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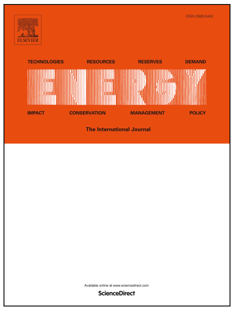

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Market Reforms and Determinants of Import Natural Gas Prices in China

Tiantian Wang[a], Dayong Zhang[b], Qiang Ji[c,d], Xunpeng Shi*[e,f]

[a] Finance school, Nanjing Audit University, China
[b] Research Institute of Economics and Management, Southwestern University of Finance and Economics, Chengdu, China.
[c] Center for Energy and Environmental Policy Research, Institutes of Science and Development, Chinese Academy of Sciences, Beijing, China
[d] School of Public Policy and Manag ement, University of Chinese Academy of Sciences, Beijing, China
[e] Australia-China Relations Institute, University of Technology Sydney, Ultimo, NSW 2007, Australia.
[f] Center of Hubei Cooperative Innovation for Emissions Trading System & School of Low Carbon Economics, Hubei University of Economics, Wuhan, Hubei, China.
*Corresponding Author. X. Shi. Xunpeng.shi@uts.edu.au

Abstract: We use a time series approach to investigate the determinants of import natural gas prices in China with the aim to understand the impact of natural gas market reform and liberalization. We pay special attention to the impacts on import liquefied natural gas (LNG) and pipeline gas prices. The liberalisation of the domestic natural gas market and the reformation of pricing mechanisms in the country have caused systemic structural changes. Our results provide clear evidence of a slow but steady departure from oil indexation, in which China's import gas prices are increasingly affected by market fundamentals such as economic growth, climate factors, policies and other market factors. The empirical results provide supporting evidence to further market reform in China. Moreover, we can generalise the present study to the development of East Asian natural gas price benchmarks. It is important for China and the East Asian region to develop their own natural gas price benchmarks that better reflect regional market fundamentals.
Keywords: market reform; natural gas; import gas; oil indexation; pricing reform; China

JEL: C22, Q31, Q32, Q48

1. Introduction

The East Asian gas market has been increasingly liberalised. Traditionally, natural gas prices were linked to crude oil prices, but traded gas pricing is now moving away from the oil indexation. The experience in the United States (US) and European gas markets demonstrates that hub pricing is a more effective pricing method than oil indexation (EIA, 2017; IEA, 2013). For East Asia, the destination of 70% of globally traded Liquefied Natural gas (LNG), hub pricing is attractive due to its potential capability to resolve the 'Asian Premium', which refers to a persistently higher natural gas import prices in Asian market than in US and Europe (IEA, 2013). This is partially related to the negotiation power of exporting and importing countries based on the market environment (Doh, 2005; Choi and Heo, 2017). By exploring the extent to which oil prices and market fundamentals contribute to variations in gas prices in Japan, the United States, and Germany, Zhang et al.(2018a) pointed out that Asian premium is more likely due to the existing oil indexed pricing mechanism, rather than market fundamentals. Widely accepted benchmark price is the key for hub pricing system, and such price benchmarks need to be produced within each region (EIA, 2017; IEA, 2013). Past analyses suggest that there could be multiple gas price hubs in East Asia, and that these hubs are not exclusive of one another (Shi et al., 2019). In order to create a hub, the hosting market must be liberalised so that sufficient market competition exists to reveal the market fundamentals – not only in the spot market, but also in future markets).

China is in the process of liberalising its gas markets and establishing a competitive gas market with its own gas hubs. As the world's largest natural gas importer (including pipeline natural gas and LNG), China is also reforming its natural gas pricing mechanisms to more closely align its domestic natural gas prices with international gas prices (Zhang, 2018). The market reform starts from 2014 when China allowed prices for unconventional gas and imported LNG to be market-determined (National Development and Reform Commission (NDRC), 2014). The government claimed that more than 80% of non-residential natural gas consumption is subject to market-determined prices (NDRC, 2017). This price reform has created competition in the Chinese gas markets, and the two established gas exchanges – Shanghai and Chongqing Petroleum and Natural Gas Trading Centres – provide platforms where such competition can generate price signals.

How much China's natural gas import prices are affected by factors other than crude oil prices – such as natural gas supply, demand or climate change policy – is an interesting question. Following traditional practices, China's natural gas import prices are mainly indexed to crude oil prices. While imported gas prices are subject to long-term oil-indexed contracts, the fast-growing gas market has made significant room for new contracts and spot trading that may be less dependent on oil prices. Whether China's gas import prices have been less dependent on oil prices is a useful indicator for verifying the impact of China's gas market liberalisation.

Since changes in natural gas import prices are closely related to natural gas import costs, and energy price is an important factor affecting energy consumption (Zhou & Lin, 2008), the pricing mechanism in China matters significantly not only to China but also the global gas sector. China's natural gas consumption is expected to grow quickly; it exceeds 280 billion cubic meters in 2018, but it only accounts for 8% of China's total primary energy supply (TPES). In contrast, the world average share of natural gas in the energy mix is 23% (British Petroleum (BP), 2019). Researchers expect that China's natural gas import volume and import dependence will continue to grow (Lin & Wang, 2012; Li et al., 2016; Wang et al., 2016). Due to the large amount of domestic consumption and import, Shi et al. (2017) show that uncertainties in the Chinese gas market have a significant global impact. Understanding which factors influence natural gas trading in the Chinese pricing mechanism reform can provide effective evidence to help stakeholders liberalise gas markets and establish natural gas hubs in Asia.

Although important, empirical studies on the determining factors of China's natural gas prices are largely absent from the literature. Most studies on energy prices focus on oil prices, such as (Khan et al., 2019a). Limited previous studies on natural gas prices mostly focus on the oil–gas price relationship or on the natural gas price relationship between different sectors in the US. A few studies on China's gas prices have not considered how various factors determine prices. The study that most approximates ours is by Geng et al. (2014). The authors analyse the impact of global economic activity and international crude oil prices on natural gas import prices in three major natural gas markets. In another relevant study, Zhang et al. (2018a) examine how market fundamentals and oil prices have played a role in natural gas prices in Japan, Germany and the US. Neither of these gives specific evidence on what happened in China, and whether the influencing factors of natural gas price have changed in the process of China's natural gas marketization.

We aim to fill this gap by analysing the determining factors of China's pipeline natural gas and LNG import prices. Specifically, we explore changes in the determining factors of natural gas import prices overtime. Our particular interest is to assess the extent to which China's imported gas prices are determined by non-oil price factors such as supply, demand and climate. China's massive demand for natural gas and phenomenally increasing import from international natural gas markets have made researches on relevant issues critical to both the Chinese authorities and other countries in this region. This study is among the first attempts to explicitly investigate natural gas price determinants in China by considering marketization reform and a broader category of factors other than oil prices. Lacking of a competitive market is not only for China, but also other Asia Pacific countries (e.g. Japan, Korea) and middle east countries (EIA, 2017). Findings in this study can bring new evidence and ideas to countries in the region as well, and this evidence can contribute the process of creating a competitive natural gas market in this region.

Builds up on the prior literature, the vector error correction model (VECM) is used by incorporating non-stationary exogenous variables into the estimation of long-run equilibrium. The model allows us to analyse the long-run co-integrating relationship between global crude oil prices and China natural gas import prices, and at the same time, explore the short-term determining factors of China's natural gas import prices. VECM has been widely used to study the influencing factors of natural gas prices in the previous literature (e.g., Brown & Yücel, 2008; Ramberg & Parsons, 2012; Erdōs, 2012; Brigida & Matthew, 2014; Caporin & Fontini, 2015), and it is an effective technique to explore the determinants of China gas import prices.

Our empirical results show that, except for crude oil prices, LNG import prices in China are affected by the total gas import volume and also by the Henry Hub natural gas prices. Further, the imported gas prices from the pipeline are affected by changes in domestic natural gas supply and climate factor. Using China's industrial economic growth rate as an indicator of China's economic development, we find that China's economic development also affects imported gas prices. This is consistent with some recent studies (e.g., Khan et al., 2017; Khan et al., 2019b) that macroeconomic factors tend to hold certain long-run relationship with asset prices. The results of different periods show that the impact of crude oil prices on China's natural gas import prices (LNG and pipeline natural gas) has been decreasing since 2014 when the domestic pricing were liberalized, but the adjustment process of the natural gas import prices to a long-term equilibrium associated with crude oil prices has accelerated. The impact of natural gas production and climate factors on pipeline natural gas prices, and the link between China's LNG market prices and the US natural gas market, both have strengthened after 2014.

