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The price and income elasticity of China's natural gas demand: A multi-sectoral perspective

Yi Zhang[a,b], Qiang Ji[a,b,*], Ying Fan[c]

[a] Center for Energy and Environmental Policy Research, Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China
[b] School of Public Policy and Management, University of Chinese Academy of Sciences, Beijing 100049, China
[c] School of Economics & Management, Beihang University, Beijing 100191, China

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ABSTRACT

Natural gas as a clean, low-carbon energy will play an important role in the world's low-carbon energy transformation. In this paper, research on the elasticity of natural gas demand is surveyed, and it is found that the price and income elasticities of natural gas demand in different sectors are distinctive. In particular, this paper constructs an autoregressive distribution lag model to study the elasticity of natural gas demand in various sectors of China. The results show that, except for the residents sector, the long-run price elasticity of natural gas demand in other sectors is greater than 0, which is contrary to the estimates of developed countries. The demand for natural gas is complementary to coal in industrial and power generation sectors, which is also different from developed countries. The elasticity of natural gas demand in residents sector is lack in price elasticity but abundant in income elasticity, which is similar to the developed countries. The results also shows that natural gas and oil are substitutes for each other in the transportation sector, and natural gas and coal are substitutes for each other in service sector.

1. Introduction

Natural gas is a clean, high-efficient, low-carbon energy and constitutes one of the three pillars of the world energy mix along with oil and coal. In 2016 natural gas accounted for 24.13% of the world's primary energy consumption mix (BP, 2017b), and this proportion will rise to 25.17% in 2035 (BP, 2017a). In the background of energy security and climate change, the competitive advantage of natural gas relative to other energy sources is gradually emerging. As a clean fossil energy, natural gas is more economical than coal and oil. Natural gas prices in the North American fell sharply relative to coal and oil due to the North American shale gas revolution. The natural gas industry has become an important part of energy development strategy in many countries.

China's natural gas demand is expected to account for a growing share of the world total demand (Shi et al., 2017). But, at present, China's energy consumption mix is still coal-based, and there is pressure to optimize and upgrade the energy consumption mix. At the end of 2015, China committed to lowering carbon dioxide emissions per unit of gross domestic product (GDP) by 60–65% compare to that of 2005 by 2030, posing a great challenge for China's transition to a low-carbon economy. Natural gas was expected to be an important way to achieve the goal of carbon dioxide emissions reduction and became the focus of China's 13th Five-Year Plan. The plan proposed that by 2020 the proportion of China's natural gas consumption would rise from 5.9% in 2015 to about 10%, and reach about 360 billion cubic meters. Per estimates, the average annual growth of natural gas consumption in China will exceed 30 billion cubic meters from 2016 to 2020, with an average annual growth rate of about 17%. However, China's economy has entered a new normal, with slowed economic growth and weak energy demand, and natural gas consumption in 2016 increased by only 8%, well below the average of nearly 10 years. China's future demand for natural gas is not only affected by its own supply and demand, price and industrial policies, but also by coal, oil, electricity and other related energy prices and supply capacities. China's current coal production is surplus, and its price is relatively low. International oil prices are also at low levels. However, natural gas prices continue to rise with the market-oriented reforms, so natural gas is at a disadvantage in competition with coal and oil. There are many factors including economic growth, structural change in markets, environmental regulations, price and institutional changes contribute to the uncertainties in Chinese gas market (Shi et al., 2017). Thus, promoting the growth of natural gas consumption demand and achieving consumption targets is a challenge.

In order to encourage, guide and standardize the use of natural gas,

* Corresponding author at: Center for Energy and Environmental Policy Research, Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China.
E-mail addresses: jqwxnjq@163.com, jqwxnjq@casipm.ac.cn (Q. Ji).

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optimize the energy mix, develop a low-carbon economy, promote energy conservation and improve the proportion of natural gas in the primary energy consumption mix, in 2012, the National Development and Reform Commission promulgated the "Natural Gas Utilization Policy". The document classifies natural gas users into four categories: priority, allowing, restricted and prohibited, which covers different sectors, including industry, power generation, transportation, public services and residents. For different sectors, natural gas and other energy sources may be substitutional or complementary, and the different relationship of substitution or complement dictates the need for different policies to promote natural gas use. Natural gas demand price elasticity can accurately reveal the relationship between natural gas demand and coal, oil and electricity, providing a theoretical basis for policy measures to promote natural gas consumption.

At present, there is little research on the elasticity of natural gas demand in China, especially about different sectors. Based on the literature review of natural gas demand elasticity, this paper investigates the price and income elasticities of natural gas demand for China's subsectors and reveals the substitutional or complementary relationship between natural gas and other major energy sources. It provides the basis for carrying out scientific and rational measures to promote natural gas consumption.

In the second part of this paper, the research on natural gas elasticity is reviewed, and the existing conclusions about natural gas elasticity are compared with each other. The third part establishes the autoregressive distribution lag model of natural gas demand. The fourth part systematically studies the elasticity of natural gas demand in China's industrial sector, the power generation and supply sector, the transportation sector, service sector and the residents sector, and reveals the influence of price and income on natural gas demand. The fifth part elaborates on the main research conclusions and their policy implications.

