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The future natural gas consumption in China: Based on the LMDI-STIRPAT-PLSR framework and scenario analysis

Jian Chai[a,d], Ting Liang[b,*], Kin Keung Lai[a,c], Zhe George Zhang[d], Shouyang Wang[e]

[a] School of Economics & Management, Xidian University, Xi'an 710126, China
[b] Business School, Hunan University, Changsha 410082, China
[c] Department of Management Sciences, City University of Hong Kong, Hong Kong 999077, China
[d] College of Business & Economics, Western Washington University, Bellingham, WA, United States
[e] Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, China

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ABSTRACT

Due to the growing pollution concerns in China, there have been major efforts to design interrelated environmental protection policies. As the policy of reducing coal consumption is implemented, China's natural gas consumption is expected to commensurately rise. Such a trend may lead to the significant impacts on China's energy security and the global gas market. This paper empirically investigates the relationship between the natural gas consumption and influencing factors in a comprehensive LMDI-STIRPAT-PLSR framework. It is found that fossil energy structure and non-clean energy structure are the most important factors followed by urbanization, per capita GDP, industrialization, and industrial energy intensity. And then, these factors from LMDI decomposition are innovatively divided into economic development and cleaning indicators when using scenario analysis to forecast China's natural gas consumption. The prediction results suggest that economic development with high clean energy system would make a significant increase in gas consumption, a commensurate increase in demand even the system of economic-energy under scenario of low economic development and low clean. As China would depend on gas imports to meet this demand, there may be a serious supply shortage by 2020. Therefore, the government should consider the future energy security issue in making economic and environmental policies.

1. Introduction

Over the past decade and a half, China has become the world largest contributor to global greenhouse gas emission, and producing 27.3% of the world's CO_2 emissions in 2016 by the statistics of the BP and thus plays an important role in addressing climate change (BP, 2017). As a result, emissions mitigation in China as well as elsewhere in the western and developing world has become a major focus of the international community (Qi et al., 2016). Whether CO_2 emissions or other environmental pollutants generally are the by-products of energy and resource use in the process of the economic and social development. Therefore, the environmental issue is directly related to the energy consumption. To address this issue, China has intensified its environmental protection measures by controlling and reducing coal consumption and replacing it with clean energy.

Because natural gas has more cost advantage compared with wind energy, renewable energy and other types of clean energies, the natural gas related technology is well developed and not subject to geographical and time limitations. Therefore, as a clean energy with low-carbon and high-quality, natural gas is being seen as the ideal solution to optimizing energy structure. Increasing the share of the natural gas in primary energy consumption also has been included in 13th Five Year Plan of China. In fact, recently, the substantial reduction in China's station price has generated significant demand increase of downstream consumers. China's natural gas consumption in 2015 only accounted for 6% of primary energy consumption, even though China was the second to Iran as the large natural gas consumer among the emerging economies. However, it still far behind the global average (It has been reported that the global natural gas consumption increased by 1.7% in 2015, accounting for 23.8% of primary energy consumption (BP, 2016)). Therefore, China has a long way to go in optimizing its energy structure to improve air and environmental quality. To stimulate the natural gas demand, we need to analyze the influence factors for natural gas consumption, and then find the appropriate means to achieve the natural gas consumption goals.

However, to the best of our knowledge, owing to the energy reserve

* Corresponding author.
E-mail address: liangting07031992@163.com (T. Liang).

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structure of “coal rich, oil poor, gas little” in China, some supply and demand problems may occur if the growth in natural gas consumption will be as aforementioned estimated or expected. These problems could adversely affect China's energy security. The mismatch between supply and demand in natural gas may pose some challenges to achieving the desired goals of cleaning energy and low carbon economy. Hence, it is necessary to forecast the future natural gas consumption. Such a forecast is needed in addressing the issues in energy security and in the natural gas trading market with other countries besides the concerns in environmental pollution.

The contributions of this paper are as follows. Firstly, factors affecting natural gas consumption are complex. Although there are some past studies on these factors in the literature, they do not address the internal structural effect in energy-economic system. This paper investigates the influencing factors for natural gas consumption based on LMDI method in China, which is different from the previous studies. Our work is also practically motivated as the policy makers may be more concerned as about the fossil energy structure and non-clean energy structure. Secondly, to address the issue of balancing the environmental pollution and economic development, the factors based on LMDI method are innovatively divided into economic development indicators and clean indicators in analysis of future natural gas consumption. This is new in the literature. The method of this classification will help government and policy makers to implement appropriate policies according to planned development in the future. Lastly, we have fully integrated the future performance of supply system into the solution to energy security issue.

The remainder of this paper is organized as follows. Section 2 briefly reviews the literature on the topic of natural gas consumption and indicates that the method of this paper is innovative. In Section 3, the LMDI method is used to analyze the influencing factors affecting natural gas consumption in China. Section 4 establishes the STIRPAT model for natural gas consumption in China and utilizes the PLS regression to estimate the model parameters. In Section 5, the influencing factors are classified and different scenarios are established to conduct natural gas consumption segmentation predictions and analyses. Section 6 concludes the paper with some policy recommendations.