The remainder of this paper is organised as follows. Section 2 briefly explains the research background and reviews relevant literature. Section 3 and Section 4 explain the empirical model and data. Section 5 reports empirical results with discussions. Section 5 concludes the paper and outlines policy implications.

2. Literature Review

Previous studies have shown that the determinants of natural gas prices include crude oil price, climate factor, the volume of the natural gas supply, demand and storage (Brown & Yücel, 2008; Ramberg & Parsons, 2012; Erdös, 2012; Brigida & Matthew, 2014; Caporin & Fontini, 2015). Brown and Yücel (2008) and Ramberg and Parsons (2012) use VECM model to study the relationship between the Henry Hub natural gas prices and global crude oil prices in the US, pointing out that the price of natural gas in the US is affected not only by crude oil prices but also by domestic natural gas reserves, shortages and climate. Short-term disequilibrium between market supply and demand have significant impacts on natural gas prices in North America, and temperature changes in the winter can cause Henry Hub spot prices to fluctuate (Geng et al., 2016). Goor and Scholtens (2014) investigate how gas price volatility can be explained by market fundamentals in the UK gas market, and Misund and Oglend (2016) find daily deviations in aggregate gas demand significantly affect natural gas volatility in UK market.

The overall impact of global crude oil prices on Henry Hub natural gas prices has weakened. Caporin and Fontini (2015) take US shale gas production as a factor affecting US natural gas prices. Erdös (2012), Brigida and Matthew (2014) also use the error correction model to study the influencing factors of natural gas market prices in the US. They all point out that the long-term correlation between the Henry Hub gas prices and crude oil prices in the US has gradually weakened since the large-scale development of shale gas; further, the co-integrating relationship between the two prices disappeared at the end of the 2008 global financial crisis. Apergis et al. (2015) study the city gate prices and residential retail prices of natural gas in the US. They find out that the co-integrating relationships between these two prices exist for all 50 states. In summary, with the development of shale gas in North America, the influencing factors of the US' natural gas prices have gradually diversified – the price of alternative energy, changes in natural gas supply and demand and financial factors have become important determinants of the US Henry Hub natural gas prices (Wang et al., 2019). Besides, with the increasing use of natural gas in U.S. market, future natural gas prices would be the main driving factor of electricity prices (Dias & Ramos, 2014; Pineau et al., 2015; Alexopoulos, 2017).

The decoupling between crude oil prices and hub prices has also been documented in the European gas markets. Asche et al. (2012, 2013) use VECM to study the relationship between European (UK, Britain, Belgium and the Netherlands) natural gas prices and Brent crude oil prices, pointing out that there is a stable long-term relationship between European natural gas prices and global crude oil prices. Geng et al. (2017) deconstruct the regional gas and crude oil prices at different timescales using the ensemble empirical mode decomposition method. They find that unidirectional linear Granger causality exists from crude oil markets to European gas markets.

By studying the integration of the international natural gas market, Chiappini et al. (2019) indicate that in recent years, the integration and natural gas trade system relations in the US, Europe and Asia have gradually become closer. They also find the existence of an asymmetric adjustment to long-term equilibrium between the Henry Hub natural gas prices and the Japan Korea Marker (JKM) natural gas prices. The shale gas revolution has promoted the gradual integration of global LNG markets, and the fluctuation of natural gas prices in the US market have affected the prices of natural gas in the Asian market (Wakamatsu & Aruga, 2013; Geng et al., 2014).

As for the study of the Chinese natural gas market, most existing research focuses on the forecast of natural gas supply and demand under the condition of rapid economic development in China, pointing out that China's natural gas demand is growing rapidly (Li et al., 2011; Lin & Wang, 2012; Wang & Lin, 2014; 2016; Zhang & Yang, 2015). Further, the gap between supply and demand for natural gas will continue to expand (Lin & Wang, 2012; Li et al., 2016; Wang et al., 2016). Wang and Lin (2014) analyse the natural gas consumption of residential, industrial and commercial sectors through a co-integration test. They first introduce climate factors to analyse China's natural gas market. The results show that beside economic growth, industrialisation and urbanisation, China's natural gas consumption is also driven by temperature fluctuations, indicating that peak shaving is still an important issue in natural gas supply, especially for the residential sector. Thus, it is necessary to adjust the peak demand for natural gas in winter, as the seasonal pressure for natural gas consumption will grow in China (Liu et al., 2018). Li et al. (2016, 2018) take Zhengzhou and Beijing as examples to consider the effect of residential gas pricing policy on Chinese household natural gas consumption. Based on these results, future directions and actions for the design and improvement of residential natural gas pricing system are suggested.

In general, existing studies on natural gas prices in China mostly focus on the price elasticity of gas demand (Wang & Lin, 2016; Zhang et al., 2018) or price subsidies (Wang & Lin, 2014; Liu & Lin, 2018), and there are few studies on the influencing factors of the natural gas prices in the Chinese market. Following the rich literature on the US and other well-developed markets, and also taking into account of the recent market reform in China, this paper therefore aims to bring forward a solid empirical research on the pricing mechanisms of the natural gas market in China.

3. Methodology

Empirically, VECM is firstly used to establish the long-term relationship between natural gas import prices and crude oil prices, if exists. The model is then augmented by incorporating the short-term influencing of various factors, including the volume of natural gas production and total gas import in China, weather variables (cooling degree days [CDD] and heating degree days [HDD]), China's industrial growth rate and the Henry Hub natural gas prices. We include oil prices as a long-term factor because the majority of China's imported gas prices are linked to oil prices. Gas prices are often approached as a fraction of a moving average of immediate past oil prices (Komlev, 2016; Shi & Variam, 2017). Our key interest is the extent to which non-oil price components determine China's imported gas prices and its recent trends.

Engle and Granger (1987) introduce error correction models to study long-run equilibriums among a set of non-stationary economic variables. The VECM model is an important extension to the single-equation model. Firstly, we establish a two-variable vector autoregressive model:

$$\begin{bmatrix} \mathrm{P}_{GAS} \\ \mathrm{P}_{OIL} \end{bmatrix}_t = \begin{bmatrix} \mathrm{a}_{GAS} \\ \mathrm{a}_{OIL} \end{bmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \varphi_{GAS,GAS} & ,\varphi_{OIL.GAS} \\ \varphi_{GAS.OIL} & ,\varphi_{OIL,OIL} \end{bmatrix}_i \begin{bmatrix} \mathrm{P}_{GAS} \\ \mathrm{P}_{OIL} \end{bmatrix}_{t-i} + \sum_{j=1}^{q} \begin{bmatrix} \phi_{GAS} \\ \phi_{OIL} \end{bmatrix}_j X_{j,t} + \begin{bmatrix} \epsilon_{GAS} \\ \epsilon_{OIL} \end{bmatrix}_t \quad (1)$$

$\mathrm{P}_{GAS,t}$ and $\mathrm{P}_{OIL,t}$ represent the natural gas import prices and crude oil prices, respectively; $X_{j,t}$ contains the stationary exogenous variables in the model; q represents the number of exogenous variables. φ and ϕ are parameters to be estimated. Besides, p is the optimal lag order of the vector autoregressive model, a_{GAS} and a_{OIL} are constants, $\varepsilon_{GAS,t}$ and $\varepsilon_{OIL,t}$ are residuals of the model. Let $\varphi_i = \begin{bmatrix} \varphi_{GAS,GAS} & ,\varphi_{OIL.GAS} \\ \varphi_{GAS.OIL} & ,\varphi_{OIL,OIL} \end{bmatrix}_i$, the formula can be transformed into

$$\begin{bmatrix} \Delta\mathrm{P}_{GAS} \\ \Delta\mathrm{P}_{OIL} \end{bmatrix}_t = \begin{bmatrix} \mathrm{a}_{GAS} \\ \mathrm{a}_{OIL} \end{bmatrix} + \psi \begin{bmatrix} \mathrm{P}_{GAS} \\ \mathrm{P}_{OIL} \end{bmatrix}_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \begin{bmatrix} \Delta\mathrm{P}_{GAS} \\ \Delta\mathrm{P}_{OIL} \end{bmatrix}_{t-i} + \sum_{j=1}^{q} \begin{bmatrix} \phi_{GAS} \\ \phi_{OIL} \end{bmatrix}_j X_{j,t} + \begin{bmatrix} \epsilon_{GAS} \\ \epsilon_{OIL} \end{bmatrix}_t \quad (2).$$

