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RESEARCH ARTICLE

A time series forecasting analysis of overall and sector-based natural gas demand: a developing South Asian economy case

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Abstract

Pakistan is developing South Asian country which is currently considering alternative energy sources including coal, solar, compressed natural gas, and wind energy to cope with the worst energy crisis in its history. Moreover, the policy promotion of compressed natural gas especially in the transport sector has raised concerns about the demand management of natural gas to avoid future shortages and ensure sustainable use of this precious non-renewable source of energy. Against this background, this study aimed to forecast natural gas demand in Pakistan for the 2016–2030 period by applying relevant univariate time series econometric methods. Apart from forecasting the overall natural gas demand, the forecasting analysis is also conducted for natural gas demand in Pakistan's total natural gas consumption and also for natural gas consumption across the household, industrial, commercial, transport, fertilizer production, power generation, and cement production sectors. Overall, the findings revealed that ARIMA is the appropriate model for forecasting gas consumption in Pakistan. Further, the growth of increase in the level of compressed natural gas consumption in the household sector is more as compared to all other sectors of the economy up to the year 2030. The key findings show that (a) natural gas consumption is likely to grow with time, (b) mixed projection trends are observed for the overall natural gas consumption and other sector-based natural gas consumption trends, and (c) the difference between natural gas consumption and production in Pakistan is likely to grow leading to 2030. As part of the policy recommendation in line with the findings, policymakers in Pakistan should increase the availability of natural gas, particularly in sectors where its consumption is likely to be declining. In addition, more proactive measures should be undertaken to explore the existing natural gas reserves in the long run while also importing natural gas from the neighboring nations in the short run. Furthermore, the government of Pakistan should seriously consider strategizing the development of the nation's compressed natural gas sector.

Keywords Natural gas demand · ARIMA · Holt-Winter · Forecasting · Forecast evaluations · Pakistan

JEL Classification C5 · E2 · O2

Introduction

Energy has become a dire necessity in the current era whereby ensuring energy security has acquired significant importance worldwide (Sharma et al. 2021; Ahmed et al. 2021). Consequently, to cope with the growing energy demand, global economies are trying to exploit indigenous natural resources to extract primary energy supplies. In addition, relevant policies are also being adopted to manage the domestic energy resources in such a manner so that new environmentally friendly energy resources can be added to the global energy mix (Destek and Sinha 2020; Zafar et al. 2020; Herrero and Ibañez 2018). Conventionally, much emphasis was devoted to extracting crude oils for petroleum production; however, growing climate concerns related to extraction and consumption of these highly carbon-intensive energy resources have triggered the importance of looking for low carbon-intensive alternatives (Sharif et al. 2020; Bandyopadhyay and Rej 2021; Bandyopadhyay et al. 2022). Among the different alternative energy sources, compressed natural gas (CNG) has been a widely focused energy source

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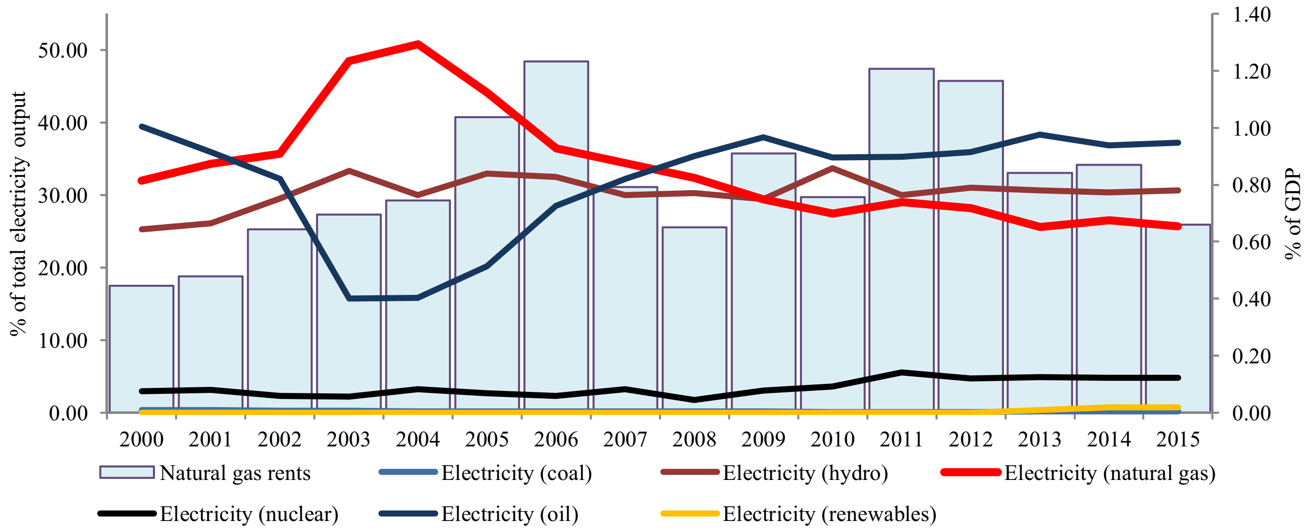

Fig. 1 An overview of the energy portfolio of Pakistan (2000–2015). **Source**: The shares of different fuels in the electricity output are shown along the primary axis; the natural gas rents (% of GDP) are shown along the secondary axis. **Source**: World Development Indicators (World Bank 2022)

that is comparatively cleaner than the conventionally utilized gasoline and diesel (Kanat et al. 2022; Sohail et al. 2022).

