Sino-Russian natural gas cooperation: structure and situation

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Abstract. Sino-Russian natural gas cooperation has an important impact on natural gas trade in both Russia and China. Based on the Herfindahl-Hirschman Index (HHI), this paper has established a natural gas import and export security evaluation system to scientifically assess Sino-Russian gas cooperation with respect to the Sino-Russian natural gas structure and situation under the influence of different factors. The research shows: the diversification of natural gas imports in China has gradually increased. China's natural gas imports from Russia are on the rise; When accounting for the export potential of the importing countries, China’s HHIC-PE reveals a wavy upward trend after falling to a low in 2008, and then, upon reaching a peak in 2013, it presents a stable, albeit slightly declining, trend; After accounting for price, the overall HHIC-PE-OP declines, rises and declines again; HHIR shows a sharp decline after it increases, and it then rises again; After accounting for the import potential of exporting countries, the Russian natural gas export risk exhibits two M-type declines; The drop in natural gas prices in recent years has had a significant negative impact on Russian natural gas export security; In the next few years, the sharp increase in Sino-Russian natural gas trade volume will increase the import concentration of both Russia and China, which should guard against the rising natural gas import and export risk.

1. Introduction

With China’s energy consumption and demand continuing to increase, China has become the world's largest energy consumer [1]. China's natural gas dependence increased to 39% in 2017 and its natural gas consumption and foreign dependence will increase rapidly in the future [2]. Russia is a major oil and natural gas producer and exporter at the global level. Its oil and natural gas exports to Europe account for 65% to 70% of its total exports. Accordingly, Russia must strengthen its energy cooperation with the Asia-Pacific region, especially with China, if it wants to eliminate its excessive dependence on the European energy market and enhance its position in the international energy landscape [3]. In recent years, China and Russia have increased their cooperation in the development of natural gas in the Arctic region. On November 1, 2017, during the 22nd regular meeting between the Chinese and Russian prime ministers, PetroChina and Russia Novatec signed a strategic cooperation agreement, and the two sides will continue to work closely together on the Yamal LNG project. By 2019, after the completion of the Yamal LNG project, the three production lines of the
project will supply 4 million tons (equivalent to 6 billion cubic meters) of liquefied natural gas to China each year.

Much research has been performed on the progress, situation, significance, problems and countermeasures of the Sino-Russian energy cooperation project. Yang et al. [3], Sun et al. [4], Yang [5], Xu et al [6] reviewed and summarized the progress of Sino-Russian energy cooperation since the collapse of the Soviet Union. Zhang et al. [7], Chen [8], Wang [3], Guo et al. [9] each analyzed the problems and constraints of Sino-Russian energy cooperation. In recent years, increasingly more studies have begun to use quantitative analysis to evaluate the security of the energy trade [2].

In 1974, the International Energy Agency (IEA) was established and defined energy security as the ability to obtain a sufficient energy supply at a reasonable price [10]. Many scholars started to work on energy security from different angles under the leadership of the IEA [11]. In 1975, Willrich first mentioned the term “energy security” in his book [12]. Mauil [13], Deese [14] considered energy security to be the unification of energy economic security and energy ecological security and promoted energy economic security as the basic goal of national energy security. The Asia-Pacific Energy Research Center contends that energy security refers to a state in which energy is available and acceptable [15]. Based on the definition of HHI index and energy security, this paper constructs a natural gas import and export security evaluation system for Sino-Russian natural gas cooperation and scientifically evaluates the security pattern and situation of Sino-Russian natural gas trade between 2005 and 2016 under the influence of different factors and providing scientific guidance for promoting natural gas cooperation between the two countries.

2. Models and Methods

2.1. Models and Methods

The most commonly used index for measuring energy import security is the HHI, which is based on the measure of diversity. This paper improves the HHI index and builds a natural gas import risk assessment index that comprehensively reflects China's natural gas import security and creates a natural gas export risk assessment index that reflects the security of Russian natural gas exports.