In which $\psi = \sum_{i=1}^{p} \varphi_i - I$, $\Gamma_i = -\sum_{j=i+1}^{p} \varphi_j$. When the co-integration relationship exists between oil and gas prices, ψ can be decomposed into the product of two two-dimensional vectors ∂ and β', and $\psi = \partial\beta'$,

$$\begin{bmatrix} \Delta\mathrm{P}_{GAS} \\ \Delta\mathrm{P}_{OIL} \end{bmatrix}_t = \begin{bmatrix} \mathrm{a}_{GAS} \\ \mathrm{a}_{OIL} \end{bmatrix} + \partial\beta' \begin{bmatrix} \mathrm{P}_{GAS} \\ \mathrm{P}_{OIL} \end{bmatrix}_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \begin{bmatrix} \Delta\mathrm{P}_{GAS} \\ \Delta\mathrm{P}_{OIL} \end{bmatrix}_{t-i} + \sum_{j=1}^{q} \begin{bmatrix} \phi_{GAS} \\ \phi_{OIL} \end{bmatrix}_j X_{j,t} + \begin{bmatrix} \epsilon_{GAS} \\ \epsilon_{OIL} \end{bmatrix}_t \quad (3).$$

Let $\mathrm{ECM}_{t-1} = \beta' \begin{bmatrix} \mathrm{P}_{GAS} \\ \mathrm{P}_{OIL} \end{bmatrix}_{t-1} = \mathrm{P}_{GAS,t-1} + \beta\, \mathrm{P}_{OIL,t-1}$; Parameter β is used to represent the long-term co-integration relationship between natural gas price and crude oil price. Then, the VECM model is established as follows:

$$\begin{bmatrix} \Delta\mathrm{P}_{GAS} \\ \Delta\mathrm{P}_{OIL} \end{bmatrix}_t = \begin{bmatrix} \mathrm{a}_{GAS} \\ \mathrm{a}_{OIL} \end{bmatrix} + \begin{bmatrix} \partial_{GAS} \\ \partial_{OIL} \end{bmatrix} \mathrm{ECM}_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \begin{bmatrix} \Delta\mathrm{P}_{GAS} \\ \Delta\mathrm{P}_{OIL} \end{bmatrix}_{t-i} + \sum_{j=1}^{q} \begin{bmatrix} \phi_{GAS} \\ \phi_{OIL} \end{bmatrix}_j X_{j,t} + \begin{bmatrix} \epsilon_{GAS} \\ \epsilon_{OIL} \end{bmatrix}_t \quad (4)$$

In formula (4), $\Delta\mathrm{P}_{GAS,t}$ and $\Delta\mathrm{P}_{OIL,t}$ represent the first-order difference of natural gas prices and crude oil prices, respectively. ECM_{t-1} is error correction term, it reflects the long-term equilibrium relationship between variables. The coefficient ∂ reflects the adjustment speed of the variables to the equilibrium state when they deviate from the long-term equilibrium state. When the model is expanded, it can be written as

$$\Delta \mathrm{P}_{GAS,t} = \mathrm{C}_{GAS} + \partial_{GAS}\left(\mathrm{P}_{GAS,t-1} + \beta\, \mathrm{P}_{OIL,t-1} + \alpha\right) + \sum_{i=1}^{p-1} b_{GAS,i}\, \Delta P_{GAS,t-i} + \sum_{i=1}^{p-1} c_{GAS,i}\, \Delta P_{OIL,t-i} + \sum_{j=1}^{q} d_{GAS,j} X_{j,t} + \varepsilon_{GAS,t} \quad (5)$$

$$\Delta \mathrm{P}_{OIL,t} = \mathrm{C}_{OIL} + \partial_{OIL}\left(\mathrm{P}_{GAS,t-1} + \beta\, \mathrm{P}_{OIL,t-1} + \alpha\right) + \sum_{i=1}^{p-1} b_{OIL,i}\, \Delta P_{GAS,t-i} + \sum_{i=1}^{p-1} c_{OIL,i}\, \Delta P_{OIL,t-i} + \sum_{j=1}^{q} d_{OIL,j} X_{j,t} + \varepsilon_{OIL,t} \quad (6)$$

C_{GAS} and C_{OIL} are constants. The coefficients of difference terms (b and c) reflect the lagged effects of the short-term fluctuations of each variable. p is the optimal lag order of the vector autoregressive model and q represents the number of exogenous variables. The coefficient $d_{GAS,j}$ and $d_{OIL,j}$ reflect the short-term impact of each exogenous variable on the natural gas import prices and crude oil prices respectively.

Referring to Brown and Yücel (2008) and Ramberg and Parsons (2012), we can measure the determinants of natural gas prices conditioned on the assumption that the crude oil price can be taken as predetermined. Then Formula (5) is the equation estimated for changes in gas prices. In addition, Chinese natural gas import mainly has two forms: LNG and pipeline natural gas. The equations for changes in China natural gas import prices are as follows:

$$\Delta \mathrm{P}_{\mathrm{LNG,t}} = \mathrm{C}_{LNG} + \partial_{\mathrm{LNG}}\left(\mathrm{P}_{\mathrm{LNG,t-1}} + \beta_{LNG}\, \mathrm{P}_{\mathrm{OIL,t-1}} + \alpha_{\mathrm{LNG}}\right) + \sum_{\mathrm{i=1}}^{\mathrm{p-1}} \mathrm{b}_{\mathrm{LNG,i}}\, \Delta \mathrm{P}_{\mathrm{LNG,t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{p-1}} \mathrm{c}_{\mathrm{LNG,i}}\, \Delta \mathrm{P}_{\mathrm{OIL,t-i}} + \sum_{\mathrm{j=1}}^{\mathrm{q}} \mathrm{d}_{\mathrm{LNG,j}} \mathrm{X}_{\mathrm{j,t}} + \varepsilon_{\mathrm{LNG,t}} \quad (7)$$

$$\Delta \mathrm{P}_{\mathrm{PIPE,t}} = \mathrm{C}_{PIPE} + \partial_{\mathrm{PIPE}}\left(\mathrm{P}_{\mathrm{PIPE,t-1}} + \beta_{PIPE}\, \mathrm{P}_{\mathrm{OIL,t-1}} + \alpha_{\mathrm{PIPE}}\right) + \sum_{\mathrm{i=1}}^{\mathrm{p-1}} \mathrm{b}_{\mathrm{PIPE,i}}\, \Delta \mathrm{P}_{\mathrm{PIPE,t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{p-1}} \mathrm{c}_{\mathrm{PIPE,i}}\, \Delta \mathrm{P}_{\mathrm{OIL,t-i}} + \sum_{\mathrm{j=1}}^{\mathrm{q}} \mathrm{d}_{\mathrm{PIPE,j}} \mathrm{X}_{\mathrm{j,t}} + \varepsilon_{\mathrm{PIPE,t}} \quad (8)$$

Among these, P_{OIL} refers to the global crude oil price, P_{LNG} refers to the import price of liquefied natural gas in China, and the import price of pipeline natural gas is P_{PIPE}. We processed the price data we used in the model logarithmically. Figure 1 provides a flowchart illustrating our empirical strategy.

