The Symmetric Relationship Between Natural Gas Consumption and sustainable Economic Growth in Saudi Arabia

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Abstract

This paper attempts to investigate the symmetric relationship between natural gas consumption and economic growth in Saudi Arabia over the period 1990–2021 by extending the production function including capital, labor, external trade, and financial development. The study applied the autoregressive distributed lag (ARDL) technique. The result of Granger causality test indicates a causal relationship from NGC to RGDP, i.e. the results supported the growth hypothesis in KSA which is known in the literature as energy consumption-led growth hypothesis. The short- and long-run results also supported the growth hypothesis that NGC contributes to economic growth. The result also showed that the accumulation of capital, labor force, and economic openness contribute to stimulating economic growth in the KSA in the long run, while the results showed the negative impact of bank credit on economic growth in the long run. The study suggests that it is possible in the near future that KSA will be able to meet its energy needs by adopting renewable energy alternatives. However, energy policies should be implemented sufficiently to promote sustainable economic growth In line with achieving the Kingdom's Vision 2030.

Keywords: Saudi Arabia, Natural Gas Consumption, Economic Growth, ARDL

Introduction

The debate on economic growth is intertwined with sustainable development, and the focus is on the optimal use of economic resources, specifically energy resources. It is known that per capita energy consumption is one of the indicators that describes the economic development of a country (Pirlogea & Cicea, 2012). Optimization of non-renewable energy sources has faced widespread criticism due to its unsustainable nature and large carbon emissions. In line with the increasing importance of climate change and increasing awareness about environmental conservation, the importance of switching to renewable energy sources is increasing. Natural gas plays a vital role in the process of energy transition and the elimination of carbon emissions harmful to the environment, in parallel with the trend towards renewable energy sources (Alzyadat, 2022a). Natural gas has been a major supporter of the transition to clean energy, although it is one of the fossil fuels. It can be described as an alternative in reducing carbon, whether by saving energy or utilizing gas infrastructure to transport clean fuels. Natural gas is the cleanest and fastest-growing fossil fuel, contributing nearly a third of total energy demand growth over the past decade. Natural gas offers a number of environmental benefits compared to other fossil fuels, particularly in terms of air quality, Global Warming, gas emissions.

The natural gas market is becoming increasingly globalized, driven by the availability of shale gas and increasing supplies of flexible LNG. As gas trade increases, so does the interconnectedness of gas markets, creating new aspects and dimensions of natural gas security, where demand or supply shock in one region may have repercussions in others.

Saudi Arabia is the world's largest exporter of crude oil and has the fourth-largest natural gas reserves in the world. KSA supports the natural gas industry to meet the increasing demand for energy and energy production, which is the preferred fuel and water desalination. Therefore, natural gas is an essential part of the long-run economic development of Saudi Arabia. The Saudi General Authority for Statistics revealed, in its report on gas and petroleum statistics for the year 2021, that natural gas reserves amounted to about 8.293 billion tons of oil equivalent by the end of the year 2021, compared to 8.218 billion tons of oil equivalent in 2020. The amount of natural gas production also reached about 126 million tons. Oil equivalent, which is equivalent to 4,928 billion cubic feet, an increase of 2.94% compared to 2020. natural gas consumption also witnessed an increase of 1.32% compared to 2020, as the amount consumed reached 99.21 million tons of oil equivalent, which is equivalent to 3.894 billion cubic feet. In addition, the per capita consumption of liquefied petroleum gases increased from 79.68 liters per capita in 2020 to 81.98 liters in 2021. The high rate of population and economic growth in the KSA is followed by a high rate of energy consumption, in order to preserve current resources, achieve balance, meet the life requirements of future generations, and achieve economic development. The Kingdom has taken serious steps to use renewable energy sources in addition to oil and gas within the national energy mix (Alzyadat, 2022a). The government has instituted an energy policy aimed at diversifying energy sources and suppliers and attracting the private sector. As a result, the government has developed and implemented several energy efficiencies projects, with the aim of increasing energy efficiency in the industrial, transportation, and residential sectors (Demirbas, et al 2016).

This study contributes to the existing literature by highlighting the relationship between natural gas consumption and economic growth in one of the largest natural gas producing and consuming countries, the Kingdom of Saudi Arabia. So far - according to the researcher's knowledge - the importance of natural gas consumption for economic growth has not been specifically studied for the Saudi case, with the exception of a study by Akadiri, et al. (2019). This study will be carried out within the framework of economic growth models and the expansion of the production function with capital and labor force, and the inclusion of control variables for economic openness and financial development, the results will be discussed in relation to various hypotheses about the relationship between natural gas consumption and economic growth. Most studies were conducted in a bivariate framework based on the assumption that natural gas is the only major factor in the production, this leads to biased and inconsistent estimates, due to omitted relevant variables that affect economic growth. Therefore, including some other variables in a multivariate framework will provide better and more reliable results for analyzing the relationship between natural gas consumption and economic growth. This study within a multivariate framework applies the ARDL technique, to instigate the symmetric effects of natural gas energy consumption on economic growth. Furthermore, extend the study period to include recent years in which interest in natural gas has increased locally and globally.

