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The Price and Income Elasticity of Demand for Natural Gas Consumption in Saudi Arabia

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ABSTRACT

Natural gas consumption in Saudi Arabia (KSA) has grown at an annual rate of approximately 7% as a result of population growth and other economic and non-economic factors. This study aims to estimate the short- and long-run price and income elasticities of natural gas demand in Saudi Arabia using time series data from 1990 to 2020, applying the Autoregressive Distributed lag Procedure (ARDL). Employ an Error-correction model to obtain estimates of adjustment speeds with long and short-run elasticities. The elasticity of demand for natural gas was calculated by including population growth as a control variable. The short-run dynamics evaluated indicate that the speed of adjustment is 70% annually, the long-run income and the price elasticities are 0.0002 and −2.09 respectively. The short-run income and price elasticities are 0.0002, −1.17 respectively. This means that price changes have a greater impact on natural gas demand than changes in income in the short and long run. Population growth has contributed to the increase in natural gas consumption in Saudi Arabia in the short and long run. In general, based on the results, the trend of Saudi Arabia to increase the consumption of natural gas needs to maintain low prices, due to the high price elasticity of demand.

Keywords: Saudi Arabia, Natural Gas Consumption, Income Elasticity, Price Elasticity, ARDL
JEL Classifications: N55, N73, O13, Q31, Q41

1. INTRODUCTION

The world is witnessing an increasing demand for energy utilization, so the energy problem, as well as the environmental problem, has become a major topic in global energy and environmental policy discussions globally. The demand for energy increases with population growth and other economic and non-economic factors and leads to an increase in global warming and climate changes due to the continuous emission of greenhouse gas emissions into the atmosphere. Hence, global warming and climate change remain two sources that threaten global energy sustainability (Akintande et al., 2020). At the same time, the world is witnessing an energy transition from high-carbon fuels to non-renewable, low-carbon energy options The energy transition also entails a strong move toward increasing ecosystem sustainability (Chikezie, 2020). Natural gas is characterized as the least emitting fossil fuel. And a low carbon content; Thus, it links fossil fuels with renewable fuels (Solarin and Ozturk, 2016), Natural gas is also the cleanest and richest in hydrogen among all hydrocarbon energy sources, and it has high efficiency in energy conversion for power generation.) Economides and Wood, 2009). Therefore, Natural gas is seen as a transitional fuel from hydrocarbons to renewable energy sources. The competitiveness of natural gas has increased recently, outpacing the growth rate of other non-renewable energies (Chen et al., 2019). Natural gas is not only used in household units, but also in economic sectors, especially industrial ones. In addition, natural gas is alternative energy for electricity generation due to its efficiency (Solarin and Ozturk, 2016) Natural gas can be produced and consumed locally or imported and exported to and from other countries, to meet diversified demands (Chen et al., 2019).

Natural gas will play a major role in the energy transition in the future, thus enhancing the position of renewable energy sources in protecting the climate, and ensuring that the largest number of the world's population has access to electricity. Figure 1 shows the percentage of oil and natural gas consumption of the total energy consumed in the world, where the percentage of natural gas consumption increased from 16% in 1965 to about 24% in 2019 compared to a decrease in the percentage of oil consumption of the total energy consumed from 41% in 1965 to 33% in 2019.

The demand function for a commodity in the theoretical literature is a function of income and its price, other determinants are given, as well as the function of demand for energy (Bilgili, 2014. literature has analyzed the relationship between natural gas consumption and economic growth, the research still has to identify the factors that have enhanced the competitiveness of natural gas consumption, as well as knowing the factors that determine the demand for natural gas, import and export (Chen, et al. 2019) the Price and income elasticities of supply and demand are key inputs for many projections of energy consumption and production (Arora, 2014).

