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Modeling and Forecasting Natural Gas Production in Nigeria

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ABSTRACT: This paper examined the future outlook of natural gas production in Nigeria. The Modified Hubbert model was used to Model and forecast Nigeria natural gas production up to 2035. Interestingly, the model put into consideration several parameters like the annual gas production in billion barrels for year t, the Peak gas production (PM), the total aggregated gas price at peak (GP), the year of the peak production (tm), the actual production (Pact), the calculated production (Pcal), and $K \leq 1$ was a constant, b was the slope of the cure in the model. It was observed that the total gas production forecasted for 2035 was 0.04bscf of gas. This is an indication that natural gas production will not be able to meet up the demand of natural gas by various sector in 2035, if drastic measures are not been put in place to avert the situation. Based on this finding, the paper recommended that government should embark on aggressive gas exploration activities and to encourage active players in gas sector in order to enhance natural gas production and demand for sustainable development in Nigeria.

KEYWORDS: Natural Gas production; Gas consumption; Gas utilization

I. INTRODUCTION

Natural gas is a crucial energy resource for countries of the world, contributing significantly to the nation's energy supply, economic growth, and export revenues. Globally, there are significance surge in natural gas production due to exploration of new wells and high energy demand. Bob (2018) stated that global natural gas production was expected to grow by 131bcm which was about 4 percent grown rate. It was also noted that Russian, Iran and Australia surge by 46cm, 21bcm and 17cm respectively while gas usage rose to about 96cm, which was about 3 percent growth rate. These surge in gas usage was driven by China, Middle East and Europe gas demand. They consumed about 31cm, 28cm and 26cm respectively. Nigeria, with its vast natural gas reserves, plays a crucial role in the global gas market as it ranks as the largest natural gas reserve holder in Africa and the 9th largest in the world. As of 2022, Nigeria's proven natural gas reserves are estimated at 206 trillion cubic feet (tcf), with the potential for another 600 tcf yet to be discovered (International Energy Agency (IEA) (2022). This resource holds significant potential for bolstering Nigeria's energy security, reducing its dependence on crude oil exports, and driving sustainable economic growth through industrialization.

However, despite holding substantial gas reserves, Nigeria's production and utilization remain suboptimal. For instance, the country produced about 1,450 billion cubic feet (bcf) of natural gas in 2020 but faced significant losses due to flaring and inadequate infrastructure (OPEC Annual Statistical Bulletin, 2022). Gas flaring, a practice where excess gas from oil extraction is burned, remains a significant environmental and economic concern in Nigeria. Also, despite government initiatives to curb flaring, such as the Gas Flare Commercialization Programme, approximately 7% of Nigeria's associated gas is still flared which resulted in decrease in gas production, lost revenue and environmental degradation. This notwithstanding, the global demand for liquefied natural gas (LNG) has presented a lucrative opportunity for Nigeria, with projects like the Nigeria Liquefied Natural Gas (NLNG) playing a vital role in the country's exports but the potential of the domestic market remains largely untapped, with only 13% of produced gas being supplied to the domestic market. This highlights the need for a strategic focus on developing a more reliable, long-term forecast for gas production, considering domestic consumption needs and export market demands (World Bank Group, 2021). Hence, modeling and forecasting natural gas production are essential for creating a clear roadmap for the future of Nigeria's energy sector. Accurate forecasts will help policymakers and industry stakeholders make informed decisions regarding investments, supply chain development, and policy frameworks aimed at optimizing gas production. It is against this backdrop that study aimed to address these challenges by creating a comprehensive model to forecast natural gas production in Nigeria.

