The uncertainty of natural gas consumption in Tanzania to support economic development. Evidence from Bayesian estimates

Mwoya Byaro[‡] and Derick Msafiri[†]

Abstract
Using a Bayesian regression model, this study evaluates the impact of natural gas use on economic growth in Tanzania from 2004 to 2016. Natural gas consumption, economic growth (as assessed by real GDP per capita), and labor supply and capital were all controlled as factors in the model. The empirical findings of this study reveal that natural gas usage during the study period is highly uncertain in terms of economic contribution. The mean value of natural gas consumption in 95 percent credible intervals ranges from negative to positive. This means that natural gas consumption and market demand are unlikely to have a significant impact on the country's economic progress. The findings, on the other hand, demonstrated that the labor force supply has a favorable impact on economic growth. To affect economic development, we advocate providing additional labor force to the Tanzanian economy, as well as upgrading and strengthening natural gas consumption policies, such as gas power production, industrial use and an efficient natural gas market.

Keywords: Bayesian model, natural gas consumption, economic growth
JEL Classification Codes:

[‡] Corresponding Author, IRDP, P.O BOX 11957, Mwanza, Tanzania, Email: mwoyabyaro2018@gmail.com
[†] Former Researcher at REPOA, 157 Mgombani Street Regent Estate,P.O. Box 33223, Dar es Salaam, Tanzania.

1. Introduction

Natural gas is a vital resource in the generation of energy for a variety of applications, and it emits less CO2 than other fossil fuels (Shahbaz et al., 2014). Due to the world's transformation to cleaner energy supplies that are highly efficient, ecologically friendly, and reliable, it is widely used in various sectors of the economy (WEO, 2012). Many economies throughout the world are switching to natural gas as a substitute for other fossil fuels, helping to meet the Kyoto target of reducing CO2 emissions (Farhani et al., 2014).

For a variety of reasons, this study focuses on natural gas consumption and economic growth in Tanzania: - First, the country has discovered natural gas, estimated at 57 trillion cubic feet, both onshore and offshore, which is projected to revolutionize the economy (Henstridge, 2018). Second, the country has been using natural gas for domestic power generation (Songa Songa and Mnazi Bay Plants), accounting for nearly 80% of all natural gas produced annually, with the remainder being consumed domestically by households, commercial and public institutions, and a number of industries. Third, over the next decade, the country has the potential to become a significant hydrocarbon exporter, which will almost certainly raise national income. In this sense, it is critical to assess if the impact of natural gas use on the country's economic prospects is positive or negative.

Our work intends to contribute to the energy economics literature by examining the influence of natural gas use on economic growth in Tanzania using Bayesian statistics. Unlike previous studies (e.g. Shahbaz et al., 2013; Solarin and Shahbaz, 2015; Oztuk and Al-Mulali, 2015; Farhani et al., 2014; Isik, 2010; Abdul and Liang, 2017) that used maximum likelihood techniques (frequentist), this study uses the Bayesian method (Markov Chain Monte-Carlo) to avoid the problems and limitations of frequentist and to fill a gap in the existing literature.

The Bayesian technique has a number of advantages. One of them is to estimate the parameters based on observed data by simulating a small sample to a bigger sample using Markov Chain Monte-Carlo (MCMC), which can reach up to 10,000 samples, to obtain a posterior distribution with higher statistical power (Byaro et al., 2018). Second, despite the small sample size available, it can be used (Byaro et al., 2018). Third, unlike maximum likelihood techniques, which require a larger sample size and associated likelihood, Bayesian estimation accounts for small sample sizes collected over time by using prior information and the probability of observed data in the model parameters to produce posterior distribution.

The early empirical findings of this study reveal that natural gas usage in Tanzania over the study period is highly speculative in terms of economic contribution. This means that natural gas consumption and market demand in the country are unlikely to have a significant economic impact. Natural gas consumption projections that are subject to ambiguity also show that the gas sector is in jeopardy. As a result, the full extent of its economic influence is yet to be realized. In contrast, only the supply of labor has a beneficial impact on the economy, according to the research.