Empirical Literature Review

Researches have been conducted to study the link between natural gas consumption (NGC) and economic growth in the contexts for a group of countries or a specific country. Many studies have used panel data while others have used time series data for different time periods. According to the economic model used, studies can be classified into four models. The first model is a bivariate model, the second model is multivariate based on the production function to include capital and labor, the third model is based on expanding the production function to include the indicator of trade and financial development, while the fourth model uses natural gas with several other classified categories of energy such as coal and oil Electricity, etc. Moreover, researchers used different econometric techniques by applying Granger causality, VECM, ARDL, and nonlinear

ARDL techniques to examine the cointegration and causality relationship between the variables in both the short and the long run. The results of empirical studies on the relationship between NGC and economic growth also presented four hypotheses describing this relationship. Conservation Hypothesis, Feedback Hypothesis, growth hypothesis; and Neutrality Hypothesis (Ozturk, 2010).

The growth hypothesis states that energy consumption plays an important role in economic growth either directly or indirectly in the production process as a complement to labor and capital. Therefore, energy is considered a factor of production and thus economic growth, therefore shocks to the energy supply will have a negative impact on economic growth. literatures provided empirical evidence that NGC plays an important role in stimulating economic growth, as natural gas is an essential source of energy and a major determinant of economic growth. the results supported the growth hypothesis that reflects a unidirectional causal relationship from NGC to economic growth, which is known in the literatures the energy consumption-led growth hypothesis. Therefore, any attempt to adopt the Conservation policy to reduce gas utilization would be detrimental to such an economy. Rather, it is to improve the level of natural gas consumption in order to enhance economic growth. Among the studies that confirmed the growth hypothesis: Omisakin, and Olusegun, (2008) for Nigeria. Shaari, et al. (2013) for Malaysia, as well as Akhmat and Zaman (2013), for Bangladesh, Bhutan, India and Maldives. Farhani, et al (2014) for Tunisia. Lach, (2015) for Poland. (Furuoka, 2016; Zhi-Guo, et al. 2018). in the case of China. Destek and Okumus, (2017) for Italy, Japan, UK, and USA. Solarin and Ozturk, (2016) for Iraq, Kuwait, Libya, Nigeria, and Saudi Arabia. (Muhammad, et al. 2011; Ali, et al. 2019; Sohail, et al. 2021) for Pakistan. Rahman, et al. (2020) for China. Foye and Benjamin, (2021) for the selected sub-Saharan African countries. Furthermore, other empirical literatures have demonstrated the positive relationship between NGC and economic growth, i.e., supporting the growth hypothesis, including: Shahbaz, et al. (2013). Hassan, et al. (2018) for Pakistan. Solarin and Shahbaz, (2015) for Malaysia. Galadima and Aminu (2018) for Nigeria. Aydin (2018) for the top 10 natural gas-consuming countries from 1994 to 2015. Wu, et al (2021) for China. Awodumi and Adewuyi (2020) for the consumption of both petroleum and natural gas in Africa's largest oil-producing economies. Etokakpan, et al. (2020) found that a 1% increase in natural gas consumption leads to a 0.02% increase in production in the Malaysian economy.

The feedback hypothesis states that energy consumption and economic growth are jointly determined and affected by each other at the same time. That is, energy consumption promotes economic growth, and at the same time, economic growth stimulates energy consumption. empirical literatures have provided evidence of bidirectional causality between natural gas consumption and economic growth and supported the feedback hypothesis, including: Yang, (2000) for Taiwan. Kum, et al. (2012). for France, Germany, and United States. Lim and Yoo, (2012) for Korea. Heidari, et al. (2013) for Iran. Bildirici and Bakirtas (2014) for Brazil, Russia, and Turkey. As well, (Erdal, et al. 2008; Dogan, 2015) for Turkey. Furuoka, (2016) in the case of Japan. Ummalla and Samal (2019) for both China and India. Sinaga (2019) for Indonesia. Magazzino, et al. (2021) for Germany and Japan. Likewise, Apergis and Payne, (2010) supported the feedback hypothesis for a panel of 67 countries within the period 1992–2005, in both the short- and long-run. as well as Solarin and Ozturk (2016), for a panel of 12 OPEC countries over the period (1980–2012).

The conservation hypothesis holds if an increase in GDP leads to an increase in energy consumption. Therefore, energy conservation policy is implemented with little or no impact on economic growth. Some studies have supported the conservation hypothesis and the existence of a unidirectional causal relationship from economic growth to NGC, where economic growth drives the NGC. Such as (Ghosh & Basu, 2006; Behera, 2015) for India. Payne, (2011) for USA 1949 - 2006. Akhmat and Zaman (2013) for Nepal, Sri Lanka, and Pakistan. Das, et al. (2013) for Bangladesh. Alshehry and Belloumi (2014) for Saudi Arabia. Destek, and Okumus (2017) for Germany. Solarin and Ozturk (2016). for Algeria, Iran, United Arab Emirates and Venezuela.