According to a report by the International Energy Agency (IEA 2019), between 2010 and 2018, switching from coal to natural gas consumption accounted for a saving of 500 million tonnes of carbon dioxide (CO2) emissions. Besides, the CO2-saving potential of natural gas is substantially high since CO2 emissions generated per unit of natural gas combustion are 40% and 20% lower than those generated from coal and oil, respectively (IEA 2017). However, despite natural gas being relatively cleaner, a significant proportion of the total global natural gas reserve is left untapped. According to the global reserve-to-production ratios shown in Table 4 in the Appendix, a little more than half of the world's natural gas reserves are utilized for natural gas production. Although natural gas has multidimensional roles to play within the economy, CNG, in particular, is mostly consumed within the transportation sector. Natural gas-fuelled vehicles emit a quarter of the traditional gasoline-fuelled vehicles (IEA 2010).

Like all other global economies, ensuring energy security is a major concern for the South Asian economy of Pakistan. Besides, Pakistan is also significantly reliant on its indigenous natural gas reserves for meeting its energy demand. However, the recent chronic natural gas shortages have compromised the nation's prospects of attaining energy sufficiently and have forced the nation to import liquefied natural gas (LNG) to natural gas supply shortfalls (Raza and Lin 2022). Nevertheless, the recent hike in LNG prices in the world market has further jeopardized the issue of energy security in Pakistan. As a consequence, energy shortfalls have severely affected the growth of the Pakistan economy in the current decade. The power shortages cost the industrial sector of Pakistan $3.8 billion in the year 2009 which is about 2.5% of the total GDP in Pakistan (Shahbaz, 2015). In addition, due to energy shortages, about 0.5 million jobs were lost and also cost a loss of $1.3 billion to the national exports (Shahbaz, 2015). Therefore, considering these adverse economic effects of energy shortages, especially in respect of natural gas, it is important to forecast the future natural gas demand in Pakistan so that effective measures can be taken to ensure an adequate supply of natural gas in the future.

Despite some measures taken by the Pakistan government to cope with the energy shortages, the progress regarding the bridging of the deficit in energy demand and supply was too stymied. This was mainly due to poor governance and a lack of long-term planning. The past political regimes paid little attention to constructing mega-dams for water storage and generating electricity in the country. This was not possible to meet the energy requirements of the residential, power, and fertilizer sectors. Consequently, the ultimate burden of meeting the nation's energy demand was largely shifted to the consumption of CNG. Among the leading countries using CNG-operating vehicles, Pakistan was ranked second after Iran in 2016, while the nation was the leading global economy in terms of the number of natural gas fueling stations (refer to Table 5 in the Appendix).

A look into Pakistan's historical energy consumption profile (refer to Fig. 1) reveals that until the mid-2000s, natural gas accounted for more than half of Pakistan's total electricity output before experiencing a downward trend from 2005 onwards. This was mainly driven by the acute natural gas supply shortages faced in the country whereby the government had to enhance its reliance on imported oil

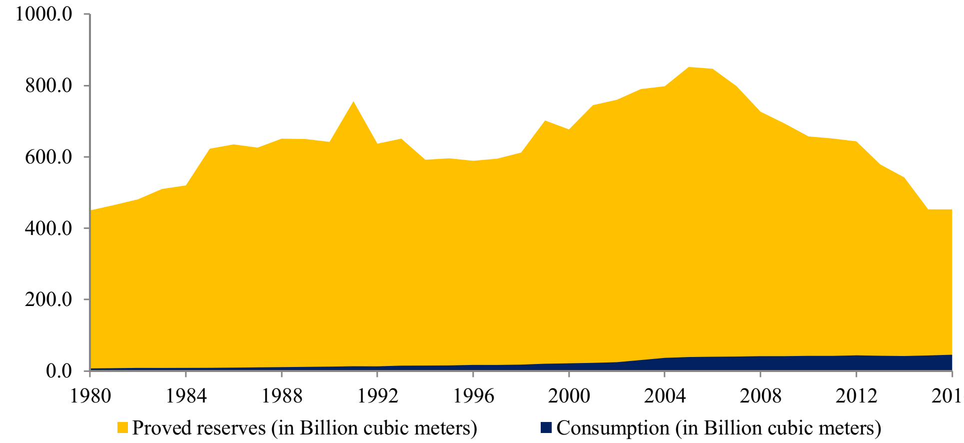

Fig. 2 Natural gas reserves and consumption trends (1980–2016). **Source**: BP Statistical Review of World Energy (British Petroleum 2018)

to counter the natural gas shortages. Besides, Fig. 1 also shows that Pakistan generates a substantial amount of energy from hydroelectric sources. However, due to water scarcity and simultaneous growth in the nation's energy demand, the country had to utilize other energy sources for electricity generation purposes in order to complement its hydroelectricity supplies. On the other hand, it can be observed that the renewable electricity sector of Pakistan is largely underdeveloped since it accounts for a negligible share of the nation's aggregate electricity outputs. Hence, it can be assumed that Pakistan has to rely on non-renewable energy before it can undergo a renewable energy transition within its power sector. Moreover, the trends in Pakistan's natural gas rent shares in its gross domestic product (GDP) also from the mid-2000s these shares have on average declined. This further indicates the scenario of the natural gas crisis in Pakistan.