Natural gas consumption has grown rapidly in recent years in Saudi Arabia, in line with population growth, increased economic activity, investments in infrastructure, and local prices. Figure 2 shows that the Saudi Arabia's consumption of natural gas reached 6 million barrels in 1977 and continued to rise until it reached 604.88 million barrels in 2020, an increase of 4.3% over 2019 which amounted to 579.74 million barrels, and it constituted 44.7% of the total domestic total energy consumption. Saudi Arabia occupies sixth place globally by the end of 2020, accounting for 4.5% of the world's natural gas reserves, which amount to 7,298.9 trillion standard cubic feet. As the Saudi reserves of natural gas increased by the end of 2020 by 0.4% (1.2 trillion standard cubic feet), to reach 326.1 trillion standard cubic feet, compared to 324.5 trillion standard cubic feet at the end of 2019.

Saudi Arabia is one of the most important gas producers in the world to be added to its position as the most important oil producer. Saudi Arabia's programs in developing renewable energies will lead to the best consumption of energy types locally and support its position in protecting and sustaining the environment. It enhances the continuation of development efforts, economic diversification, and exploitation of Saudi Arabia's comparative advantages and strengthens its leading position in the global energy market. Despite the growing interest in natural gas in Saudi Arabia, so far, there are no studies that have explored the determinants of Saudi demand for natural gas by estimating the price and income elasticity of natural gas demand. Moreover, studies of natural gas demand in Saudi Arabia are still very few. Efforts have been made to model the demand for other sources of energy, especially electricity. Previous attempts have been made to model aggregate electricity demand (Mikayilov et al., 2020a, 2020b). Or studies on aggregate industrial energy demand in Saudi Arabia (Alarenan et al., 2020).

2. LITERATURE REVIEW

A large number of studies have estimated the price-income elasticity of natural gas demand at the aggregate level in different countries and regions for different periods using different econometric approaches, with conflicting and varied results.

Eltony (1996) Estimates of natural gas demand in Kuwait for the period 1975-93 using the cointegration and error correction model. It has been found that the demand for natural gas is inelastic with respect to price and income in the short and long run. Yoo et al. (2009)

Figure 1: Ratio of oil and natural gas to total energy consumption

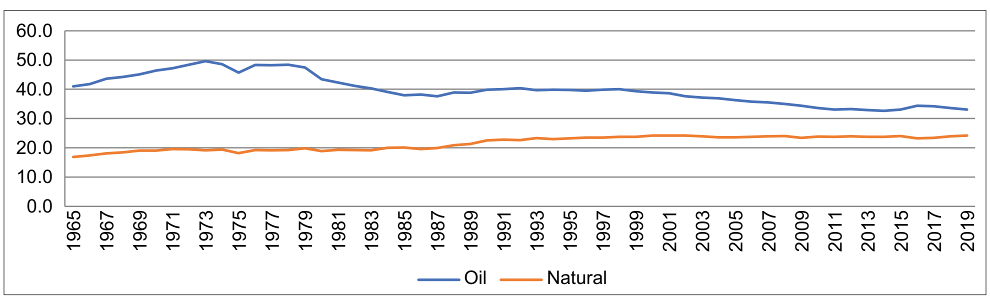
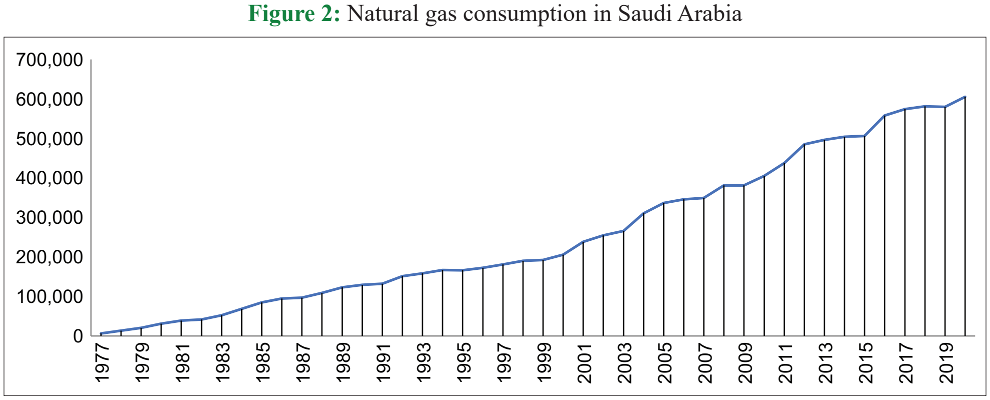


