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CAN NATURAL GAS PRICING REFORM ESTABLISH AN EFFECTIVE MECHANISM: EMPIRICAL EVIDENCE FROM CHINA

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ABSTRACT
Due to the requirements of clean development and economic transition, China's natural gas consumption has grown rapidly over the years. However, the price of natural gas in China has been regulated by the government for a long time. Cross-subsidy and price inversion have distorted price mechanism, and are not conducive to the development of the natural gas market. In June 2013, nationwide price reform was implemented in the non-residential sector. To explore the effect of the reform on price distortion, this paper uses monthly data from 27 key cities to estimate the scale and rate of natural gas price subsidy from 2008 to 2017. The results show that the natural gas subsidy is still severe, and there are differences between sectors. The time interval in the implementation of the policy provides a quasi-natural experiment for studying the reform. The difference-in-difference-in-difference estimations prove that the natural gas pricing reform has significantly cut down the subsidy rate in the non-residential sector, and an effective terminal pricing mechanism has been conducted.

Keywords: Subsidy rate Pricing reform Policy evaluation China

1. INTRODUCTION

Since Reform and Opening-up, China's economy and society have achieved leapfrog development. Economic growth and rapid urbanization are supported by increased energy consumption [6-8]. Development is accompanied by environmental deterioration, especially air quality. Air problems such as smog have seriously affected people's health and social welfare, and have raised warnings for China's traditional development pattern. The Chinese government has gradually changed the mode of economic growth and increased the proportion of clean energy in the energy consumption structure [9-13]. Natural gas, as a clean, efficient, and green energy source, meets the standards of China's low-carbon clean development [14-16]. In recent years, China's natural gas market has developed rapidly. In 2018, China's natural gas consumption reached 281.9 billion cubic meters, accounting for 7.8% of the primary energy consumption structure .

To ensure the widespread use of clean energy, the price of natural gas in China has been controlled by government for a long time. The high degree of regulation and opaque price mechanisms have caused price distortions [17-19]. So does there exist subsidy in the Chinese natural gas market? Intuitively, the Chinese government has no obvious financial subsidy for the natural gas industry. However, China's energy supply is controlled by the centralization of government, natural gas production and import are monopolized by state-owned enterprises [20, 21]. State-owned enterprises are often motivated by the national goal of regulating the economy, not profit.

The following two points clearly show that there is a serious subsidy problem in China's natural gas industry. First of all, from the perspective of microeconomics, industrial and commercial users have greater and more concentrated natural gas demand than residential consumers. Hence, the natural gas manufacturers have a lower marginal cost of supply to industrial and commercial users, and the end-user price in the industrial or commercial sector should be lower than that of the residential sector. It can be seen from Figure 1 that the terminal price in the residential sector is higher and more volatile than that in the industrial and commercial sectors in the U.S., which is consistent with the cost-benefit analysis above. The situation in China is just the opposite. The terminal price in the residential

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sector is lower than that in the non-residential sector. So there exists cross-subsidy in China which aims to protect the consumption of residents by overcharging industrial and commercial users. Besides, due to the resource endowment, China is the world 's largest natural gas importer. In 2018, China's dependence on natural gas imports reached 43.14% . Due to the high transportation cost of imported natural gas, the import cost is even higher than the regulated price in some periods, resulting in price inversion. According to the financial data, the cost of natural gas imported by PetroChina in 2012 was 41.9 billion yuan, while its natural gas sales revenue was 39.8 billion yuan, and its net profit was negative .

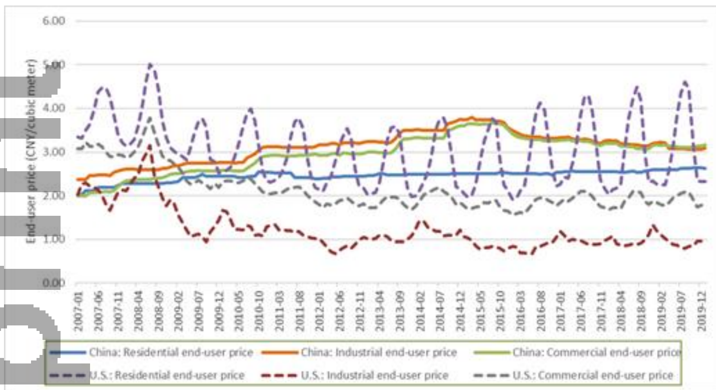

Fig.1 Natural gas of end-user prices in China and the U.S..