2. Literature review

With regards to the natural gas consumption investigating its influencing factors was important. Energy consumption and particularly natural gas consumption have been a significant energy research focus for decades. For example, Kum et al. (2012) and Apergis et al. (2009) proved that there was a causal relationship between natural gas consumption and economic growth using the Granger causality, Zamani (2007) applied a vector error correction model and found that there was a long-term two-way causal relationship between industrial added value and natural gas consumption besides GDP, and Kani et al. (2014) found that GDP, natural gas prices and the temperature will have a nonlinear impact on Iran's natural gas demand using STR model, and so on. But these traditional methods of analysis the influencing factors may often ignore the internal structure and substitution effect between different energy types. As the *Logarithmic Mean Divisia Index* (*LMDI*) approach is a mature method for studying internal factors and influence intensity, it has been widely used to assess carbon emissions, energy consumption, and energy intensities. For example, Qi et al. (2016) used LMDI to analyze the driving factors behind energy-related CO2 emissions reductions in China, and Torrie et al. (2016) used LMDI to decompose energy intensity to find that the decline in Canada's energy intensity could be attributed to inter-sector structural changes in the economy. The LMDI method has also been applied to examine total energy consumption in different sectors. Numerous researches, such as Zhang et al. (2011) for energy consumption in China's transportation sector, Mraihi et al. (2013) for Tunisian road energy consumption, Wu and Xu (2014) for China's freight energy consumption, Xu and Zhang (2011) for China's manufacturing energy consumption, have focused on total energy consumption from sectional perspective.

There have been many studies sought to predict natural gas consumption using a variety of methods, such as fuzzy theory (Azadeh et al., 2011), neural networks (Gorucu, 2004; Szoplik, 2015), system dynamics (Li et al., 2010), genetic algorithms (Aras, 2008) and Grey Theory (Kumar and Jain, 2010). For example, Kumar and Jain (2010) used a theoretical grey model to predict conventional energy consumption including natural gas in India, and Aras (2008) used genetic algorithms to predict short-term demand for residential natural gas. However, these methods have generally failed to grasp the phased characteristics of the factors in the energy development process. Scenario analysis was initially used by the military to assess the use of land and water resources (Steinitz, 1990). The advantage of this method is that it is able to describe the characteristics of the phased development of the variables associated with the development of the research object and provides a variety of possible predictions under uncertainty (Kepner et al., 2004). Therefore, scenario analysis has been widely used for the analysis of strategic planning of energy resources and the environment (Yamamoto et al., 2000; Karvetski et al., 2011), energy policy (Simões et al., 2008), and decision management (Hong et al., 2013). Before the scenario analysis, multiple regression models are used to investigate the basic relationship among variables. In multivariate regression, the core idea is generally the least squares method, however, as the *ordinary least squares* (*OLS*) has been found to cause model estimation errors if there is multi-collinearity between the variables (Zhang et al., 2009). However, the partial least squares (PLS) method has been preferred when there are limited observed values and numerous variables, numerous missing values, or multi-collinearity between the variables (Frank and Friedman, 1993). It has also been successfully used to predict energy consumption (Zhang et al., 2009; Chai et al., 2008).

The precious researches enrich our investigating of the important influencing factors of natural gas consumption and predicting of the future development. Concerning the scales of research, most of previous works selected some given or certain macroeconomic factors but fail to consider its internal structure effect. As natural gas is important primary fossil fuel energy, the internal structure and substitution effect between different energy types must be accounted for when examining the natural gas consumption influencing factors. LMDI method allows us to more detailed understanding of the impact of these factors such as the energy consumption structure and economic structure on natural gas consumption, and which has been widely used in field of carbon emissions, energy consumption, and energy intensities , but has rarely been used to assess a single energy consumption source such as the decomposition of natural gas consumption (Wang et al., 2011; Liu et al., 2016). Therefore, this paper uses the LMDI method to decompose China's natural gas consumption and analyze its main influencing factors. The partial least squares (PLS) method can perfectly estimate SPIRPAT model for natural gas consumption. Scenario analysis is meaningful for us to describe the characteristics of the phased development of the variables associated with the development of the research object and provides a variety of possible predictions under uncertainty.

This paper makes efforts to make up the gap as follows. First, we propose a comprehensive framework for investigating the relationship between the natural gas consumption and its influencing factors by combining LMDI, STIRPAT and PLSR techniques. Especially, this paper investigates the influencing factors of China's natural gas consumption based on the LMDI method that has not been applied in the previous studies in terms of natural gas consumption. These decomposed factors not only can reflect internal structural effect in energy and economic system on natural gas consumption, but also highly match what policy makers concern about environment, energy and economy. Second, this paper provides a new classification method for the factors from LMDI method when predicting future China's natural gas consumption. Since