Recognizing the inability of Pakistan to undergo a renewable energy transition, the government is considering augmenting low-carbon and environment-friendly energy sources into the national energy mix, particularly by enhancing the use of natural gas. Notably, since CNG has a low carbon impact compared to other traditional oil and petroleum energy resources, the government of Pakistan is particularly interested in scaling up CNG use. It is to be noted that in the mid-1980s, the Pakistan government started promoting CNG use by relaxing import duties on imports of natural gas equipment and machinery necessary for the extraction and production of natural gas and natural gas-utilized electricity, respectively. However, Fig. 2 illustrates that despite having remarkable natural gas reserves, Pakistan has not been able to properly utilize its indigenous natural gas supplies whereby a major proportion of this reserve has remained unexplored (this can be perceived from the region shaded orange in Fig. 2). The minimal amount of natural gas extracted is consumed in various sectors of the economy. The major consumer of gas is the domestic power and fertilizer sectors in Pakistan which consumes about 28% and 20% of the total gas consumption respectively. Nevertheless, the recent natural gas crisis in Pakistan demands enhancing the rate of extraction of natural gas and making proper use of this untapped energy resource.

Pakistan is currently considering the use of both low-carbon and renewable energy resources including CNG, solar, and wind energy, in particular, to cope with the ongoing worst energy crisis in its history. Against this backdrop, this study forecasts natural gas demand in Pakistan for the 2016–2030 period by applying relevant univariate time series econometric methods. This study, apart from tackling the overall energy crisis in Pakistan, is also important because the promotion of CNG use especially in Pakistan's transport sector has raised concerns regarding efficient demand management of this key energy source to avoid future supply shortfalls and simultaneously ensure sustainable use of this precious low-carbon non-renewable energy source. Furthermore, since a great deal of difference exists between the natural gas reserve and use in Pakistan, the policymakers are striving to design relevant policies than can curb this demand–supply gap. Although previous studies have focused on forecasting the overall energy demand and natural gas demand in Pakistan, this current study adds to the limited literature by specifically probing into Pakistan's natural gas demand, both at the overall level and across different sectors that rely on natural gas supplies. In this study, the forecasting analysis has been conducted for Pakistan's total natural gas consumption and also for natural gas consumption across the household, industrial, commercial, transport, fertilizer production, power generation, and cement production sectors. Consequently, the outcomes from this study can help in policymaking in this regard for which it is instrumental to have an understanding of the future demand for natural gas in Pakistan.

In the subsequent sections, the literature review, methodology, analysis of findings, and concluding remarks with relevant policy suggestions are chronologically presented.

Literature review

Preceding studies documented in the energy demand-related literature have applied diverse short-run and long-run econometric models to forecast the future energy consumption level in the context of various global countries. These econometric models include both univariate and multivariate time series models (Deb et al. 2017; Tsai et al. 2016). Such models may not predict the exact amount of energy consumption for countries due to many non-predictable factors including both natural and anthropogenic factors. The anthropogenic factors include an increase in the population size, expansion in the housing sector, industrial expansion, higher standard of living, and improvements in energy efficiency levels, in particular. On the other hand, the natural factors include natural destruction in the energy systems and other natural calamities such as floods, earthquakes, etc. It is cumbersome to determine and accommodate such factors in the econometric and mathematical models for energy demand forecasting purposes. However, for precise forecasting, accommodating such factors is essential. Besides, it is also not an easy task to develop a perfect model which could be used for forecasting all types of energy supply and consumption. Nevertheless, the majority of the receding studies have not provided adequate concerns in addressing the inefficiencies in the traditionally utilized forecasting tools.

In the context of Pakistan, the previous studies have mostly emphasized the forecasting of the overall energy demand. Using the Long-range Energy Alternative Planning (LEAP) software, Raza et al. (2022) forecasted Pakistan's energy demand from 2018 to 2030. Besides, the authors also estimated the electricity generation capacity of Pakistan using both renewable and non-renewable energy resources. The results indicated that energy demand in Pakistan is likely to reach around 312–399 terawatt-hours by 2030 while the corresponding power generation capacity is anticipated to reach around 500 terawatt-hours. Similarly, utilizing the Autoregressive Integrated Moving Average (ARIMA), LEAP, and Holt-Winter forecasting models, Rehman et al. (2017) projected the overall energy demand in Pakistan up to 2035. The results showed that energy demand in Pakistan would be most within the nation's industrial sector followed by transport and other domestic sectors. Moreover, it was also concluded that the shares of oil, natural gas, electricity, coal, and liquefied petroleum gas (LPG) in the nation's energy mix in 2030 are likely to be 38.16%, 36.57%, 16.22%, 7.52%, and 1.52%, respectively. Rehman and Deyuan (2018) also forecasted Pakistan's commercial energy demand and supply from different sources and found that by 2030 both the demand and supplies of energy are likely to significantly grow. Therefore, it is apparent that sectoral natural gas demand forecasting has not attracted much interest in the literature which is the core gap this current study aims to bridge.