Figure 2: Natural gas consumption in Saudi Arabia



Used data from a household survey in Seoul, household income has a positive impact on natural gas demand. While the price of gas hurts the natural gas demand. The results of Erdogdu (2010) showed that the price and income elasticity of sectoral demand for natural gas in Turkey in the short and long run is low, that is, consumers do not respond to higher prices by reducing their demand or substituting natural gas with other energy sources. While the results of Wadud et al. (2011) showed a significant long-run income elasticity of about 1.5 of the aggregate demand for natural gas in Bangladesh Also, in a study of the impact of economic and non-economic factors on the demand for natural gas in Ghana, Ackah (2014). indicates that the estimated short-run price elasticity of total demand for natural gas is −0.36, while the short-run income elasticity is 0.38. The long-run price and income elasticities are −1.81 and 1.95 respectively. As well as Bilgili (2014) confirmed that the consumption of natural gas follows the law of demand, for a pane data of the eight- OECD countries, where estimates indicated the high sensitivity of natural gas consumption to income and price in the long run. Further, Dilaver et al. (2014) Findings indicate that income and natural gas prices play a significant role in increasing natural gas consumption in OECD countries and Europe during the period)1978-2011), The long-run estimated income and price elasticities were 1.19 and −0.16, respectively. Khan (2015) concluded that consumer indifference towards the escalation of natural gas prices in Pakistan during the period 1978-2011. Whereas real GDP per capita has a greater impact on gas consumption than its price. The short and long-run price elasticities and cross elasticities are also relatively low.

A number of literatures have applied econometric approach in estimating the income and price elasticities of demand for natural gas in the residential sector, including Bernstein, and Madlener (2011) Analyze residential natural gas demand in twelve OECD countries using ARDL technique and error correction model, the long-run income and price elasticities are 0.94, −0.51 respectively. In the short run, the income and price elasticities are 0.45, −0.24 respectively.

Payne et al. (2011) estimates the demand for residential natural gas in the state of Illinois using the ARDL approach and annual data (1970-2007). The study reveals that the real residential natural gas price elasticity in the short and long run is <1 in absolute value and statistically significant. While the long-run elasticity estimates are larger than the short-run elasticity estimates.

Yu et al. (2014) estimated the price and income elasticity of residential demand for natural gas in China. The study found that natural gas consumption is price-elastic and income-inelastic. In addition, there are significant differences in demand behavior across regions of China. There is a significant income impact on natural gas demand in Southern China, while the price effect in the northern region was found to be higher. In addition, the substitution effect between coal and natural gas is significant in North China but not significant in South China also, Chai et.al (2018) found that the price elasticity of demand for natural gas in China are -1.52 and 0.41 in the short and long term, respectively. While Dong et al. (2019) indicate that the demand for natural gas in China is positive price elasticity. Moreover, China's natural gas demand is becoming more sensitive to income changes. The results also indicate significant differences in the price and income elasticity of demand for natural gas across regions of China. Natural gas demand is more price elastic in southwest China and northwest China.

Zeng et al. (2018) estimate the price elasticity of natural gas demand for households and investigate the factors that affect residential natural gas consumption in China. The non-residential natural gas price has been adopted as the instrumental variable for residential natural gas price. Results demonstrate that the natural gas demand of Chinese households responds significantly to the price change, with an overall price elasticity coefficient of 0.898.