Although the subsidy ensures the large-scale use of natural gas, the cross-subsidy is not beneficial to the effective allocation of resources, and the price inversion will also affect profits in the short-term and development in the long-term of natural gas producers. Also, the price distortion cannot accurately reflect changes in the supply and demand of the natural gas market, which will hinder the marketization of the natural gas industry. In June 2013, summarizing the pilot experience of Guangdong and Guangxi, the new natural gas pricing mechanism was implemented nationwide. The natural gas pricing reform first started in the non-residential sector, and it was not until June 2018 that the residential sector was involved by the reform. Whether the policy effectively solves the problem of subsidy and whether the new natural gas price mechanism is effective requires in-depth research.

By reviewing the existing literature, we find many scholars have studied the effectiveness and impact of energy pricing reform [22, 23], especially in developing countries [24-28]. China is actively pursuing energy subsidy reform. The price of coal in China has been market-oriented, but the marketization of the natural gas industry did not begin until 2013 when the pricing reform began. Besides not many works of literature on the evaluation of natural gas pricing reform have been recorded, some researches [20, 29] analyzed from the perspective of the natural gas industry chain, studying the pricing mechanism of the upstream, midstream and downstream. The study sorted out the new mechanism established by the pricing reform, but it lacked a quantitative assessment of the policy. At the same time, some literature [30, 31] used computable general equilibrium (CGE) method to explore the impact of natural gas price changes on macroeconomics. But the results are limited by scenario simulations, and there is a certain gap between the results and the reality. Lin & Li [1] and Liu & Lin [32] estimated the scale and rate of natural gas subsidy, then compared changes in subsidies before and after the policy. However, the relevant researches by intuitive comparison of the sectoral subsidy do not fully evaluate the effectiveness and dynamic impacts of the policy. The expansive research can be based on the estimation of subsidy, to explore the impact of the reform on removing subsidy and improving the pricing mechanism through empirical research.

This paper first measures the degree of price distortion in the natural gas market through the estimation of the subsidy rate and uses the price-gap method to calculate the subsidy scale and rate before and after the pricing reform in 27 key cities across China. It is found that there is a serious subsidy phenomenon in China's natural gas industry. The subsidy rate of each sector has declined since 2013, and the end-user price of the non-residential sector has preliminarily achieved market-oriented in recent years. Due to the time lag in the implementation of the policy in different sectors, quasi-natural experiments have been provided for the research. We then use the difference-in-difference-in-difference (DDD) approach to explore the effectiveness of the pricing reform. Empirical results show that compared with the residential sector, the subsidy rate of the non-residential sector has dropped significantly after the reform, and the policy effectively alleviates price distortions in the non-residential sector.

Compared with previous studies, the theoretical contributions of this paper are reflected in the following four aspects: (1) Because the natural gas price subsidy is caused by market price distortions, it cannot be directly observed. We use the price-gap method to estimate the subsidy in 27 key cities of China, and thus further calculate the subsidy scale of the whole nation in 2008-2017. (2) In the model, due to the requirement for policy evaluation, this paper makes some modifications to the standard DDD model. Besides, research from three dimensions of time, region, and sector, will help in-depth exploration of the impact of the natural gas pricing mechanism. (3) Through the difference between the subsidy in the residential and the non-residential sectors, this paper combines the price-gap method with the DDD method, to empirically analyze the effectiveness, and dynamic effects of the pricing reform. The results show that the price subsidy has been basically eliminated in the non-residential sector, and an effective market-oriented pricing mechanism has been initially established. In 2018, the Chinese government began to implement the reforms in the residential sector. The experiences in the non-residential sector have important policy implications for the residential sector price reform and other energy price reforms. (4) Even though this paper focuses on the pricing reform of China, the energy subsidy and pricing distortion issue is a global concern. The findings of this research can provide some policy implications for countries in the same situation, especially the developing countries.

We organize the remainder of the paper as follows: Section 2 sorts out the policy background and the highlights of the pricing reform. Section 3 measures the subsidy scale and subsidy rate. Section 4 designs the empirical framework and then conducts policy evaluation. The last part concludes and provides policy recommendations.

2. POLICY BACKGROUND

2.1 *An overview of the natural gas system in China*

Considering energy security and the characteristics of long investment cycles, China's natural gas production and import are fully occupied by four state-owned enterprises, including PetroChina, Sinopec, CNOOC, and Shaanxi Yanchang Petroleum Group. Although the government issued relevant documents on the introduction of private capital, the effect was limited, and the upstream of natural gas industry is still controlled by state-owned enterprises.