Among the preceding studies focusing on other global economies, it is apparent that different studies have used diverse methods to forecast different forms of energy across the globe. Rogan et al. (2012) studied Ireland's gas consumption trends in residential areas and applied Log-Mean Divisia Index I (LMDI-I) model. Gutierrez et al. (2005) forecasted natural gas consumption in Spain using a stochastic Gompertz innovation diffusion model that considered the macroeconomic characteristics and gas consumption pattern in forecasting. Aras and Aras (2004) forecasted the gas consumption for Turkey using autoregressive time series models taking into account the time and seasonal variations. Khotanzad et al. (2000) used the combination of forecasting models to estimate gas consumption and found that the combination strategies performed well as compared to other approaches. Wadud et al. (2011) used dynamic econometric methods to forecast natural gas consumption in Bangladesh and found that the demand will further increase in the future. Similarly, in a recent study on Bangladesh by Anik and Rahman (2021), the authors found that commercial energy demand in Bangladesh is likely to rise by 400% between 2019 and 2038.

In the context of China from 2020 to 2025, Gao and Shao (2021) forecasted the trends in natural gas consumption utilizing a hybrid model comprising support vector machine and improved artificial fish swarm algorithm techniques. The results showed that the growth rate in natural gas consumption in China is likely to rise by 9.47% in the first 2 years before decreasing gradually; in 2025, the growth rate of natural gas consumption is likely to reach 7.51%. In another related study, Yucesan et al. (2021) utilized regression-based, time series, and machine learning algorithms and forecasted how the Turkish daily natural gas demand is likely to rise. Rehman et al. (2022) recently conducted a forecasting analysis of hourly natural gas demand in five cities in Spain utilizing both conventionally used and deep learning methods. Therefore, once again it can be observed that natural gas demand forecasting has mostly been conducted at the aggregate level while the sector-based foresting issue has largely remained overlooked.

Data and methodology

Nature of data and source

This study is based on secondary data for the period spanning from 1972 to 2016, except for CNG consumption and natural gas production data which covers the 1992–2016 period. The data for the analysis have been obtained from Pakistan Economic Survey (various issues). The projections have been made for total gas production, total gas consumption, and its sectoral demand in the household, commercial, cement, fertilizer, power, industrial, and transport sectors. The forecasting period is from 2016 to 2030.

Forecasting methods

Researchers proposed various models for the projection of gas energy consumption such as linear regression models, support vector regression model, hybrid neural network, Adaptive Network-Based Inference System model, novel hybrid model, Gompertz-type innovation diffusion model, Bayesian models, and multivariable time series models. For forecasting, the opinions of energy experts are also sometimes taken into consideration since they are believed to have in-depth knowledge about the energy markets.

For the projection of natural gas energy consumption in Pakistan, this study uses the Holt-Winter and ARIMA forecasting models. These models are widely used for projections and are suitable techniques for analysis involving time series data (Raza et al. 2022). Firstly, the general form of the ARIMA forecasting model can be shown as:

$$Y_t = c + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \dots + \beta_q Y_{t-q} + \mu_t - \alpha_1 \mu_{t-1} - \alpha_2 \mu_{t-2} - \dots \mu_{t-r} \quad (1)$$

where Y_t is the present value of the time series forecasted, while c is constant and μ_t is the random term, α is the coefficient of moving average (MA), and μ_{t-r} is the past random error of period r (Box et al. 2011). To estimate the ARIMA, the order of differencing, order of moving average, and order of autoregressive schemes were identified for each variable.

For the forecasting of the demand for natural gas consumption and its components, the exponentially smoothed and trend components have been obtained from:

$$U_t = \alpha A_t + (1 - \alpha)(U_{t-1} + V_{t-1}) \quad (2)$$

$$V_t = \beta (U_t - U_{t-1}) + (1 - \beta) V_{t-1} \quad (3)$$

where α and β are both exponentially smooth and trend components taking the values between 0 and 1. α controls the smoothness of U_t while for β choice near 0 emphasizes more on past, while choice near 1 emphasizes more on current values of the time series. The forecast at the time $(t+1)$ gives observed values up to time t is given by:

$$F_{t+1} = U_t + V_t \quad (4)$$

The study variables have been forecasted using smoothed component (U_t,) and trend component (V_t).

The k-period ahead forecast is estimated as:

$$Ft + k = Ut + kVt \quad (5)$$

Equations 2–5 are used to derive the forecast for each CNG variable through HWF models.

Evaluation of the forecasts

The forecasting has been made for total natural gas consumption and natural gas consumption in the household, industrial, commercial, transport, fertilizer production, power generation, and cement production sectors in Pakistan. For the evaluation of forecasts, the mean absolute percentage error (MAPE) was used calculated using the following formula:

$$\text{MAPE} = \frac{\sum[(S_t - R_t)/R_t)]}{n} \times 100 \; (S_t \neq 0) \quad (6)$$

R_t Actual value of the time series.
S_t Forecasted value of the time series.
n Total number of observations.

The forecasts of ARIMA and Holt-Winter models have been compared with the help of mean absolute percentage error using the Minitab and EViews softwares.