1.2 Overview of Tanzania Natural Gas Extraction and Economic Growth

Natural gas has been used as a primary source of energy since 1952, with the first discovery being in the SongoSongo area of the Kilwa District in the Lindi region in 1974 (Kinyondo and Villanger, 2017). In 1982, another discovery was found in the Mnazi Bay area of the Mtwara Region. In 2007, another significant discovery was found in Mkuranga. In general, the history of oil and natural gas in Tanzania can be divided into five parts: the first component in 1952-1954, the second component in 1969-1979, the third component in 1980-1991, the fourth component in 1992-1999, and the fifth component in 2000.

The British Petroleum Group was tasked with researching and extracting natural gas in the coastal region as the initial component. Mafia Islands, Pemba, and Zanzibar are among these regions. However, they did not find enough hydrocarbons for commercial usage, and it appeared at the time to have no economic benefits (Bishoge et al., 2018).

The second component (1969-1979) included the formation of the Tanzania Petroleum Development Company in 1969 and the greatest natural gas discovery in the Lindi region, Songo Songo, in 1974. Tanzania Petroleum Development Company confirmed the discovery and began investigating natural gas in coastal areas (Bishego et al., 2018). The third component, which lasted from 1980 to 1991, included the government's approval of the Petroleum (Research and Production) Act in 1981 and the discovery of gas in the Mnazi Bay area (Bishego et al., 2018). In general, natural gas exploitation in the country began in the third component. New research activities and government efforts to strengthen the Songo Songo area were part of the fourth component, which ran from 1992 to 1999. Tanzania Petroleum Development Company and Tanzania Electric Supply Company have agreed to cooperate in the supply and usage of energy at the Songo Songo Plant at this time. Five licensed businesses were hired to work on the fifth component (from 2000 to the present). The granting of these permits was accompanied by research and extraction, which resulted in a substantial natural gas discovery. Songo Songo and Mnazi Bay Plants were successful in their first years of operation, between 2004 and 2006. (Bishoge et al., 2018).

These two plants are the country's primary source of gas production and consumption. In general, natural gas plants have benefited the country in terms of energy production, industrial use, and revenue collecting. In addition, the government adopted the Natural Gas Policy in 2013 to oversee the country's natural gas industry. This policy intends to ensure that home markets take precedence over international markets, and to lead the growth of Tanzania's gas industry for the countries and citizens' benefit (URT, 2013). Figure 1 depicts the country accessible and discovered natural gas reserves. The deep sea discovery has sparked a fresh wave of hydrocarbon exploration ambitions in Tanzania and across the Western Hemisphere.

