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Forecasting natural gas demand in China: Logistic modelling analysis

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ABSTRACT

Natural gas has increasingly appeared as an important policy choice for China's government to modify high carbon energy consumption structure and deal with environmental problems. This study is aimed to develop the logistic and logistic-population model based approach to forecast the medium- (2020) to long- (2035) term natural gas demand in China. The adopted modelling approach is relatively simple, compared with other forecasting approaches. In order to further improve the forecasting precision, the Levenberg–Marquardt Algorithm (LMA) has been implemented to estimate the parameters of the logistic model. The forecasting results show that China's natural gas demand will reach 330–370 billion m^3 in the medium-term and 500–590 billion m^3 in the long-term. Moreover, the forecasting results of this study were found close in studies conducted by the national and international institutions and scholars. The growing natural gas demand will cause significant increase in import requirements and will increase China's natural gas import dependency. The outcomes of this study are expected to assist the energy planners and policy makers to chalk out relevant natural gas supply and demand side management policies.

Introduction

China's 1978 economic reforms boosted its economic and industrial development, leading to a significant increase in its energy consumption. Current energy consumption structure in China highly relies on fossil fuels and is carbon dominated (85.4%), which has caused severe implications on the environment globally [1]. Particularly, fog and haze lead to big spike in pollution level covering most cities in China, causing severe health problems [2]. Therefore, a clean energy alternative path is necessary to strengthen the development of low-carbon economy in the future.

Natural gas is now increasingly deemed as a low carbon and an environmentally friendly energy option, amid of the uncertain future of renewable and nuclear energy technologies after Fukushima accident [3,4]. Natural gas is a less energy intensive and highly efficient source, compared with other fossil fuels such as coal and oil, which is widely considered as an economical and environmentally suitable energy option for cooking, heating and vehicle fuel in the growing urbanization the country. In recent years, China's government has shown strong support, and introduced some pro-natural gas policies to modify current energy consumption structure and reduce GHG emissions. These policies have resulted very well in increasing the penetration of natural gas in the primary energy mix [5,6]. Natural gas consumption has surged to 161 billion m^3 in 2013 (Fig. 1), keeping an average growth rate of 15.5% per year during 2003–2013 and ranking the 3rd, 6th and 7th in the world natural gas consumption, production and import, respectively [7,8]. Under the current situation, natural gas has been playing a more and more important role in energy consumption structure adjustment and low-carbon economy transition.

Forecasting energy/natural gas demand is a very important aspect of any country's energy policy and planning. Improper estimation of the natural gas consumption may subject to economic losses to final consumers and mismanagement of its supplies and infrastructures. Therefore, it is very essential to forecast natural gas demand with a satisfactory degree of accuracy to organize the indigenous production, foreign supply contracts and infrastructures in a better way.

Over the years, numerous researchers and practitioners have focused on developing different forecasting approaches. The main motive behind these models was to investigate the underlying relationship among various energy demand driving variables to estimate the future energy demand. While, electricity or overall energy demand forecasting has been the main focus of the research community in the past, and studies on natural gas demand

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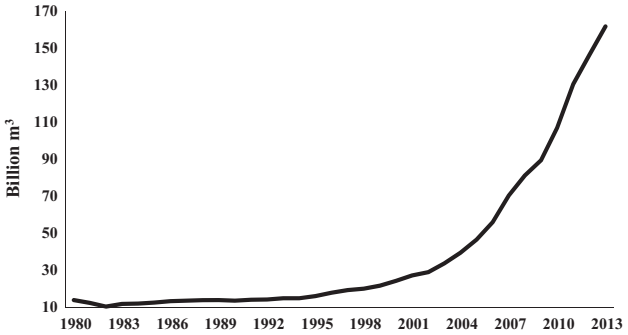

Fig. 1. Historical natural gas consumption of China [7].

forecasting have not been conducted to the same extent. A comprehensive literature review of various forecasting approaches used since more than 50 years for natural gas consumption forecasting can be accessed at [7]. Some of the recent studies conducted in various countries for natural gas consumption forecasting concerning various economic factors and horizons are presented below.