The neutrality hypothesis means that neither conservative nor expansionary policies regarding energy consumption have any effect on economic growth. some studies have confirmed the neutrality causality relationship between natural gas consumption and economic growth in some countries. Chang, et al. (2016) for the panel of G7 countries 1965 – 2011), excluding the case of the UK. Likewise, (Güvenek, et al. 2017; Erdoğan, et al. 2019) for Turkey. As well as, Arora, (2016) for USA. Sharaf (2016) for Egypt. Destek and Okumus (2017) for Canada and France. Solarin and Ozturk (2016) for Angola and Qatar. Mallick (2009) concluded that no evidence that the various components of energy, including NGC, significantly affect the components of economic growth in India.

The impact of natural gas consumption on economic growth in the short or long run varies according to country, the empirical studies have proven this difference in the results obtained, like Işik, (2010) showed that natural gas consumption positively affects economic growth in the short run and negatively in the long run in Turkey (1977 – 2008). Lash (2015) also concluded, based on quarterly data (2000–2009), that NGC caused short-run GDP growth in Poland. While the long-run causality was in the opposite direction. In the same context, Makala and Zongmin (2019) indicated that there is no long-run relationship between NGC and economic growth in Tanzania. Conversely, Destek (2016) revealed that NGC positively affects economic growth in the long-run in 26 Organization for Economic Co-operation and Development (OECD) countries (1991 – 2013). Dolgopolova, et al. (2014) found that there are long-run relationships between real GDP, labor force, real capital, oil consumption, electricity consumption, gas consumption, and coal consumption for 7 non-OPEC members. Likewise, Fadiran, et al. (2019) confirmed the long-run, rather than short-run, impact of NGC on economic growth in 12 European countries.

Some empirical literatures have relied on growth models to examine the relationship between natural gas consumption and economic growth by expanding the production function to include, in addition to labor and capital, other variables, such as energy consumption. Shahbaz, et al. (2014) concluded that the impact of NGC on economic growth is greater than other factor inputs suggesting that energy is a critical driver of production and growth in Pakistan. also, Dogan, (2015) discovered that for Turkey economy the coefficient estimation of the NGC became smaller in the long run and turned negative in the short run after the exhaustion of capital and labor. Farhani, et al (2014) added capital. Solarin, & Shahbaz, (2015) included foreign direct investment, capital and trade openness. Rafindadi and Ozturk, (2015) investigated the nexus between NGC, exports, capital, labor and economic growth in Malaysia, the results revealed that NGC has an indirect effect on the Malaysian economic growth. Destek (2016) revealed that natural gas consumption, GDP growth, gross fixed capital formation, and trade openness are cointegrated. Farhani, and Rahman. (2019) turned out to be that natural gas consumption, exports, capital and labor are the contributing factors to France's economic growth. Balitskiy, et al. (2016) amended the neoclassical growth model to include capital and labor as explanatory variables the results showed that the increased economic output in the European Union member states leads to increased NGC. Additional NGC requires more investment in infrastructure that would allow natural gas to be processed. However, the increase in natural gas consumption also leads to a decline in economic development. On the other hand, Li, et al. (2019) proven that the higher the level of economic development, the greater impact of natural gas consumption on economic growth.

Most previous studies examined the long- and short-run linear relationship between NGC and economic growth. some researchers measure the nonlinear correlation. Hu, and Lin, (2008) emphasized the long-run nonlinear equilibrium relationship between GDP and energy consumption in Taiwan, when energy consumption exceeds a certain threshold level in the energy-inefficient periods in which energy consumption grows faster than GDP. also, Galadima, and Aminu. (2018). estimated the value of the NGC threshold in Nigeria, and found that the level of consumption is less than the optimal level. The same authors Galadima and Aminu, (2019) examined the asymmetric effects of NGC on economic growth, the increase in NGC can stimulate long-run growth and the negative impact is minimal. Therefore, energy conservation policies do not lead to a decline in economic growth. In 2020, the same researchers did another study on Nigeria, Galadima, and Aminu (2020) concluded that NGC and economic growth follow a non-linear process. The positive change of NGC is consistent with the "feedback hypothesis" and the negative effect of NGC is consistent with the conservation hypothesis. Sohail, et al. (2021) found evidence that positive changes in NGC and financial development boost Pakistan's economic growth.

In the Saudi context. Despite the importance of natural gas consumption and production in the Saudi economy, the empirical evidence on the relationship between natural gas consumption and economic growth in Saudi Arabia is still less explored and limited, except for some studies that dealt with the Saudi issue with the OPEC group or the Gulf Cooperation Council, or in the context of carbon dioxide emissions Alshehry, and Belloumi, (2014) used the multivariate cointegration approach to study the causal relationships between fossil fuels consumption, CO_2 emissions, and economic activity. The results supported the conservation hypothesis. The study suggested that energy conservation policies might be enforced without affecting economic growth. While in another study on 12 OPEC countries over the period (1980-2012), by Solarin, and Ozturk, (2016). showed evidence for the feedback hypothesis in a panel OPEC country and the growth hypothesis in Saudi Arabia. Ozturk, and Al-Mulali, (2015) added trade openness, labor force, and gross fixed capital formation as determinants of GDP growth in the Gulf Cooperation Council countries 1980-2012. The results supported the feedback hypothesis and the positive effects of the NGC on the

GCC country's economic growth in the long run. Akadiri, et al. (2019) Examineded the contribution of NGC and trade to the real GDP of Saudi Arabia over the period 1968-2016, using the ARDL method, found a long-run co-integration relationship between NGC, trade, and real GDP. The study also confirmed the Growth hypothesis. The study suggested that the policy of preserving natural gas will harm the demand for natural gas, impede total trade and thus delay domestic output.

