationary variables may be stationary. The study performs a cointegration test to find out whether a linear combination of these series converges to equilibrium or not.

The ZA test results show that there is a break in the series, and the variables have a mixed order of integration, I(0) and I(1). The dependent variable is stationary at the first difference, i.e., I(1); while the regressors were either I(1) or I(0). The study employed the GH and bound cointegration tests.

3.2.1 GH Cointegration Test

The GH cointegration test is robust in the presence of a potential single structural break in the cointegrating relationship among the variables in the estimation model (Akinboyo et al., 2016). Table 4 presents the GH cointegration test results.

Table 4: GH Cointegration Test Results

The GH Models	ADF		Z_t		Z_α	
	Statistic	*Breakpoint*	*Statistic*	*Breakpoint*	*Statistic*	*Breakpoint*
Intercept shift (1)	**-5.85** [b]	2012q2	**-5.71**[b]	2012q1	**-40.29**[b]	2012q1
Intercept shift with trend (2)	**-8.98**[b]	2011q1	**-7.79**[b]	2010q3	**-54.71**[b]	2010q3
Intercept shift with slope (3)	**-7.74**[b]	2011q4	**-7.15**[b]	2011q3	**-50.56**[b]	2011q3

Note: [b] denotes significance at 5% level. The 5% critical values for ADF (and Z_t) are -5.28, -5.57 and -6.00 for models 1, 2 and 3, respectively, while the Z_α for the models are -53.58, -59.76 and -68.94, respectively - the optimal lag structure is chosen by the Bayesian Information Criterion (BIC).

Source: Computed by the authors

In all the three models in Table 4, the ADF, Z_α and Z_t statistics are higher than the 5% critical values; therefore, the null hypothesis of no cointegration is rejected, favouring the existence of one cointegration with one unknown structural break in each of the three GH models. The breakpoint date is 2012q1 for the model with intercept shift; 2010q3 for the model with intercept shift with trend; and 2011q3 for the model with intercept shift with a slope. As reported by Banafea (2014), the breakpoint of the smallest Z_t value of a three test statistics is chosen as a break date. Therefore, 2012q1 is selected as a break date. The year 2012 was the time when Tanzania enacted the National Energy Policy (NEP), which aimed to provide comprehensive guidelines for developing the natural gas industry in Tanzania to ensure optimal benefits to the nation.

3.2.2 Bound Cointegration Tests

Once the study identifies the breakpoint—i.e., 2012q1—the structural break is resolved by splitting the sample into two: a split sample before a break (2005q1 to 2011q4); and a split sample after a break (2012q1 to 2017q2). Then the optimal lag lengths for the ARDL models in the split samples are obtained using the AIC. The study chose the lag of four for both models. The optimal lag structure for the split sample before a break was ARDL (1,0,0,0); and ARDL (2,1,1,2) for the split sample after a break. Table 5 summarizes the ARDL bound cointegration test results.

From Table 5, the bound cointegration test results for both split samples show that the calculated F-statistics are higher than the upper bound critical values at 1% significance level. The null hypothesis of no cointegration is rejected, implying cointegration among the dependent and independent variables in the split samples.

Table 5: ARDL Bound Cointegration Test Results

			Period: 2005q1–2011q4, (ARDL 1,0,0,0) regression)	Period: 2012q1– 2017q2 (ARDL (2,1,1,2) regression)
Significance Level	*Lower Bound*	*Upper Bound*	*F-statistic*	*F-statistic*
10%	2.72	3.77	24.521***	14.535***
5%	3.23	4.35		
1%	4.29	5.61		
Significance Level	*Lower Bound*	*Upper Bound*	*t-statistic*	*t-statistic*
10%	-2.57	-3.46	-8.815***	-7.539***
5%	-2.86	-3.78		
1%	-3.43	-4.37		

Note: *, ** and *** show significance at 10%, 5% and 1% levels of significance, respectively.

Source: Computed by the authors

3.3 *Analysis of ARDL-ECM*

Once the study confirmed cointegration based on the split samples, then it performed long-run and short-run analyses. Table 6 (Panels A and B) summarizes the long-run and short-run results. Table 6 (Panel C) summarizes the post-diagnostic test results.