The domestic production of natural gas in China is mainly distributed in the Sichuan Basin, Qaidam Basin, and Ordos. There are three main modes of transportation for pipeline gas: Central Asia to Xinjiang, Myanmar to Yunnan, and Russia to Heilongjiang. LNG imports are mainly in southeast coastal ports. The use of natural gas is nationwide and requires long-distance transportation. Pipeline transportation is completely monopolized by the three state-owned companies: PetroChina, Sinopec, and CNOOC [20].

The main end-users of natural gas are roughly divided into residential, industrial, and commercial sectors. The non-residential sector (industrial sector and commercial sector) has long occupied most of the natural gas consumption structure, and consumption in the residential sector has grown rapidly. In 2017, natural gas consumption in the industrial, commercial, and residential sectors accounted for 65.9%, 16.5% and 17.6%, respectively .

The natural gas price before the reform is determined by the cost-plus method, which is controlled by the NDRC, the central and local pricing bureau in China. The price negotiation among producers, transportation companies, and consumers are limited. The ex-plant price of upstream producers has gradually transitioned from the government pricing mechanism to the government guidance pricing mechanism. But the bargaining power of both the supply and demand sides is limited, and the price can only fluctuate around 10% of the guidance price. China's natural gas production and transportation are fully integrated. Considering the natural monopoly, the price of transportation has been subject to government control. After natural gas is transported to various regions of the country, the price of natural gas paid by the local distribution companies to the pipeline companies is called the city-gate price. City-gate price is the sum of ex-plant price and transportation cost. The distribution companies will sell natural gas to different consumers according to the purposes and set different prices according to the distribution cost and the heterogeneity of demand, to obtain maximum profit. However, under the management of the local pricing bureau, the distribution fee is also strictly controlled. And higher prices in the industrial and commercial sectors can be regarded as a subsidy to end-user price in the residential sector. The terminal price is the sum of the city-gate price and the distribution fee.

The old pricing mechanism was originally set up for domestic natural gas. Based on the guidance of ex-plant price, the costs of transportation and distribution were gradually added to maintain natural gas at a low price level for a long time. With the rapid growth of China's natural gas consumption, China began to import natural gas in 2007. Whether the imported natural gas is LNG or pipeline gas, the requirements of transportation technology and equipment are extremely severe. The transportation cost of imported gas makes the import cost higher than the city-gate price in some periods [29]. Since the city-gate price is controlled by the government, the profit of natural gas importers is compressed or even damaged, which is detrimental to the development of supply sides, and the pricing mechanism of natural gas needs to linked to the international market [33, 34]. What's more, the cross subsidy to ensure the use of natural gas in the residential sector has increased the cost burden of the industrial and commercial sectors, which affects the growth of the real economy. Above all, the old pricing mechanism is not suitable for the current development of the natural gas market.

2.2. *Natural gas pricing reform*

At the end of 2011, the Chinese government launched a pilot policy of the natural gas pricing reform in Guangdong and Guangxi, to adjust the pricing management from the ex-plant price to the city-gate price. The policy aimed to regulate the highest price and to set up a dynamic adjustment mechanism linking the price of natural gas to prices of fuel oil, liquefied petroleum gas, and other alternative energy.

In June 2013, after summarizing the experience of the pilot, the Chinese government promoted the new mechanism for natural gas prices nationwide. At the same time, a distinction was made between stock gas and incremental gas. The price of incremental gas was adjusted directly to a level that maintains reasonable price parity with the price of alternative energy, while the price of stock gas was planned to be adjusted in three steps. In September 2014, the government released the document to raise the price of stock gas, narrowing the gap with the price of incremental gas. In April 2015, according to changes in price of alternative energy, prices of stock gas and incremental gas adjusted to be consolidated. In August 2017, combined with the reduction of the price of pipeline transportation and the adjustment of value-added tax (VAT) rates, the city-gate price for the non-resident sector was adjusted again.

In June 2018, the government started to extend the pricing reform to the residential sector, to gradually adjust the city-gate price level of the residential sector to that of the non-residential sector.

Taking into account the rapid growth of natural gas demand in China and the energy security of economic and social development, the reform does not directly dictate the price negotiation to both supply and demand sides. The market-oriented pricing mechanism was gradually established step by step. Regarding the relevant documents issued by the NDRC, a clear and transparent pricing mechanism can be established. The new pricing mechanism takes city-gate price as the core and makes each link in the upstream, midstream and downstream of the natural gas industry more reasonable By establishing linkage with imported alternative energy, the city-gate price has increased the volatility of price in the non-residential sector and weakened the government control of the natural gas industry.