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HHI_i = \sum_{j=1}^{n} w_{ij}^2
\]  

Natural gas import source country distribution (Wcj), natural gas import source country export potential (PEj) and international natural gas price (OP) are key factors that directly affect China's natural gas import security. HHIc, HHIc-PE, and HHIc-PE-OP are China's natural gas import risk indexes, which, respectively, only consider the distribution, the distribution and the export potential, and, comprehensively, the distribution, the export potential and international prices.

\[
HHI_c = \sum_{j=1}^{n} w_{cj}^2
\]  

\[
HHI_c - PE = \sum_{j=1}^{n} w_{cj}^2 \times \frac{1}{PE_j}
\]  

\[
HHI_c - PE - OP = \left( \sum_{j=1}^{n} w_{cj}^2 \times \frac{1}{PE_j} \right) \times OP
\]

The distribution of natural gas export destinations (WRj), the import potential of natural gas exporting countries (PIj) and the international natural gas price (OP) are important factors that affect the security of Russian natural gas exports. HHIR, HHIR-PE, and HHIR-PE-OP are Russia's natural gas export risk indexes which, respectively, only consider the distribution, the distribution and the export potential, and, comprehensively, the distribution, the import potential and international prices.
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\[
HHI_R = \sum_{j=1}^{n} w_R^2 j
\]  
(5)  

\[
HHI_R - PI = \sum_{j=1}^{n} w_R^2 j \times \frac{1}{P_I j}
\]  
(6)  

\[
HHI_R - PI - OP = \left( \sum_{j=1}^{n} w_R^2 j \times \frac{1}{P_I j} \right) \times \frac{1}{OP}
\]  
(7)  

2.2. Data
The data were obtained from the 2006 to 2017 BP Statistical Yearbook. Since there are different dimensions between the indicators, the original data must be standardized.

3. Results and Discussion

3.1. China's natural gas import security

3.1.1. China's natural gas import risk index that only includes natural gas import sources (HHIC)  
China's HHIC experienced a rapid decline after 2005, reaching its lowest point in 2010 before recovering to a relatively high point in 2013, after which it began to decrease again. (figure 1). Prior to 2009, China's natural gas import sources were clustering. In 2005, China's natural gas imports from Indonesia and Malaysia accounted for 51.51% and 42.66%. Driven by China's energy import diversification strategy, China's major natural gas import sources began to expand (figure 2). In 2016, the number of countries from which China imports natural gas accounting for more than 5% of its total natural gas imports was five. The concentration of China's natural gas imports has gradually decreased. During this same period, the amount of natural gas imported from Russia increased from before 2009 to 2.18% in 2016. The increase in the proportion of imported natural gas from Russia and other countries plays an important role in reducing the risk of natural gas imports.

3.1.2. China's natural gas import risk index that includes natural gas sources and natural gas export potential (HHIC-PE)  
China's HHIC-PE shows a wavy upward trend after hitting a low in 2008 and then, after reaching a relatively high value in 2013, it experiences a relatively stable decline (figure 1). This is significantly different from HHIC as a whole, thus indicating that the export potential of natural gas import sources has an important impact on China's natural gas import security. From 2008 to 2013, the export potential of China's major natural gas importing countries exhibited either stability or a wavy decline. After 2014, the export potential of China's major natural gas importing countries showed a steady or slow upward trend. In 2010, the impact of the increase in the import risk index caused by the decline in exporting power of importing countries exceeded the impact of the decline in the import risk index caused by decentralization. It is further noted that with Russia's emergence and its proportion in China's natural gas import market, Russia's increasing natural gas export potential will play an important role in improving China's import security.

3.1.3. China's natural gas import risk index that includes natural gas import sources, natural gas export potential and natural gas price (HHIC-PE-OP)  
After considering the natural gas import source, export potential and price fluctuations, HHIC-PE-OP revealed a downward trend followed by an increase and then a decrease (figure 1). From 2005 to 2016, international natural gas prices fluctuated drastically, resulting in dramatic fluctuations in China's natural gas import security (figure 3). Before 2008, international natural gas prices exhibited an upward trend, but the outbreak of the financial crisis caused a serious oversupply in the international natural gas market, which caused the price to fall. Since then, with the recovery of the world economy, natural gas demand has gradually
recovered, and the huge natural gas supply and demand gap has caused international natural gas prices to increase rapidly. However, since 2013, due to the U.S. shale gas revolution, the overcapacity caused by increased natural gas imports, a slowdown in global economic growth, international natural gas prices have fallen rapidly, which has greatly reduced China's natural gas import risk index in the short term.

Figure 1. HHIC, HHIC-PE and HHIC-PE-OP for the period from 2005 to 2016.

3.2. Russia's natural gas export security

3.2.1. Russia's natural gas export risk index that only includes oil export markets (HHIR) The HHIR expresses an upward trend prior to 2007 and then a wavy downward trend until 2009, after which it experiences another upward trend (figure 4). Before 2007, Russia's natural gas exports exhibited a trend of concentration. As the target of natural gas exports diversified, the number of Russian natural gas export countries increased from 18 in 2008 to 29 in 2009. As a result, the Russian natural gas export risk index plummeted in 2009. The rapid, high concentration of export targets caused the
Russian natural gas export risk index to rebound from 2010 to 2011. The HHIR continued to rise slowly between 2012 and 2016.