Zhu et al. [8] introduced structural time series approach to forecast the short-term natural gas demand in the United Kingdom (UK). The modelling approach adopted was successfully validated on historical data and outperformed the ARMA (autoregressive moving average) and ANN (artificial neural network) methods. Bianco et al. [9] constructed various scenarios by employing regression approach. A combination of economic and climatic factors was incorporated into the regression model to project the long-term non-residential natural gas demand in Italy. Soldo et al. [10] introduced solar radiation variable to test the performance of various linear and non-linear models to forecast the one day ahead demand for natural gas consumption. They concluded that solar radiation should be used as an input variable for building natural gas demand forecasting models. Szoplik [11] employed multilayer perceptron based artificial neural network approach to estimate the natural gas demand of individual consumers and small industries in Poland. The adopted approach was tested to estimate the natural gas demand for a day, a week and a month. Kialashaki and Reisel [12] compared the performance of various regression and artificial neural network models by introducing various household and economic factors to estimate the residential natural gas demand in United States. Khan [13] examined the short- to long-term dynamics of natural gas demand in Pakistan by using an econometric model. Khan used sector-specific price, income and cross price elasticity to estimate the long-term natural gas demand of various sectors in Pakistan. Majazi Dalfard et al. [14] proposed a combined adaptive network-based fuzzy inference system by considering a price hike to estimate various scenarios of the long-term natural demand in Iran.

It can be noticed from the above-mentioned selected studies [8–14] conducted in various countries that all the modelling approaches were utilized based on various factors and forecasting horizon.

Despite of the fact that the role of natural gas in China's primary energy mix is increasing fast due to current pro-natural gas policies, few attentions [15–18] have been paid in the scientific literature to forecast the medium- to long-term natural gas demand in China.

Zhaofang [15] used an input–output model to estimate the long-term natural gas demand in China. Duan constructed low, medium and high scenarios of natural gas demand by employing socio-economic variables such as population (urbanization rate), gross domestic production (GDP) and industrial structure to forecast the long-term natural gas demand. Similarly Li et al. [16] used a system dynamic modelling tool, considering similar socio-economic variables like Zhaofang [15] to estimate the long-term natural gas demand in China. Kang [17] and Lin and Wang [19] used econometric based co-integration model to estimate the natural gas demand.

Currently, natural gas demand in China is experiencing a high growth rate due to pro-natural gas policies of the government. However, it should be noted that such an increase in the natural gas demand would not be persistent because of two main notions:

Firstly, China's economic growth has witnessed the lowest GDP (7.5%) in 2014 since 1990 [1]. China has formally announced the entrance of its economy into a new normal state. The new normal state of the economy is a notion, in which the economy is characterized by the sustainable, slow but quality growth. Sustainable and quality growth can only be achieved by maintaining the standards of the quality and quantity of the environment in all walks of society and economy. It is very much likely that China's future economic growth would not be growing at the same rate, as it was observed during the past two decades. This would have a profound impact on China's overall primary energy consumption.

Secondly, it is a primary rule of market settlement that as China would reach at a certain level of the development in the next 20–30 years, all the macroeconomic indicators including population and gross domestic production (GDP) would first slow down and then settle to follow the saturation characteristics. This observation can be noted in the report [1] released by Chinese government, containing projected growth rates of various macroeconomic indicators. Moreover, similar growth trend was also witnessed in many European Union (EU) countries during the transition of their economies in the last decade [20].

Finally, it can be deduced that China's natural gas demand is expected to follow a logistic growth pattern in the long-term. Thus, it is reasonable to investigate the complementary modelling approach which does not only express the similar trend in the development of natural gas but also is not found in the scientific literature for the case of China.

In the present case, logistic modelling approach may be regarded as a complementary approach for forecasting the medium- to long-term natural gas demand in China. Logistic modelling approach is used to express the life-long process and has been widely applied to demonstrate the growth process in different fields in general [21–24] and natural gas forecasting in particular [25–27]. Logistic modelling approach has the ability to capture historical trend of the data pattern and precisely forecast the future values. It is believed that optimal estimation of the parameters of logistic models can greatly enhance the forecasting precision.

The natural gas forecasting studies based on logistic modelling analysis conducted in other countries are presented as follows. Seimek et al. [25] employed logistic modelling approach to estimate the long-term natural gas demand in Poland. They implemented Gauss–Newton Algorithm to estimate the parameters of logistic model and reported that average error prognosis may reach up to 20%. Forouzanfar et al. [26] used logistic modelling approach to project the residential and commercial natural gas demand in Iran. They estimated the parameters of the logistic model by using a genetic algorithm (GA) and non-linear programming (NLP) and found that the average percent error was less than 10%. Melikoglu [27] used logistic modelling approach to estimate the long-term natural gas demand in Turkey. The results were further compared with linear modelling approach. Melikoglu [27] used optimization software SigmaPlot 11 to estimate the parameters of logistic model and reported that the performance of logistic model was better than linear model.

Against this background, main contributions of this study are as follows: 1) Logistic modelling approach is used to extend the