Results and discussion

The total natural gas consumption has been projected with the help of the Holt-Winter and ARIMA forecasting models and the appropriate model has been identified and selected through the mean absolute percentage error shown in Table 1 while the required parameters of the ARIMA model are reported in Table 2. The forecast evaluation measures suggested that the ARIMA model is an appropriate model for forecasting natural gas demand overall and also for all other sectors except for the case of natural gas demand in the transport sector of Pakistan.

The projections of total and sectoral natural gas demands derived using the ARIMA and Holt-Winter Forecasting (HWF) methods are presented in Table 3. Although the main focus of the study was forecasting the natural gas consumption trends, the natural gas production trends have also been forecasted. The projections through the HWF model are made for each variable[1] with the help of different combinations of weights (*m*

[1] For each variable, the possible combinations of *m* and *n* are 81. In the text, only the optimum combinations (selected on the basis of mean absolute percent error) have been reported. The optimum combinations of "*m*" and "*n*" possess the minimum mean absolute percent error as compared to other combinations.

Table 1 Forecasts evaluation through mean absolute percent error

Variables	Mean absolute percent error (%)	
	ARIMA	Holt-Winter
Total	3.69	9.00
Household sector	6.42	64.00
Commercial sector	4.35	9.00
Cement industry	31.06	37.00
Fertilizer industry	7.99	8.00
Power sector	8.18	13.00
Industrial sector	4.78	10.00
Transport sector	17.38	5984
Natural gas production sector	2.93	4.00

Source: Authors' compilation

and *n*) of exponential and trend components. Table 3 presents only the optimum combinations (*m* and *n*) which have been selected with the help of minimum mean absolute percentage error as compared to other combinations. The results of the forecast evaluation show that ARIMA has the minimum mean absolute percentage error as compared HWF model. So, the ARIMA model is the appropriate model for forecasting natural gas consumption for household, commercial, cement, fertilizer, power, and industrial sectors in Pakistan. However, it is better to forecast the natural gas (CNG) demand in the transport sector with the HWF model.

To check the validity of the forecasts, the 95% bounds both upper and lower have been constructed for each variable on the best forecasting model as shown in Fig. 3. The figure shows that all the forecasts generated are within the 95% confidence interval which further validates the forecasts.

Notably, the results of the optimal forecast of ARIMA show that the household and transport sectors have an increasing trend in natural gas consumption (in the form of CNG) in the transport sector. The transport sector has a substantial share in the overall consumption of CNG. This is because both the numbers of registered and non-registered vehicles are increasing over time in Pakistan. The non-registered vehicles particularly in some of the areas of the province of Khyber Pakhtunkhwa have legal status under the Customs Act 1969. These vehicles create an economic and environmental burden for the country. These vehicles have low prices whereby the majority of the local community in these areas prefer to own them; thus, ultimately putting pressure on the overall demand for CNG, oil, and diesel. Due to the low supply of the CNG, the local filling stations cannot meet the consumption requirements of the CNG for vehicles.

For the overall and sectoral natural gas consumption forecasts, it can be seen that the forecasts depict either low variation or decreasing trends over time. This is due to the low availability of CNG to these sectors. To overcome the increasing demand for CNG in the economy, the government has different options such as generating energy from huge coal resources in Pakistan and improving the governance of this sector. In the year 2013, the 5th largest coal reserves in the world were held by India (Mining Technology 2013) while the 7th largest coal reserves were held by Pakistan (Imamuddin, 2013). In terms of electricity generation, India produced 67.9% of the total electricity from coal while Pakistan produced only 0.1% of the total electricity from coal in the year 2011 (World Bank 2022). Pakistan also has the option to generate energy from coal resources but there is a need to use clean coal technologies for sustainable energy and lessen the environmental burden. In the year 2010, the per capita carbon dioxide emissions of Pakistan were 0.9 metric tons which were quite low compared to those of India (1.7 metric tons), the USA (17.6 metric tons), the UAE (19.9 metric tons), and Qatar (40.3 metric tons) (World Bank 2022). So, by substituting the coal energy, the pressure on the gas consumption can be reduced. In the year 2011, the gas consumption in the cement sector was almost switched off and

Table 2 Determining the parameters for ARIMA

Variable	Order of autoregressive scheme (*p*)	Order of differencing (*d*)	Order of moving average (*q*)
Total	2	1	0
Household sector	2	1	1
Commercial sector	2	1	0
Cement industry	2	1	2
Fertilizer industry	1	0	0
Power sector	1	1	0
Industrial sector	2	2	2
Transport sector	1	1	0
Natural gas production sector	2	2	1

Source: Authors' compilation

Table 3 Projections of natural gas demand with optimum combinations from 2016 to 2030 in Pakistan