3. NATURAL GAS SUBSIDY IN CHINA

3.1 *Price-gap method*

Due to the price distortion caused by the government regulation, the natural gas subsidy in China cannot be directly observed. The degree of price distortion needs to be measured and estimated. There exist many studies on the estimation of subsidy, and the commonly used approaches include the price-gap method [35], producer/consumer subsidy equivalent [36, 37], program-specific approach [38, 39]. Because the price-gap method directly targets the terminal price, it requires less data than other methods. Therefore, the price-gap method is widely used in the research of energy subsidy [17, 40-42]. Meanwhile, the price-gap approach focuses on the impact of government subsidy on the demand side, therefore it is the applicable method for this paper to study natural gas terminal price distortion.

The price-gap method can be expressed by formulas (1)-(3). The degree of price distortion is measured by the gap between the end-user price and the reference price, and the scale and rate of subsidy can be further calculated based on the gap.

$$\text{Price Gap: } PG = RP - P \tag{1}$$

$$\text{Subsidy Scale: } S = PG \times C \tag{2}$$

$$\text{Subsidy Rate: } SR = \frac{PG}{RP} = \frac{RP - P}{RP} \tag{3}$$

RP=Reference Price, P=End-user Price, C=Consumption

3.2 *Results and analysis*

It can be seen from the formulas of the price-gap method that the key of the subsidy estimation is the determination of the reference price. The selection of the reference price will serve as a criterion for judgment, reflecting the gap between the regulated price and the market-oriented price. China's natural gas are extremely dependent on imports, and the proportion of imported gas in natural gas consumption is nearly half. Therefore, natural gas price affected by both prices of domestic gas and imported gas. Referring to Liu & Lin [32], we first carry out weighted average of reference prices of imported gas and domestic gas based on external dependence, plus VAT and cost of transportation, then we get the natural gas reference price. The reference price of imported gas is directly related to the international natural gas market, which can be expressed by the CIF prices of pipeline gas and LNG. However, domestic gas did not start the market-oriented process until the pricing reform. For the steady progress of pricing reform, the policy directly adjusted the incremental gas in place at the initial stage of implementation, so the price of incremental gas can be regarded as the domestic reference price.

According to the announcements of NDRC, the pricing mechanism of the incremental gas (excluding VAT) is given by formula (4).

$$P_{natural\ gas} = K * (\alpha * P_{fuel\ oil} * \frac{H_{natural\ gas}}{H_{fuel\ oil}} + \beta * P_{LPG} * \frac{H_{natural\ gas}}{H_{LPG}}) \quad (4)$$

Where P represents the price. H represents the net calorific value. K is the discount coefficient, which is 0.9. α, β are the weights of fuel oil and LPG, which are 60% and 40%, respectively.

Before the reform, the price of natural gas in China was based on cost-plus method and was strictly controlled by the government from the production to the terminal consumption. At the beginning of the pricing reform, the price of stock gas was maintained at the old pricing regime. Due to the characteristic of monopoly in transportation, the midstream of the supply chain is still controlled by the government. Therefore, the cost of transportation can be estimated based on the gap between the stock gas price and the end-user price.

China 's natural gas pricing reform was launched in two pilot provinces in January 2012 and started nationwide in June 2013. After implementation, NDRC publishes reference city-gate price as the highest guidance price. The city-gate price before the reform can be calculated according to formulas (4)-(5).

3.3 Data description

When estimating natural gas subsidy in China, the following analysis distinguishes between residential and non-residential sectors (industrial and commercial sectors). Due to the lack of data in the commercial sector, this paper uses the end-user price in the industrial sector as the terminal price in the non-residential sector. Liu & Lin [32] pointed out the terminal prices in the industrial and the commercial sectors are based on city-gate price of the non-residential. Due to the difference between the industrial sector and the commercial sector during the transmission and distribution stage, there is a bit of inconsistent in the end-use prices of the industrial and commercial sectors. However, according to Fig 1, the difference between the end-user prices in the two sectors is small and the fluctuations are consistent. Hence, the two sectors can be merged into a non-residential sector for further analysis.