II. LITERATURE REVIEW

Theoretical Framework

This study is anchored on Hubbert's Peak Theory. Hubbert's Peak Theory was developed by geophysicist M. King Hubbert in 1956. This theory is a widely used model for predicting the production rates of finite natural resources, such as oil and natural gas. Hubbert

originally applied his theory to the United States oil production, predicting that it would peak around 1970 and subsequently decline. The fundamental premise of this theory is that the production of a finite resource follows a bell-shaped curve, rising sharply after initial discovery, reaching a peak when approximately half of the total reserves have been extracted, and then declining as the resource becomes harder to extract. The theory posits that the production of natural resources follows a bell-shaped curve: it increases rapidly after discovery, reaches a peak when approximately half of the resource has been extracted, and then declines as resources become harder to extract. Hubbert's Peak Theory can be applied to model natural gas production in Nigeria and help in predicting when production will reach its peak and eventually decline. Given that Nigeria is a major natural gas producer with 206 trillion cubic feet of proven reserves), understanding the lifecycle of production is essential for long-term planning. Hubbert's curve would allow Nigeria to forecast when natural gas production might plateau, thus preparing for future supply constraints or declines. This theory sheds light into the importance of investing in new exploration technologies and alternative energy sources to avoid the economic downturns that could accompany the decline in natural gas production. While Hubbert's theory was initially developed for crude oil production, it has been successfully adapted to natural gas and other finite resources. It serves as a valuable tool in determining Nigeria's future production capacity and in planning strategies to optimize extraction before reaching the peak.

Conceptual Literature

Gas Production

National gas is the global solution for sustainable energy security and economy development, this is because of it cleaner and environmentally friendly nature. The demand for Natural gas is increasing globally when compared to other energy sources. The increase in demand for natural gas is driven by its use for power generation, industrial feed stock and LNG project globally. Gas Production is a process whereby natural gas and other solid properties are produced from the reservoirs. Typically, there are Non-Associated Gas (NAG) reserves and Associated Gas (AG) reserves. The Associated Gas are gas that is produced with crude oil and other impurities while Non-Associated Gas are gas that are produced with the tendency of any impurities except water.