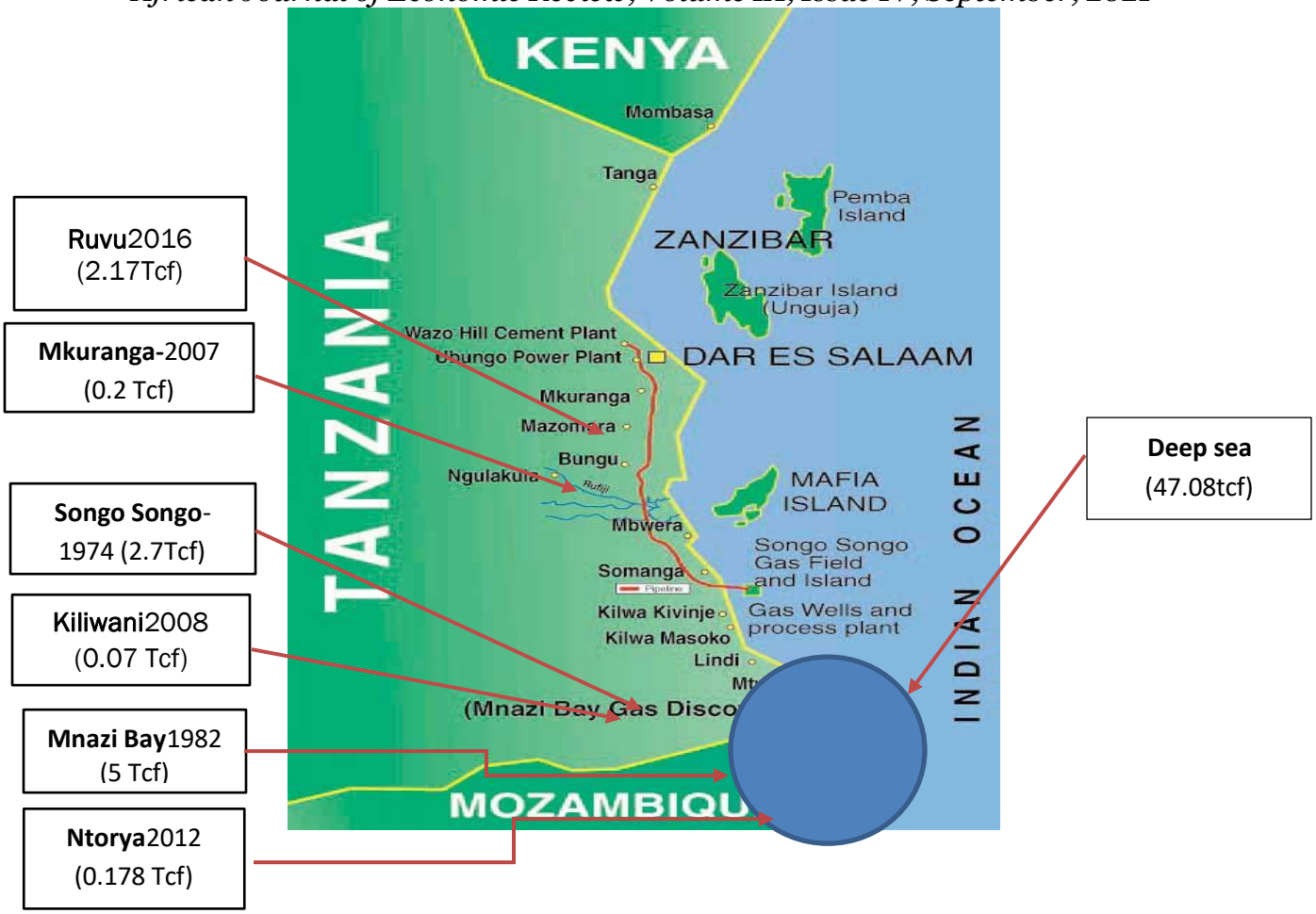

Figure 1: Reserved and Discovered Gas quantity in Tanzania
Source: Tanzania Petroleum Development Corporation (2016).

It's also crucial to understand the relationship between GDP per capita growth rate and natural gas usage over time. Figure 1 depicts the fluctuations in GDP per capita growth over time, although natural gas consumption remains constant. Overall, natural gas usage is not substantially linked to increases or decreases in GDP per capita.

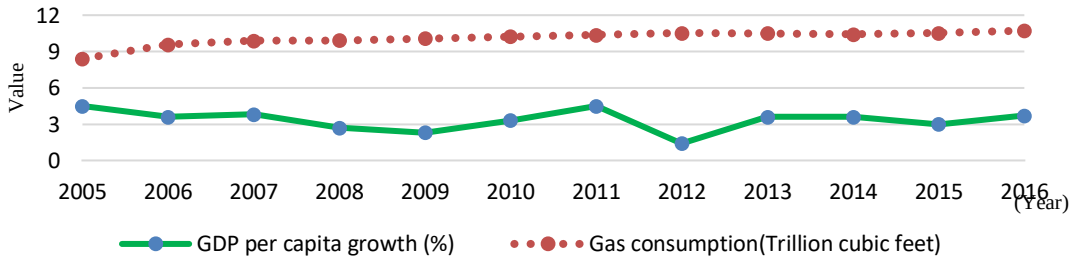

Figure 2: Natural gas consumption versus economic growth (%) in Tanzania over the period 2005 to 2016
Source: World Bank Indicators (2017); Tanzania Petro Data Hub (2018).