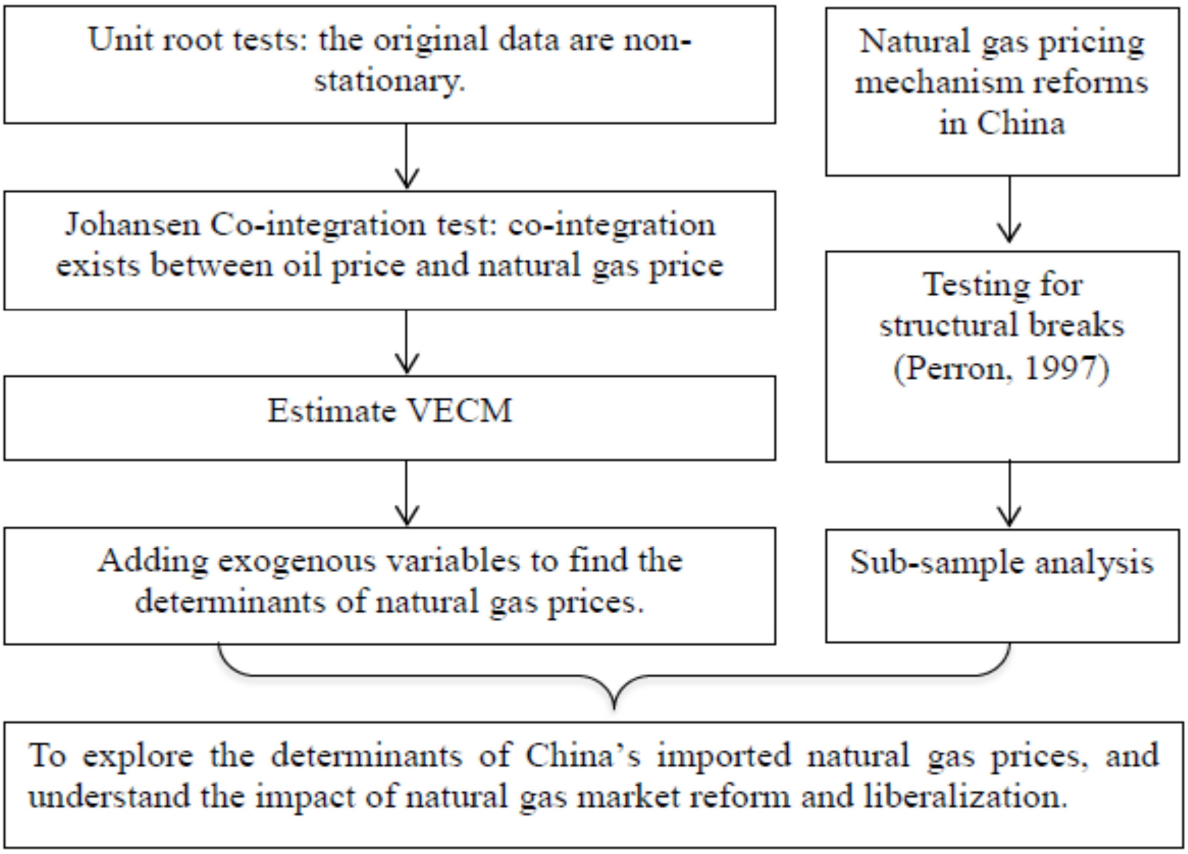


Figure 1. Flowchart illustration of the empirical strategy

4. Data and Sample Analysis

Imported gas in China can be divided into LNG import and pipeline natural gas import. In 2018, China's LNG import is 53.6 billion cubic meters (bcm), and its pipeline natural gas import is 36.8 bcm, together accounting for approximately 36% of China's total natural gas demand[1]. The monthly prices of LNG import from the period of June 2006 to April 2019 are used in this paper. We also examine the monthly price of pipeline natural gas import from February 2010 to April 2019. For market fundamentals, we use China's total natural gas production, total import, climate factors (HDD and CDD) and industrial growth rate in our

1 Data source: Bloomberg database

VECM models as exogenous variables. Climate factors and China's industrial growth rate can both be considered as proxies of demand factors. In addition, considering the gradual integration of the global natural gas markets (Chiappini et al., 2019), the steady transition away from oil indexation toward hub indexation (Shi et al., 2019) and that US natural gas prices affect Japanese LNG import prices (Wakamatsu & Aruga, 2013; EIA, 2017) because Japan is the world's largest LNG importer, we also study the impact of the Henry Hub natural gas prices on China's import natural gas prices. The data are mainly from EIA and the Bloomberg Database.

Figure 2 shows the trends of international crude oil prices and Chinese natural gas prices from different sources. We find that the trends of Chinese natural gas import prices are similar to, but may lag behind, global crude oil prices. This similarity is due to the prevailing oil indexed natural gas trading prices (Shi & Variam, 2017; Zhang et al., 2018a). Additionally, LNG import prices are similar to, but higher than pipeline natural gas import prices. This is mainly due to two factors: the liquefaction cost of LNG and the different pricing points. The pipeline natural gas trade in China is priced in the western border of China, whereas the settlement point of LNG is mainly in the eastern coast. The eastern coast region is the primary demand centre of natural gas and thus has higher prices than the western region.

From 2014, China no longer regulated domestic LNG prices, and the records of domestic LNG ex-factory prices start from January 2014. The fluctuation trend of domestic average LNG ex-factory prices is mostly similar with natural gas import prices, but there is a sharp increase at the end of 2017, which is related to China's radical push of its coal-to-gas switch policy, which created an extremely tense gas market. The coal-to-gas switch policy, together with the increased fuel demand in winter, caused a sharp increase in the gas demand and a sharp increase in domestic LNG prices.

The price of domestic LNG is higher than that of imported LNG, which is also because that domestic LNG is priced at the end-market. In addition to the transportation cost, the price gap is also boosted by the limited capacity of LNG receiving terminals that prevent LNG import from flowing into the domestic market[2]. With further market liberalisation, the

[2] We must highlight that import LNG prices are not always lower than domestic LNG prices.

construction of more LNG-receiving terminals and the participation of non- national oil companies (non-NOCs), researchers expect China's natural gas import volume and import dependence to continue to grow (Lin & Wang, 2012; Li et al., 2016; Wang et al., 2016).

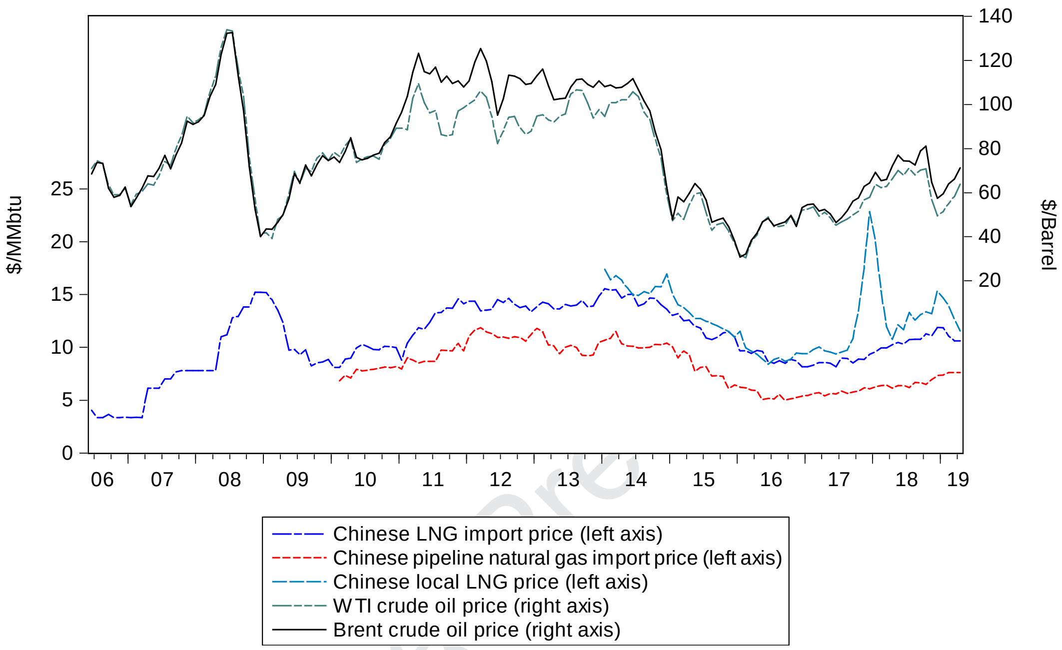


Figure 2. Chinese natural gas prices and global crude oil prices

The basic characteristics of the data are shown in Table 1 and Figure 2. In the sample period, the mean value of the LNG import price is 10.74$/MMbtu in China, which is higher than the mean value of the pipeline natural gas import price (8.236$/MMbtu), both of which are much higher than the Henry Hub spot prices in the U.S. market ($4.258/MMbtu). The mean values of the LNG import price and the pipeline natural gas import price in China are both positive after taking first-order log difference. As shown in Table 1, and the mean value of the total output and import volume of natural gas in China is also positive after taking first-order log difference.