Sectoral terminal prices of natural gas are obtained from the monthly prices of 36 key cities released by the NDRC. But due to the limitation of data in some cities and the requirement for policy evaluation in Section 4, the chosen cities has reduced to 27 cities[1]， and the time ranges from October 2007 to June 2018[2]. The CIF prices of imported fuel oil, LPG, pipeline natural gas, and LNG are calculated according to the data sourced from the General Administration of Customs. Besides, import prices are converted into CNY based on the monthly average exchange rate, and the data of USD to CNY exchange rate comes from the People's Bank of China. The consumer consumption index (CPI), purchasing price index of raw material, fuel, and power (PPIRM) and natural gas consumption are obtained from the National Bureau of Statistics.

Changes in VAT also need to be noted. According to relevant documents of the Ministry of Finance of China and NDRC, the VAT was 13% at the beginning of the reform. Starting from October 2017, the VAT on natural gas was adjusted to 11%.

3.4 Results and analysis

According to formulas (1)-(4), the natural gas subsidy scale and rate in China can be estimated and the results are shown in Fig 2. China's natural gas subsidy rate and scale in 2008-2017 are roughly divided into two stages. From 2008 to 2012, the subsidy scale and rate were at a relatively high level. In 2012, the scale of subsidy reached the highest level, at 259 billion CNY. In 2009, due to the impact of the North American shale gas revolution, the international natural gas price began to decrease. Meanwhile, the cold winter in China stimulated the consumption of natural gas. The two parties worked together to reduce the price gap and temporarily decrease the natural gas subsidy [43]. After 2013, the Chinese government began to implement the

[1] The 27 cities studied in this paper include Beijing, Tianjin, Shijiazhuang, Taiyuan, Huhehaote, Shenyang, Changchun, Harbin, Shanghai, Nanjing, Hangzhou, Ningbo, Hefei, Jinan, Qingdao, Zhengzhou, Wuhan, Changsha, Nanning, Haikou, Chengdu, Chongqing, Xian, Lanzhou, Xining, Yinchuan, Wulumuqi.

[2] According to the document, NDRC announced that it will improve the natural gas pricing mechanism of the residential sector from June 10, 2018. To construct a quasi-natural experiment, the research deadline for this paper is June 1, 2018.

pricing reform across the country, and both the rate and the scale of subsidy showed significant downward trends. In 2017, due to the advancement of the coal-to-gas conversion process and the lack of pipeline gas supply, a nationwide gas shortage appeared in winter, and the price of imported LNG increased sharply [44]. Natural gas subsidy started to rebound, especially in the non-residential sector.

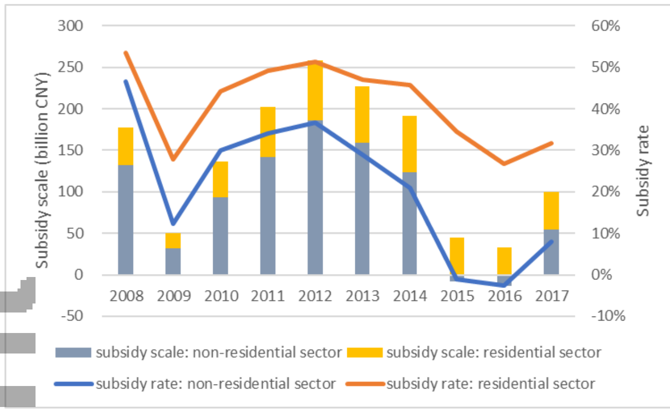

Fig. 2 Subsidy scale and rate of natural gas in China.[3]

It can also be seen from the results that before the full implementation of the reform, the trend of subsidy rates in both sectors was similar. After 2013, the subsidy rate in both the resident and non-resident sectors showed significant downward trends. However, the decline in the non-residential sector was more significant, and subsidy were roughly eliminated. Liu & Lin [32] decomposed the natural gas subsidy and found that the biggest factor affecting the subsidy scale is the price mechanism, followed by changes in natural consumption. Considering the heterogeneity in consumption among different sectors and the complexity of demand analysis, the following research on policy evaluation will mainly focus on the natural gas subsidy rate.