Year	Total		Household sector		Commercial sector		Cement industry		Fertilizer industry		Power sector		Industrial sector		Transport sector	
	ARIMA	HWF	ARIMA	HWF	ARIMA	HWF	ARIMA	HWF	ARIMA	HWF	ARIMA	HWF	ARIMA	HWF	ARIMA	HWF
2016	1240072	1252485	286453	239886	33383	36252	966	108	224968	228821	380526	373501	240859	229853	44372.2	79381
2017	1239271	1272756	294801	248385	32399	36882	998	−506	224424	232934	384173	377270	237442	213206	19991.6	81921
2018	1249590	1293027	303069	256884	31752	37512	1000	−1120	223883	237047	385658	381039	235605	196559	−5546.2	84461
2019	1246518	1313298	311261	265383	31435	38142	999	−1733	223342	241159	386262	384808	234617	179912	−32044	87000
2020	1254153	1333569	319378	273882	31191	38773	998	−2347	222803	245272	386508	388577	234086	163265	−59189	89540
2021	1250227	1353840	327421	282381	31100	39403	998	−2961	222265	249385	386608	392346	233800	146618	−86810	92080
2022	1256284	1374111	335391	290880	30999	40033	997	−3575	221728	253497	386649	396115	233647	129972	−114769	94620
2023	1252176	1394382	343287	299379	30983	40663	997	−4188	221193	257610	386665	399884	233564	113325	−142969	97159
2024	1257225	1414653	351111	307878	30934	41293	997	−4802	220659	261723	386672	403653	233520	96678	−171343	99699
2025	1253244	1434924	358863	316377	30942	41923	997	−5416	220126	265835	386675	407422	233496	80031	−199841	102239
2026	1257589	1455194	366544	324876	30912	42553	997	−6030	219595	269948	386676	411191	233483	63384	−228427	104779
2027	1253867	1475465	374155	333375	30926	43183	997	−6644	219064	274061	386676	414960	233476	46737	−257077	107319
2028	1257680	1495736	381696	341874	30906	43814	997	−7257	218536	278173	386676	418729	233472	30090	−285773	109858
2029	1254260	1516007	389168	350373	30920	44444	997	−7871	218008	282286	386676	422498	233470	13443	−314501	112398
2030	1257643	1536278	396572	358872	30905	45074	997	−8485	217482	286399	386676	426267	233469	−3204	−343253	114938
% change	1.42%	22.66%	38.44%	49.60%	−7.42%	24.34%	3.21%	−7956.48%	−3.33%	25.16%	1.62%	14.13%	−3.07%	−101.39%	−873.58%	44.79%

The figures are consumption demands in million cubic feet; % change stands for change in the figures between 2016 and 2030. Source: Authors' compilation

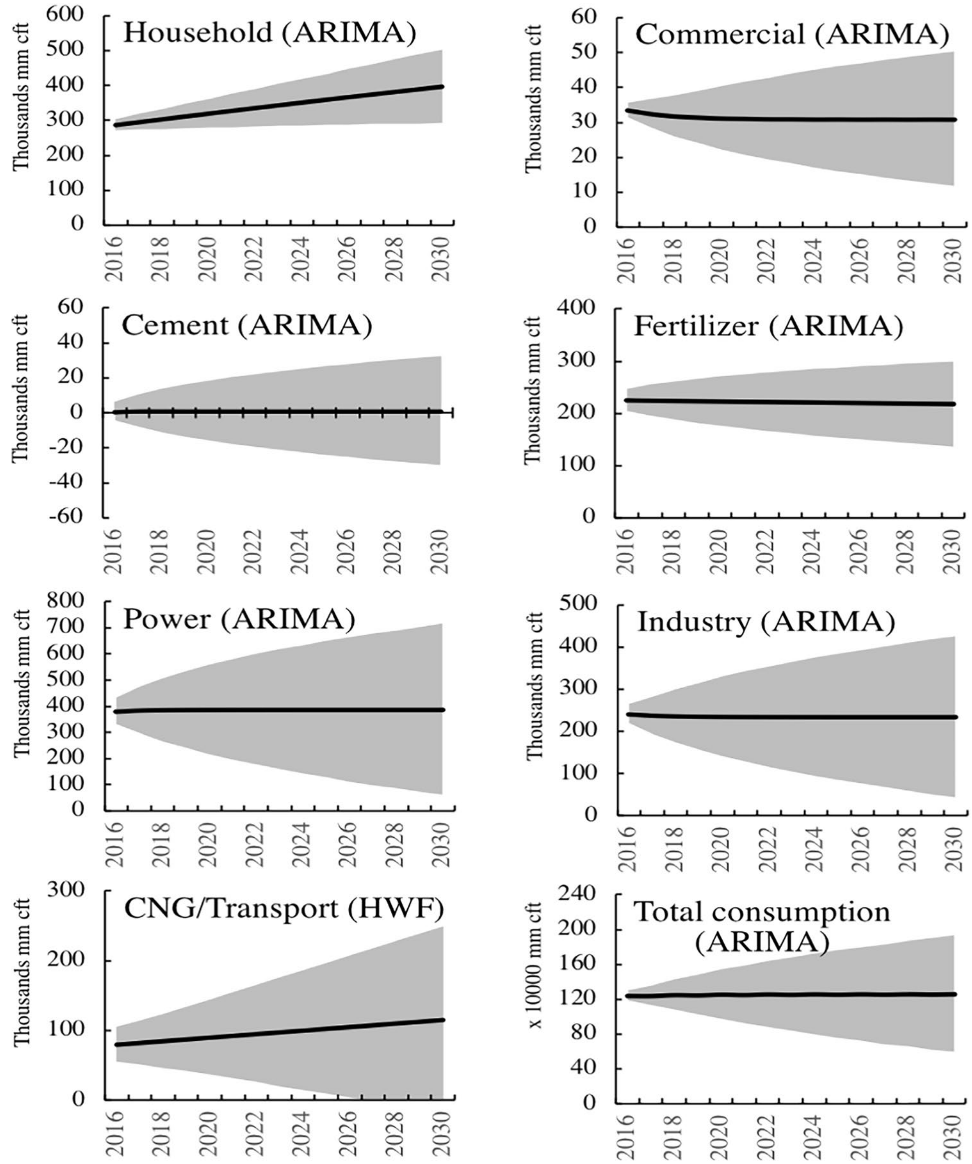

Fig. 3 Upper and lower 95% bounds for all forecasts. Source: Authors' compilation

decreased to 64.7% while in the industrial and power sectors, it decreased to 9.2 and 0.2% respectively, while the production of total gas increased to 1,109,930.16 million cubic feet. The decreasing trend in gas consumption in these sectors is due to the shifting from gas to coal-fired systems for its production activities (APP 2011).