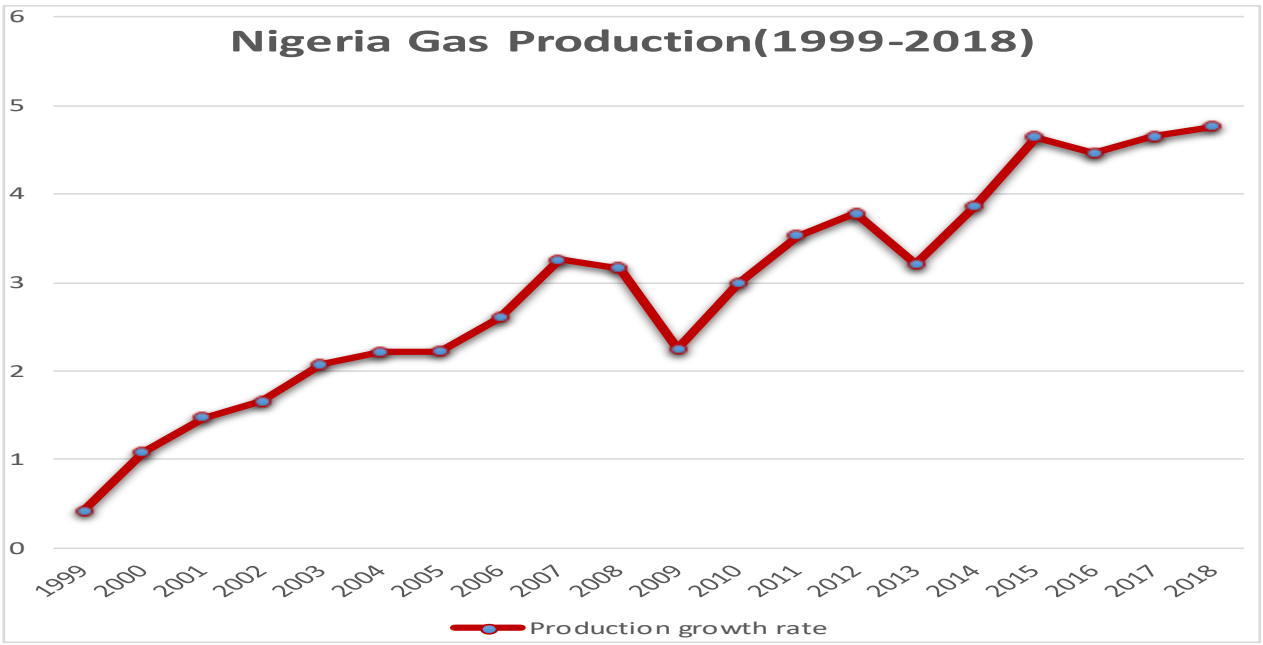

Figure 1: Nigeria Gas Production

Source: BP Statistical

Figure 1. show that there has been rapid increase in gas production growth rate from 199 to 2018. Although, there were Sharpe decline in the year 2009 and 2014 respectively due to gas pipeline vandalisms and other related operational challenges that hamper decline in gas production during this period. However, accordingly to annual Energy outlook, United states of America natural gas production and consumption was expected to grow at an increasing pace in 2020, then production supposed to grow faster than production after 2020 (Figure 2).