Brown and Yücel (2008) discuss the ratio of crude oil price to natural gas price; they introduce the burner tip parity rule. Under this rule, a $50 per barrel price for West Texas Intermediate (WTI) would mean a natural gas price of $7.06 per million Btu at Henry Hub. In the long run, the ratio of the crude oil price to the natural gas price should follow a certain law – the burner tip parity of this ratio should be around 7. We calculate the ratio of the Brent crude oil prices to the Chinese natural gas import prices. As shown in Figure 3 and Table 1, the mean values of the ratio of the Brent crude oil prices to the LNG import prices and the pipeline natural gas import prices in China are 7.987 and 9.724, respectively.

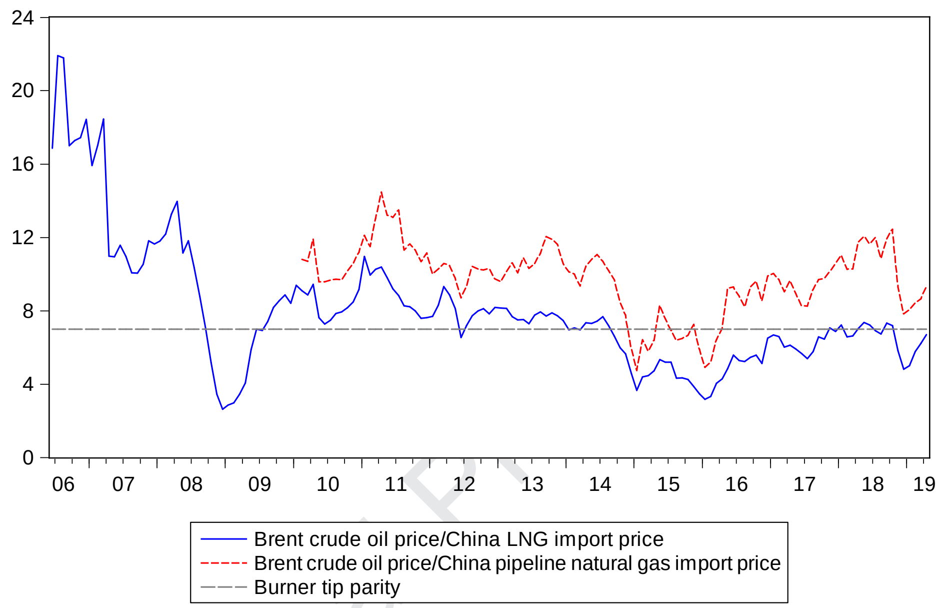


Figure 3. The ratio of the Brent crude oil prices to China's natural gas import prices

By observing skewness, kurtosis and variance, we can see that the values of these three parameters for the crude oil–LNG price ratio are all higher than that of the crude oil and pipeline natural gas prices. As Figure 3 illustrates, the ratio of the Brent crude oil prices to China's LNG import prices fluctuates greatly between 2006 and 2008. After the economic crisis, the ratio of the Brent crude oil prices to China's LNG import prices shows a slight downward trend, but it does not deviate from the reference value on a very large scale.

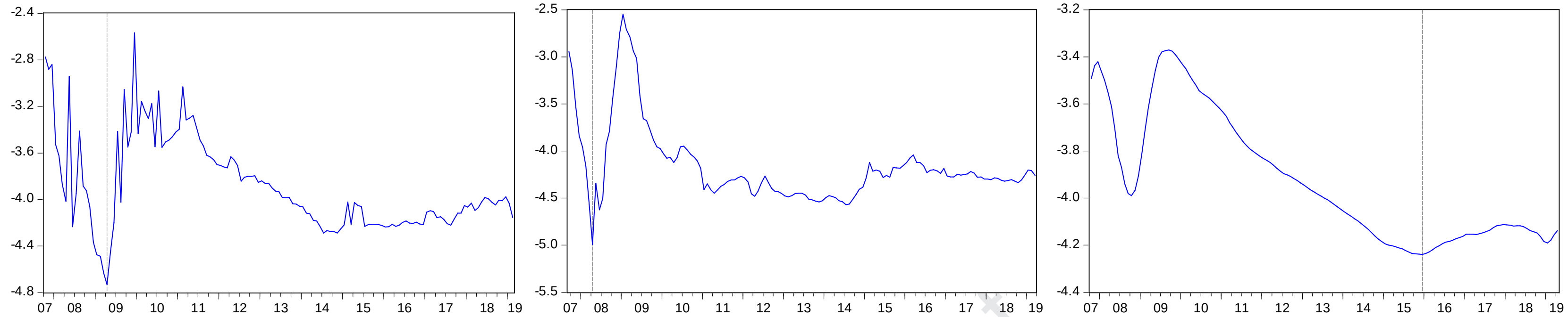
Following Caporin and Fontini (2015), we use the Perron (1997) unit root test with structural break on the ratio of crude oil prices to China's natural gas import prices (as shown in Figure 4 and Figure 5). We consider three different cases: break in both trend and intercept; break in intercept only; break in trend only. The results show that the breakpoints of the oil–gas price ratio in China LNG import occurred in the period of 2008–2009 economic crisis and 2014–2015 Chinese natural gas pricing reform. The relationship between crude oil prices and LNG import prices in China is particularly unstable during the crisis. And in 2014, China changes its natural gas pricing mechanism from cost-plus pricing to net-back pricing and liberalised the domestic LNG price such that it would be determined by the market. Following Erdös (2012), we divide the sample of China's LNG import price into three intervals: June 2006 to December 2008, January 2009 to December 2013 and January 2009 to April 2019.

The data recording of pipeline natural gas import price started in 2010, the breakpoint of oil-gas price ratio in China pipeline natural gas all occurred in the period of 2014–2015 Chinese natural gas pricing reform. So, the sample of China's pipeline import price is divided into two intervals: February 2010 to December 2013 and January 2014 to April 2019. We set VECM with January 2014 as breakpoint (including both LNG and pipeline natural gas prices) to explore the influence factors of natural gas import prices before and after the reform of China's natural gas pricing mechanism.

Table 1: Descriptive Statistics of the Data

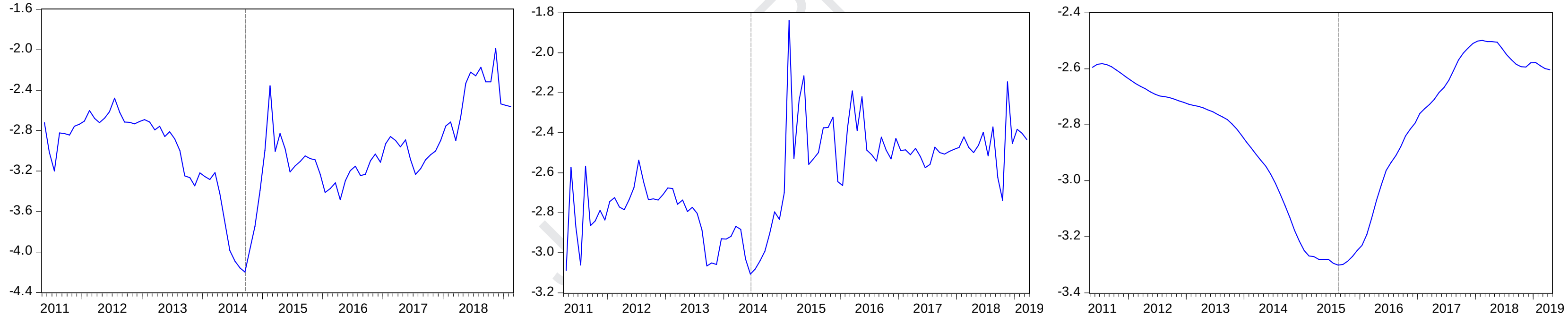
Note：J.B. = Jarque-Bera statistic. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. P_{GAS} and P_{PIPE} = the Chinese LNG import price and pipeline natural gas price, respectively. Brent = Brent crude oil price. LN_P_{LNG}, LN_P_{PIPE} and LN_Brent indicate that the import price of LNG and pipeline natural gas in China and the price of Brent crude oil are logarithmic processed, respectively. D_LN_P_{LNG}, D_LN_P_{PIPE} and D_LN_Brent = the first-order log difference of the import prices of natural gas in China and the prices of Brent crude oil, respectively. D_LN_GAS_PRO and D_LN_GAS_IM = the first-order log difference of total production and total import of natural gas in China, respectively. HDD and CDD = climatic data. D_HDD and D_CDD = the first-order difference terms of HDD and CDD. D_LN_P_{HH} = the first-order difference term after the logarithm of the Henry Hub natural gas price. IGR is the industrial growth rate; it is an incremental variable, so we do not treat it as having a first-order difference. Brent/P_{LNG} and Brent/P_{PIPE} = the ratio of the Brent crude oil prices to China's LNG import prices and China's pipeline natural gas import prices, respectively.