Table 6: Results of ARDL Regression for the Estimation Model

Regressor	Split Sample: 2005q1–2011q4 (ARDL (1,0,0,0) regression)		Split Sample: 2012q1–2017q2 (ARDL (2,1,1,2) regression)	
	Coefficient (Std. Error)	*Probability*	*Coefficient (Std. Error)*	*Probability*
Panel A: Long-run coefficients- Dependent variable is Log of GDPPC				
Log of GR(-1)	0.160(0.031)	0.000	0.132(0.022)	0.000
Log of HE(-1)	-0.093(0.033)	0.011	0.187(0.050)	0.003
Log of EXR(-1)	-1.275(0.137)	0.000	-0.727(0.069)	0.000
Panel B: Short-run coefficients - Dependent variable is d (Log of GDPPC)				
d(log of GDPPC (-1))			0.830(-0.195)	0.001-
d(log of GR)	0.151(0.029)	0.000	0.535(0.210)	0.026
d(log of HE)	-0.088(0.031)	0.010	-1.191(0.723)	0.125
d(log of EXR)	-1.204(0.139)	0.000	0.475(0.322)	0.165
d(log of EXR (-1))			0.704(0.317)	0.046
Constant	11.043(1.161)	0.000	17.425(2.884)	0.000
ECT(-1)	-0.945(0.107)	0.000	-2.175(0.288)	0.000
Panel C: Diagnostic tests				
F-statistic		F(4, 22) = 39.30***		F(9, 12) = 43.05***
R-squared		0.8772		0.9700
Adjusted R-squared		0.8549		0.9474
D-Watson-statistic		(5, 27) = 2.21823		(10, 22) = 2.97991
Breusch-Godfrey LM Test of residual serial correlation *(p-value)*		1.576(0.2093)		8.530(0.0141)

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity – dependent variable (p-value)	0.08(0.7713)	1.55(0.2138)
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity – independent variables *(p-value)*	3.09(0.5431)	6.99(0.6383)
Heteroskedasticity: *white test (p-value)*	20.57(0.1133)	22.00(0.3995)
Skewness test for Normality *(p-value)*	(0.0002)	(0.0135)
Kurtosis test for Normality *(p-value)*	(0.0847)	(0.5424
Joint test for normality *(p-value)*	13.44(0.0012)	6.05(0.0487)
CUSUMSQ (Cumulative Sum of Square)	Stable	Stable

Note: *, ** and *** show significance at 10%, 5% and 1% levels of significance, respectively. ECT is the error correction term generated from the long-run model. The F-statistic reported is for the short-run model. d is the first difference operator.

Source: Computed by the authors

3.3.1 Long-run Analysis

From Table 6 (Panel A), the long-run analysis for the variables of the estimation model shows that the coefficients of the first lag of GR positively affect the GDPPC—i.e., 0.160 and 0.132 at 1% level—before and after a break. An increase of 1% in GR leads to an approximately 0.160% increase in GDPPC before a break, and an increase of 0.132% in GDPPC after a break, all things being equal. This is similar to prior expectations: that an increase in natural gas revenue tends to increase economic growth as it increases government expenditure. Ogbonna and Ebimobowei (2012), Nwoba and Abah (2017), and Asagunla (2018) found similar long-run results.

The coefficient of the first lags of HE negatively affects the GDPPC before a break, but affects it positively after a break, i.e., -0.093 at a 5% level of significance before a break, and 0.187 at 1% level after a break. A 1% increase in HE leads to an approximately 0.093% decrease in GDPPC before a break, but a 0.187% increase after a break; all things being equal. This indicates that before a break, the productivity of a country does not improve as investment in health increases. However, after a break they are invested in productive projects, and therefore, facilitate economic growth in a country. The findings are similar to those of Bedir (2016) and Erçelik (2018).

The coefficient of the first lags of EXR, both before and after the breaks, negatively affects the GDPPC, i.e., -1.275 and -0.727, at 1% levels of significance.

A 1% increase in EXR leads to an approximately 1.275% decrease in GDPPC, before a break, and approximately 0.727% decrease in GDPPC after a break; all things being equal. These results imply that an appreciation of exchange rate hurts economic growth in Tanzania. This observation is consistent with the findings by Akinleye et al. (2021) and Baz et al. (2020).

3.3.2 Short-run Analysis

From Table 6 (Panel B), a short-run analysis of the estimation model shows that the current GR coefficients, both before and after a break, have significant positive effect on GDPPC, i.e., 0.151 and 0.535, at 1% and 5% significance levels, respectively. The percentage change in the current GR is associated with a 0.535% increase in GDPPC, after a break, on average *ceteris paribus* at 5% statistically significant level. Natural gas revenue stimulates more economic growth in the period after a break. This is similar to prior expectations: that the higher the level of natural gas revenue generated, the higher the economic growth. Similar results were obtained by Aregbeyen and Kolawole (2015), Olayungbo and Adediran (2017) and Akinleye et al. (2021).