The remainder of the paper is laid out as follows: Section 2 examines theoretical and empirical literature; part 3 examines methodology; and section 4 examines empirical findings. The last section concludes with policy implications.

2. Literature Review

2.1 Theoretical framework

Solow (1956) established neoclassical economic theory to shed light on the factors that influence per capita income in different countries. Furthermore, researchers and academicians prefer to use the Cobb-Douglas function to investigate the drivers of economic growth. Similarly, Harrod (1939) and Domar (1946) explained the determinants of economic growth, with savings and investment productivity as the primary drivers of growth in their models. According to the model, growth is determined by the amount of capital and labor available, implying that the more individuals with high incomes, the stronger the growth generated by high savings. This work, like other studies (Li et al., 2019; Zhi-Guo et al., 2018; Farhani et al., 2014), used an extended Cobb-Douglas function to examine the impact of natural gas consumption on economic growth.

2.2 Empirical Review

Previous studies in different parts of the world have attempted to explain the relationship between economic growth and natural gas consumption, with varying methodologies and time frames. There are numerous studies on the relationship between natural gas consumption and economic growth in the literature. The majority of empirical conclusions linking natural gas consumption and economic growth are based on one-way and feedback causality, according to the review. A frequentist approach is part of the methodology used (e.g., panel cointegration, Granger causality, ARDL, VECM, etc). Table 1 summarizes conflicting findings, and no previous study has used Bayesian statistics to examine the impact of natural gas usage on economic growth. As a result, the study's goal is to close this knowledge gap.

Table 1: Economic Growth Nexus of Natural Gas Consumption

Author & year	Time	Country	Methodology	Findings
Etokakpan *et al.* (2020)	1980-2014	Malaysia	Cointegration and Granger causality Test	NGC → EG
Balsalobre-Lorente et al (2019)	1990-2017	Iran	ARDL, Toda and Yamamoto Granger Causality Test	NGC → EG
Zhi-Guo *et al*., (2018)	1991 - 2015	China, Japan and Korea	Granger causality test	NGC ⇔ EG
Akadiri and Akadiri (2018)	1980-2013	Iran	ARDL, Toda and Yamamoto Causality Test	NGC X EG
Bay& Hong (2017)	1999-2015	Mozambique	Granger causality test	NGC → EG
Destek (2016)	1991 - 2013	OECD Countries	FMOLS (Fully Modified Ordinary Least Square), Dynamic Ordinary Least Square (DOLS)	NGC ⇔ EG
Balitskiy et al. (2016)	1997-2011	EU-26 countries	Panel cointegration	NGC ⇔ EG
Solarin and Ozturk (2016)	1980-2012	OPEC countries	Panel Granger causality test	NGC ⇔ EG
Furuoka (2016)	1980-2012	China	ARDL, Granger causality Test	NGC → EG
Solarin and Shahbaz (2015)	1971-2012	Malaysia	ARDL and VECM (Vector error correction model)	NGC → EG
Solarin and Shahbaz (2015)	1971-2012	Malaysia	ARDL and VECM (Vector error correction model)	NGC → EG
Ozturk & Al-Mulali (2015)	1980-2012	Gulf Cooperation Council (GCC) countries	Pedroni cointegration test	EC ⇔ EG
Dogan (2015)	1995-2012	Turkey	VECM, Granger causality Test	NGC ⇔ EG
Shahbaz et al. (2014)	1972-2011	Pakistan	ARDL approach, Granger causality	NGC → EG

Author & year	Time	Country	Methodology	Findings

Farhani et al. (2014)	1970 – 2010	France	ARDL bounds testing approach	NGC ⟷ EG
Yazdi &Mastorakis (2014)	1975 -2011	Iran	ARDL (Autoregressive Distributed Lag)	NGC→ EG
Kum et al. (2012)	1967-2007	Korea	Granger causality	NGC ⟷ EG
Işik (2010)	1977-2008	Turkey	ARDL approach	NGC→ EG
Apergis and Payne (2010)	1992-2005	67 countries	Pedroni cointegration test	NGC ⟷ EG
Amadeh et al. (2009)	1973- 2003	Iran	ARDL, VECM	EG → NGC
Fatai et al (2004)	1960-1999	New Zealand and Australia	ARDL and Toda & Yamamoto Causality	NGC X EG

Source: Authors Computation, (2021)
Note: the symbols → , ⟷ and X indicates, unidirectional causality, bidirectional causality and no causality respectively. NGC and EG indicates natural gas consumption and economic growth respectively.