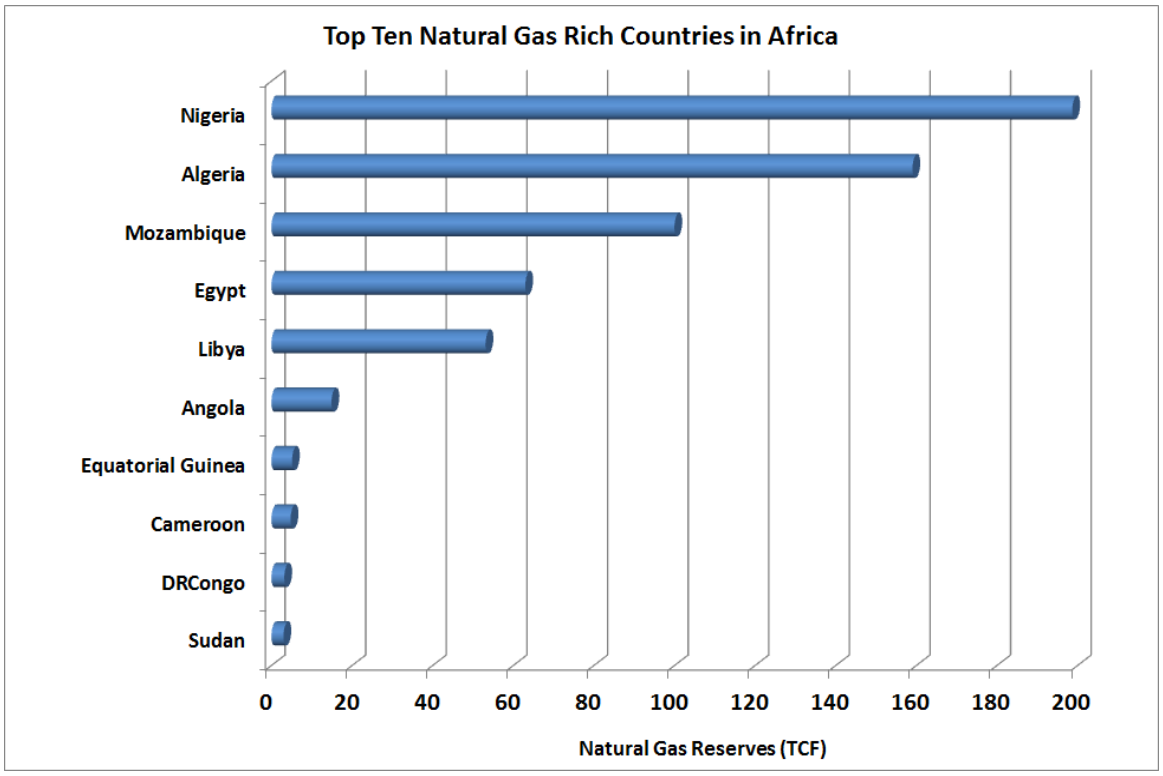

Figure 2: Top Ten Natural Gas Rish Countries in Africa

Nigeria total gas Reserves is about 202TCF; these make Nigeria the largest gas Reserves holder in Africa. However, other Africa countries like Algeria and Mozambique has a total gas Reserves of about 159TCF and 100TCF respectively which make them rank 2rd and 3rd gas Reserves holders in Africa. (Fig.2B) Interestingly, the total gas reserves in Africa is about 614TCF with the Top Ten Natural Gas Rich Countries having a total of about 605TCF which is about 98.5% of the total gas reserves in Africa. Nigeria natural gas composition is of high quality, the gas is rich of natural liquid, it also has zero percentage of Sulphur and with low carbon dioxide content. These is essential because to assist to meet the customer's specification.

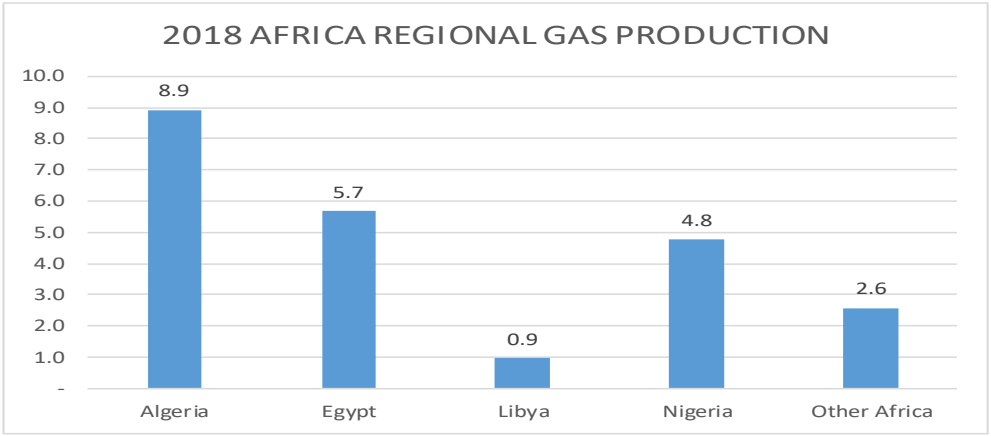

Figure 3: 2018 Africa Regional Gas Production

Nigeria is one of the major gas producing nation in the world. These attributed for the country to be rank as the 18th gas producing nation in the world and 3rd in Africa as at 2018. Nigeria gas production as at 2018 was about 4.8MMsc/d when compared to other Africa countries like Algeria and Egypt which has about 8.9MMsc/d and 5.7MMsc/d respectively. Although, most of the gas produced are been re-injected into the reservoirs or been flare which in turn resulted to insufficient gas supply to the domestic market and wasted of national resources. However, the total gas production by increase to 8,033MMSCFD and the daily average gas supply to gas power plant was about 854MMSCFD which is equivalent to 3,492MW. Interestingly, Natural gas production and consumption are experiencing an increasing trend in Nigeria as shown in figure 12, owing to the growth in domestic power , industrial, and household activities and the favorable characteristics of natural gas, such as being clean, environment friendly and highly efficient as well as its strategic status, the accurate modeling of gas demand by various sectors is crucial.

