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Modelling an optimal foreign natural gas import scheme for China

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ABSTRACT

Following China's pledge to mitigate GHG emissions, natural gas has become an important choice for promoting low-carbon development in the country. China has introduced natural gas-friendly policies to increase the penetration of natural gas into its total energy consumption, causing an increase in the demand for foreign natural gas in China. This study attempts to devise a foreign natural gas import scheme for China by constructing a mathematical programming model. Various aspects of energy security, such as diversification, lower dependency, supplier export capacity, minimizing the import cost, transport distance and political instability associated with each of the foreign natural gas suppliers, were incorporated in the decision-making model for a foreign natural gas import scheme for the years 2015–2020. The proposed model optimizes China's strategy by utilizing the existing capacity of the piped natural gas (PNG) infrastructure and gradually increasing the liquefied natural gas (LNG) supply from the top six suppliers in the world, i.e. Qatar, Malaysia, Australia, Nigeria, Indonesia, Trinidad & Tobago and Algeria. Furthermore, the analysis of the existing and planned LNG and PNG import infrastructure suggests that China will have more than enough import capacity to fulfil the demand for foreign natural gas in the country until 2020.

1. Introduction

The Chinese government has pledged to reduce greenhouse gas (GHG) emissions to 60–65% of the total for 2005 by the year 2030 (Cui et al., 2014). Natural gas is low carbon and contributes lower GHG emissions than its counterpart fossil fuels such as oil and coal (Shaikh and Ji, 2016). This has made natural gas an important fuel choice in policy circles. In the last decade, natural gas has been experiencing a rapid penetration into China's total energy consumption. Natural gas production was 42.8 billion cubic metres (BCM) in 2004, grew at an average annual rate of 12.8% and reached 134.5 BCM in 2014. Similarly, natural gas consumption was equal to its domestic production, at 42.8 BCM, in 2004, grew at an average annual rate of 16.5% and reached 185.5 BCM in 2014 (BP, 2014a). However, domestic natural gas production in China was not sufficient to keep pace with growing consumption during this time and China became a net importer in 2007. China's natural gas import dependency was reported as 5% in 2007 and grew very fast to reach 28% in 2014 (BP, 2014a).

A number of investigations have been carried out into various aspects of China's natural gas industry in recent years. Zhang et al. (2017) adopted computation general equilibrium model to analyse the impacts of natural gas price reform in China. They found that an increase in the price of natural gas would increase consumer price index (CPI) and reduce the gross domestic production (GDP) growth of the country. Shaikh et al. (2017) adopted ecological network analysis to evaluate network of China's natural gas supplies. They found that China's natural gas supply network had exhibited considerable network complexity, demonstrating high level of development, flexibility and sustainability. Dong and Kong (2016) quantified the impacts of natural gas import risks on China's economy. They found that a 10% increase in natural gas import risks would decrease China's GDP by 0.24%. Wang and Lin (2016) investigated the influencing factors of China's natural gas consumption across 30 regions of mainland China by adopting panel data analysis. They found that the potential of gas consumption across different

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regions differed considerably depending on the rate at which population in these regions were getting access to it. Wang et al. (2016) forecasted China's unconventional natural gas production in various scenarios and concluded that it would increase rapidly in high scenario settings, reaching 469.7 BCM in 2069. Shaikh et al. (2016) evaluated China's existing natural gas supply security and found that it had been increasing since 2007, owing to a policy of source and route diversification. Tian et al. (2015) studied the competition between the gas- and coal-fired power in a deregulated market using game theoretic model. They concluded that deregulating the price of natural gas, imposing carbon tax and adopting environmental subsidy would greatly promote gas fired power generation in China. Paltsev and Zhang (2015) analysed the recently implemented new natural gas pricing mechanism and found that it was much closer to an international gas pricing system. However, the new pricing mechanism was required to create a system in which both supply and demand were considered. Wang and Lin (2014) quantified the natural gas consumption subsidy for various sectors of China's economy and found that, in the long term, the residential sector would be more sensitive to the natural gas price than the industrial and commercial sectors. Lin and Wang (2012) calculated that China's conventional natural gas production was likely to peak at 149.81 BCM in 2022, exerting considerable impact on the national and international energy market.

The results of all these above studies carry important implications for the natural gas industry in China. Further studies (CEFC, 2013; Li et al., 2011; Lin and Wang, 2012; Shaikh and Ji, 2016) analysed the supply and demand of natural gas in China and found that domestic production would not be sufficient to match the growing demand and hence import dependency might reach 50–60% by the year 2020.