2. Literature review

2.1. Elastic definition and comparison

Elasticity as commonly used in research has included the price elasticity of demand, Allen's elasticities of substitution and the Morishima elasticities of substitution (Griffin, 1977; Uri, 1978; Pindyck, 1979; Renou-Maissant, 1999; Urga and Walters, 2003; Serletis et al., 2010, 2011). There are differences as well as relations among them. Price elasticity of demand measures how sensitive the demand for a good is to changes in related prices. Allen's elasticities of substitution reflect how sensitive the ratio of two input factors is to changes in their price ratio. The Morishima elasticities of substitution reflect how sensitive the ratio of two input factors is to changes in one of their prices.

Frondel (2004) deduces the quantitative relationship between the price elasticity of demand, Allen's elasticities of substitution and the Morishima elasticities of substitution, as shown in formulas 1, 2 and 3.

The price elasticity of demand (η_{ij}) is calculated by taking the percent change in quantity of a commodity demanded (x_i) and dividing it by a percent change in price (p_j), which reflects the response of factor demands to changes in the price of the relevant element. When $i=j$, it is called own-price elasticity, and when $i\neq j$, it is called cross-price elasticity. As shown in formula 1, it is a measure of absolute substitution (Frondel, 2011). In formula 1, if the denominator is replaced by an income factor, the income elasticity of demand can be obtained.

$$\text{Price elasticity of demand:}\eta_{ij} = \frac{\partial \ln x_i}{\partial \ln p_j} \tag{1}$$

Allen's elasticities of substitution (σ_{ij}^a) are calculated by taking the percent change in the ratio of two demand factors ($\frac{x_i}{x_j}$) and dividing it by a percent change in their price ratio ($\frac{p_j}{p_i}$), reflecting that the impact of the relative price changes of the two related elements on their relative input changes. It is symmetry, as shown in formula 2. Uzawa (1962) deduced that Allen's elasticities of substitution can be calculated from the cost function. C represents the cost function; C_{ij} represents the mixed derivative of the cost function with respect to the prices of element *i* and the element *j*; C_i and C_j represent the partial derivative of the cost function with respect to the price of element *i* and *j*, respectively; and s_j is the proportion of the input element *j* to the total cost, namely the cost share of input element *j*. Obviously, when the price elasticity of demand is the same, the element whose cost share is smaller the Allen's elasticities of substitution is larger, and the Allen's elasticities of substitution do not have an intuitive explanation.

$$\text{Allen's elasticities of substitution:}\sigma_{ij}^a = \frac{\partial \ln \frac{x_i}{x_j}}{\partial \ln \frac{p_j}{p_i}} = \frac{CC_{ij}}{C_i C_j} = \frac{\eta_{ij}}{S_j} \tag{2}$$

The Morishima elasticities of substitution (σ_{ij}^m) are calculated by taking the percent change in the ratio of two demand factors ($\frac{x_i}{x_j}$) and dividing it by a percent change in price (p_j), reflecting the impact of a factor price change on the relative input of the two elements, as shown in formula 3. Frondel (2011) pointed out that when the element's own-price elasticity is less than 0 and small enough, the Morishima elasticities of substitution make it easier to conclude substitution compared to the cross-price elasticity and Allen's elasticities of substitution.

$$\text{Morishima elasticities of substitution:}\sigma_{ij}^m = \frac{\partial ln\frac{x_i}{x_j}}{\partial ln p_j} = s_j(\sigma_{ij}^a - \sigma_{jj}^a) = \eta_{ij} - \eta_{jj} \tag{3}$$

In practice, energy price policy, energy control measures and energy demand analyses are more concerned with the direct impact of energy price changes on related demand, and demand elasticity is the basis of Allen's elasticities of substitution and the Morishima elasticities of substitution. So this paper mainly focuses on the price elasticity of natural gas demand.

2.2. Research methods on demand elasticity

The studies on demand elasticity can be divided into three categories based on the research method. The first kind of method establish a cost function or a cost share function deduced from a production function, then uses the translog cost function or the linear logit cost share function to study the price elasticity of demand. The second kind of method studies the short-run demand elasticity and long-run demand elasticity through the error correction model and cointegration analysis, respectively. The third kind of method examines the energy price elasticity and income elasticity of demand by establishing the energy demand function.

The translog cost function is deduced from the production function according to dual theory based on a series of assumptions such as weak separability, homothetic, optimization and so on (Griffin, 1977; Uri, 1978; Pindyck, 1979; Renou-Maissant, 1999; Serletis et al., 2010). The cost function should satisfy the regular condition for the homogeneous, non-decreasing, continuous concave function of the factor price. Diewert and Wales (1987) point out that the regular conditions of the translog cost function impose an unacceptable premise constraint on price elasticity and cross-price elasticity. Another flaw in the translog cost function is that the impact of income on demand cannot be considered. The linear logit function is used to express the cost share derived from the translog cost function, ensuring the cost share is non-negative (Urga and Walters, 2003; Considine, 1989; Jones, 1995). Jones (1995) compared the logarithmic cost function and the linear logit cost share function based on US industrial sector data. When considering the time trend term, the linear logit cost share function performed better. There is no significant difference in the price elasticity of the two functions. These two models require an introduction of time factors into the functions to measure the short-run and long-run price elasticities of demand.