The coefficient of the current HE, before a break, has a significant negative effect on GDPPC, i.e., -0.088 at a 5% level. The percentage change in the current HE is associated with a 0.088% decrease in GDPPC, on average *ceteris paribus* at a 5% statistically significant level. The finding indicates that an increase in health expenditure, before a break, does not stimulate economic growth in the country. This is contrary to the findings of Atilgan et al. (2017).

The coefficient of the current EXR had a significant adverse effect on GDPP, i.e., -1.204 at 1% level before a break. However, after a break the coefficient of the first lag of EXR had significant positive effect on GDPPC, i.e., 0.704 at a 5% level. Before a break the percentage change in the current EXR is associated with a 1.204% decrease in GDPPC, on average *ceteris paribus* at a 1% statistically significant level. This indicates that exchange rate appreciations affect economic growth in the short-run before a break. Similarly, Zhu et al. (2022) report that the anticipated appreciation of nominal exchange rate has significant adverse effects on output growth. After a break, due to innovation introduced, the percentage change in the first lag of EXR is associated with a 0.704% increase in GDPPC, on average *ceteris paribus* at a 5% statistically significant level. This may be due the flexible exchange rate regime adopted in Tanzania in since 1987, which insulates the economy against economic shocks resulting in lower output losses. Similar results were obtained by Katusiime et al. (2016) and Adewuyi and Akpokodje (2013).

The coefficients of the adjustment term in the estimation model (ECT), in the periods before and after a break, are negative (i.e., $\lambda = -0.945$ and $\lambda = -2.175$); and significant at 1% level. Thus, this confirms cointegration among the variables. The ECT shows approximately 217.5% of disequilibrium from the previous quarter's shock back to the long-run equilibrium in the current quarter in the estimation model after a break, which is very high compared to approximately 94.5% before a break.

3.4 Post-diagnostic and Stability Tests for the Estimation Model

Table 6 (Panel C) shows the split samples post-diagnostic test results. The regression for the underlying ARDL equations (10) and (11) for the split samples and estimation models fit very well. The R-square and adjusted R-square values for the split samples before and after breaks were reasonably high and represented a good model fit.

The estimation models for the split samples before and after breaks pass the diagnostic tests against serial correlation, heteroskedasticity, non-normality errors, and functional form misspecification. The model stability test—i.e., the cumulative sum of squares (CUSUMQ) plot expressed in Figures 3 and 4—forms recursive residuals of the estimation models split samples.

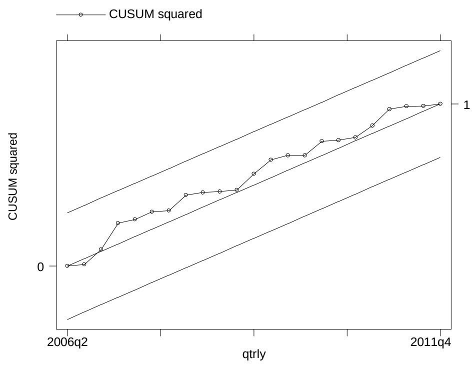

Figure 3: ***Plot of CUSUM Square for the estimation model Period (2005q1 to 2011q4)***

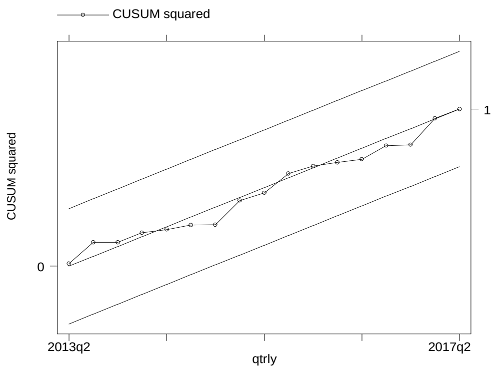

Figure 4: ***Plot of CUSUM Square for the estimation model Period (2012q1 to 2017q2)***

Source: Computed by the authors

From Figures 3 and 4, all the values (the lines) fall within critical boundaries at the 5% statistical significance level in both plots for the estimation models of the split samples. The study rejects the null hypothesis, and the models pass the parameter stability test, confirming the stability of the long-run parameters. Thus, both models are stable and consistent in both long- and short-term results.

4. Conclusion and Policy Implications

There is statistical evidence that natural gas sales revenue stimulates real GDP per capita in both the short-run and long-run. This implies that Tanzanians benefit from natural gas reserves in both the short-run and long-run. The results consider the benefits of government expenditures on health, which is crucial for socio-economic well-being. Natural gas revenues had a large positive long-run impact on the living standards of Tanzanians during the period under review. Thus, it validates the non-existence of the resource curse hypothesis in the context of Tanzania Mainland.