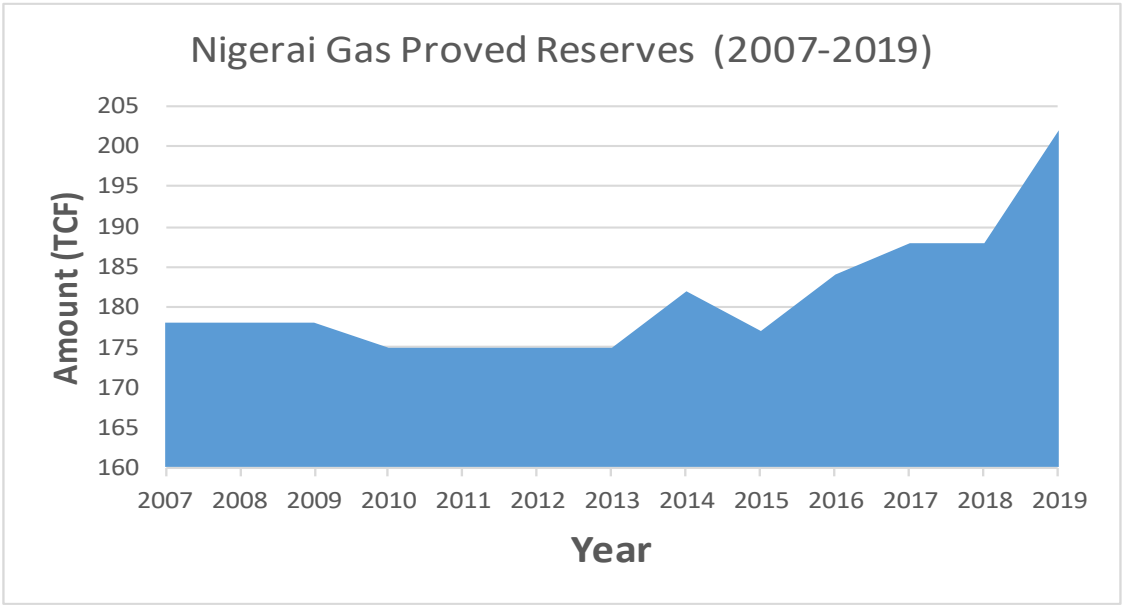

Figure 4: Nigeria Gas Proved Reserves

Interestingly, Nigeria's gas production has been increasing over the years, owing to demands from the Nigerian liquefied natural gas project (NLNG), the west African gas pipeline project (WAGP) as well as for power generation. Although, a large quantity of the gas produced is re-injected into the well for reservoir pressure and some others flared (figure 4). Despite a 70% decline in flaring over the past decade. In 2015, ~1,000 MMSCFD of gas was flared in Nigeria, exceeding the ~800 MMSCFD utilized for power generation and ~450 MMSCFD utilized in domestic industry

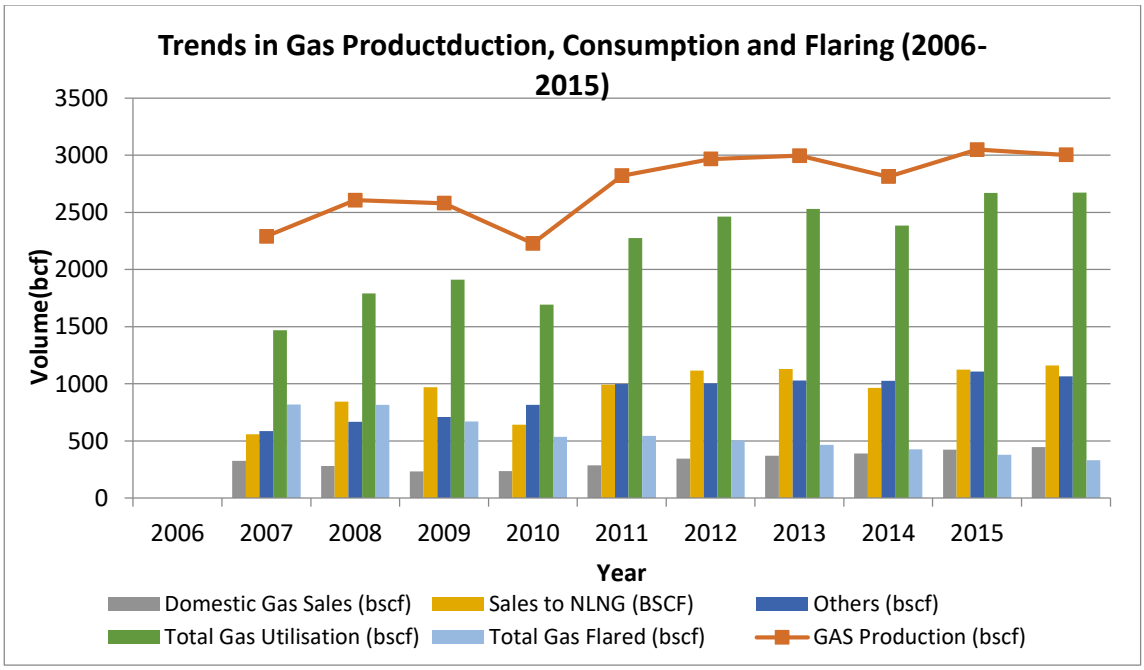

Figure 5 Nigeria Gas Production and Consumption (2006-2015).