3. Methodology and Sources of Data

3.1 Model Estimation

In contrast to prior studies that used frequentist (classic) models (where data is random and unknown estimation parameters are fixed), this study used Bayesian statistical analysis (i.e. the data observed is fixed while the estimation model parameters are random). The Bayes rule, which provides estimates based on both prior information and evidence, is used in Bayesian analysis. The mathematical expression of the Bayes Theorem, which underpins Bayesian statistical inferences, is:

$$p(\theta/X) = \frac{p(X/\theta)p(\theta)}{p(X)} \quad (1)$$

Where:
$p(\theta/X)$ = distribution of the parameters given the data (posterior distribution)
$p(X/\theta)$ = Likelihood of the data series
$p(\theta)$ = prior information or belief
$p(X)$ = normalization constant

The specification for Bayesian linear regression model for economic growth (y) is given as follows: -

$y_i \sim N(\mu_i, \tau)$, where $\mu_i = X'_i\beta$, i=1……, n and $\tau = \frac{1}{\delta^2}$ (2)

Prior distribution is specified as:-

$$P(\beta, \tau) = \prod_{j=0}^{k} P(\beta_j)P(\tau)$$

Where $B_j \sim N(\mu_{B_j}, C_j^2)$ and $\tau \sim gamma(a, b)$

Where by y_i = dependent variable (economic growth)

X'_i = vector of explanatory variables (natural gas consumption, capital stock and labour supply)
β = coefficient of the unknown parameter estimates
μ_i= mean of the estimated regression coefficients
$\frac{1}{\delta^2} =$ precision or tau

Using a normal distribution with substantial variance, we assumed a non-informative prior for each unknown parameter in the model (See, Byaro et al., 2018). The prior mean for tau (τ), is 1 and the variance is 100, resulting in a = b = 0.01

3.2 Data Sources

The World Bank Development Indicators (WDI) provided by the World Bank (2017) and Tanzania Petro Data Hub (2018) were utilized to compile the data for this study. The real GDP per capita was used as a proxy for economic growth after adjusted for inflation at constant 2010 US dollars. The natural gas consumption was measured in trillion cubic feet (tcf). Both capital stock in terms of gross fixed capital formation (i.e. share of GDP) and total labour force were extracted from World Bank Development indicators (2017). The time period was chosen due to availability of the natural gas consumption dataset in Tanzania.

The data was given a normal distribution of mean (μi) and precision (τ). Where the Mean (μi) was given a normal prior with a mean 0 and a precision of 0.001, and τ was given a gamma (0.0, 0.01). To obtain the posterior distribution, the estimation strategies used the Markov Chain Monte Carlo (MCMC) simulation. The data was analysed using WinBUGS.

4. Results and Discussions

Table 2 shows the results of Bayesian modeling estimates for the impact of natural gas consumption on Tanzanian economic development from 2004 to 2016. The mean for natural gas consumption, capital stock, and labor force supply, as well as the credible intervals range for economic growth, are all expected to be positive.