Figure 2. The distribution of China’s natural gas import sources.

Figure 3. OP for the period from 2005 to 2016.

3.2.2. Russia’s natural gas export risk index that includes natural gas export markets and natural gas import potential (HHIR-PI) From 2005 to 2016, the HHIR-PI showed a wave-shaped downward trend and two M-type evolutions. It peaked in 2007, 2009, 2012, and 2014 and then experienced a downward trend. In 2020, the HHIR-PI was relatively stable (figure 4). Comparing the HHIR and the HHIR-PI, the import potential of Russian natural gas export targets has an important impact on Russia's natural gas export risk. Before 2007, the HHIR-PI experienced steady growth because the
demand for natural gas in Russia’s main export destinations was gradually decreasing. In 2009, affected by the financial crisis, the global economy was in trouble and energy demand declined substantially. Due to factors such as the shale gas revolution from 2010 to 2012, the main export destinations of Russian natural gas were still exhibiting a downward trend. Since 2014, international gas prices have fallen rapidly, thereby stimulating the consumption of natural gas resources. From 2005 to 2016, with China maintaining a strong demand for natural gas resources, natural gas consumption and natural gas imports continued to rise.

3.2.3 Russia’s natural gas export risk index that includes natural gas export market, natural gas import potential and natural gas price (HHIR-PI-OP) Before 2008, the HHIR-PI-OP exhibited a wavy downward trend, mainly because of the significant increase in international natural gas prices between 2005 and 2008. The positive effect of the decline in natural gas export risks strengthened the positive effects of the rising import potential of major natural gas exporting countries, while the risk to Russian natural gas exports plummeted. However, in 2009, affected by the financial crisis, international natural gas prices fell, resulting in a sharp increase in the Russian natural gas export risk.
index. Since then, international natural gas prices have rebounded. Another sharp decline in international natural gas prices greatly increased Russia’s natural gas export risk index in 2014. In 2015, the positive effect of the rebound in import potential was completely offset by the negative effects of the collapse in natural gas prices. In 2013, the HHIR-PI-OP began to increase and this continued until 2016.

Figure 5. The distribution of Russia's natural gas export markets.

3.3. Prediction of the impact of Sino-Russian natural gas cooperation on the natural gas trade between the two countries under the background of “The Belt and Road”

In accordance with the natural gas cooperation agreement made by the Chinese and Russian governments and the related plans, progress continues with respect to the China-Russia natural gas pipeline construction and the China-Russia Arctic natural gas cooperation development project. By 2020, China will be importing up to 68 billion cubic meters of natural gas and 4 million tons of liquefied natural gas per year from Russia, totaling approximately 74 billion cubic meters of natural gas. Under the premise that the same amount of natural gas trade continues with other countries, by 2020, China will become Russia's largest natural gas export market, and Russia will become China's largest natural gas import market.

4. Conclusion

China's main natural gas import sources are increasingly widespread, the concentration of natural gas imports has gradually decreased and the HHIC is experiencing a downward trend. Among these points, the rising proportion of China's imports of natural gas from Russia has had an important impact on balancing the sources of natural gas imports in China; China's HHIC-PE exhibited a wavy upward trend after hitting a low in 2008. Then, after peaking in 2013, it experienced a slight decline in basic
stability; HHIC-PE-OP experienced a decline, then an increase and then another decline, which indicates that international natural gas prices have a huge impact on China's natural gas import risks. At the end of 2017, an insufficient natural gas supply in China caused prices to soar and the natural gas supply to become extremely unstable. In the next few years, China will increase the amount of natural gas it imports from Russia. In accordance with the Sino-Russian gas cooperation agreement and related plans, by 2020, Russia will become the largest exporter of natural gas to China.

Russian natural gas export targets experienced trends of concentration, dispersion and agglomeration. Among Russia’s export targets, the natural gas exports to China, when considering the proportion of total Russian natural gas exports, revealed an initial decline and then a continuous increase. To a certain extent, this single trend has an impact on the security of Russian natural gas exports: The HHIR-PI presents two M-type drops; In recent years, international natural gas prices have fallen, and there are obvious side effects on Russia’s natural gas export risks; Under The Belt and Road initiative and the construction of the China-Mongolia-Russia Economic Corridor, the Sino-Russian gas pipeline was built and ventilated and the Sino-Russian joint development of natural gas projects in the Arctic region was implemented. While Russia’s gas exports will be more concentrated in China, the export risks will not increase too rapidly because China's strong demand for Russian natural gas has an important impact on offsetting the negative effects of rising export risks caused by the falling demand for natural gas in other countries.

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