Although, gas flaring in Nigeria had continued unabated, owing to weak penalties placed on flare defaulters, as well as inadequacy of infrastructure for utilization of gas. This has constituted a major economic waste and environmental damage over the years; although, the quantity of gas flared have reduced drastically due to development of infrastructures (EIA 2012) and projects for domestic gas utilization.

Gas Utilization in Nigeria

The utilization of abundance natural gas resources for sustainable economy development of Nigeria and domestic use has been a major challenge facing the country. For instance, there are high demand by the Power, Industries, Residential, Manufacturing and Transport sectors to utilized natural gas for their operations. Nigeria is the Africa's most prolific oil-producing country, which, along with Libya, accounts for two-thirds of Africa's crude oil reserves. It ranks second to Algeria in natural gas (Sambo, 2008). Most of

Africa's bitumen and lignite reserves are found in Nigeria. In its mix of conventional energy reserves, Nigeria is simply unmatched by any other country on the African continent. It is not surprising therefore that gas export is the mainstay of the Nigerian economy. Also, primary natural gas resources dominate the nation's industrial raw material endowment. Natural gas is available in Nigeria in abundant proportions. The country possesses the world's sixth largest reserve of crude oil and second natural gas in Africa. Nigeria has an estimated oil reserve of 36.2 billion barrels. It is increasingly an important gas province with proven reserves of nearly 5,000 billion m3. The oil and gas reserves are mainly found and located along the Niger Delta, Gulf of Guinea, and Bight of Bonny. Most of the exploration activities are focused in deep and ultra-deep offshore areas with planned activities in the Chad basin, in the northeast. Coal and lignite reserves are estimated to be 2.7 billion tons, while tar sand reserves represent 31 billion barrels of oil equivalent. The identified hydroelectricity sites have an estimated capacity of about 14,250 MW. Nigeria has significant biomass resources to meet both traditional and modern energy uses, including electricity generation (Ighodaro, 2010).

Additionally, Mike (2021) state that a gas reservoir is when the reservoir temperature T, is greater than the critical temperature Tc of the hydrocarbon fluid. He went further to explain that natural production from gas Reservoir can be estimated with permeability of gas with the formula below.

$$q = \frac{219{,}220 \quad Kgh \quad (Pe - Pw)}{\mu g \, \beta g \qquad In(re/rw)}$$

where q is the flow rate, k is gas permeability, h is pay thickness, Pe is the boundary or external pressure, Pw is the wellbore pressure, re is drainage radius, rw is the wellbore radius, μg is the viscosity of gas and βg is gas formation volume factor

For instance, a gas well in the Nigeria Petroleum Development Company (NPDC) area was producing with a flow rate of 5MMSCF/D under a pressure differential of 200psi.The well and reservoir data from the field are given as Wellbore radius, ft =0. 3, Drainage radius, ft=600, Gas viscosity, cp =0.42, Reservoir temp=172 of gas form. volume factor, rb/STB =1.2 and Pay thickness, ft =50

Empirical Review

Mukhtar, Abubakar, Ibrahim, Ibrahim and Hassan (2022) investigated the short-term dynamics as well as the long-term relationship between natural gas consumption and economic growth in Nigeria, taking breaks into account. The techniques employed include Shahbaz-Omay-Roubaud unit root test with sharp and smooth breaks and autoregressive distributed lag (ARDL) model with breaks. The results revealed that natural gas consumption is positively related to growth both in the short-term and long-term but only significant in the latter.