Based on the after break split sample results, domestic general government health expenditures positively influence real GDP per capita in the long-run. The sign is positive as expected, indicating that they are directed to productive projects that bring significant positive feedback to the economy due to increased productivity and income per head.

It is essential to mention that the effects of the nominal exchange rate on real GDP per capita were negative in the long-run, but positive in the short-run. Even with the substantial natural gas revenues generated, the exchange rates continue to deteriorate. Economic growth results in currency appreciation and improves the people's standard of living. More Tanzanian shillings have been required to buy one US dollar; hence, devaluation against the dollar negatively affects economic growth in the long-run.

Since the government's share of revenues increase with gas prices, the study recommends stimulating more economic growth by promoting the use of natural gas in other sectors of the economy—i.e., industries, transport, and households—where gas prices are high. The country must also soon decide on export-oriented LNG projects to fetch a competitive gas price, and therefore increase gas revenues.

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Appendix

Table A1: Variables Used, their Measurements and Sources

Variable Names	Variable Representation	Variable Proxy	Transformation of the Variable	Data Source
Economic growth	$\ln GDP_t$	real GDP per capita	$ln\left(^{GDP}/_{\text{total population}}\right)$	BOT, NBS
Natural gas sales revenue earnings	$\ln GR_t$	Natural gas sales revenue earnings.	$ln(\text{Natural gas earnings})$	TPDC
Human capital	$\ln HE_t$	Government health expenditure as a percentage of government expenditure	$ln\left(\frac{\text{Domestic government health expenditurex100}}{\text{total government expenditure}}\right)$	WDI
Exchange rate	$\ln EXR_t$	Nominal Exchange rate	$ln(\text{Exchange rate})$	BOT

Table A2: CMR Unit Root Test Results for the Variables with One Endogenous Break

Series	Level				First Difference				Decision
	AO		IO		AO		IO		
	t-stat	*TB*	*t-stat*	*TB*	*t-stat*	*TB*	*t-stat*	*TB*	
Log of GDPPC	-4.133** (0.000)	2014q3	-2.752 (0.003)	2014q4	-3.915 (0.936)	2008q4	-6.834 (0.229)	2013q4	I(0) AO
Log of HE	-2.210 (0.000)	2010q1	-3.253 (-)	2007q4	-4.354 ** (0.001)	2013q2	0.531 (0.002)	2008q4	I(1) AO
Log of GR	-2.724 (0.000)	2011q2	-3.912 (0.001)	2009q4	-3.967 ** (0.002)	2014q3	-3.288 (0.002)	2013q4	I(1) AO
Log of EXR	-1.993 (0.000)	2015q4	-1.813 (0.021)	2014q3	-4.963 ** (0.007)	2007q2	-6.163 (0.752)	2007q3	I(1) AO

Note: TB is the breakpoint. AO is Additive Outliers. IO is Innovational Outliers. Decision was made based on the 5% significance level. P-value is given in bracket below the test statistic. The null hypothesis for these tests is that the series has a unit root with a single break. Critical values for the CMR unit root test with one structural break for AO and IO are -3.56 and -4.27, respectively at the 5% significance level.

Table A3: CMR Unit Root Test for the Variables with Two Endogenous Breaks

Series	Level				First Difference				Decision
	AO		IO		AO		IO		
	t-stat	TBs	*t-stat*	TBs	*t-stat*	TBs	*t-stat*	TBs	
Log of GDPPC	4.772 (0.000)	2009q3; 2014q3	-6.462** (0.000)	2008q2; 2014q4	-3.751 (0.733)	2008q4; 2013q3	-2.888 (0.000)	2006q3; 2008q3	I(0) IO
Log of HE	-2.717 (0.988)	2010q1; 2010q3	0.624 (0.092)	2008q1; 2010q1	-3.409 (0.000)	2008q3; 2013q2	-0.236 (0.511)	2008q4; 2014q4	
Log of GR	-4.319 (0.000)	2007q1; 2011q2	-4.505 (0.053)	2009q4; 2011q4	-3.487 (0.021)	2011q3; 2014q3	-3.288 (0.001)	2011q4; 2013q4	
Log of EXR	-4.556 (0.000)	2010q4; 2015q4	-3.729 (0.000)	2009q4; 2014q3	-5.744 (0.263)	2007q2; 2015q1	-3.014 (0.749)	2007q3; 2015q2	

Note: TB is the breakpoint. AO is Additive Outliers. IO is an Innovational Outliers. Decision was made based on the 5% significance level. P-value is given in bracket below the test statistic. The null hypothesis for these tests is that the series has a unit root with two breaks. Critical values for the CMR unit root test with two structural breaks for AO and IO are -5.490 and -5.490, respectively, at the 5% significance level.