Some studies estimate income and price elasticity of demand for natural gas in other economic sectors, such as Gautam and Paudel (2018) examine the demand for natural gas in the residential, commercial, and industrial sectors of the Northeastern United States, comprising nine states, and using annual state-level panel data over the period 1997-2016. The results show that the long-run own-price elasticities for natural gas in residential, commercial, and industrial sectors are −0.14, −0.29, and −0.28, respectively. The cross-price elasticities of fuel oil for natural gas demand in residential, commercial, and industrial sectors are 0.19, 0.52, and 0.24, respectively. In the long-run natural gas demand is not affected by income in all three sectors.

Andersen et al. (2011) estimates the response of manufacturing sectors' natural gas demand to price and output changes in selected OECD countries. The results show that price and output elasticities are heterogeneous within the same manufacturing sector across countries. Furthermore, output shocks have larger negative effects on gas demand than natural gas prices.

Rajabi and Mousavi (2019) studied the long-run determinants of demand for industrial natural gas in 15 OECD countries during 1991-2016. The majority of the results indicate that the demand for natural gas in the industrial sector is inelastic to price and income, but income is higher elasticity than price and price elasticity higher than the cross-fuel price elasticity. Altinay and Yalta (2016) revealed that the elasticity of natural gas demand does not remain constant, but rather is sensitive to the economic situation and weather fluctuations.

The previous studies of natural gas demand mentioned above indicate that there is a diverse elasticity of demand for natural gas across countries. In addition, there are no attempts to study the elasticities of demand for natural gas in Saudi Arabia. This study contributes to the previous studies that attempt to model the effect of price and income on the demand for natural gas in Saudi Arabia.

3. METHODOLOGY

To estimate the price and income elasticities of demand for natural gas in Saudi Arabia, the basic demand natural gas demand generally be expressed as a function of several determinants, linking per capita natural gas demand to the price of natural gas and per capita income:

$$NG_t = f(Y, P, X)$$

Where NG is natural gas consumption per capita, Y is per capita income, P is the natural gas price and X stands for further control variables the estimators of the price and income elasticities of demand for natural gas. income and the price are the main drivers of energy demand there are some other factors that affect energy demand such as technological progress, consumer tastes and preferences, demographic and social structure, environmental regulations, and economic structure (Dilaver et al., 2014). The price of electricity is also considered as a substitute for natural gas (Bernstein and Madlener, 2011). *POP* is the population as a proxy of the number of consumers Chen et al. (2019). Changes in economic activity also led to an unexpected change in the demand for natural gas due to the shock of economic activity (Arora, 2014).

Based on the single-equation of market demand which states that per capita natural gas demand is positively related to per capita real income, the average real price of natural gas, and real prices of substitutes (Khan, 2015).

Several functional forms are possible for the demand function. These functional forms define the mathematical relationship between the demand and its determents' variables. Since Cobb–Douglas function is the most form used for demand modeling. In such models, the parameter estimates of the explanatory variables directly give the elasticities of demand with respect to those variables. Also, log-linear models better represent the non-linear nature of the variables. According to the Cobb–Douglas function, the natural gas demand is given by (Wadud et al., 2011).

$$NG = A(Y^{\propto}, P^{\beta}, POP^{\gamma})$$

Taking logarithm on both sides, and considering the error term

$$Ln\,NG = A + \alpha\,LnY + \beta\,Ln\,P + \gamma\,Ln\,POP + \varepsilon_t$$

The natural gas demand does not respond immediately to increases in the explanatory variables. therefore, there is a lag between demand and the explanatory variables, which cannot be captured by the static models. In order to account for the dynamic time-dependent nature of natural gas demand, the study uses a dynamic model lagged dependent variable among the explanatory factors. The parameter estimates of a partial adjustment model also have useful interpretations of short and long-run elasticities (Wadud et al. 2011).

The autoregressive distributed lag model (ARDL) methods often used in the study of the relationship between energy and its related variables The ARDL has been used by many scholars (Payne et al., 2011; Bernstein and Madlener, 2011).