On average, Pakistan imports 4.2 million tonnes of diesel oil annually so strong justification exists to replace diesel oil with other alternatives. The CNG remains the best option to adopt which is environment friendly (Hilal 2018). The adoption of CNG fuel in the country will save both the economic and environmental costs of the society. The use of CNG should be encouraged which will not only meet the requirements of the transport, domestic, and fertilizer sectors but also help in reducing the air pollution and saving the health cost. This is because the CNG has low carbon content than other energy resources such as gasoline, diesel, and petroleum. Use of CNG reduces the CO exhaust emissions by 90–97%, nitrous oxide by 35–60%, CO_2 by 25%, and non-methane hydrocarbon by 50–75%. It is also important to mention that the prices of CNG are also low as compared to gasoline, diesel, and petroleum. So, CNG is both economic and environment-friendly energy for the society.

Looking over the current situation of natural gas in Pakistan, the country is still not utilizing its full potential. Although the forecasted production is more than the consumption up to 2030 (Fig. 4) but if the imports are also considered, the country would be in deficit in the natural gas production. In the years 2015–2016 and 2016–2017, Pakistan imported

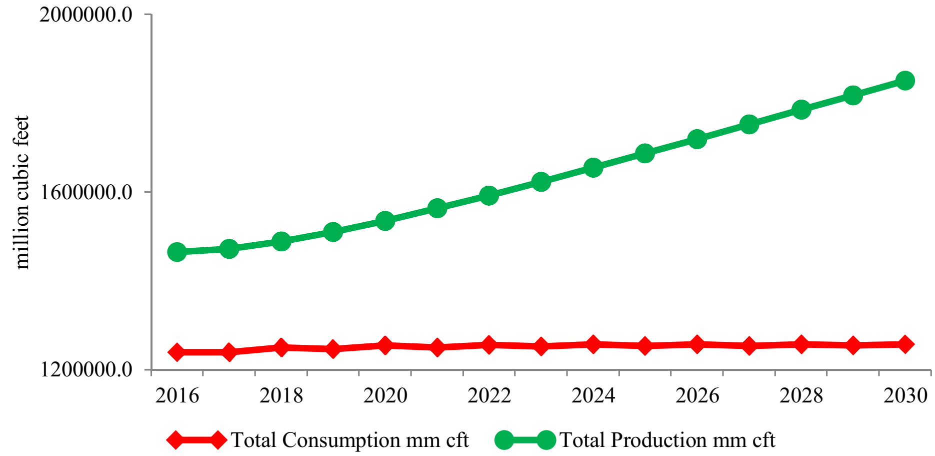

Fig. 4 Forecasts of the total consumption and production. Note: The figures are in million cubic feet. Source: Authors' compilation

60851364.2 million cubic feet and 125942851.8 million cubic feet respectively (Government of Pakistan, 2017). More importantly, Fig. 4 also reveals that the difference between natural gas consumption and production in Pakistan is likely to grow leading to 2030.

Having explored the available CNG reserves, the country not only can earn the foreign exchange by replacing the imports of diesel oil but also can extend the CNG industry. The CNG industry can be extended by using CNG buses in the urban areas and also by encouraging the CNG equipment in the economy. This is also important to mention that the current electricity crisis followed by its expected shortfall of 13651 megawatts by 2020 (Hussain et al. 2016) can be overcome by substituting electricity with CNG. In Pakistan, there are still vast areas that are in high demand of CNG but the government lacks sufficient resources to meet this demand. The increasing trend of CNG consumption calls for managing and exploring the existing CNG resources in an efficient manner. Besides, the gas import from neighboring countries such as Iran, India, Qatar, and Turkmenistan may help cope with the growing demand of the economy in the short run. Certainly, the dependence on imports is not a viable option in the long run.

Conclusion and recommendations

This study aimed to forecast natural gas demand in Pakistan for the 2016–2030 period by applying relevant univariate time series econometric methods. Apart from forecasting the overall natural gas demand, the forecasting analysis is also conducted for natural gas demand in Pakistan's total natural gas consumption and also for natural gas consumption across the household, industrial, commercial, transport, fertilizer production, power generation, and cement production sectors. Overall, this study finds that the ARIMA model is the appropriate model for the projection of gas consumption in Pakistan. The key findings show that (a) natural gas consumption is likely to grow with time, (b) mixed projection trends are observed for the overall natural gas consumption and other sectoral natural gas consumption trends, and (c) the difference between natural gas consumption and production in Pakistan is likely to grow leading to 2030.