4. EMPIRICAL RESULTS AND DISCUSSIONS

4.1 Estimation framework

The subsidy rate reflects the deviation between the current end-user price and the market-oriented price (reference price), and further reflects whether the pricing mechanism can effectively reflect market supply and demand. Then the most important target for the investigation is the impact of the pricing reform. The reform provides a quasi-natural experiment for the research in this paper, and this paper selects the difference-in-difference (DID) estimation for policy evaluation. Considering the heterogeneity of regional natural gas market development, the impact of the reform on subsidy rates varies in different regions. Referring to relative studies [45-48], this paper modifies the standard DID model, as shown in formula (5):

$$SR_{c,t} = \beta \times D_c \times Post_t + \eta_c + \eta_t + \varepsilon_{c,t} \quad (5)$$

Where $SR_{c,}$ represents the subsidy rate in region c at time t. D_c is a measure of the development of natural gas market in region c, to reflect the urgency of price reform. $Post_t$ is a dummy variable that represents the post-treatment period. Since Nanning was treated as a pilot in January 2012, so $Post_t$ equals to one when $t \geq 2012M1$, and zero otherwise. The pricing reform was not implemented in other cities until July 2013, so $Post_t$ equals to one when $t \geq 2013M7$, and zero otherwise. η_c, η_t represents the region and time fixed effect, to control the unobservable impacts of city/time factors on subsidy rate. $\varepsilon_{c,t}$ is the error term.

We want to conduct DID regression on the residential and the non-residential sector separately, and to explore the difference in the impact of pricing reforms on subsidy between the two sectors by comparing coefficients. However, time-varying region characteristics may correlate with the subsidy rate and the regressor at the same time, and then bias the estimation [49]. Besides, due to the heterogeneity in natural gas pricing mechanisms of different sectors, it is not rigorous to simply compare the estimates of DID. Referring to Cai et al. [50] and Burke & Abayasekara [51], We add the sector dummy variable in (5) and control region by time, region by sector, and time by sector fixed effects, to evaluate the pricing reform. The DDD estimation is shown as follows:

$$SR_{c,t,i} = \beta \times D_c \times Post_t \times Sector_i + \eta_{c,t} + \eta_{c,i} + \eta_{t,i} + \varepsilon_{c,t,i} \quad (6)$$

Where $SR_{c,t,i}$ represents the subsidy rate of sector i in region c at time t. $Sector_i$ is a dummy variable that indicates the non-residential sector. $Sector_i$ equals to one when i is the non-residential sector, and zero otherwise. $\eta_{c,t}$ is a region by time fixed effect to control for unobservable differences in subsidy rate in each city at each time. $\eta_{c,i}$ is a region by sector fixed effect to control for unobservable differences in subsidy rate in each city in each sector. $\eta_{t,i}$ is a time by sector fixed effect to control for unobservable differences in subsidy rate in each sector at each time. $\varepsilon_{c,t,i}$ is the error term.

The development of a certain market is mainly

[3] The subsidy scale is converted to the 2017 price level based on CPI and PPIRM. In order to intuitively show the subsidy changes from 2008 to 2017, the weighted average results according to natural gas consumption are shown from the annual national perspective.

measured from the perspective of price and consumption. The regions with the higher natural gas price are mostly concentrated in the eastern coastal

provinces, where the degree of marketization is relatively high before the pricing reform and the room for subsidy adjustment is low. Furthermore, electricity is a substitute energy for natural gas [52, 53]. So the price of electricity is negatively correlated with the price of natural gas and positively correlated with the development of the natural gas market. Therefore, we use the ratio of the electricity price index (P_c^{ele}) to the natural gas price index (P_c^{ng}), to reflect the price index (PI_c), and further show the urgency of the pricing reform in the regional natural gas market, which is shown in formula (7):

$$PI_c = \frac{P_c^{ele}}{P_c^{ng}} \tag{7}$$

Referring to Chen et al. [54], we use the weighted average based on the consumption of natural gas or electricity to obtain the electricity and natural gas price index, as shown in formula (8):

$$P_c = \sum_t \frac{Q_{c,t}}{\sum Q_{c,t}} \times \left(\sum_i p_{c,t,i} \times \mu_{t,i} \right) \tag{8}$$

Where $Q_{c,t}$ represents the natural gas consumption in region c at time t[4]. $P_{c,t,i}$ represents the end-user price of sector i in region c at time t. Price deflation is based on CPI and PPIRM. $\mu_{t,i}$ is calculated by dividing consumption of sector i at time t consumption to total consumption, as a weight. Besides, regions with fast demand growth are more urgent for the pricing reform. We also use the growth rate of natural gas consumption in different regions from 2008 to 2017 as another indicator to measure the development of natural gas to conduct a robustness test.

4.2 Main results

The estimation of the subsidy rate in the previous chapter will be empirically explored as an explanatory variable. Before the regression, we first take the absolute value of the subsidy rate to reflect the deviation between the terminal price and the reference price, and then further explore whether the pricing reform has a corrective effect on price distortion.