The ARDL was proposed by Pesaran and Shin (1998) and Pesaran et al. (2001) is as follows:

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

Where Y is the dependent variable, Xs are the explanatory variables. The maximum lag lengths of *q* and *k* for the dependent and control variables. Rewrite the ARDL technique as a conditional error correction model ECM:

$$\Delta LinNG_t = \gamma_0 + \gamma_1 LinNG_{t-1} + \gamma_2 LinY_{t-1} + \gamma_3 LinP_{t-1} + \gamma_4 LinPOP_{t-1} + \sum_{i=1}^{p} \delta_1 \Delta LinNG_{t-i} + \sum_{i=0}^{p} \delta_2 \Lambda LinY_{t-i} + \sum \delta_3 \Delta LinP_{t-i} + \sum_{i=0}^{p} \delta_4 \Delta LinPOP_{t-i} + \varepsilon_t$$

Where (δ1 – δ4) represent the coefficients off short-run relationships of the variables in the model. ε the error correction term (ECT) the speed of short-run adjustment of the model's convergence to equilibrium in the long-run, it has to be statistically significant and negative to show that the variables were converted to the long-run equilibrium. Short-run elasticities can be derived from the model. Test the hypothesis H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$. against H_A: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$. While ($\gamma_1 - \gamma_4$) represent the of the long-run coefficients, p is the lag length order of the VAR. The bounds test procedure for the relationships between variables after excluding the lag level for the variables. Testing the hypotheses: H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ against H_A: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq 0$.

The study employs annual secondary data from Central Bank of Saudi Arabia. the study applies the ARDL technique to estimate the short and long run elasticities for the period (1990-2020).

4. RESULTS AND INTERPRETATIONS

The unit root tests were applied to test whether the variables is stationary prior to the estimation of ARD. Thus, the Augmented Dickey-Fuller (ADF) test of unit root was conducted for each variable and the results of the unit root tests are presented in the Table 1. The table shows that the natural gas demand, per capita income, natural gas price and population growth are stationary at level, they are I(1) series Thus, the combinations of I(0) and I(1) orders of integration of the variables This means that the variables are stationary at the first order level I (1). That justify the use of the ARDL bounds test to examine the existence of a long-run relationship between the variables as proposed by Pesaran et al. (2001).

Table 2 presents the results of the bounds co-integration test using ARDL. since the f-statistic (4.0736) exceeds the upper bounds of the critical value bounds at the 5% and 10% levels of significance, Thus, there is evidence of a long-run relationship among the variables. That is, the natural gas demand, per capita income, natural gas price, population growth are co-integrated.

Table 3 shows the result of the short-run error-correction model of the selected ARD Model: (2, 2, 2, 2). The parameter of ECT for the error-correction term is (−0.70) which negative and significant (since the P-value is (0.0018) <5%. This indicates that the NGC adjusts to per capita income, the price of natural gas, and the population in the long run. Thus, about 70% of the disequilibrium

Table 1: Unit root augmented dickey-fuller test

Variable	Level		1st difference		Order of integration
	Intercept	Trend and intercept	Intercept	Trend and intercept	
NGC	−1.205092	−2.340264	−4.733470*	−4.580634*	I (1)
Y	−4.580634*	−4.294894*	−6.263400*	−6.211657*	I (0) I (1)
P	−6.888188*	−7.003163*	−6.700820*	−6.577750*	I (0) I (1)
POP	−3.657261*	−3.371355	−8.384651	−4.852629	I (1)

VAR lag order selection criteria
Endogenous variables: NG Y P POP
Exogenous variables: C
Sample: 1991 2020
Included observations: 26

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−101.3910	NA	0.038994	8.107000	8.300553	8.162736
1	−47.01695	87.83500*	0.002077*	5.155150*	6.122917*	5.433832*
2	−40.14457	8.986953	0.004631	5.857275	7.599255	6.358902
3	−30.66071	9.483867	0.010066	6.358516	8.874709	7.083089
4	−13.46084	11.90760	0.017246	6.266218	9.556625	7.213736