Economic model specification and data source

Energy economists assert that energy is a necessary factor in the production process since it acquires all the characteristics of a factor of production, the result is that production is determined by energy, stock capital, and labor. Robert Solow in 1956 introduced a simplified model that relied on the production Cobb-Douglas function to develop a framework for the causes of growth (Solow, 1956). Then, in 1957, noting that the rate of growth occurs due to a set of growth rates in other factors of production beyond physical and human capital, which is technical progress (Solow, 1956). according to Solow model, the production function takes the following form:

$$Y = A.f(K, L, T)$$

The variable T for time appears in the function to allow for technological change, The usage of energy determines technological change, empirical works and theoretical concepts assume that energy can be taken as a part of technology (Balitskiy, 2016) with the following aggregate production function:

$$GDP = f(K, L, E)$$

This study is Based on the neoclassical economic growth theory, following: (Furuoka, 2016; Hassan, et al. 2018; Luqman, et al. 2019; Fadiran, et al. 2019; Farhani, & Rahman, 2019; Li, et al. 2019; Awodumi & Adewuyi, 2020; Foye & Benjamin, 2021). Energy is an input in the production process, since the economy is driven by an increase in energy demand, The expanded production function according to which output growth is a function of capital stock, labor and energy is an input in the production process, and since the economy is driven by an increase in energy consumption, (Lee & Chang, 2008; Pirlogea & Cicea, 2012). Then modified production function.

$$GDP = f(K, L, E)$$

Rewritten the function using the Cobb Douglas production function form as:

$$GDP = AK^{\gamma_1}L^{\gamma_2}E^{\gamma_3}e^{\mu}$$

Then extended the model with control variables. Flowing (Furuoka, 2016; Farhani, et al. 2014; Farhani & Rahman, 2019; Foye & Benjamin, 2021). Added trade openness TO, measured by aggregates of imports and exports. Following, Sohail, et al. (2021) adding bank credit (BC) to the private sector in the economic model to represents the financial sector development. Bank credit is the main source of investment financing and thus affects aggregate demand, which ultimately boosts economic growth (Alzyadat & Alwahibi, 2021). Therefore, the extended model is expressed as:

$$GDP = (K, L, NGC, TO, BC)$$

Where GDP represents the real gross domestic product and measures for economic growth, NGC is natural gas consumption in billion cubic feet, K denotes capital and it is measured by gross fixed capital formation, L represents labor, measured by the number of labor force. TO trade openness, (BC) bank credit to the private sector. The economic model has been converted to logarithmic form to facilitate the estimation and interpretation of the regression coefficients

$$LinGDP_t = \gamma_0 + \gamma_1 LinK + \gamma_2 LinL + \gamma_3 LinNGC + \gamma_4 LinTO + \gamma_5 LinBC + \varepsilon_t$$

To assess the linear short and long-run relationships between the NGC and economic growth, this study like: (Furuoka, 2016; Farhani, et al. 2014; Farhani, & Rahman, 2019; Foye & Benjamin, 2021: among others). applies the Autoregression Distributed lags approach (ARDL) suggested by Pesaran and Shin (1998) and Pesaran et al. (2001). ARDL is a linear time series models where both the dependent variable and the explanatory variables are related not only concurrently, but also with their lagging values. Hence, the general form of the symmetry and structural break effects in short-run and long run as proposed by Pesaran and Shin (1998) is written as:

$$\Delta Y_t = \delta_{0i} + \delta_1 Y_{t-i} + \delta_2 X_{t-i} + \sum_{i=1}^{q} \alpha_1 \Delta y_{t-i} + \sum_{i=1}^{k} \propto_2 \Delta X_{t-i} + \varepsilon_{it}$$

Where Xs are the explanatory variables, and Y is the dependent variable, `q and k are the numbers of maximum lag order in the *ARDL* model. The maximum lag lengths of *q* and *k* for the dependent and explanatory variables, respectively. The ARDL bound test approach is to redefine the economic model as error correction model:

$$\Delta LinGDP_t = \gamma_0 + \gamma_1 LinGDP_{t-1} + \gamma_2 LinK_{t-1} + \gamma_3 LinL_{t-1} + \gamma_4 LinNGC_{t-1} + \gamma_5 LinTO_{t-1} + \gamma_6 LinBC_{t-1} + \sum_{i=1}^{p} \delta_1 \Delta LinGDP_{t-i} + \sum_{i=0}^{p} \delta_2\, \Lambda LinK_{t-i} + \sum \delta_2 \Delta LinL_{t-i} + \sum_{i=0}^{p} \delta_3 \Delta LinNGC_{t-i} + \sum_{i=0}^{p} \delta_5 \Delta LinTO_{t-i} + \sum_{i=0}^{p} \delta_6 \Delta LinBC_{t-i} + \varepsilon_t$$