Natural gas can be imported in two forms, liquefied natural gas (LNG) and piped natural gas (PNG). LNG, before being shipped by sea, has to go through a liquefaction process to reduce its size and remove carbon dioxide and other hydrates. PNG, on the other hand, has geographical limitations and can be imported mostly overland via collection, compression and transport units (Foss, 2007). The transport of LNG by international waters is regarded as a more flexible but more insecure form of transport than that of PNG. The transport of PNG, though inflexible, is based on a binding agreement among the stakeholders, namely the supplier, transit and importer countries.

Against this background, it is clear that secure and proper management of domestic and foreign natural gas supplies are an essential policy priority for China in order to sustain socio-economic and low-carbon development in the country. The lack of such management of foreign natural gas supplies may not only endanger China's long-term GHG emission mitigation commitments but also undermine low-carbon development and cause unparalleled loss to final consumers in the country.

In recent years, threats of foreign energy/natural gas supply interruptions have heightened around the world, owing to 1) the increase in the traded volume, 2) the rise of pirate and terrorist attacks, e.g. in the Strait of Malacca, 3) high price volatility, 4) mounting political instability in the natural gas-producing countries and regions, i.e. Yemen, Libya and Syria in the Middle East, North Africa and Russia/Ukraine, and 5) growing tensions because of territorial disputes among various parties in the pathway of natural gas supply routes, i.e. the North and South China sea disputes (Biresselioglu et al., 2015; Geng and Ji, 2014; Wu, 2014; Zhang, 2011).

Therefore, in order to permanently eliminate or at least minimize the effects of these threats, energy security experts have suggested that the foreign energy/natural gas supply should not only be diversified with regard to source and route but also should not depend too much on any one supplier (Ang et al., 2015; Martchamadol and Kumar, 2012; Sovacool and Mukherjee, 2011; Winzer, 2012; Yao and Chang, 2014). Certain recent events, such as the downing of a Russian jet by Turkish forces and the Russia–Ukraine–Europe relationship in the dispute over Crimea, in which Russia was charged with using natural gas as a weapon, underline the need for such diversification (Ellyatt, 2015; NATO, 2015).

In order to maintain a reasonable level of security of the foreign natural gas supply, the design of the potential foreign natural gas scheme should be multifaceted. It should therefore not only consider the aspects of diversification and overreliance on a single supplier but also export capacities, import costs and transport distance, as well as the domestic and political situation of the foreign supplier countries.

In view of the expected growth in China's foreign natural gas import requirements in the future, this study makes the first attempt to propose a foreign natural gas import scheme for China, taking into account the various aspects of energy security as described above, all of which have been modelled in a single mathematical programme or objective function to enable optimal decisions on the best possible import scheme for the years 2015–2020. It is hoped that such a scheme will inform policy makers in China, by specifying the precise quantity of the import volume from the potential suppliers.

The rest of the study is structured as follows. Section 2 presents the materials and methodology adopted, introducing China's existing foreign natural gas import policy and implementation of the assumptions and guiding principles for devising a foreign natural gas import scheme by constructing a mathematical programme for the years 2015–2020. Section 3 discusses the results. Section 4 analyses the existing and planned foreign natural gas import infrastructure in China. Section 5 concludes and presents the implications of the study.

2. Materials and methods

2.1. China's foreign natural gas import policy

From analysis of the existing foreign natural import policy in China, it appears that the country has effectively utilized its extensive oil import experience in framing its foreign natural gas import scheme. China has not only exploited its geographical location bordering countries that are rich in natural gas resources and can transport natural gas through a pipeline directly without passing through a transit country; it has also very well diversified its LNG supplier portfolio. Figs. 1 and 2 present the historical number of LNG and PNG suppliers and the demand for foreign natural gas in China, respectively (BP, 2014b; Shaikh and Ji, 2016).

It can be seen that, with growing foreign natural gas demand, China has continuously pursued a policy of source and route diversification to ensure a higher level of security of its supplies. Further, it can be observed that China has constantly increased the share of PNG in its foreign natural gas import mix. In 2014, of the total demand for foreign natural gas, 45% was imported from 18 LNG suppliers via sea and 55% from four PNG suppliers via two transnational pipelines, the Central Asia–China and Myanmar–China (BP, 2014a) pipelines. This is consistent with China's existing policy focus, which considers that PNG is the more economic and secure form of imported natural gas.

2.2. Devising a foreign natural gas import scheme

Devising a foreign natural gas import scheme for the future should be based on a multifaceted approach that should not only ensure a level of security of supply that is, in pragmatic terms, the