Table 2: Posterior distribution estimates for economic growth

Parameter	Mean	Standard deviation	Monte Carlo error	Credible intervals (95%)	
				2.5%	97.5%
B_0(constant)	- 9.51	7.01	0.068	-23.35	4.72
B_1(Gas consumption)	0.02	0.08	0.001	- 0.14	0.17
B_2(Labour)	2.03	0.62	0.006	0.77	3.26
B_3(Capital stock)	- 0.03	0.18	0.002	- 0.40	0.35

Source: Authors computation, (2021)

The Bayesian posterior distribution (Table 2) results are evaluated within the credible intervals, and the relationship between explanatory variables and dependent variables is seen in the signs of the posterior summaries (i.e. mean, 2.5 percent, and 97.5 percent percentiles). The corresponding relationship is concluded when the sign of posterior distribution results is entirely positive or negative (Byaro et al., 2018). The probability that the genuine parameter value resides within the interval equal to 0.95 is known as the 95 percent credible interval. It's vital to remember that in Bayesian statistics, the posterior probability is reported rather than the p-value in frequentist statistics. The mean for natural gas consumption is 0.02 with a range of credible intervals between a negative (-0.14) and a positive number (0.17). With a positive credible interval range of 0.77 and 3.26, the labor force supply mean is 2.03.

Although natural gas use is beneficial to economic development in various nations, our result findings highlight the ambiguity of natural gas consumption estimates in Tanzania. This level of uncertainty (both negative and positive credible intervals) suggests that the country's natural gas consumption is still in its infancy. Furthermore, Tanzania's newly discovered gas is yet to begin (Byaro and Kinyondo, 2020).

The robustness of parameters was further investigated using MCMC (Markov Chain Monte-Carlo) post estimate, as shown in Appendix 1. It displays the convergence of factors such as history, kernel density, and autocorrelation to obtain the posterior distribution. The robustness demonstrates that the parameters have a normal distribution, there is no autocorrelation, and all parameters have reached equilibrium (See the Appendix 1). The findings were monitored in the chains for parameter convergence, and a good chain demonstrates rapid mixing and implies a stationary distribution (See Byaro et al., 2018).

The majority of past empirical work indicates that natural gas consumption has a significant impact on economic growth in both developed and developing countries. This means that natural gas is beneficial and necessary for a country's economic progress in several ways: - First, it creates job opportunities. Natural gas exploration, production, transportation, and distribution can all help to provide these opportunities. Second, gas is utilized for cooking in the home, aircraft, and power generation. Finally, gas is cost effective, resulting in cheaper energy costs. Because of these channels, the natural gas business boosts the national economy by generating gas earnings and creating jobs. As the extraction of newly discovered gas begins, it is critical to build a liquefied natural gas (LNG) plants to boost the appeal of gas development to investors. Furthermore, increasing institutional quality structures associated to the gas sector will restructure natural gas earnings in Tanzania (Byaro and Kinyondo, 2020), resulting in stronger national economic growth. These findings are also in line with what has been found in other empirical studies. For example, Işik (2010) discovered that natural gas use had both good and negative effects on Turkey's economic growth in the short and long run. Solarin and Bello (2020) conducted a study in the United States utilizing Quintile Autoregressive Distributed Lag (QARDL) with capital stock and labor as factors. The findings demonstrated that shale gas and capital stock had a long-run considerable impact on economic growth, while labor had a favorable but small impact. For the period 1991 to 2016, Fadiran et al. (2019) evaluated the association between natural gas consumption and economic growth in 12 European nations. Labor force, gross fixed capital formation, trade openness, and real GDP were all included in their research. The findings demonstrated that there is no long-term or short-term influence of natural gas consumption on economic growth.

Lim and Yoo (2012) used quarterly data from 1991 to 2008 to analyze the causative relationship between natural gas consumption and economic growth using cointegration and Granger-causality. The results demonstrated that natural gas consumption and economic growth had a bidirectional causal relationship. Heidari et al. (2013) used a bounds test approach to investigate the association between natural gas consumption and Iranian economic growth. The findings demonstrated a bidirectional positive association between natural gas use and economic growth in both the long and short term. Aydin (2018) examined the relationship between natural gas consumption and economic growth in the top ten natural gas-consuming nations from 1994 to 2015 using panel Granger causality. According to the findings of the study, natural gas consumption and economic growth have a long-term association. In addition, natural gas consumption was discovered to have a beneficial and considerable impact on economic growth.