Where (δ1 – δ6) represent the coefficients of short run dynamics relationships of the underlying variables in the model. ε is the speed of short run adjustment of the model's convergence to long run equilibrium, the error correction term (ECT). The short-run coefficients can then be derived from the following corresponding error correction model:

$$\Delta LinGDP_t = \sum_{i=1}^{p} \delta_1 \Delta LinGDP_{t-i} + \sum_{i=0}^{p} \delta_2\, \Lambda LinK_{t-i} + \sum \delta_3 \Delta LinL_{t-i} + \sum_{i=0}^{p} \delta_4 \Delta LinNGC_{t-i} + \sum_{i=0}^{p} \delta_5 \Delta LinTO_{t-i} + \sum_{i=0}^{p} \delta_6 \Delta LinBC_{t-i} + \delta_7 EC + \varepsilon_t$$

The null and alternative hypotheses are as follows: $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ no short run relationship exists. Against the alternative hypothesis $H_A: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$ the short run relationship exists. Where ($\gamma 1 - \gamma 6$) represent the coefficients of the long-run relationships, p is the lag order of the variables are defined as before. The bounds test for the absence of any level relationships between the dependent and independent variables is through the exclusion of the lagged level variables. That is, it involves the following null and alternative hypotheses

$$LinGDP_t = \gamma_0 + \gamma_1 LinGDP_{t-1} + \gamma_2 LinK_{t-1} + \gamma_3 LinL_{t-1} + \gamma_4 LinNGC_{t-1} + \gamma_5 LinTO_{t-1} + \gamma_6 LinBC_{t-1} + \varepsilon_t \mathrm{T}$$

The null and alternative hypotheses are as follows: $H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = 0$ no long run relationship exists. Against the alternative hypothesis $H_A: \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq 0$ the long run relationship exists.

The study employs annual secondary data from different sources including Saudi Central Bank and World Development indicator (WDI). The dependent variable is economic growth measured by Gross Domestic Product (GDP). While the independent variables are NGC, gross-fixed capital formation, labor force, trade openness, and financial development proxy with the bank credit to private sector. The data cover a period from 1990 to 2021. The study adopts ARDL approach for data analysis.

Interpretation of the results

Descriptive quantitative statistics (Table 1) reveal that the average, maximum, minimum value, and the standard deviation of real gross domestic product (GDP) representing economic activity, NGC, gross-fixed capital formation, labor force, trade openness, and financial development proxy with the bank credit to private sector. Moreover, Figure 1 shows the development of real domestic product and natural gas consumption in Saudi Arabia during the study period. The general trend of variables appears to be an increase with a slight decrease in some years. This indicates the growth of gas consumption in Saudi Arabia during the period (1990-2021)

Table 1. Descriptive quantitative statistics

	RGDP	K	L	NGC	BC	EX	IM
Mean	1816247.	335971.2	8801866.	421542.9	628137.0	618976.3	303216.9
Median	1731006.	237691.0	7953098.	416897.0	452501.0	651952.0	222985.0
Maximum	2639811.	732432.0	14455587	718455.0	1782590.	1456502.	655033.0
Minimum	1102228.	83251.00	5028454.	162697.0	67119.00	145388.0	87193.00
Std. Dev.	515225.5	241473.6	3270032.	184878.5	544941.3	434104.6	207716.6
Jarque-Bera	3.282894	3.898172	3.272178	2.655245	3.539914	2.760390	3.629171
Probability	0.193700	0.142404	0.194740	0.265107	0.170340	0.251530	0.162905
Sum	56303669	10415106	2.73E+08	13067829	19472248	19188265	9399723.
Sum Sq. Dev.	7.96E+12	1.75E+12	3.21E+14	1.03E+12	8.91E+12	5.65E+12	1.29E+12