The DID estimation results corresponding to formula (5) are shown in Table 1. For both sectors, the coefficients of the interaction term are negative and significant. It can be seen from the absolute value of the coefficients that the pricing reform has a better effect in the non-residential sector. The early focus of the reform was on the non-residential sector, which did not reach the residential sector until June 2018. Therefore, the subsidy rate has fallen more markedly in the non-residential sector. Although the pricing reform was not implemented in the residential sector at the early stage, the pricing mechanism of the residential sector has also been slightly adjusted, which demonstrates the spillover effect of the policy.

Table 1
The effect of the pricing reform on subsidy based on a DID estimation strategy.

Dependent Variable: $SR_{c,s,i}$		
	non-residential sector	residential sector
	(1)	(2)
Price index * Post	-0.050*** (0.004)	-0.018*** (0.004)
Time fixed effect	Yes	Yes
Region fixed effect	Yes	Yes
R^2	0.816	0.868
Observations: 3483. Cities: 27. Time: 2007M10-2018M6 (129 months).		

i) Heteroskedasticity-robust standard errors in parentheses. ii) $*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

In order to conduct a more detailed and effective policy evaluation, we use formula (6) to analyze the main results. The DDD estimation results are shown in Table 2. When the region by time, region by time, and sector by time fixed effects are controlled, the triple interaction term is significantly negative. This shows that the pricing reform has been more effective in the non-residential sector in regions with severe price distortion. When the reform was implemented, the subsidy rate fell by 0.032, statistically significant at 1% level. The pricing reform was first implemented in the non-residential sector, providing quasi-natural experiments for research. The results of the DDD estimates show that the reform has a significant effect on reducing the subsidy rate, and has effectively alleviated price distortion in the non-

[4] Due to data limitation, we use the annual data for the province where region c locates from 2008-2017.

residential sector, which is consistent with Lin & Li [1].

Table 2

The effect of the pricing reform on subsidy based on a DDD estimation strategy.

Dependent Variable: $SR_{c,s,i}$				
	(1)	(2)	(3)	(4)
Price index * Post * Non-residential sector	-0.098***	-0.088***	-0.044***	-0.032***
	(0.002)	(0.001)	(0.001)	(0.005)
Region*time fixed effect	No	Yes	Yes	Yes
Region*sector fixed effect	No	No	Yes	Yes
Sector*time fixed effect	No	No	No	Yes
R^2	0.356	0.829	0.934	0.952
Observations: 6966. Cities: 27. Time: 2007M10-2018M6 (129 months). Sector: 2.				

i) Heteroskedasticity-robust standard errors in parentheses. ii) $* p < 0.1$, $** p < 0.05$, $*** p < 0.01$.

4.3 Estimation for variation over time

The results in Table 3 can only represent the average effect of the pricing reform after implementation. Referring to Yang et al. [55] and Lin & Zhu [56], We construct formula (9) to explore the dynamic impact of the reform on subsidy.

$$SR_{c,t,i} = \sum_{k=2012}^{2018} \beta_k \times D_c \times Post_t \times Sector_i \times T^k + \eta_{c,t} + \eta_{c,i} + \eta_{t,i} + \varepsilon_{c,t,i} \quad (9)$$

Where T^k is a dummy variable of k-th year after the non-residential sector in region c implements the pricing reform. T^k equals to one if the time t belongs to the k-th year, and zero otherwise.

As can be seen from the results in the first column of Table 3, during the pilot period, the pricing reform significantly expanded the degree of price distortion. After the full implementation of the reform, the policy effect in the first year is not significant. Since 2014, the reform has significantly reduced the price subsidy, and the effect has gradually increased. In 2015, the policy effect reached the peak, and the effectiveness of the policy gradually weakened thereafter. The mitigation effect of 2014-2018 will show an inverted "U" shape. Combined with the specific implementation of the policy, the pricing reform will first be piloted in Guangxi, Guangdong and the pilot city examined in this paper is only Nanning. At the beginning of the pricing reform in 2012, the price subsidy did not fall but rose. In the first year of full implementation, the effect of the policy on reducing the subsidy rate was very weak. The implementation of the policy has a time lag, so the result of the pricing reform are not as expected. With the advancement of policy and the refinement by NDRC, the reform has effectively eased the price distortion in the non-residential sector. As the terminal price in the non-residential sector gradually become market-oriented, the marginal utility of policy reforms diminishes. The results in the second column are estimated with the observations which exclude the pilot city from the whole sample, so the estimations show the dynamic effects of the nationwide implementation of the reform. The result is roughly the same as the first column from 2013 to 2018.