		Mean	Med	Max	Min	Std. Dev.	Skew	Kurtosis	J.B.	N
Endogenous variable	P_{lng}	10.740	10.750	15.545	3.345	3.111	-0.529	2.781	7.530**	155
	P_{pipe}	8.236	8.084	11.846	4.997	2.031	0.062	1.674	8.201**	111
	Brent	79.113	74.410	132.720	30.700	25.738	0.190	1.801	10.224***	155
Log	LN_P_{lng}	2.319	2.375	2.744	1.207	0.363	-1.544	5.520	102.556***	155
	LN_P_{pipe}	2.077	2.090	2.472	1.609	0.255	-0.192	1.717	8.294**	111
	LN_Brent	4.315	4.310	4.888	3.424	0.342	-0.263	2.112	6.876**	155
Log Difference	D_LN_P_{lng}	0.006	0.001	0.603	-0.238	0.078	3.137	26.923	3924.777***	154
	D_LN_P_{pipe}	0.001	0.004	0.136	-0.188	0.056	-0.649	4.872	23.786***	110
	D_LN_Brent	0.000	0.016	0.196	-0.311	0.092	-1.072	4.641	46.792***	154
Stationary exogenous variables	D_LN_GAS_PRO	0.007	0.006	0.168	-0.288	0.066	-1.060	6.005	86.763***	154
	D_LN_GAS_IM	0.031	0.003	1.729	-0.930	0.309	1.271	9.510	313.437***	154
	D_HDD	0.143	0.000	11.683	-14.358	5.187	-0.194	3.201	1.195	154
	D_CDD	-0.005	0.000	3.613	-3.613	0.919	-0.393	9.094	235.985***	154
	D_LN_P_{HH}	-0.006	-0.012	0.380	-0.376	0.124	0.286	4.076	9.534***	154
	IGR	10.495	9.500	19.500	5.400	4.254	0.515	1.962	13.818***	155
Henry Hub gas price	P_{HH}	4.258	3.680	12.690	1.730	1.980	1.669	6.026	131.102***	155
Oil/Gas	Brent/P_{lng}	7.987	7.412	21.921	2.627	3.499	1.658	6.491	149.713***	155
	Bent/P_{pipe}	9.724	10.003	14.486	4.752	1.896	-0.477	3.252	4.510*	111



(1) Break in trend and intercept：2009.04 (2) Break in intercept：2008.04 (3) Break in trend：2015.12

Figure 4. Breakpoint unit root test: Brent /LNG price



(1) Break in trend and intercept：2014.09 (2) Break in intercept：2014.06 (3) Break in trend：2015.08

Figure 5. Breakpoint unit root test: Brent/Pipe gas price

5. Empirical Results

5.1 Stationary test

Firstly, we use the Augmented Dickey Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationary test on the data used in the VECM model. As shown in Table 2, the first-order difference of China's LNG import prices, pipeline natural gas import prices and Brent crude oil prices are all stationary time series, whereas the original data are not. The original data on total natural gas production and HDD reject the original hypothesis of ADF detection at the 5% level but fail the PP test. The first-order difference terms of total natural gas output, total import, HDD and CDD are also stationary time series.

5.2 Co-integration test

We use the Johansen co-integration test (Johansen& Soren, 1991; Johansen & Juselius, 1992) on the relationship between Brent crude oil prices and China's natural gas import prices at different intervals. As shown in Table 3, within the sample period, the hypotheses that at the most there would exists zero and one co-integrating relation between oil–gas prices are both rejected at the 5% level, so the co-integration relationships between natural gas import prices (LNG and pipeline natural gas) and Brent crude oil prices satisfied the condition for establishing VECM.

The results of the time interval studies show that the co-integration relationship between China's LNG import prices and Brent crude oil prices in the period after 2009 is significant; however, no co-integration relationship between the two exists from June 2006 to December 2008. During this period, Brent crude oil prices and LNG import prices both fluctuate greatly, and the measurement interval is relatively short; therefore, the relationship between them is unstable.

Regarding the relationship between China's pipeline import prices and Brent crude oil prices, only trace statistics reject the original hypothesis in the research interval before 2014. The co-integration relationship between these two time series in the research interval after 2014 as well as the whole interval is stable.

Table 2: Stationary Test

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Brent crude oil prices = P_{Brent}. China's LNG import prices = P_{LNG}. Pipeline natural gas import prices = P_{PIPE}. Henry Hub natural gas prices = P_{HH}. The volume of Chinese natural gas production GAS_PRO and the total natural gas import volume GAS_IM are all logarithmically processed.

	Augmented Dickey Fuller		Phillips-Perron		Kwiatkowski-Phillips-Schmidt-Shin	
	Level	First Difference	Level	First Difference	Level	First Difference
	t-statistic	t-statistic	t-statistic	t-statistic	t-statistic	t-statistic
P_{LNG}	-2.486	-7.742***	-2.510	-12.408***	77.361***	1.136
P_{PIPE}	-1.130	-12.414***	-1.069	-12.293***	82.842***	0.033
P_{Brent}	-2.338	-7.785***	-2.068	-7.816***	37.611***	-0.138
GAS_PRO	-2.937**	-6.319***	-1.403	-23.909***	391.452***	1.340
GAS_IM	-2.154	-21.490***	-2.164	-28.358***	131.302***	1.329
HDD	-3.415**	-11.087***	-1.884	-6.302***	10.627***	0.338
CDD	-2.623*	-13.213***	-10.207***	-41.398***	4.307***	-0.068
P_{HH}	-1.985	-12.547***	-1.985	-12.548***	42.290***	-0.553
IGR	-2.414	-14.889***	-2.341	-14.884***	30.716***	-0.831

Table 3: Johansen System Co-Integration Test

Note: * denotes significance at the 5% level. Brent crude oil prices = P_{Brent}. China's LNG import prices = P_{LNG}. Pipeline natural gas import prices = P_{PIPE}. They are all logarithmically processed. Lag order is determined by the AIC criterion.

	Period	No. of cointegrating relation(s)	Eigenvalue	Trace Statistic	p-value	Max-Eigen Statistic	Prob.**
$P_{LNG} - P_{Brent}$	2006.06-2019.04	None*	0.167	33.421	0.000	27.526	0.000

		At most 1*	0.038	5.894	0.015	5.894	0.015
	2006.06-2008.12	None	0.139	4.443	0.864	4.186	0.839
		At most 1	0.009	0.257	0.612	0.257	0.613
	2009.01-2019.04	None*	0.226	35.324	0.000	31.840	0.000
		At most 1	0.028	3.484	0.062	3.484	0.062
	2009.01-2013.12	None*	0.325	26.853	0.001	23.589	0.001
		At most 1	0.053	3.264	0.071	3.264	0.071
	2014.01-2019.04	None*	0.236	21.650	0.005	17.223	0.017
		At most 1*	0.067	4.427	0.035	4.427	0.035
$P_{PIPE} - P_{Brent}$	2010.02-2019.04	None*	0.218	29.645	0.000	25.380	0.001
		At most 1*	0.041	4.265	0.039	4.265	0.039
	2010.02-2013.12	None	17.197	15.495	0.013	10.969	0.156
		At most 1*	6.228	3.841	0.005	6.228	0.013
	2014.01-2019.04	None*	0.245	25.276	0.001	18.023	0.012
		At most 1*	0.107	7.253	0.007	7.253	0.007
$P_{LNG} - P_{PIPE}$	2010.02-2019.04	None	0.110	15.379	0.052	12.113	0.107
		At most 1	0.031	3.266	0.071	3.266	0.071

5.3 Granger causality test

We use the Granger causality test to check whether the introduction of the lag terms of one variable can help predict the dependent variable more accurately. The results show that the Brent crude oil prices change is the Granger cause of China's LNG import prices and China's pipeline natural gas import prices; China's LNG import prices are also the Granger cause of global crude oil price changes (as shown in Table 4). Only significant at the 10% level, the change in the import price of LNG in China is the Granger cause of the change in pipeline natural gas import price – there is no co-integration relationship between these two kinds of natural gas import prices (Table 3).