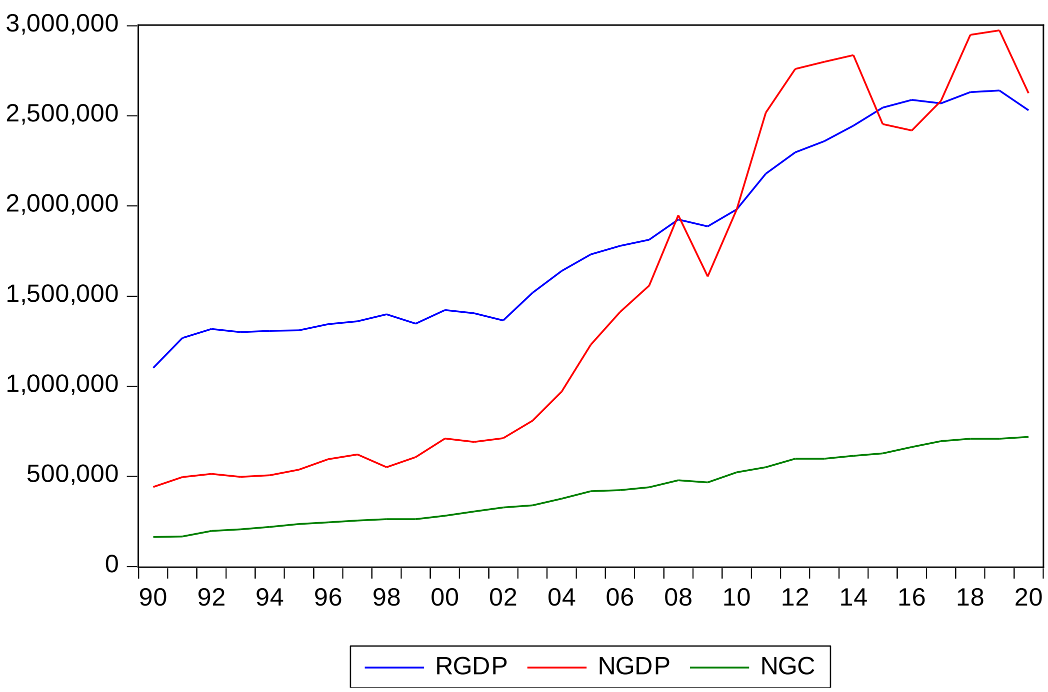

Figure 1 the RGDP, NGDP and NGC in Saudi Arabia

The study employs the Augmented Dicky-fuller to test the unit root. Table 2 presents the unit root test for the individual series The results show that the occurrence of unit root at 1st difference for all the variables, the results are also statistically significant at the 5% level of significance, this indicates that the variables stationarity at 1st difference and not at levels. Conducting cointegration tests requires that the variables be integrated of the same degree, in this case, it cannot be performed in the presence of variables that are integrated to different degrees, i.e. I(0), I(1), so the Autoregressive Distributed Lag Model (ARDL) appeared. As the best alternative because it does not require that the variables be of the same order of integration and do not exceed I(1).

Table 2. Unit Root Augmented Dickey-Fuller Test

Variable	Level		1st difference		Order of integration
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
NGC	0.486233	-2.180952	-6.079435 *	-6.039594 *	I (1)
RGDP	-0.361206	-1.391532	-3.979233 *	-3.936062 *	I (1)
K	-0.402626	-3.889033 *	-3.555838 *	-3.436322 *	I(0) I (1)
L	-1.167508	-2.534084	-3.679322	-4.309824*	I (1)
BC	1.771607	-0.969270	-1.826870	-3.588101*	I (1)
TO	-1.233032	-1.467259	-4.202794*	-4.155541*	I (1)

* Means that it is significant at the level of 5%

The optimal lag structure for the adopted model is determined as (2, 3, 3, 3, 3, 3), indicating the lag lengths for each variable. The Bounds test of long-run co-integration between economic growth and natural gas consumption and other variables reported in table 3. based on the critical F-statistic values for the lower and upper bounds. The results show that the null hypothesis of the long-run relationship is rejected at the 5% level of significance as the F-value of 7.66 exceeds critical values for 1(0) and I(1) respectively. This means that there is a long-run equilibrium relationship between economic growth and economic variables under study. After confirming the existence of a long-run equilibrium relationship, the model can be estimated, which consists of two parts. Table (5) shows the estimation of the short-run error correction model, while Table (6) shows the estimation of the long-run relationship.

Table 3 The Bounds test of long-run co-integration

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	7.660454	10%	2.08	3
K	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

The granger causality test Results in Table 4, the results indicate evidence of causality from NGC to GDP which is significant at 5% (P = 0.0418) the results supported the growth hypothesis in KSA that reflects a unidirectional causal relationship from NGC to economic growth, which is known in the literatures the energy consumption-led growth hypothesizes

Table 4 The granger causality test Results

Pairwise Granger Causality Tests		
Null Hypothesis:	F-Statistic	Prob.
LNNGC does not Granger Cause LNRGDP	3.63534	0.0418
LNRGDP does not Granger Cause LNNGC	2.61996	0.0935

The short-run results and starting with NGC, the short-run effect is positive and significant at 5% Table 5. A significant short-run effect is also observed for D(LNNGC(-1)), which is significant at 5%. It can be explained economically by saying that an increase in natural gas consumption leads to an increase in the gross domestic product, the results supported the growth hypothesis in KSA that the NGC contributes economic growth, The finding is in line with. Shahbaz, et al. (2014) concluded that the impact of gas consumption on economic growth is greater than other factors of production suggesting that energy is a critical driver of production and growth in Pakistan .there is also a direct and significant relationship between capital accumulation and economic growth, which is consistent with the economic theory that confirms that an increase in capital accumulation leads to an increase in the productive capacity of the economy and thus economic growth. Also, the results show that trade openness TO, measured by aggregates of imports and exports D(LNTO), D(LNTO(-1)) and D(LNTO(-2)) are all significant at 5% Its effect is direct and consistent with theory and economic reality. KSA depends on imports and exports, especially oil exports in high proportions, therefore higher trade openness means increased economic growth. D(LNBC(-1)) and D(LNBC(-1)) showed positive short-run coefficients. This can be explained economically by the fact that increasing bank credit for previous periods leads to an increase in investment financing and thus achieving economic growth rates for the current period. This finding is consistent with Alzyadat (2021) which showed that bank credit facilities in various sectors played an important role in promoting non-oil economic growth in the KSA, As well as the Alzyadat (2022b), which showed that the expansion of bank credit enhanced economic growth in KSA. Also, the results show that D(LNL, D(LNL(-1)) and D(LNL(-2)) are all significant at 5%

with negative short-run coefficients, respectively. The ECM has the expected negative sign (−1.016) and significant at 5% (P = 0.0001), which suggest that 100% of short-run dynamics are corrected within one year. On the overall, the study provides evidence that natural gas consumption and the economic variables under study have significant relationship with economic growth in KSA. Hence the null hypothesis is rejected. However, the effect is not the same for all variables.