Table 3

Dynamic effects of the pricing reform.

Dependent Variable: $SR_{c,s,i}$		
	(1)	(2)
Price index * Post * Non-residential sector	0.040***	
* Year dummy 2012	(0.006)	
Price index * Post * Non-residential sector	0.011	-0.002
* Year dummy 2013	(0.009)	(0.011)
Price index * Post * Non-residential sector	-0.018**	-0.017*
* Year dummy 2014	(0.009)	(0.010)
Price index * Post * Non-residential sector	-0.088***	-0.097***
* Year dummy 2015	(0.010)	(0.010)
Price index * Post * Non-residential sector	-0.071***	-0.089***
* Year dummy 2016	(0.008)	(0.008)
Price index * Post * Non-residential sector	-0.047***	-0.070***
* Year dummy 2017	(0.010)	(0.009)
Price index * Post * Non-residential sector	-0.046***	-0.070***
* Year dummy 2018	(0.013)	(0.011)
Region*time fixed effect	Yes	Yes
Region*sector fixed effect	Yes	Yes
Sector*time fixed effect	Yes	Yes
R^2	0.953	0.954
Observations	6966	6708

i) Heteroskedasticity-robust standard errors in parentheses. ii) $* p < 0.1$, $** p < 0.05$, $*** p < 0.01$.

iii) In column (2), Nanning is excluded from the observations.

5. CONCLUSIONS AND POLICY IMPLICATIONS

Has natural gas pricing reform in China effectively alleviated price distortion and established an effective price mechanism? To explore this issue, this paper first uses the price-gap method to measure the subsidy rate and scale in the demand side. Due to the time interval of the reform in different sectors, this paper explores the impact of the pricing reform on subsidy rates in different sectors and the dynamic changes in policy effect by constructing a quasi-natural experiment. The results show that after the implementation of the policy, the subsidy rate of the non-residential sector in regions with severe price distortion has been effectively removed relative to the residential sector. With the advancement of policies, the effect of the reform has shown a dynamic trend of increasing first and then decreasing.

From the estimation of the subsidy rate and the scale, it can be seen that the pricing reform in China is effective, and the price of natural gas in the non-residential sector has reached market-oriented. However, in the residential sector, the subsidy rate and scale are still very large. According to estimates, the natural gas subsidy rate of the residential sector reached 32% in 2017, with a subsidy scale of 45 billion CNY. As the process of urbanization deepens and the income of residents increases, natural gas consumption in the residential sector will continue to grow rapidly and become the driving force for the development of total consumption [57, 58]. And then, the scale of subsidy in the residential sector will be further expanded. In June 2018, the Chinese government implemented the pricing reform in the residential sector. The successful and progressive experiences in the non-residential sector have important policy implications for the residential sector. Besides, the findings in this paper provide reference and enlightenment for the formulation of subsidy policies in other energy fields (e.g. the electricity market) in China, and even for countries with similar issues.

The empirical results show that the pricing reform has effectively alleviated the price distortion in the non-residential sector. But the reform does not mean that subsidy should be eliminated completely. If the price of natural gas in the residential sector is fully market-oriented, the terminal price will rise, which may exceed residents' affordability and affect the basic natural gas consumption in the residential sector. The pricing reform in the residential sector should not only start with the pricing mechanism but also cooperate with relevant policies. The improvement of the increasing-block pricing system can help to ensure the basic living needs of residents, and exert the adjustment role of price leverage to guide residents to consume reasonably [59-61].

Subsidy of energy service is common in all countries, especially in developing countries [62]. However, price subsidy for the residential sector will distort the natural gas price market. The government should pay attention to balancing efficiency and equity to protect the basic energy consumption of the residential sector [63]. According to the related theories of welfare economics, the government can change the subsidy in price, and supplement the financial subsidy to the residents with low income. Therefore, without distorting market prices, the basic needs of the residential sector are guaranteed, furthermore, the welfare level of residents can be improved.

Although natural gas pricing reform in China has achieved desired results in the non-residential sector, the current pricing mechanism is linked to alternative energy sources and does not accurately reflect the supply and demand for natural gas. Besides, although there is room for price fluctuations, it is still regulated by the government, and there are certain problems in seasonal fluctuations [29, 44]. Reform should be more in-depth and the government should establish a more market-oriented pricing mechanism.

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