In line with the findings, it is recommended that for speeding up the economic growth and coping with the energy crisis, policymakers should increase the availability of natural gas in Pakistan, particularly in those sectors where its consumption is declining. Because the health of the economy is most closely connected with the extension in the activities of power, industrial, and cement sectors. Over time, these sectors should flourish which would ultimately speed up the economic growth. Also, the experiences show that the high economic growth of the economy is bound to stimulate the potential growth rate of these sectors, as well. The growth in these sectors is impossible without the supply of adequate energy. The options may be to manage and explore the existing CNG reserves in the economy. Furthermore, the growing demand for CNG can also be met by importing CNG from Iran, India, Qatar, and Turkmenistan. Despite the increasing imports of CNG, the import bill can be reduced if the CNG is substituted with other expensive energy sources such as oil, diesel, and petroleum. This will also help the country in saving the foreign exchange. Moreover, the existing energy insecurity and imbalances in their prices will be stabilized. The development of the CNG sector will also help in saving environment-friendly energy as against the polluting fossil fuels.

Appendix

Table 4

Table 4 Global proven natural gas reserves

Country/region	1996 Trillion cubic meters	2006 Trillion cubic meters	2015 Trillion cubic meters	2016 Trillion cubic meters	*R*/*P* ratio (2016)
USA	4.7	6.0	8.7	8.7	11.6
Canada	1.9	1.6	2.2	2.2	14.3
Mexico	1.8	0.4	0.2	0.2	5.2
Argentina	0.6	0.4	0.4	0.4	9.2
Bolivia	0.1	0.7	0.3	0.3	14.2
Brazil	0.2	0.3	0.4	0.4	15.8
Colombia	0.2	0.1	0.1	0.1	11.9
Peru	0.2	0.3	0.4	0.4	28.5
Trinidad and Tobago	0.5	0.5	0.3	0.3	8.7
Venezuela	4.1	4.7	5.7	5.7	166.3
Kazakhstan	n/a	1.3	1.0	1.0	48.3
Netherlands	1.6	1.2	0.7	0.7	17.4
Norway	1.5	2.3	1.9	1.8	15.1
Poland	0.1	0.1	0.1	0.1	23.0
Romania	0.4	0.6	0.1	0.1	12.0
Russian Federation	30.9	31.2	32.3	32.3	55.7
Turkmenistan	n/a	2.3	17.5	17.5	261.7
Ukraine	n/a	0.7	0.6	0.6	33.2
UK	0.8	0.4	0.2	0.2	5.0
Uzbekistan	n/a	1.2	1.1	1.1	17.3
Bahrain	0.1	0.1	0.2	0.2	10.5
Iran	23.0	26.9	33.5	33.5	165.5
Kuwait	1.5	1.8	1.8	1.8	104.2
Oman	0.6	1.0	0.7	0.7	19.9
Qatar	8.5	25.5	24.3	24.3	134.1
Saudi Arabia	5.7	7.1	8.4	8.4	77.0
Syria	0.2	0.3	0.3	0.3	79.1
United Arab Emirates	5.8	6.4	6.1	6.1	98.5
Yemen	0.3	0.3	0.3	0.3	365.8
Algeria	3.7	4.5	4.5	4.5	49.3
Egypt	0.8	2.0	1.8	1.8	44.1
Libya	1.3	1.4	1.5	1.5	149.2
Nigeria	3.5	5.2	5.3	5.3	117.7
Australia	1.3	2.3	3.5	3.5	38.1
Bangladesh	0.3	0.4	0.2	0.2	7.5
Brunei	0.4	0.3	0.3	0.3	24.6
China	1.2	1.7	4.8	5.4	38.8
India	0.6	1.1	1.3	1.2	44.4
Indonesia	2.0	2.6	2.8	2.9	41.1
Malaysia	2.4	2.5	1.2	1.2	15.8
Myanmar	0.3	0.5	0.5	1.2	63.0
Pakistan	0.6	0.8	0.5	0.5	10.9
Thailand	0.2	0.3	0.2	0.2	5.4
Vietnam	0.2	0.2	0.6	0.6	57.6
Total world	123.5	158.2	185.4	186.6	52.5

The figures are figures for the end of the respective year; *R*/*P* ratio stands for the reserve-to-production ratio

Source: BP Statistical Review of World Energy (British Petroleum 2018)

Table 5

Table 5 Natural gas-run vehicles and refueling stations in the year 2016

Rank	Country	Natural gas vehicles	Refueling stations
1	Iran	4,000,000	2,380
2	Pakistan	3,000,000	3,416
3	Argentina	2,295,000	2,014
4	Italy	1,001,614	1,072
5	Thailand	474,486	502
6	Bolivia	360,000	156
7	Russia	145,000	303
8	Germany	93,964	885

Total vehicle populations include motorcycles and mopeds

Source: NGV (2017)

Author contribution AH: conceptualized and wrote the final manuscript. JAM: analyzed the data and helped in drafting the original manuscript. MM: conceptualized and wrote the final manuscript. MSA: wrote the original draft and assisted in analysis and discussions. UM: helped in discussions and analysis. MNA: aided in drafting the original manuscript. MR: contributed data and helped in analysis and discussions. UH: wrote the conclusion and policy recommendations.

Data availability Data will be made available upon request.

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