Table 4 ARDL Error Correction Regression

Selected Model: ARDL(2, 3, 3, 3, 3, 3)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNNGDP(-1))	1.513564	0.155003	9.764766	0.0002
D(LNK)	0.213782	0.044750	4.777203	0.0050
D(LNK(-1))	-0.230010	0.058566	-3.927347	0.0111
D(LNK(-2))	-0.350933	0.049791	-7.048155	0.0009
D(LNL)	-2.548422	0.292700	-8.706589	0.0003
D(LNL(-1))	-0.826164	0.316305	-2.611923	0.0476
D(LNL(-2))	-4.198670	0.423318	-9.918479	0.0002
D(LNNGC)	1.601456	0.145684	10.99270	0.0001
D(LNNGC(-1))	-1.508513	0.172915	-8.723995	0.0003
D(LNNGC(-2))	-0.802954	0.114216	-7.030122	0.0009
D(LNBC)	-0.888702	0.087792	-10.12278	0.0002
D(LNBC(-1))	0.905623	0.101504	8.922019	0.0003
D(LNBC(-2))	0.515458	0.059761	8.625273	0.0003
D(LNTO)	0.598162	0.021237	28.16560	0.0000
D(LNTO(-1))	-0.823352	0.077051	-10.68574	0.0001
D(LNTO(-2))	0.132688	0.024068	5.513123	0.0027
CointEq(-1)*	-1.016267	0.093566	-10.86145	0.0001
R-squared	0.997308	Mean dependent var		0.058284
Adjusted R-squared	0.993392	S.D. dependent var		0.115901
S.E. of regression	0.009421	Akaike info criterion		-6.211724
Sum squared resid	0.000976	Schwarz criterion		-5.402886
Log likelihood	103.9641	Hannan-Quinn criter.		-5.964454
Durbin-Watson stat	2.930319			
* p-value incompatible with t-Bounds distribution.				

Table (5) shows that the probability values for all parameters of economic variables in the long run are less than 0.05, i.e. reject the null hypothesis. This means that all parameters are statistically significant at the 5% level of significance, so the relationship between economic growth and other variables can be interpreted as a significant relationship. as well the long-run results show the positive impact of natural gas consumption on economic growth in KSA, as shown in Table 5. The result indicates that a 1% increase in natural gas consumption leads to an increase in GDP by about 2.2%, the results supported the growth hypothesis in KSA that the NGC contributes economic growth, the finding is in line with Solarin, and Ozturk, (2016). showed evidence the growth hypothesis in Saudi Arabia. the results also show that capital accumulation, labor force and economic openness contribute to stimulating economic growth in Saudi Arabia in the long term, while the results show the negative impact of bank credit on long-run economic growth, This is consistent with Alsalamat and Alzyadat (2023), which showed that bank-based financial development has an unclear impact on economic growth in the KSA, While market-based financial development promoted economic growth.

Table 5 ARDL Long Run Test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNK	1.084271	0.271022	4.000667	0.0103
LNL	0.780509	0.268672	2.905064	0.0336
LNNGC	2.160464	0.767040	2.816623	0.0373
LNBC	-1.806345	0.580412	-3.112175	0.0265
LNTO	0.561642	0.142126	3.951724	0.0108
C	-23.71402	6.931170	-3.421358	0.0188

EC = LNNGDP - (1.0843*LNK + 0.7805*LNL + 2.1605*LNNGC -1.8063 *LNBC + 0.5616*LNTO -23.7140)

The stability and changes in data structure were tested through Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUMQ) tests, these two tests are considered among the most important tests in this field because they clarify two important things, namely, showing the presence of any structural change in the data and the extent of stability and consistency of the long-run parameters with the short-run parameters. studies have shown that such tests are always found accompanying the (ARDL) methodology. The results depicted in Figures 2 and 3. The line chart for both tests lies within the two red lines that represent the critical bounds at 5% significance level, indicating the stability of the estimated parameters as well as the non-existence of structural break.