Molly, Richard and Edwin (2022) analyzed influence of gas consumption on economic growth in Kenya. The study period was 2008-2020. Neo Classical growth and Depletion theories were employed. Explanatory research design was employed. Secondary data sourced from the World Bank database. General Method of Moment (GMM) model was adopted. Over identifying test and normality tests were conducted before making inferences. Both descriptive and inferential statistics were carried out. Results were presented in form of graphs and tables. The results indicated that coefficient of gas consumption was -2.1673, p=0.024. This implied that 1% increase in gas consumption would result in a reduction of GDP growth rate by 2.1673%.

Nwabueze, Ogbonna and Nwaozuzu (2021) investigated the relationship between natural gas consumption, natural gas price, crude oil price, Foreign direct Investment and per capita GDP in Nigeria to ascertain their causal effects and dependencies by using time series data from 1990 to 2020 in an econometric platform using Vector Error Correction model (VECM). The result of VECM estimate, Granger causality test and Variance decomposition test all suggest the presence of a strong positive correlation between natural gas consumption and economic growth (represented by per capita GDP) in Nigeria, even though the price of natural gas is not consumption determined.

Itoua, Manguet and Mouanda-Mouanda (2021) investigated the impact of the gas production, gas use and gas flaring on economic growth of the Republic of Congo during the period 2006-2019. The results of the unit root test reveal that the bulk of variables are stationary at level and therefore integrated of order zero, however, labor input which is stationary at first difference and integrated of order one. The test of Johansen cointegration shows that all-time series are cointegrated and have a long-run equilibrium relationship. The study also performed the Granger-causality test which proves that only gas production and gas utilization cause economic growth in our study. The OLS regressions suggest gas production impacts adversely and significantly on GDP while gas utilization significantly stimulates GDP.

Nwatu and Ezenwa (2020) estimate the relationship between natural gas consumption, economy growth and carbon (iv) oxide emission. The usual preliminary analysis and formal tests were performed on the data, cointegration test was performed using Johansen's method and with the application of the Akaike information criterion (AIC), a lag value of one was selected. The results coefficients for the multi-directional relationships between natural gas consumption, economic growth and carbon dioxide emission were obtained in the short run for Nigeria.

Abdul and Liang (2017) investigated dynamics of the natural gas industry and economic growth in Mozambique for the period of 1999 to 2015. Times series data is collected from Index Mundi, produced by World Bank and it includes export and labor. This study employs Error Correction model. Results report that the natural gas industry, export, and labor are positively cointegrated with

economic growth, and they have a long-run relationship. In a short-run term, results revealed that the natural gas industry has a positive effect and it is significant to influence economic growth in Mozambique

Mastorakis and Yazdi (2014) investigated the impact of the gas production, gas use and gas flaring on economic growth of the Republic of Congo during the period 2006-2019. The results of the unit root test revealed that the bulk of variables are stationary at level and therefore integrated of order zero, however, labor input which is stationary at first difference and integrated of order one. The test of Johansen cointegration showed that all-time series are cointegrated and have a long-run equilibrium relationship.

III. METHODOLOGY

In this study, we used the modified Hubbert model equation to forecast Nigeria gas production over a period of time with cost. The model was derived from Hubbert model which was used to forecast OPEC countries crude oil production. Hence the model was modified with the introduction of aggregate gas cost at peak. The equation is as follows:

$$P = \frac{(2Pm \times GP)}{(1+k \times \cosh(b(t-tm))} \quad (1)$$

Where:

$$PM = \frac{2Pmi}{K+1}$$

The Root-Means-Square of the error (RMSE) is utilised for validating and testing of the model.

$$RMSE = \frac{\sqrt{\sum(Pact-Pcal)2}}{n} \quad (2)$$

Where P is the annual production in billion barrels for year t, Pm is the Peak gas production, GP is the total aggregated gas cost at peak, tm is the year of the peak production, PM is the peak production, Pact. is the actual production, Pcal. Is the calculated production, $K \leq 1$ is a constant, b is the slope of the curve.

The gas cost here is the aggregated gas cost for various sectors.