*indicates lag order selected by the criterion
LR: Sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	0.05 Critical value	Prob.**
None*	0.651224	73.17828	47.85613	0.0000
At most 1*	0.535677	43.68513	29.79707	0.0007
At most 2*	0.517651	22.20420	15.49471	0.0042
At most 3	0.061920	1.789757	3.841466	0.1810

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
*Denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) P-values

Unrestricted cointegration rank test (maximum eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-eigen statistic	0.05 Critical value	Prob.**
None*	0.651224	29.49315	27.58434	0.0281
At most 1*	0.535677	21.48093	21.13162	0.0447
At most 2*	0.517651	20.41445	14.26460	0.0047
At most 3	0.061920	1.789757	3.841466	0.1810

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) P-values

Table 2: F-Bounds test results

Test statistic	Value	Signif.	I (0)	I (1)
F-statistic	4.073568	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

of the previous periods has returned to the equilibrium state in the current period and, consequently, the model has been restored to the equilibrium state. The results indicate that in the short run, the demand for natural gas in Saudi Arabia is elastic with respect to the price, as the price elasticity of demand for natural gas has reached lagged periods. In the first lag period P_{t-1}, the elasticity was −1.17. It is worth noting that the coefficient of price elasticity was negative, and this is consistent with the law of demand, which states that there is an inverse relationship between the quantity demanded and the price of the commodity, with other factors remaining constant.

Table 3: ARDL error correction regression

Selected model: ARDL (2, 2, 2, 2)				
Variable	Coefficient	SE	t-Statistic	Prob.
D (NG(-1))	0.866103	0.237841	3.641518	0.0034
D (Y)	0.000143	4.07E-05	3.497974	0.0044
D (Y (-1))	0.000162	6.19E-05	2.613993	0.0226
D (P)	−0.148633	0.379735	−0.391412	0.7007
D (P(-1))	−1.170713	0.349206	−3.352498	0.0040
D (POP)	0.404454	0.824067	0.490803	0.6324
D (POP(-1))	1.382670	0.690302	2.002993	0.0683
CointEq (-1)*	−0.697738	0.186635	−3.738506	0.0018
R-squared	0.840400	Sum squared resid		34.11389
Adjusted R-squared	0.784540	Log-likelihood		−42.49528
S.E. of regression	1.306022	Durbin-Watson stat		2.111270

*P-value incompatible with t-Bounds distribution

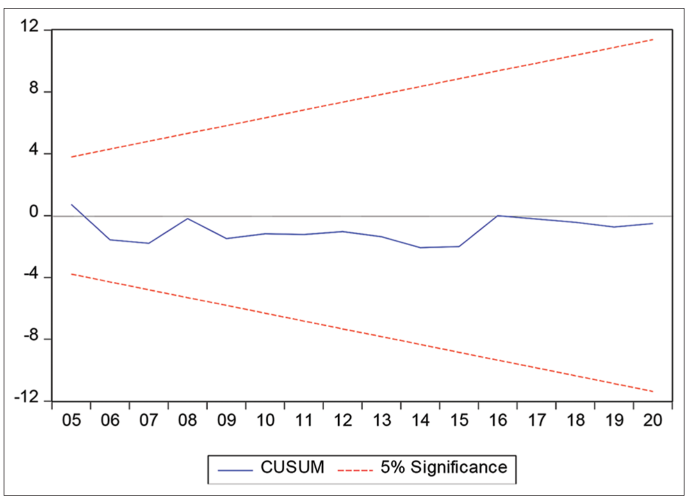
As for the income, the elasticity coefficient was very low, reaching 0.0002, but the sign is positive and statistically significant, this means that the effect of income on consumption of natural gas is weak, and it can be said based on the result that natural gas is considered a normal commodity because of the existence of a positive relationship between the per capita income and the consumption of natural gas in Saudi Arabia.