Galadima and Aminu (2018) employed the Smooth Transition Regression (STR) model to see if natural gas consumption has an impact on Nigerian economic growth, and the results revealed an unbalanced link. Galadima and Aminu (2019) employed the Non-Linear Autoregressive Distributed Lag (NARDL) model to look at both the positive and negative effects of natural gas consumption on economic growth and no clear association was found. Furuoka (2016) used Autoregressive Distributed Lag (ARDL) to analyze the relationship between natural gas use and economic development in China and Japan between 1980 and 2012. In both China and Japan, his findings revealed a cointegration link between natural gas use and economic development. However, the findings also demonstrated that the results were unidirectional and bidirectional between the natural gas consumption and economic development in China and Japan respectively. Makala and Zongmin (2020) used ARDL (Autoregressive Distributed Lag) to investigate Tanzania's natural gas consumption and economic growth from 1995 to 2018. They found no long-term link between natural gas consumption and Tanzania's economic growth. Natural gas use has little effect on economic growth, according to their findings. Finally, our findings confirm that our hypothesis is correct. Our findings also show that the labor force supply has a positive mean value as well as credible intervals. This means that the Tanzanian workforce contributes to the country's economy.

Based on prior literature reviews, there has been an increasing interest in analyzing the influence of natural gas use on economic growth in various countries. Since the majority of literature revealed causality and non-causality outcomes, most investigations of this type create inconsistent empirical findings. The causality test simply reveals the direction of the variable relationships, not their magnitude. This suggests that the previous literature's seeming inconsistency (in terms of causality analysis) could be due to the bivariate and multivariate frequentist frameworks used. Omitted variable bias (model misspecification) and endogeneity (reverse causality) are key flaws in bivariate and multivariate frequentist models, and as a result, their estimation outputs and policy implications are unreliable.

In this study, we used a Bayesian statistics model to overcome frequentist problems (such as sample size and omitted variable bias), thus controlling endogeneity (see Montes-Rojas, 2014) and other omitted variable bias by introducing priors on every parameter of estimates to produce posterior distribution within a range of certain/uncertain credible intervals. Our findings revealed that there was no evidence of a connection between natural gas consumption and economic growth.

5. Conclusion and policy implication

Using annual data from 2004 to 2016, this study evaluates the impact of natural gas consumption on economic growth in Tanzania while controlling for labor force supply and capital stock. According to the findings, only labor force supply has a positive impact on economic growth in Tanzania, meaning that a rise in labor force supply is linked to an increase in economic growth. Furthermore, because the mean value ranges from a negative to a positive value within the credible intervals, the result illustrates the uncertainty of natural gas consumption's contribution to Tanzania's economy. This means that natural gas consumption and market demand are unlikely to improve the country's economic growth. The country's natural gas consumption is also affected by the uncertainties. Our study suggests that the country's natural gas consumption policies, such as gas power generation, industrial use, and efficient markets, be improved and strengthened.

We urge that the natural gas sector undergo thorough investment planning (e.g., the construction of LNG plants) in order for the sector to realize its full potential and, as a result, to support the national economy in the future. Future research employing a Bayesian framework to re-examine

the influence of natural gas consumption on economic growth in various nations are needed to provide meaningful policy recommendations.