Furthermore, in view of the foregoing, this review ascertained the value of gas in Nigeria through a statistical link of energy demand with time by means of past studies on energy demand.

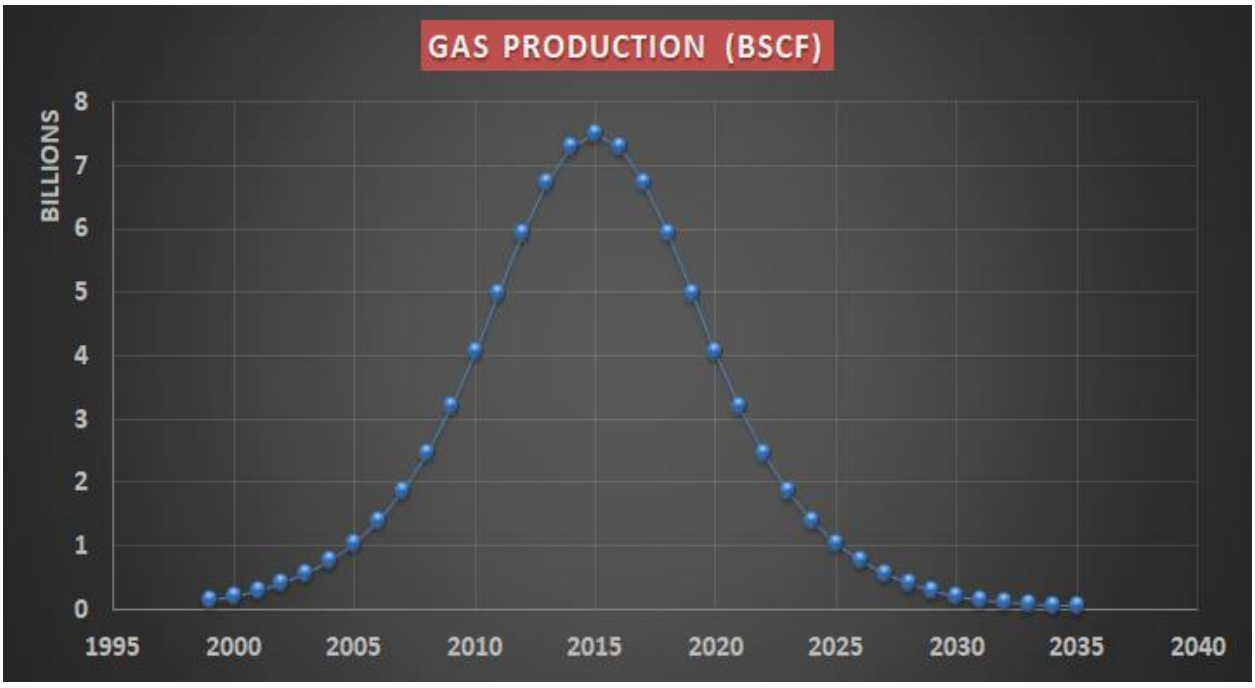

Figure 6: Nigeria gas production forecast from 2020 to 2035

Above figure 6 is the graphical representation of Nigeria gas production forecast from 2020 to 2035. It shows that Nigeria gas production will be 0.04BSCF by 2035 if nothing is been done. We recommend that the country should embark on aggressive gas exploration activities in order the avert the situation and be able to meet up the demand.

IV. CONCLUDING REMARKS

This study has modeled and forecasted natural gas production in Nigeria. This is crucial for optimizing the country's vast gas resources and securing its position as a key player in the global energy market. From the result, it could be seen that Nigeria's gas

production of 0.04 BSCF by 2035 will be inadequate to meet the increasing demand for natural gas required to provide energy needed for household consumption and industrial use. This result call for concern for policymakers and industry stakeholders to plan future gas production, identify infrastructure and investment needs, and mitigate challenges like gas flaring, regulatory inefficiencies, and fluctuating global demand. With this model, Nigeria can better align its natural gas production with domestic consumption needs and global market opportunities, positioning itself to fully leverage its gas reserves while transitioning toward a more diversified and sustainable energy economy.

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