Table 4: Granger Causality Test

Note: Brent crude oil price = P_{Brent}. China's LNG import price = P_{LNG}. China's pipeline natural gas import price = P_{PIPE}. They are all processed using first-order log difference.

Null Hypothesis	Obs	F-Statistic	Prob.
P_{Brent} is not Granger cause of P_{LNG}	154	2.019	0.071
P_{LNG} is not Granger cause of P_{Brent}		2.749	0.017
P_{Brent} is not Granger cause of P_{PIPE}	110	2.620	0.020
P_{PIPE} is not Granger cause of P_{Brent}		0.950	0.462
P_{PIPE} is not Granger cause of P_{LNG}	110	0.750	0.611
P_{LNG} is not Granger cause of P_{PIPE}		2.045	0.068

5.4 Results analysis

Considering the co-integration relationship between Brent crude oil prices and China's natural gas import prices, we set six VEC models and obtain the optimal lag order using the AIC criterion. The regression results are listed in Table 5 and Table 6.

5.4.1 VECM of China's LNG import prices

Because the relationship between Brent crude oil prices and China's LNG import prices before 2009 is unstable, we focus on the period after 2009. Two sample periods, January 2009 to December 2013 and January 2014 to April 2019 are considered to study the determinants of China's LNG import price.

Table 5 shows the regression results of the VECM between China's LNG import prices and Brent crude oil prices. First, all the results show that the co-integration relationship between Brent crude oil prices and LNG import prices is linear; the estimated value of linear parameter β has a certain gap before and after the natural gas pricing reform. In the period after the economic crisis (Model 1), the estimated value of β is -0.724, indicating that the change in crude oil price per 1% causes the average level of the change in LNG import price in China to be around 0.724%. In Model 2, every 1% change of Brent crude oil price causes a 1.475% fluctuation of China's LNG import price, whereas the average impact of crude oil prices on China's LNG import prices declined to 0.622% after 2014 (Model 3). Analysing the short-term lag effect of Brent crude oil prices on China's LNG import prices in Model 2 and Model 3, the first order difference of oil price has a significant impact on China's LNG import price, but the short-term impact after 2014 is not significant; the impact of crude oil prices on China's LNG import prices decreases after 2014.

The parameter of the error correction term $\mathrm{ECM}_{LNG,t-1}$ indicates the adjustment speed of China's LNG import prices to the long-term equilibrium price associated with crude oil prices. As shown in Table 5, taking the whole study period as an example, the error correction coefficient of Model 1 is -0.137, indicating that if the long-term correlation between China's LNG import prices and Brent crude oil prices deviates, the monthly price adjustment is 13.7% of the distance between the current price and the long-term equilibrium price. Different period results show that after 2014, the adjustment of LNG import prices to long-term equilibrium prices has accelerated.

In addition, China's LNG import prices are also affected by domestic gas demand, industrial growth and the Henry Hub natural gas prices. As shown in Model

1, the change of natural gas import per 1% will cause about a 0.063% fluctuation of the LNG import price in China. The LNG import price will change by about 0.088% when the Henry Hub natural gas price changes by 1%. In the sub-interval models, the industrial growth rate has a significant impact on China's LNG import prices before 2014; the Henry Hub natural gas prices have a significant impact on China's LNG import prices after 2014, the integration and natural gas trade system relations in the US and Asia have become closer (Chiappini et al., 2019).

In a word, the import prices of LNG in China are not only influenced by global crude oil prices, but are also affected by China's demand for natural gas and the Henry Hub natural gas prices. Since the start of market-oriented natural gas pricing reform, the impact of crude oil prices on the import prices of LNG in China has declined, while the connection between China's LNG market and the international gas market has strengthened. This result suggests that China's market fundamentals have had an increasing impact on LNG import prices after the market reform. In the period of China's natural gas pricing marketization reform, the ability of LNG import price to reflect market information has enhanced.

Table 5: Vector Error Correction Model: China's LNG Import Prices and Brent Crude Oil Prices

$P_{LNG,t} = -\alpha_m - \beta_m P_{Brent,t}$			
Period	2009.01-2019.04	2009.01-2013.12	2014.01-2019.04
	Model 1	Model 2	Model 3
β	-0.724***	-1.475***	-0.622***
	[-8.513]	[-4.697]	[-4.644]
α	0.688	4.159	0.184
Explanatory variables:	ΔP_{LNG}	ΔP_{LNG}	ΔP_{LNG}
$ECM_{LNG,t-1}$	-0.137***	-0.068***	-0.141***
	[-5.461]	[-3.404]	[-4.106]
ΔP_{LNG}(-1)	0.030	-0.076	0.008
	[0.372]	[-0.611]	[0.073]
ΔP_{Brent}(-1)	-0.148***	-0.272***	-0.071
	[-2.935]	[-2.655]	[-1.265]
C	0.017	-0.048	0.009
	[1.184]	[-1.540]	[0.308]

ΔGAS_PRO	-0.005	0.021	-0.073
	[-0.072]	[0.165]	[-0.841]
ΔGAS_IM	-0.063***	-0.063**	-0.053*
	[-3.135]	[-2.135]	[-1.714]
ΔHDD	0.001	0.000	0.001
	[0.634]	[-0.115]	[1.253]
ΔCDD	-0.002	0.001	-0.004
	[-0.461]	[0.082]	[-0.808]
ΔP_{HH}	-0.088**	-0.108	-0.096**
	[-2.411]	[-1.596]	[-2.385]
Industrial Growth Rate	-0.002	0.004*	-0.002
	[-1.309]	[1.729]	[-0.498]
R-squared	0.335	0.407	0.324
Adj. R-squared	0.282	0.301	0.211
F-statistic	6.376	3.817	2.874

Note: [ ] = t-value. ( ) = lag order. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Brent crude oil price = P_{Brent}. China's LNG import price = P_{LNG}. Pipeline natural gas import price = P_{PIPE}. Henry Hub natural gas price = P_{HH}. The volume of Chinese natural gas production GAS_PRO and the total natural gas import volume GAS_IM are logarithmically processed. $P_{LNG,t} = -\alpha_m - \beta_m P_{Brent,t}$ is introduced to show the co-integration relationship between LNG import price and crude oil price.

5.4.2 VECM of Chinese pipeline natural gas import prices

The VEC model for the relationship between China's pipeline natural gas import prices and global crude oil prices is shown in Table 6. We establish three models for the whole interval and the sub-interval of the study, with January 2014 as a breakpoint. The results are similar to those of the LNG import prices: the co-integration relationship between China's pipeline natural gas import prices and Brent crude oil prices is linear and significant. Overall, the change in crude oil price per 1% will cause about a 0.598% change in pipeline natural gas import price. In the research period after 2014, the influence of Brent crude oil prices on pipeline natural gas prices is about 0.659% – which is lower than that before the natural gas pricing reform (1.397%). The speed of adjustment of China's pipeline natural gas import prices to the long-term equilibrium prices associated with crude oil prices is 22.2% for the whole interval (Model 4), and the adjustment period is less than five months. After 2014, the adjustment speed accelerates to 28.6%.

In the short term, Brent crude oil prices have significant lagged effects on China's pipeline gas import prices. China's total domestic gas production, domestic climate change (HDD and CDD) and industrial growth also have short-term impacts on pipeline natural gas import prices. Overall, every 1% change in China's natural gas production will cause about a 0.299% change in the pipeline natural gas import prices. In the period after 2014 (Model 6), China's natural gas output varies by 1%, resulting in a 0.383% change in pipeline natural gas import prices. The impact of climate change is not significant before 2014, but in the sub-interval model after 2014, every one unit of change in HDD will cause a change of pipeline natural gas import prices of about 0.003%. The change of natural gas price caused by the climate reminds us to pay attention to the construction of natural gas storage, establish and improve the gas emergency storage system, and enhance China's natural gas peak shaving capacity (Liu et al., 2018). The influence of industrial growth rate is significant in the whole interval, and the influence of the Henry Hub natural gas prices on China's pipeline natural gas import prices is only significant in the research interval before 2014. Due to a lack of market priced spot trading, the import price of pipeline natural gas is less affected by the fluctuation of Henry Hub gas price than that of LNG market.