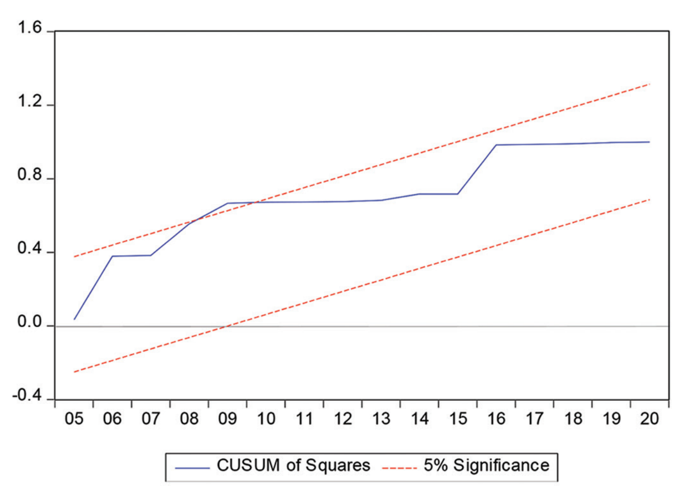
As for the impact of population growth, the results indicated that there is a positive relationship between population growth and the increase in consumption of natural gas, with a coefficient of elasticity of 1.38. This indicates that the growth in the population as a proxy of the number of consumers leads to an increase in consumption of natural gas in Saudi Arabia.

Table 4 shows a long-run outcome for ARDL. The results were confirmed in the short run, as the coefficient of income elasticity in the long run was weak in value and strong significantly, amounting to 0.0002. As for the price elasticity of demand, the coefficient of elasticity was −2.09 this means that the demand for gas is an elastic demand in the long run. As for the impact of population growth, it was a coefficient of 1.95 and is statistically significant at the 10% level. In other words, the population growth contributed to the increase in the demand for natural gas in Saudi Arabia.

Table 4: The long-run ARDL results

Variable	Coefficient	SE	t-Statistic	Prob.
Y	0.000184	8.97E-06	20.46892	0.0000
P	−2.088706	0.615429	−3.393901	0.0053
POP	1.952475	0.595565	3.278355	0.0066
C	40.85037	1.758086	23.23571	0.0000





5. CONCLUSION

Natural gas consumption has grown rapidly in recent years in Saudi Arabia, in line with population growth, increased economic activity, investments in infrastructure, and local prices. The ECT indicates that the NGC adjusts to per capita income, the price of natural gas, and the population growth in the long run. About 70% of the disequilibrium of the previous periods has returned to the equilibrium state in the current period. The results indicate that in the short run, the demand for natural gas in Saudi Arabia is elastic with respect to the price, as the price elasticity of demand for natural gas has reached lagged periods. The price elasticity of natural gas demand indicates that rising natural gas prices in the future will reduce its consumption. Moreover, the implementation of pricing policies to encourage the use of natural gas may be beneficial, due to the relatively high price elasticity.

The effect of income on consumption of natural gas is weak, and it can be said based on the result that natural gas is considered a normal commodity because of the existence of a positive relationship between the per capita income and the consumption of natural gas in Saudi Arabia. Low-income elasticity indicates that changes in income do not have an important effect on the demand for natural gas.

The results indicated that there is a positive relationship between population growth and the increase in consumption of natural gas. This indicates that the growth in the population as an indicator of the number of consumers leads to an increase in consumption of natural gas in Saudi Arabia.

The results were confirmed in the short run, as the coefficient of income elasticity in the long run was weak in value and strong significantly, amounting to 0.0002. As for the price elasticity of demand, the coefficient of elasticity was −2.09. This means that the demand for gas is an elastic demand in the long run. This means that changes in price have a greater impact on demand for natural gas than changes in income in the short and long term.

As for the impact of population growth, it was a coefficient of 1.95 and is statistically significant at the 10% level. In other words, the population growth contributed to the increase in the demand for natural gas in Saudi Arabia. The high rate of population and economic growth in Saudi Arabia is followed by a rise in the rate of energy consumption, whether in fuel, electricity, or water desalination, in order to preserve current resources, achieve balance, meet life requirements for 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.

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