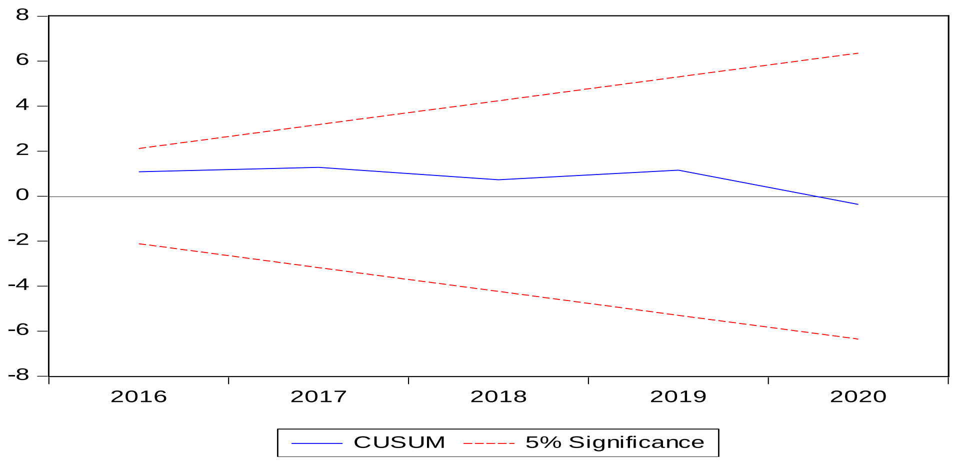

Figure 2: CUSUM results

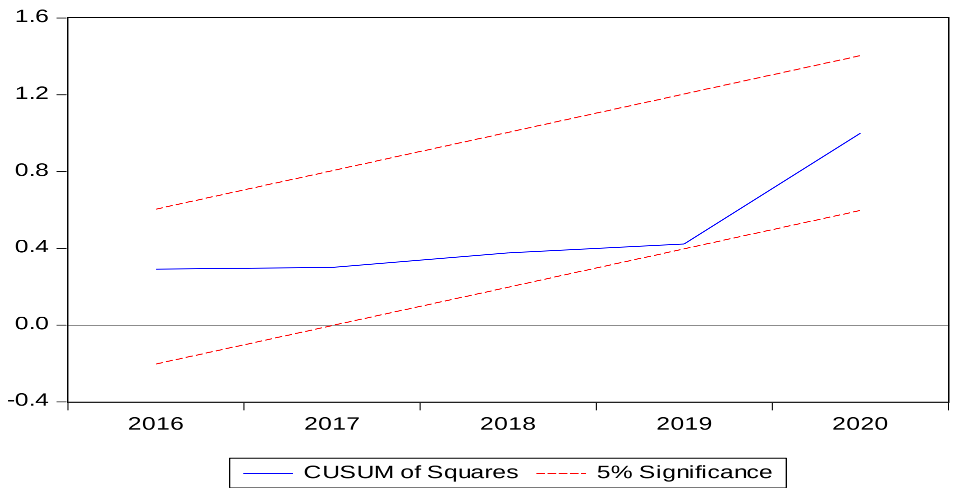

Figure 3: CUSUMQ results

Conclusion and policy recommendations

Natural gas plays a vital role in the process of energy transition and the elimination of carbon emissions harmful to the environment, in parallel with the trend towards renewable energy sources. Natural gas has been a major supporter of the transition to clean energy, although it is one of the fossil fuels. It can be described as an alternative in reducing carbon, whether by saving energy or utilizing gas infrastructure to transport clean fuels. Natural gas is the cleanest and fastest-growing fossil fuel, contributing nearly a third of total energy demand growth over the past decade. Natural gas offers a number of environmental benefits compared to other fossil fuels, particularly in terms of air quality, Global Warming, gas emissions. researches have been conducted to study the link between natural gas consumption (NGC) and economic growth in the contexts for a group of countries or a specific country. The results of empirical studies on the relationship between NGC and economic growth presented four hypotheses describing this relationship namely: Conservation Hypothesis, Feedback Hypothesis, growth hypothesis; and Neutrality Hypothesis.

Saudi Arabia is the world's largest exporter of crude oil and has the fourth-largest natural gas reserves in the world. Saudi Arabia supports the natural gas industry to meet the increasing demand for energy and energy production, which is the preferred fuel and water desalination.

This paper investigates the symmetric relationship between natural gas consumption and economic growth in Saudi Arabia over the period 1990–2021 by extending the production function including capital, labor, trade, and financial development.

The granger causality test provides evidence of the causality from NGC to GDP the results supported the growth hypothesis in KSA that reflects a unidirectional causal relationship from NGC to economic growth, which is known in the literatures the energy consumption-led growth hypothesizes. the short-run effect is positive and significant and supported the growth hypothesis in KSA that the NGC contributes economic growth, The finding is in line with. Shahbaz, et al. (2014). On the overall, the study provides evidence that natural gas consumption, capital, labor, trade, and financial development have significant relationship with economic growth in KSA. the long-run results show the positive effect of natural gas consumption on economic growth in KSA. The result indicates that a 1% increase in natural gas consumption leads to an increase in GDP by about 2.2%, the results supported the growth hypothesis in KSA that the NGC contributes economic growth, the finding is in line with Solarin, and Ozturk, (2016). the result also shows that capital accumulation, labor force and economic openness contribute to stimulating economic growth in Saudi Arabia in the long run, while the results show the negative impact of bank credit on long-run economic growth.

The study suggests that it is possible in the near future that KSA will be able to meet its energy needs by adopting renewable energy alternatives. However, energy policies should be implemented sufficiently to promote economic growth In line with achieving the Kingdom's Vision 2030.

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