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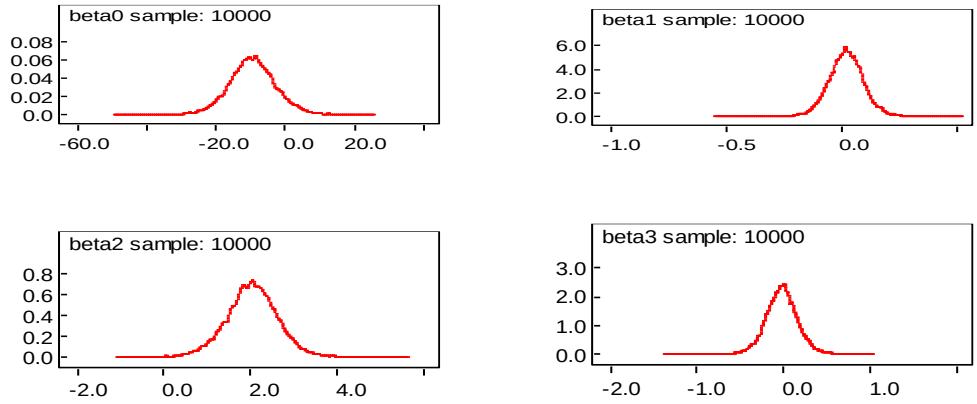
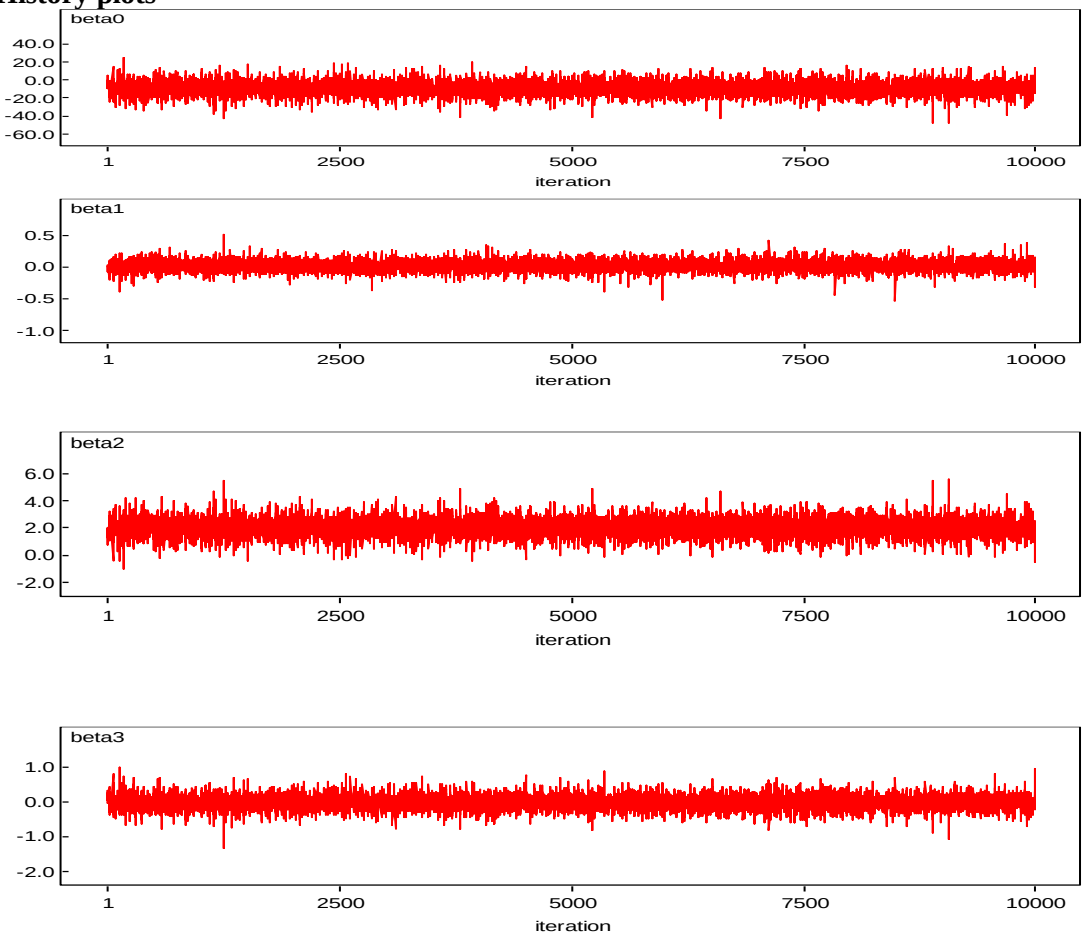
Appendix 1: Diagnostic Tests

a) Kernel density



b) History plots



c) Autocorrelation plots