From the above results, China's pipeline natural gas import prices are not only affected by the fluctuation of crude oil prices but also by domestic gas production, climate and economic growth. After the market-oriented reform of the natural gas pricing mechanism, the influence of natural gas supply and climate factors on China's pipeline natural gas import price increased and the influence of crude oil price fluctuation decreased. This suggests that the gas market reform has made China's pipeline import prices more responsive to China's domestic market fundamentals.

Table 6: Vector Error Correction Model: China's Pipeline Gas Import Prices and Brent Crude Oil Prices

	$P_{PIPE,t} = -\alpha_m - \beta_m P_{Brent,t}$		
Period	2010.02-2019.04	2010.02-2013.12	2014.01-2019.04
	Model 8	Model 10	Model 12
β	-0.598***	-1.397**	-0.659***
	[-8.757]	[-2.392]	[-7.549]
α	0.509	4.245	0.759
Explanatory variables:	ΔP_{PIPE}	ΔP_{PIPE}	ΔP_{PIPE}
$ECM_{PIPE,t-1}$	-0.222***	-0.084	-0.286***
	[-3.946]	[-0.781]	[-3.606]
ΔP_{PIPE}(-1)	-0.153*	-0.287	-0.143
	[-1.740]	[-1.357]	[-1.342]
ΔP_{PIPE}(-2)	0.004	-0.019	-0.025
	[0.046]	[-0.098]	[-0.215]
ΔP_{PIPE}(-3)	0.041	-0.086	0.069
	[0.478]	[-0.477]	[0.591]
ΔP_{PIPE}(-4)	-0.041	-0.368*	0.033
	[-0.488]	[-1.878]	[0.312]
ΔP_{PIPE}(-5)	-0.087	0.208	-0.282**
	[-1.008]	[1.057]	[-2.512]
ΔP_{PIPE}(-6)	0.293***	0.619***	0.210*
	[3.417]	[3.198]	[1.877]
ΔP_{PIPE}(-7)		0.018	
		[0.088]	
ΔP_{Brent}(-1)	-0.174**	-0.306	-0.219***
	[-2.455]	[-1.540]	[-2.754]
ΔP_{Brent}(-2)	-0.001	0.466*	-0.089
	[-0.020]	[1.955]	[-1.100]
ΔP_{Brent}(-3)	-0.224***	-0.101	-0.200**
	[-3.173]	[-0.372]	[-2.547]
ΔP_{Brent}(-4)	-0.023	0.018	-0.093
	[-0.342]	[0.083]	[-1.189]
ΔP_{Brent}(-5)	0.052	0.032	0.033
	[0.788]	[0.127]	[0.430]
ΔP_{Brent}(-6)	-0.144**	0.120	-0.218***
	[-2.133]	[0.568]	[-2.882]
ΔP_{Brent}(-7)		-0.259	
		[-1.467]	
C	-0.034**	-0.012	-0.062*
	[-2.080]	[-0.169]	[-1.640]
ΔGAS_PRO	0.299***	0.360**	0.383***
	[3.623]	[2.036]	[3.550]
ΔGAS_IM	0.023	0.049	0.040
	[0.789]	[0.662]	[1.053]
ΔHDD	-0.002**	-0.001	-0.003***
	[-1.999]	[-0.322]	[-2.576]
ΔCDD	-0.003	-0.008	-0.008

	[-0.597]	[-0.874]	[-1.410]
ΔP_{HH}	-0.055	-0.295**	-0.001
	[-1.258]	[-2.059]	[-0.021]
Industrial Growth Rate	0.004*	0.001	0.007
	[1.949]	[0.153]	[1.331]
R-squared	0.516	0.734	0.650
Adj. R-squared	0.407	0.406	0.499
F-statistic	4.721	2.236	4.298

Note: [ ] = t-value. ( ) = lag order. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Brent crude oil price = P_{Brent}. China's LNG import price = P_{LNG}. Pipeline natural gas import price = P_{PIPE}. Henry Hub natural gas price = P_{HH}. The volume of Chinese natural gas production GAS_PRO and the total natural gas import volume GAS_IM are both logarithmically processed. $P_{PIPE,t} = -\alpha_m - \beta_m P_{Brent,t}$ is introduced to show the co-integration relationship between pipeline gas import price and crude oil price.

6. Conclusions and Policy Implications

A time series approach is used to study the determinants of natural gas import prices in China. In addition to the estimation of a long-run oil-gas relationship, this paper further explores whether and how market fundamentals in China affect gas prices. A number of China's domestic supply and demand factors have been included into the long-run VECM as exogenous variables. China's on-going market liberalisation process of the natural gas market is also taking into consideration.

The empirical findings can be summarized as follows: first, our results showed that crude oil price is the main factor affecting China's natural gas import prices (both LNG and pipeline natural gas). It confirms that the oil indexed pricing mechanisms still play important role in pricing China's natural gas imports (Zhang et al., 2018a; 2018b). Brent crude oil prices have both a stable long-term effect and a significant short-term influence on China's import prices of LNG and pipeline natural gas prices.

Second and perhaps the most important findings here is that China's own market fundamentals have played important roles in determining import prices. Despite the prevailing role of oil indexation, Chinese natural gas import prices were also affected by domestic natural gas supply, demand, temperature changes and industrial growth. Specifically, the LNG import price in China was affected by import demand (total import volume of natural gas). The import prices of pipeline natural gas were affected by the change of domestic natural gas supply and by climate factors. The impact of China's industrial growth on the import prices of pipeline natural gas was significant in the whole study period, whereas the impact on LNG import prices was only significant before 2014.

Third, our results show an increasing role of market fundamentals. This provides evidence that the market reform or liberalisation process in China has been successful and brought changes to the existing pricing mechanism. Comparing the results of the VECM, we find that crude oil prices have played a less important role in both the import prices of LNG and pipeline natural gas since the reform of the natural gas pricing mechanism in 2014. Further, the adjustment speed of natural gas import prices to the long-term equilibrium price associated with the price of crude oil has accelerated. At the same time, the influence of natural gas production and domestic climate factors on the import prices of natural gas pipelines in China increased after 2014. The effect of the Henry Hub natural gas price changes on LNG import prices was also more significant after 2014, suggesting that the link between China's LNG market and the US natural gas market has strengthened. In other words, China's LNG market is gradually integrating with the international gas market.

Our research has the following implications. First, China should continuously liberalise its gas markets, making gas price a better reflection of fundamental factors. As a key player in the international gas markets, China's liberalisation will make gas pricing more efficient, and thus will reduce distortions in the global gas market (Shi et al., 2017).

Second, China should pay attention to the supply structure and storage of domestic natural gas market. Referring to the shale gas revolution in the United States, unconventional gas development is an important measure to increase domestic gas supply. This will have two benefits. On the one hand, it could reduce China's dependence on imported natural gas and thus strengthen its gas supply security. On the other hand, increasing its domestic natural gas supply could make imported prices more relevant to domestic market fundamentals and thus more acceptable to domestic users than an internationally determined price. The significant influence of HDD on pipeline natural gas import prices indicates that proper seasonal supply management, such as storage, could generate significant benefits for China.

Third, although there is not an acceptable price benchmark in China and East Asia, market fundamentals are increasingly reflected in gas import prices. We expect the impact of fundamental factors, such as market supply and demand, on China's natural gas import prices will increase, whereas the impact of crude oil price fluctuations will continue to decrease. This further implies that China's gas price benchmark, if generated, will play a role in determining gas trade prices with China, and it is important for China and the East Asian region to establish its own natural gas benchmark price.

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Highlights

We use a time series framework to investigate the determinants of import gas prices in China

We pay special attention to the influence of market reforms on these prices.

The market liberalisation and the pricing reformation cause systemic structural changes.

China's import gas prices are increasingly affected by its market factors.

China and the East Asian region need to establish its own natural gas benchmark

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: