Natural Gas Pricing Reform in China: Getting Closer to a Market System?

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Natural Gas Pricing Reform in China: Getting Closer to a Market System?

Sergey Paltsev[1] and Danwei Zhang[1]

Abstract

Recent policy in China targets an increase in the contribution of natural gas to the nation's energy supply. Historically, China's natural gas prices have been highly regulated with a goal to protect consumers. The old pricing regime failed to provide enough incentives for natural gas suppliers, which often resulted in natural gas shortages. A new gas pricing reform was tested in Guangdong and Guangxi provinces in 2011 and was introduced nationwide in 2013. The reform is aimed at creating a more market-based pricing mechanism. We show that substantial progress toward better predictability and transparency of prices has been made. China's prices are now more connected with international fuel oil and liquid petroleum gas prices. The government's approach for temporary two-tier pricing when some volumes are still traded at old prices reduced potential opposition during the new regime implementation. Some limitations created by the natural gas pricing remain: it created biased incentives for producers and favors large natural gas suppliers. The pricing reform at its current stage falls short of establishing a complete market mechanism driven by an interaction of supply and demand of natural gas in China.

Contents

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1. INTRODUCTION

One of the recent key energy policy objectives in China is increasing the contribution of natural gas in the energy mix (NEA, 2014). This objective is driven primarily by lower emissions of carbon dioxide and air pollutants from natural gas in comparison to coal, which is currently China's main energy source. Natural gas in 2013 accounted for approximately 6% of China's total energy consumption (NBS, 2014a)[2]. According to China's *National Energy Strategy Action Plan* released in 2014, the natural gas share in China's primary energy supply is planned to exceed 10% by 2020 (NEA, 2014). To achieve this substantial increase, China has reformed its natural gas pricing, as highly-regulated and non-transparent prices were limiting the expansion of the natural gas supply.

China's natural gas price reform was introduced nationwide in 2013. Before the reform, wholesale gas prices were set on a cost-plus approach and price differentials were distinguished by end users, with residential users paying lower prices than industrial users (IEA, 2012). This cost-plus approach was developed when China's natural gas use was covered by domestic sources, and the existing suppliers were compensated for the cost of production. After 2010, China's natural gas imports increased due to construction of pipelines from Central Asia and LNG terminals on the East coast. Importers of natural gas began losing money, as the contract prices for China's imported natural gas were higher than the regulated domestic prices. The old pricing approach also failed to provide incentives for an expansion of domestic natural gas supply, both conventional and unconventional[3]. At the same time, China's government was promoting an increase in natural gas use. As a result, China's gas supply failed to keep pace with the surging demand, and gas shortages occurred in some places (IEA, 2012).

To deal with the imbalance of demand and supply, the Chinese government launched a set of policies—including the nationwide natural gas pricing reform program—to encourage domestic and imported gas supply expansion and promote efficient gas use. The gas pricing reform was introduced in Guangdong and Guangxi provinces in 2011 and was implemented nationwide in 2013. The primary rationale for the pricing reform is that natural gas prices should be determined ultimately in the market (NDRC, 2013), so a key element of the new approach is a connection to imported oil and gas prices—the price of gas is set by a formula that includes the weighted average prices of imported fuel oil and liquefied petroleum gas (LPG). These international fuel prices are market-driven, and because fuel oil and LPG are close substitutes for natural gas, the formula provides a link to market forces. The new regime has been exercised for three years.

The goal of this paper is to assess these recent developments in China. We address the impacts of the reform and its success in achievement of its policy objectives. We analyze the pricing reform as follows. We begin with an overview of the natural gas market in China, focusing on the existing and prospective supply and consumption by sector. This overview sets

[2] Energy statistics is organized differently in different agencies. For example, the International Energy Agency (IEA) counts traditional biomass use in the total energy use in China (IEA, 2014), while agencies in China usually do not include it. Shares of natural gas in total energy use are larger when biomass is not counted.

[3] Unconventional natural gas resources include shale gas, tight gas, and coal-bed methane.

the stage for the analysis, identifying the latest developments in China's natural gas sector. Then, we provide an analysis of the old pricing regime and the main dimensions of the pricing reform. We underline the shortcomings of the approaches—notably, although China's government documents the new price formula and the resulting natural gas prices by provinces, they do not provide full information. We perform a price simulation based on the available data to compare with the natural gas prices listed by the government. We then analyze the impact of the pricing reform on natural gas producers, distribution companies and end users. Based on our analysis, we discuss the major limitations of the current reform and offer some suggestions for future reform directions.

2. OVERVIEW OF THE NATURAL GAS SYSTEM IN CHINA

The government of China regards the expansion of natural gas use as a critical component of shifting away from a coal-dominated energy structure, necessitated by an interest in tackling air pollution problems and reducing carbon emissions. China's natural gas consumption climbed from 46.4 billion cubic meters (bcm) in 2005 to 167.6 bcm in 2013 with an average annual growth rate of 17.4% (CNPC, 2014)[4]. As shown in **Figure 1**, the natural gas share in China's primary energy supply increased from 2.6% in 2005 to 5.8% in 2013 (NBS, 2014a)[5]. The contribution of natural gas to China's energy supply is well below coal and oil, which were approximately 66% and 18%, respectively, in 2013 (also depicted in Figure 1). It is also lower than the 2013 global average of 23.7% (BP, 2014). According to China's national energy

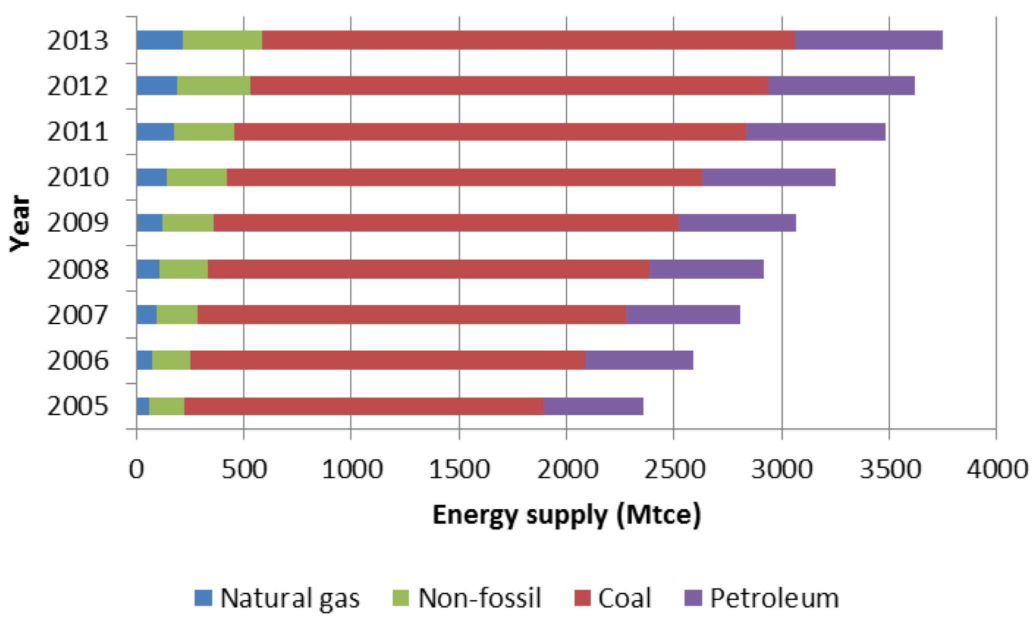


Figure 1. Natural gas in China's total energy supply (Mtce). Data source: NBS (2014a).

[4] Data from different sources vary. For example, BP reports 46.8 bcm for 2005 and 161.6 bcm for 2013 (BP, 2014).
[5] China usually reports its statistics in million tons of coal equivalence (mtce). 1 mtce = 0.786 bcm.

program during the Twelfth Five Year Plan, China's goal for natural gas consumption is 230 bcm by 2015, which would account for 7.5% of its total primary energy consumption (NDRC, 2012). This would require more than quadrupling natural gas use in ten years (from 2005).

Prior to 2006, China's natural gas supply had come from domestic production sources (**Figure 2**). Since then, imports have grown rapidly, especially since 2010, when the Central Asia – China pipeline started operations. By 2013, approximately 31% of annual natural gas consumption came from imports (CNPC, 2014). The Myanmar–China pipeline and the liquefied natural gas (LNG) receiving terminals in Guangdong, Hebei, and Tianjin started operation in 2013, significantly expanding China's gas import capacity. In 2013, 54% of China's gas imports were delivered through the Central Asia and Myanmar pipelines, with the rest coming from LNG (CNPC, 2014).

2.1 Gas Supply

In 2013 China's domestic gas production contributed 115 bcm, or approximately 69% of the total gas supply (**Figure 3**). Conventional gas production accounts for about 97% of domestic production. The three top gas basins—Tarim, Ordos, and Sichuan—currently play a dominant role in China's supply, accounting for over 90% of China's total domestic gas production. China's current unconventional gas production capacity is rather limited. Unconventional gas production was 1.95% (3.3 bcm) of China's domestic gas supply in 2013, of which coal bed methane (CBM), shale gas, and coal to gas constituted 1.77%, 0.06% and 0.12%, respectively. According to BP (2014), China's natural gas proven reserves are 3,272 bcm. This number does not include more speculative conventional and unconventional resources, which we will discuss later.

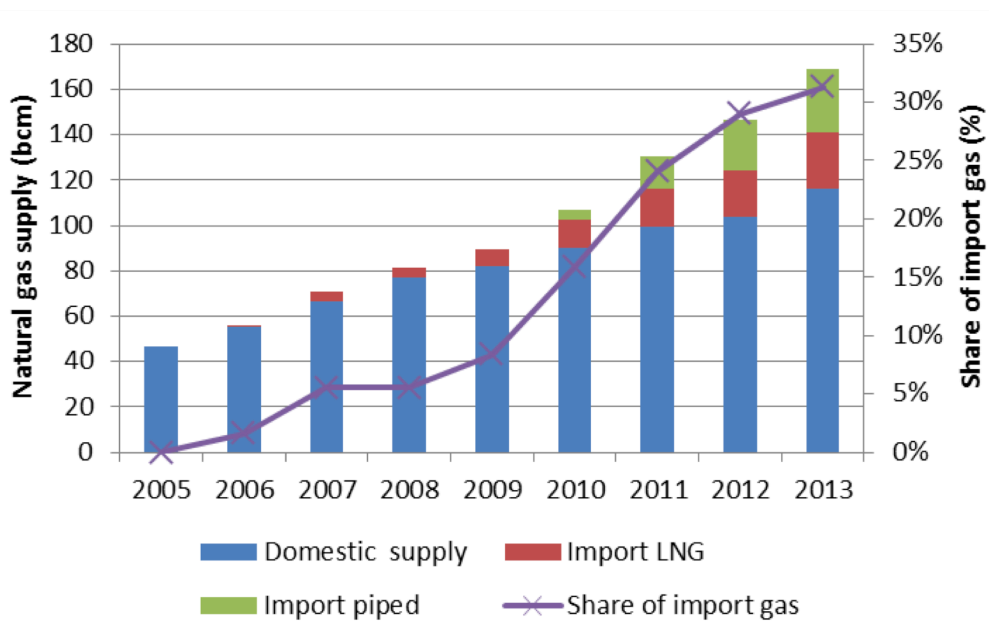
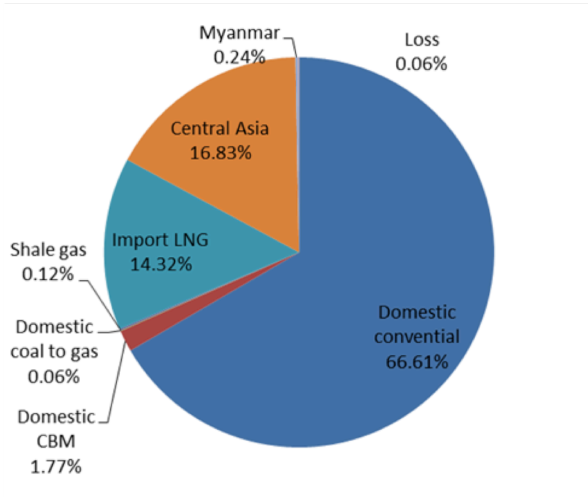


Figure 2. Supply structure of natural gas in China in 2013 (bcm). Data source: domestic supply data (NBS, 2014a), imports by source (CNPC, 2014).



	2013
Domestic:	
Conventional	111.6
CBM	3.0
Shale gas	0.2
Coal to gas	0.1
Import:	
LNG	24
Central Asia	28.2
Myanmar	0.4
Loss	0.1
Total	167.6
	bcm

Figure 3. Supply structure of natural gas in China in 2013. Data source: BP (2014) and personal communications with industry experts.

2.2 Import Capacity

The 2014 import pipeline capacity is 30 bcm for the combined two lines of the Central Asia–China pipeline and 12 bcm for the Myanmar–China pipeline. Construction of a third line of the Central Asia–China pipeline was mostly completed in 2014 and a capacity of 55 bcm for the combined three lines is expected to be operational by the end of 2015. All three lines originate in Turkmenistan, and pass through Uzbekistan and Kazakhstan. The first two lines get natural gas from Turkmenistan, while for the third line some additional gas from Uzbekistan (10 bcm) and Kazakhstan (current amounts are not specified[6]) is contracted as well. The pipelines are connected to China's West–East gas pipeline that passes through China from its western border all the way to Shanghai.

A fourth line (with a capacity of 30 bcm) of the Central Asia–China pipeline is under construction with expected completion by 2020. This line will also originate in Turkmenistan, but will pass through Uzbekistan, Tajikistan and Kyrgyzstan. Out of the total capacity of 85 bcm planned for 2020, Turkmenistan has signed an agreement to supply 65 bcm annually to China starting in 2020.

China has also signed an agreement with Russia to supply 38 bcm by 2018 from the Power of Siberia pipeline. An advantage of this project is that it will cross China's border in the northeast (in close proximity to industrial centers) rather than supplying gas through the West–East pipeline. Altai, another pipeline from Russia (30 bcm capacity) is under consideration, and is expected to connect to the Russian fields that currently supply Europe. In China, it would be linked to the West–East pipeline. LNG is another import option. In 2014, China had 12 regasification terminals with a combined capacity of about 50 bcm, or 35 million tonnes (Mt) of LNG (Interfax, 2015).

[6] A potential expansion to Kazakhstan gas fields on the Caspian Sea would create another sizeable source of supply

It is expected that by 2020 China will have an estimated pipeline import capacity of 165 bcm (85 bcm from Central Asia, 12 bcm from Myanmar, and 68 bcm from Russia) and a LNG import capacity of 88 bcm. Another 58 bcm of LNG capacity has been proposed, but these projects may be postponed or cancelled depending on natural gas demand development (BMI Research, 2013; Du and Paltsev, 2014). In total, by 2020, China's import capacity (both pipeline and LNG) will be 223 bcm considering existing capacity and the projects under construction, with an additional 88 bcm possible if both Russia's Altai pipeline and the additional LNG projects move forward.

2.3 Gas Consumption

China's natural gas consumption by sector from 2005 to 2013 is presented in **Figure 4**. In 2005, most of consumption occurred in three sectors: as a fuel in Industry (36%), as feedstock in chemical production (30%), and Residential use (17%). Consumption in the Power & Heating sector and the transport sector was very limited in 2005, but increased rapidly from 2008, and by 2013 they accounted for 30% of gas consumption.

As of 2013, Industry was still the largest natural gas user in China, consuming approximately 50 bcm of gas (31% of China's total gas consumption). The Residential sector consumed 30 bcm (19% of total consumption). The Power & Heating sector became the third largest (at 18% of China's total natural gas consumption), followed by Chemicals (16%) and Transport (12%). Gas use increased substantially in all sectors except for Chemicals; hence, most of the increased gas consumption has been used as fuel by substituting for coal rather than as a feedstock for the production of chemical products. This largely reflects China's natural gas policy that discourages use of gas as a feedstock in the chemical sector, while encourages fuel switching from coal to gas to tackle air pollution and mitigate CO_2 emissions (NDRC, 2012).

Over the past decade, China has increased its efforts in constructing natural gas pipeline distribution systems. As a consequence, around 32% of medium- and large-sized cities in China

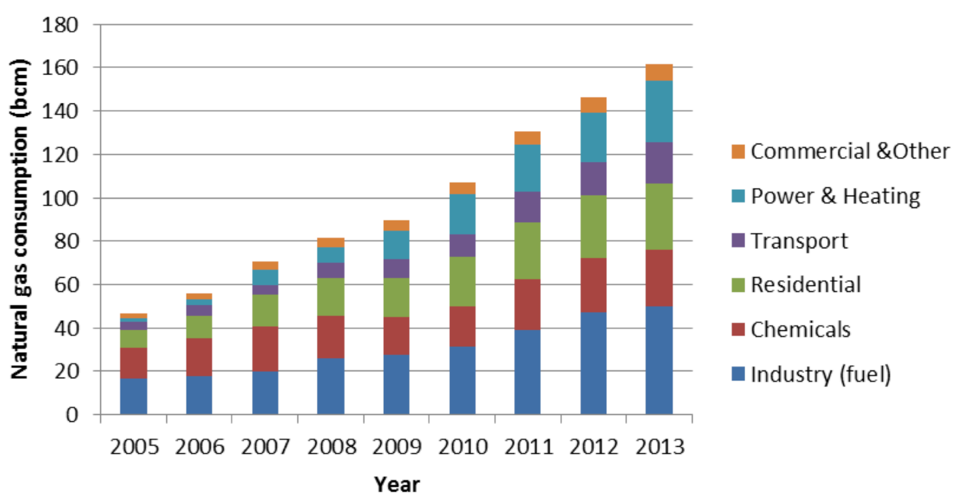


Figure 4. Gas demand by sector 2005–2013. Data Source: 2005–2012 data (NBS 2014b); 2013 data (personal communication with industry experts).

(or approximately 240 million people) have access to gas pipelines (CNPC, 2014). **Figure 5** shows the picture of China's gas consumption by regions. As denoted by blue-shaded areas, natural gas consumption is mainly concentrated in four regions: Southwest (Sichuan, Chongqing), Bohai Bay Area (Liaoning, Beijing, Tianjing, Shandong, Hebei), Yangtze River Delta (Shanghai, Jiangsu, Zhejiang), and the Southeast Coastal Area (Fujian, Guangdong). These four regions together contributed more than 60% of China's gas consumption in 2012 (NBS, 2014b). The large consumption of gas in Sichuan, Chongqing and Xinjiang is because they are located in the major natural gas production areas of China. The major gas consumers in the eastern coastal area of China such as Beijing, Tianjin, Shanghai, Jiangsu, and Guangzhou are among China's most developed provinces. The rapid growth of natural gas consumption in these rich areas is largely attributed to their efforts to promote the substitution of gas for coal to reduce the frequent smog incidence which has recently caused unprecedented health concerns in these areas.

Relative to the consumption centers depicted in Figure 5, major domestic producing areas are Tarim in Xinjiang, Ordos (located in part in Shaanxi, Shanxi, Gansu, Ningxia), and Sichuan. As for the points of entry for imports, the pipeline from Central Asia enters China in Xinjiang; the pipeline from Myanmar goes to Yunnan, Guizhou, and Guangxi; and the Power of Siberia pipeline from Russia will enter in Heilongjiang with the potential to reach Jilin, Liaoning, and Beijing. LNG terminals are located in coastal provinces.

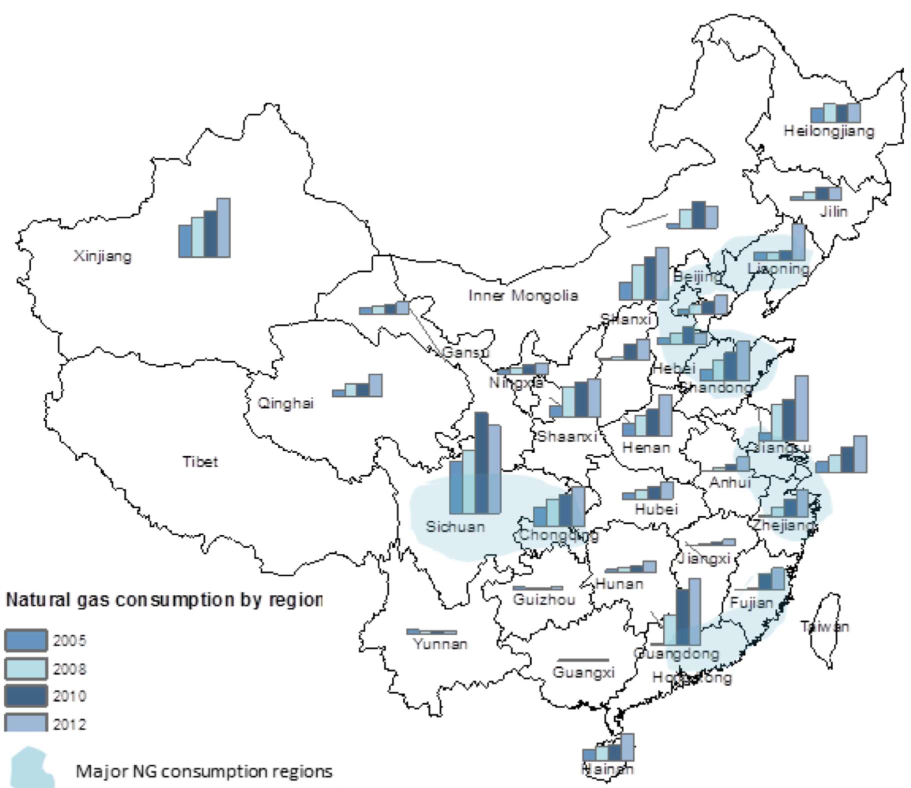


Figure 5. Gas consumption (in bcm) by region during 2005-2012. The vertical bars for each province represent relative consumption over time. 2012 consumption is 15 bcm in Sichuan and 10 bcm in Xinjiang. Data Source: NBS (2014b).

3. NATURAL GAS PRICING

3.1 The Pricing Regime Before the Reform

China's natural gas pricing has been highly regulated. Before the new pricing regime was introduced nationwide in July 2013, China's pricing approach was characterized as *costs plus profit margin*. **Figure 6** presents the institutional framework of the old pricing regime. The key players in the old approach included the National Development and Reform Commission (NDRC), the central government pricing authority, provincial/local government pricing agencies, gas producers/importers, transmission operators, and gas users.

The natural gas price formulation process involved ex-plant price, transmission tariff, city gate price, distribution fee, and end user price. Below we discuss these components.

Ex-plant Prices. These prices were determined by NDRC based on proposals from gas producers. These ex-plant prices were different for large users (some industrial users and fertilizer manufactures, or "Direct user" in Figure 6) and smaller industrial, transport and residential gas users (who pay "Retail prices" in Figure 6). Ex-plant prices were formulated based on a costs-plus-appropriate-margin approach (as shown by the formula below) that includes wellhead cost, purification fee, and applicable taxes and margins. Producers and buyers were able negotiate up to a 10% price increase or decrease based on the ex-plant prices set by NDRC.

Ex-plant price = Wellhead cost + Purification fee + Taxes + Appropriate margin

Transmission Tariff. The transmission tariff was also determined by NDRC, based on tariff proposals by gas transmission pipeline operators. The pipeline operators and gas producers are often the same companies in China. The transmission tariff is largely determined by the formula below that includes coverage of construction cost, operation cost, taxes and margins, and additional terms based on the distance from a gas source to a user.

Transmission tariff = Construction cost + Operation cost + Appropriate margin
+ Cost Variation of distance from gas source to city gate +Taxes.

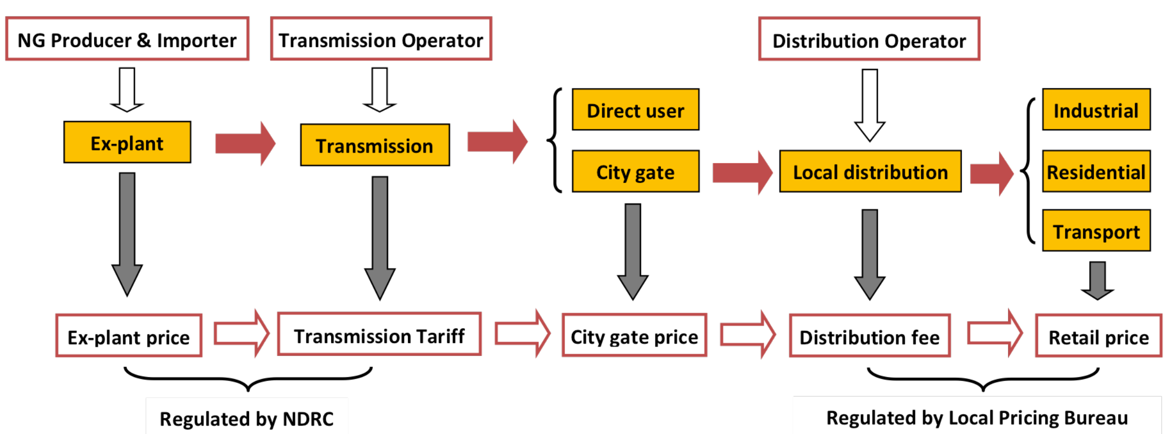


Figure 6. The institutional framework of the old natural gas pricing regime in China. Source: Adopted from Zhao (2011).

City Gate Prices. The wholesale prices that local gas distributors pay to pipeline operators to purchase gas. Under the old pricing approach, the city gate prices are in principle the sum of the ex-plant price and transmission tariff. Since the ex-plant prices are differentiated by user, the city gate prices are also different for the four categories of users mentioned above.

Distribution Fee. This fee is determined by the provincial/local pricing authority (often a department of the provincial development and reform commission) based on fee proposals by local distribution operators. The distribution fee calculation is similar to the transmission tariff calculation in that it includes coverage of construction and operation costs and appropriate margins and taxes.

Distribution fee = Construction cost + Operation cost + Appropriate margin + Taxes

End User Prices. The retail prices that gas consumers pay to local distributors. End user prices are proposed by local distributors and reflect the city gate price and the distribution fee. Ultimately, they are set by the local pricing agency after a check of the cost report prepared by the distributor. Since city gate price varies by user, the end user price does as well.

As discussed, the old pricing regime was established when natural gas was supplied domestically; as such, it was based on the cost of domestic production. After 2010, with the substantial increase of LNG imports and construction of the pipeline from Turkmenistan, in many situations the city gate prices set by the old pricing approach were much lower than the contract prices for imported natural gas. Natural gas importers incurred significant losses, which discouraged natural gas imports. In addition, being tied to the cost of supply only, the old approach did not reflect the fast growth in natural gas demand. As a result, many cities experienced severe shortages of natural gas (IEA, 2012).

3.2 Pricing Reform Highlights

Here, we provide a summary of the key points of the reform based on key policy documents (NDRC, 2010; NDRC, 2011). Given the problems that had emerged in gas markets, China launched a national natural gas pricing reform program in the early 2010s. The basic reform was to link gas prices with prices of imported fuels, enabling the market to play a more important role in the city gate price formulation. The reform was tested in two provinces, Guangdong and Guangxi, in 2011 before being implemented nationwide in 2013. Two new concepts were introduced: an *existing volume,* defined as the amount of natural gas consumption in 2012, and an *incremental volume*, the amount added in 2013, 2014, and 2015 beyond that in 2012. The new pricing approach was applicable only to the incremental volumes of pipelined natural gas. Pricing of imported LNG and unconventional gas are based on negotiations between producers and users, while the prices for household uses are unchanged from the levels determined by the old pricing regime.

A three-step transition process was introduced: 1) in 2013 the nationwide city gate prices for the incremental volumes of natural gases were formulated by the new pricing approach; 2) in

2014 the city gate prices for the existing volumes were increased, and those for the incremental volumes were adjusted by the new pricing approach; 3) in 2015 the city gate prices for the existing volumes were scheduled to increase to the level of the incremental volumes, and the city gate prices for the incremental volumes were scheduled to be adjusted again by the new pricing approach. As a result, a new single natural gas price for the existing and incremental volumes would be formulated by the end of March 2015.

Energy pricing reform is politically sensitive and involves several conflicts of interests. As China's natural gas was underpriced for a long time because of government control, natural gas prices were expected to increase as a result of the reform. To minimize the political risks associated with the rise in natural gas prices, the Chinese government decided to include the division of the natural gas consumption into the existing volume and incremental volume and adopt a differentiated pricing approach.

The primary rationale for the new pricing is that the value of natural gas can be largely represented by the value of its two substitutes in terms of providing energy services – fuel oil used in the industrial sector and liquefied petroleum gas (LPG) used in the residential sector. Based on this rationale, a new natural gas price basis was created. The new formula represents a weighted composite of the imported fuel oil price and the imported LPG price. The new natural gas price basis is termed as P_{CGPIN} (City Gate Price for Incremental Volume in Shanghai). The ex-plant prices and retail prices are based on this price. The formula for calculation is set by NDRC as follows (NDRC, 2011; NDRC, 2013).

$$P_{CGPIN} = K \times \left(\alpha \times P_{FO} \times \frac{H_{NG}}{H_{FO}} + \beta \times P_{LPG} \times \frac{H_{NG}}{H_{LPG}}\right) \times (1 + R) \quad (1)$$

The terms in the formula are: P_{CGPIN}, the city gate price for the incremental volume in Shanghai; K, a constant discount rate to promote gas uses (currently set at 85% by NDRC); α and β, the weights for fuel oil and LPG respectively, representing their relative contribution to China's energy supply; P_{FO} and P_{LPG}, the average imported fuel oil and LPG prices; H_{NG}, H_{FO}, and H_{LPG} are the heating value of natural gas, fuel oil and LPG, respectively; and R, the value added tax (VAT) rate for natural gas.

Under the new pricing regime, Shanghai is chosen as a starting point for the calculation of natural gas prices because Shanghai is both a large natural gas consumer and an important energy trade center in China. Shanghai's city gate price is set by P_{CGPIN}. **Figure 7** depicts how other prices are determined by the institutional framework of the new pricing paradigm. The major difference between the new pricing approach and the old one lies in the formulation of the ex-plant prices. Under the old approach, the ex-plant price of natural gas was largely based on the production cost; now it is a result of the P_{CGPIN} (or Shanghai's city gate price) minus the transmission tariff (based on the distance from the natural gas production site to Shanghai). The calculation of the transmission tariffs and the retail prices under the new regime, however, is almost the same as under the old approach.

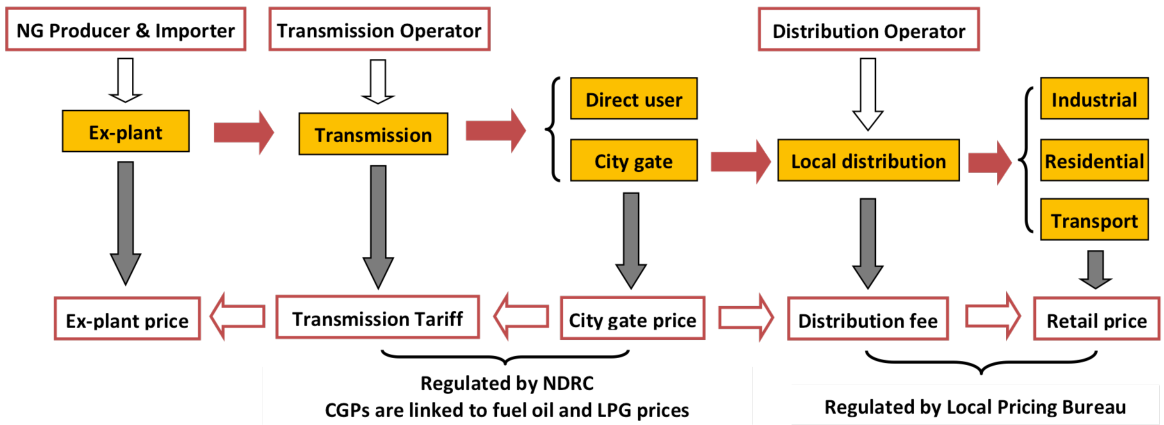


Figure 7. The institutional framework of the new natural gas pricing regime in China. Source: Adopted from Zhao (2011) and modified based on NDRC (2013).

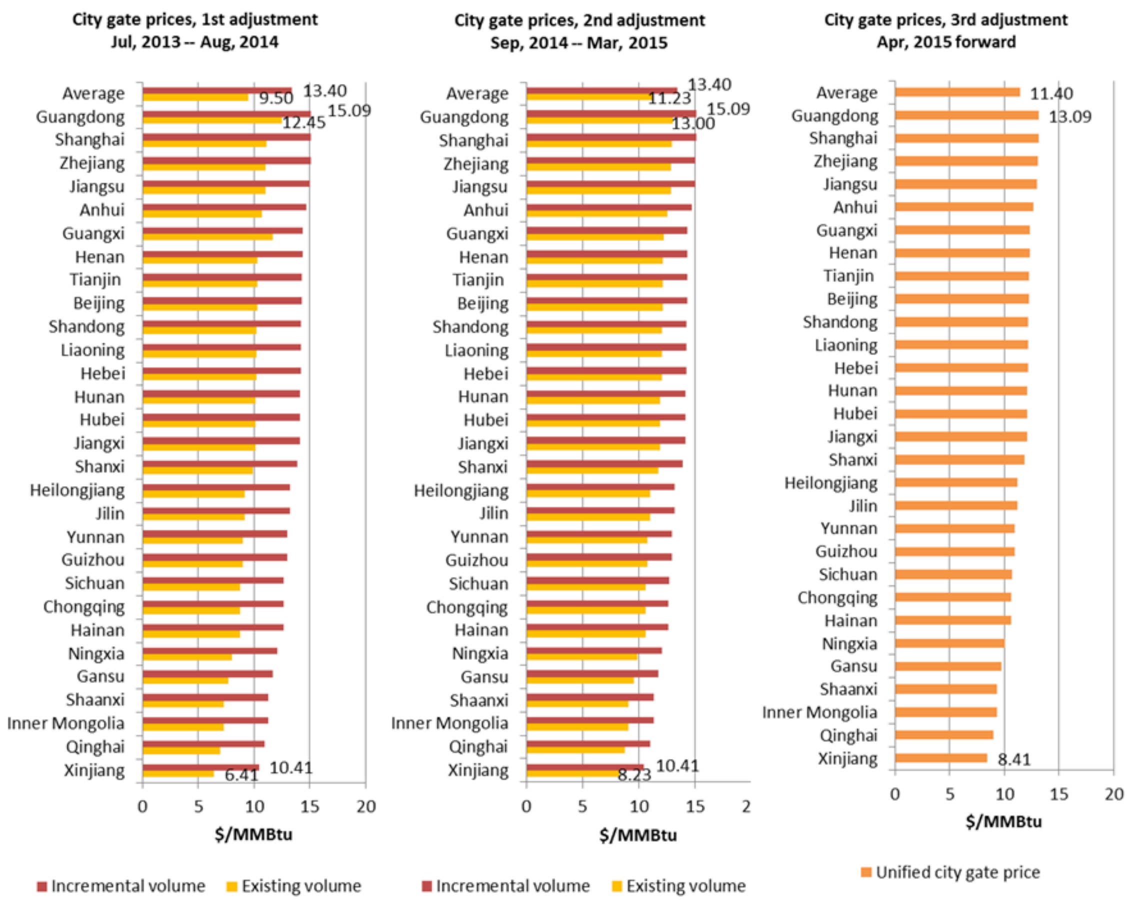


Figure 8. City gate prices by region in China, 2013–2015. Data Source: city gate prices after first adjustment (NDRC, 2013); city gate prices after second adjustment (NDRC, 2014); city gate price after third adjustment (NDRC, 2015).

Prices reported by NDRC are converted into $/MMbtu using the following conversion factors: 1000 m^3 of natural gas = 35.7 MMBtu (BP, 2014), 1$ = 6.16 yuan (average exchange rate for 2014 from USForex, 2015).

3.3 Price Adjustments

The pricing reform program has been implemented largely through the three NDRC directives on city gate price adjustments released in 2013, 2014, and 2015. The directives specified the starting dates when new pricing is planned to be implemented, but they did not specify for how long these prices will stay in place and when they will be revised next. **Figure 8** presents the city gate price changes in each region caused by each of the NDRC directives[7]. The first time period was governed by the first NDRC directive on city gate price adjustment (NDRC, 2013) and lasted for 417 days, from July 10, 2013 to August 31, 2014. The incremental volume price was significantly higher than the existing volume price (which represented natural price levels before the reform). This created incentives for natural gas companies to increase natural gas supply because they were able to sell additional gas at higher prices.

NDRC issued its second directive on August 10, 2014 as a second step of the reform (NDRC, 2014). The existing volume price was increased by 0.55 \$/MMBtu (0.12 yuan/m^3) in Guangdong and Guangxi[8] and by 1.82 \$/MMBtu (0.40 yuan/m^3) in the other provinces. The incremental volume price was left unchanged. As demonstrated in the middle panel of Figure 8, the price gap between existing and incremental volumes was significantly narrowed. This pricing period was shorter than the first, lasting for 212 days—September 1, 2014 to March 31, 2015. The end of the second period was determined by NDRC's third directive, released on February 28, 2015 (NDRC, 2015).

As can be seen in Figure 8, the city gate price for the incremental volume is higher than for the existing volume in all provinces, indicating that the introduction of the new pricing approach increased the gas price level for the whole nation.

In the third directive, NDRC increased the city gate price for the existing volume once more, but decreased that of the incremental volume to a large extent (as shown in the right panel of Figure 8). Since the international price of fuel oil and LPG was lower, the price for the incremental volume fell. With the third price adjustment, the prices for the existing and incremental volumes reached the same level, ending the two-tier pricing. NDRC applied this approach and announced elimination of the two-tier natural gas pricing in April 2015. There is no information how long the third period will last and when new price recalculation will occur.

Since the new natural gas pricing approach is based on a weighted composite of the imported fuel oil price and the imported LPG price, natural gas prices in the third period of the reform reflect price changes in the international oil market. For example, as shown in **Figure 9**, in October 2014 a significant drop in the international market oil price caused a decrease in the city gate price for the incremental volume.

[7] NDRC reports prices in yuan/m^3. In this report we report prices in \$/MMBtu using the following conversion factors: 1000 m^3 of natural gas = 35.7 MMBtu (BP, 2014), 1\$ = 6.16 yuan (average exchange rate for 2014 from USForex, 2015).

[8] We could not find a justification why these two provinces have separate schedules for price increase.

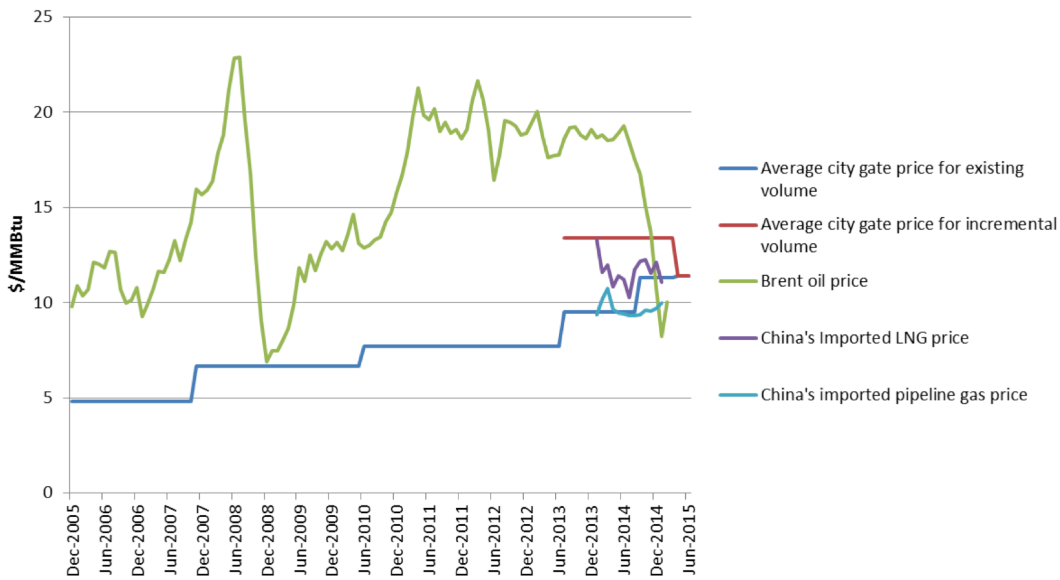


Figure 9. Chinese city gate prices for natural gas, weighted average import prices and Brent oil price. Data source: NDRC (2013), NDRC (2014), NDRC (2015), EIA (2015).

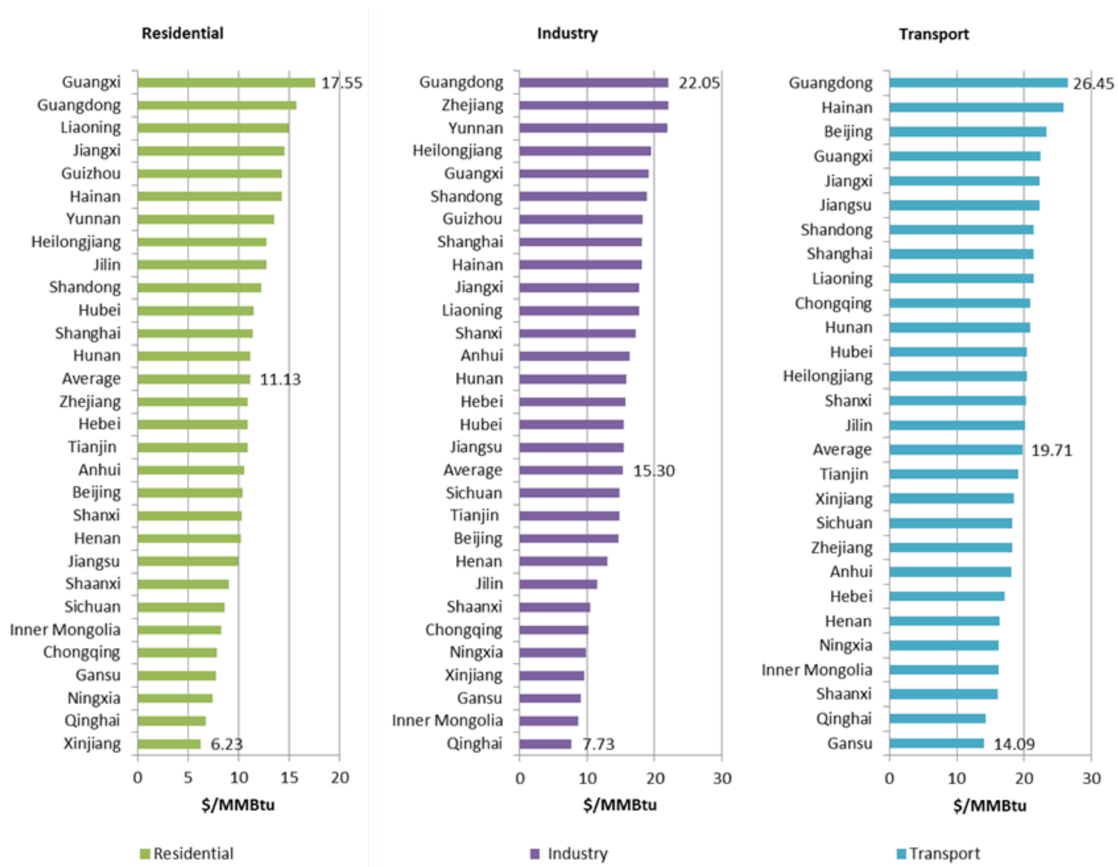


Figure 10. End user prices by region in July, 2014. Data Source: CNPC (2014).

Prices reported by NDRC are converted into $/MMbtu using the following conversion factors: 1000 m^3 of natural gas = 35.7 MMBtu (BP, 2014), 1$ = 6.16 yuan (average exchange rate for 2014 from USForex, 2015).

The approaches for local distribution fee charging and retail pricing under the new pricing paradigm are essentially the same as under the old one. In practice, the local pricing authorities take city gate price differences between the existing and incremental volumes into account when determining retail prices for end users, but often do not provide existing or incremental volume-specific retail prices. Instead, they provide only one price for each category of end users—a combination of the service prices from the existing and incremental volumes.

Figure 10 lists end user prices by province in July 2014. The retail prices vary by province. The average price level for residential use was 11.13 $/MMBtu, which is slightly higher than the average city gate price for existing volume gas supply (9.50 $/MMBtu during that period), but much lower than the average city gate price for incremental volume gas supply (13.40 $/MMBtu). The retail price for the Industry sector averaged at 15.30 $/MMBtu, ranging from 7.73 $/MMBtu to 22.05 $/MMBtu by province. The average price level for transportation uses was 19.71 $/MMBtu. In all provinces, the price level for industrial use is higher than for residential use, and the retail price for the Transportation sector is among the highest.

Residential prices for natural gas are lower than industrial in China, which is the opposite of the price levels in developed countries. For example, in the US in 2013, with Henry Hub price of 3.66 $/MMBtu, the delivery prices to electric power users were 4.39 $/MMBtu, industrial users – 4.66 $/MMBtu, commercial users – 8.44 $/MMBtu, residential users – 10.54 $/MMBtu, and transportation - $15.68 $/MMBtu (EIA, 2014). In Italy in 2011, the residential price was 19.45 $/MMBtu, while the industrial price was 12.05 $/MMBtu (Honore, 2013). The relationship between residential and industrial prices in China is driven by the desire to subsidize residential use of natural gas.

3.4 Price Simulations

Transparency in price formulation is critically important for market players and analysts. Prices provided in Figures 8 and 10 are based on the NDRC documents that give the resulting prices, but they do not provide detailed information on how they are calculated. To replicate the results, we decided to use formula (1) with the publicly available data for inputs. In order to simulate the resulting prices, we follow the procedure depicted in Figure 7. First, we calculate the P_{CGPIN}. Then we determine the ex-plant prices for the major natural gas production areas, and establish the city gate gas prices by region.

Table 1 presents the input data provided in NDRC documents. Because NDRC does not provide all the details of their price calculations, we have to make several assumptions. First, NDRC states that formula (1) is calculated based on the price of imported fuel oil and imported LPG. However, there is no information on which prices were actually used in their calculation, what the corresponding data sources are, and what period the prices were chosen for. We rely on the reputable source for public data on import and export information: China Export and Import Statistics, released by General Administration of Customs of China (GACC). We also assumed that prices in formula (1) are the most recent imported fuel oil and LPG prices at the time of the price adjustment announcement. Our price simulations focus on the third adjustment, so we used the average prices for imported fuel oil and LPG during the period from July 2014 to December 2014. **Table 2** shows our assumptions for the imported fuel oil and LPG prices.

NDRC also did not release the transmission tariffs that they used for the price adjustment. For this information we had to rely on our individual communications with Chinese natural gas experts. **Table 3** presents the transmission tariffs of the natural gas pipelines. They are based on a distance from Xinjiang. For example, a tariff from Xinjiang to Gansu is 0.3 yuan/m^3 (or 1.35 \$/MMBtu), while a tariff from Xinjiang to Shanghai is 1.1 yuan/m^3 (or 5.00 \$/MMBtu). **Figure 11** provides information on geographic locations along the West–East pipeline.

Table 1. Data used for city gate price calculation.

Parameter	Value	Source
K	85%	NDRC 2013
α	60%	NDRC 2011
β	40%	NDRC 2011
H_{NG}	8000kcal/m3	NDRC 2011
H_{FO}	12000kcal/kg	NDRC 2011
H_{LPG}	10000kcal/kg	NDRC 2011
R	15%	NDRC 2011

Data source: NDRC (2011), NDRC (2013).

Table 2. Average price of imported fuel oil price and LPG, July 2014-December 2014.

	Imported Volume (million kg)	Value (million yuan)	Average price (yuan/kg)
Fuel Oil	8,040	28,650	3.56
LPG	12,419	57,258	4.61

Data Source: GACC (2014a), GACC (2014b).

Table 3. Transmission tariffs.

From	To	Transmission tariff (yuan/m3)
Xinjiang	**Gansu**	0.3
	Ningxia	0.35
	Shaanxi	0.4
	Shanxi	0.75
	Henan	0.85
	Anhui	0.95
	Jiangsu	1.05
	Zhejiang	1.08
	Shanghai	1.1

Source: Authors' estimates based on communication with industry experts.

Using the information provided above we re-calculated city gate and ex-plant prices, which are provided in **Table 4.** Ex-plant prices are estimated to be 1.775 yuan/m^3 (which is an equivalent of 7.93 \$/MMBtu). NDRC does not provide ex-plant prices in their documents on pricing. Comparing our simulated city gate prices with those provided by NDRC shows a relatively close agreement for most of the locations. The differences are smaller than 4%, except for Shaanxi, where the difference is about 6.5%. Except for Shaanxi again, our simulated prices are slightly lower than the NDRC prices, which suggest that our assumptions about the input prices and/or transmission tariffs are slightly lower than those used by NDRC. As mentioned before, Shaanxi is a domestic natural gas producer, and a large portion of its natural gas demand

Figure 11. West–East natural gas pipeline frame in China. Source: PetroChina (2002).

Table 4. Comparing published regional city gate prices with results from our simulation (yuan/m^3).

	Our calculation			NDRC*	Difference
	Transmission Tariff	Ex-plant price	city gate price	City gate price	
Xinjiang	-	1.775	1.775	1.85	-0.075
Gansu	0.3	1.775	2.075	2.13	-0.055
Ningxia	0.35	1.775	2.125	2.21	-0.085
Shaanxi	0.4	1.775	2.175	2.04	0.135
Shanxi	0.75	1.775	2.525	2.61	-0.085
Henan	0.85	1.775	2.625	2.71	-0.085
Anhui	0.95	1.775	2.725	2.79	-0.065
jiangsu	1.05	1.775	2.825	2.86	-0.035
Zhejiang	1.08	1.775	2.855	2.87	-0.015
Shanghai	1.1	1.775	2.875	2.88	-0.005

*Source: NRDC (2015).

is supplied by local production. The price difference in Shaanxi could be explained by negotiations of the local governments with NDRC.

Our simulations show that the new pricing mechanism is more transparent than the old regime when price information was hard to obtain. However, transparency and predictability can be further improved if the complete information about all inputs required for calculations are provided by NDRC. This may help to establish confidence in the new pricing scheme among market players.

4. DISCUSSION

4.1 Impacts on Gas Producers and Importers

Gas producers and importers appear to benefit the most from the price reform due to the price increases. **Figure 12** shows the natural gas market share (in terms of domestic production) among the three state-owned oil and gas giants: PetroChina[9], Sinopec and CNOOC. These three companies together own and operate over 90% of China's gas infrastructure covering gas production, import, transmission, and storage business. PetroChina is the largest gas supplier and pipeline operator in China and provided 67.3% of China's domestic gas supply in 2013.

Next, we focus on PetroChina to see the impacts of the natural gas pricing reform. **Figure 13** compares the margins of PetroChina's gas and pipeline business under the old and new pricing paradigm. Under the old pricing regime, the ex-plant pricing approach applied for both domestic and imported pipeline gas. According to their 2013 annual report (PetroChina, 2014), in 2012 PetroChina earned about 40 billion yuan on the sales of natural gas and pipeline operations. At the same time, they paid about 42 billion yuan for the imported gas from Central Asia. As a result, the company lost 2 billion yuan in 2012. In 2013, PetroChina paid a similar amount for imported gas, but after the introduction of the new pricing system in 2013 PetroChina earned

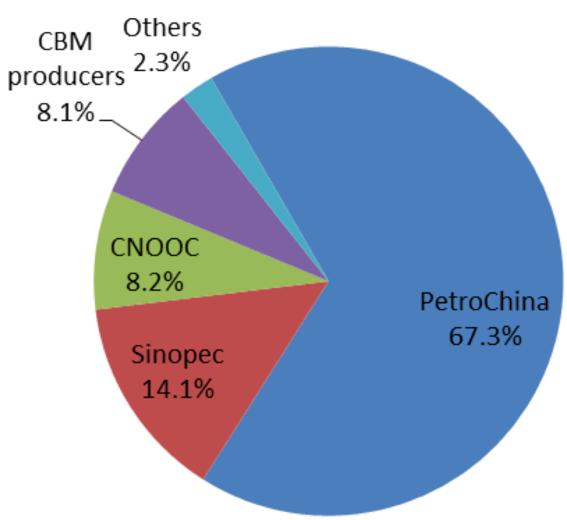


Figure 12. Major gas suppliers in China in 2013. Data Source: Xinhua News (2014).

[9] PertoChina is controlled and sponsored by China National Petroleum Corporation (CNPC).

about 71 billion yuan from the sales of natural gas and pipeline operations. As a result, PetroChina earned 31 billion yuan (or about 5 billion dollars) more in 2013, after the reform.

The details of the difference in performance in 2012 and 2013 can be illustrated by price information provided in **Figure 14.** VAT-included border prices of pipeline imports were similar in 2012 and 2013,—11.10 $/MMBtu and 11.00 $/MMBtu, respectively. However, the ex-plant prices at Xinjiang were quite different. Starting at 5.50 $/MMBtu in 2012, in 2013 they were increased by 1.82 $ /MMBtu for the existing volume and by 4.64 $/MMBtu for the incremental volume, allowing PetroChina to make a profit of 28.9 billion yuan in 2013.

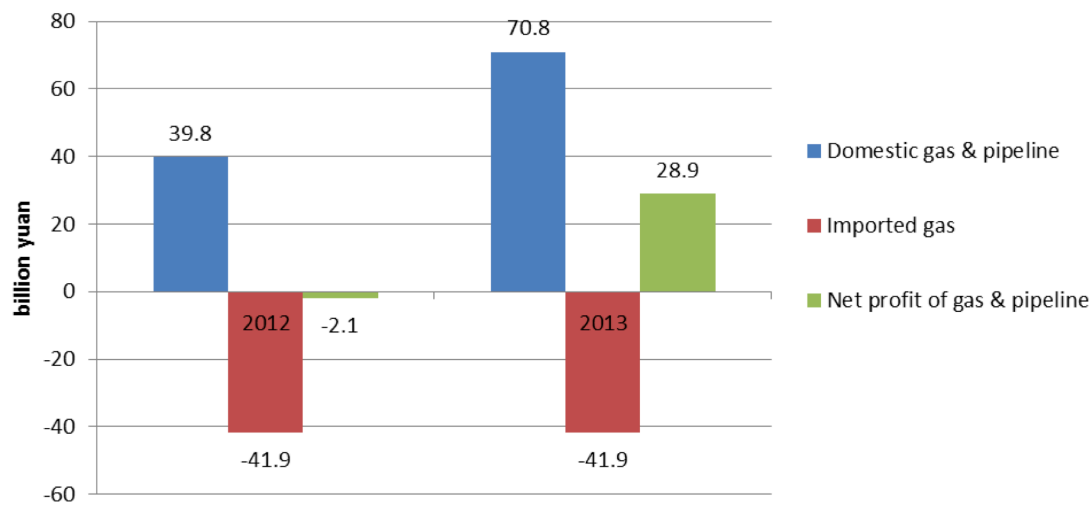


Figure 13. Margins of PetroChina's gas and pipeline business in 2012 and 2013. Data source: PetroChina (2014).

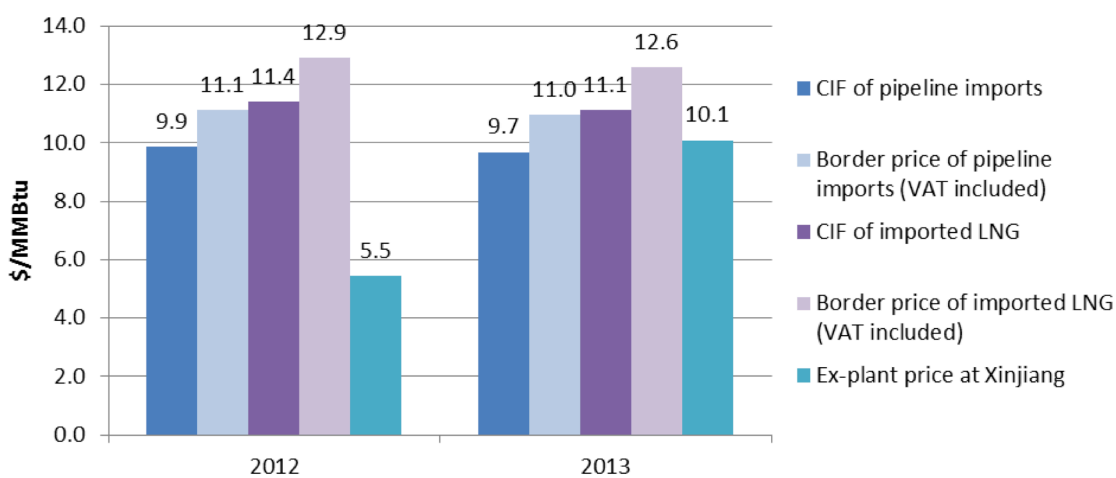


Figure 14. Border price vs. ex-plant price in 2012 and 2013. Data Source: import LNG & pipeline gas prices (CNPC, 2014), ex-plant prices at Xinjiang (authors' estimates based on NDRC, 2010; NDRC, 2013).

Prices are converted into $/MMbtu using the following conversion factors: 1000 m^3 of natural gas = 35.7 MMBtu (BP, 2014), 1$ = 6.16 yuan (average exchange rate for 2014 from USForex, 2015).

4.2 Impacts on Distribution Companies

Since local governments regulate end user gas prices, the interests of natural gas distributors may be undermined if local distribution companies fail to pass on the city gate price increase to the end users. We illustrate this issue in **Figure 15,** which compares the margins of a gas distributor in Harbin City in 2012 and 2013.

The distributor sells natural gas to industrial users under the old and new pricing paradigms. Panel (a) of Figure 15 shows the price components under the old pricing. Panel (b) shows pricing under the new regime for the existing volume. Panel (c) shows pricing under the new regime for the incremental volume. The data on all three panels in Figure 15 have the same ex-plant price of 7.32 \$/MMBtu (or 1.61 yuan/m^3). The old and new pricing regimes added different amounts to

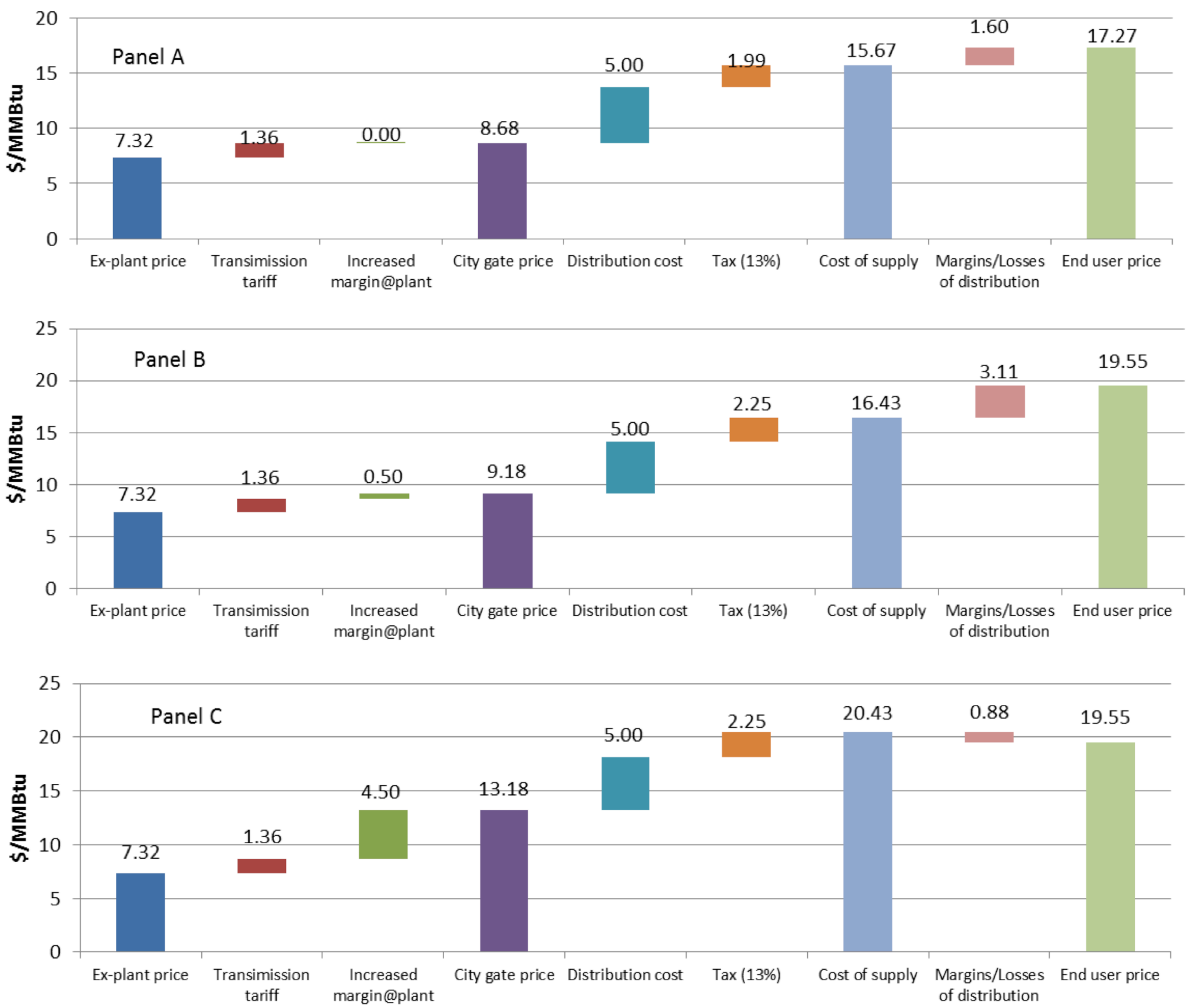


Figure 15. Margins of natural gas distributors in Harbin for non-residential use: (a) with old pricing; (b) with new pricing for the existing volume; (c) with new pricing for incremental volume. Data source: Ex-plant prices (NDRC, 2010), City gate prices (NDRC, 2013), Distribution costs (Xinhua News, 2012), End user prices (Harbin Pricing Bureau, 2013), Transmission tariffs (authors' estimates based on personal communication with industry experts).

that price to determine the city gate prices.

Under the old pricing, the city gate price was 8.68 $/MMBtu. Natural gas reform raised the city gate prices to 9.18 $/MMBtu for the existing volume and to 13.18 $/MMBtu for the incremental volume. Under old pricing, gas distributors made a gain of 1.60 $/MMBtu on a difference between their cost of supply and end user price. After the reform, with the same distribution costs and slightly different taxes, gas distributors now make a profit of 3.11 $/MMBtu (0.69 yuan/$m^3$) on the existing volume natural gas being sold to the industrial users, but lose 0.88 $/MMBtu (0.19 yuan/$m^3$) on the incremental volume natural gas to the same users. The city gate prices are regulated by NDRC, while the end user prices are regulated by the local governments. Depending on their objectives, they may keep the end user prices low, which may result in a loss of money for a distribution company, as it happened in Harbin.

4.3 Impacts on End Users

As discussed before, the major end use sectors are Industry, Residential and Power & Heating. In the residential sector, gas tariffs should increase because of the rise in the city gate prices. However, China's retail prices for natural gas are regulated by the local governments. Social stability considerations might give some resistance to residential price increases. For example, residential prices were unchanged for years in Shanghai and Beijing, including the period of the pricing reform. **Figure 16** compares the retail price for the Residential sector, the city gate price for existing volume gas supply, and the city gate price for incremental volume gas supply for the first adjustment period (July 10, 2013 to August 31, 2014) (CNPC, 2014; NDRC, 2013). The retail price for the Residential sector is lower than the city gate price for the incremental volumes in most provinces, and for some provinces (e.g., Xinjiang, Ningxia, Sichuan, Jiangsu) even lower than the city gate price for the existing volumes. It means that the natural gas use in the Residential sector is subsidized either by the government or by other end users. The natural gas pricing reform at this stage has not substantially affected the residential sector, as consumers are protected by the subsidy scheme. For the long term, however, it would be difficult to maintain the current residential gas price level if the city gate prices keep changing.

Industry prices are higher than residential in all provinces. **Figure 17** provides a comparison between the prices for different users for Beijing, Shanghai, and Zhejiang for the first adjustment period. While the Residential prices in these provinces were 10.40, 11.40, and 10.90 $/MMBtu, respectively, Industrial prices were 14.70, 18.10, and 22.00 $/MMBtu. The prices in the Industry sector have not been protected by the government. It appears that the Industry sector is impacted the most by natural gas price increase. Furthermore, the sector often has to pay for a part of the natural gas use in the residential sector through a cross-subsidy scheme arranged by the local governments.

The third largest natural gas sector, Power (& Heating), is especially sensitive to the changes in natural gas prices. The prices of gas as an input and heat as an output are mostly regulated by local governments, while the price of electricity as an output is regulated by the China's central government. The price level of gas use in the Power sector varies by province, but is higher than the Residential sector in all provinces. In Figure 17 we also provide Power sector prices in three

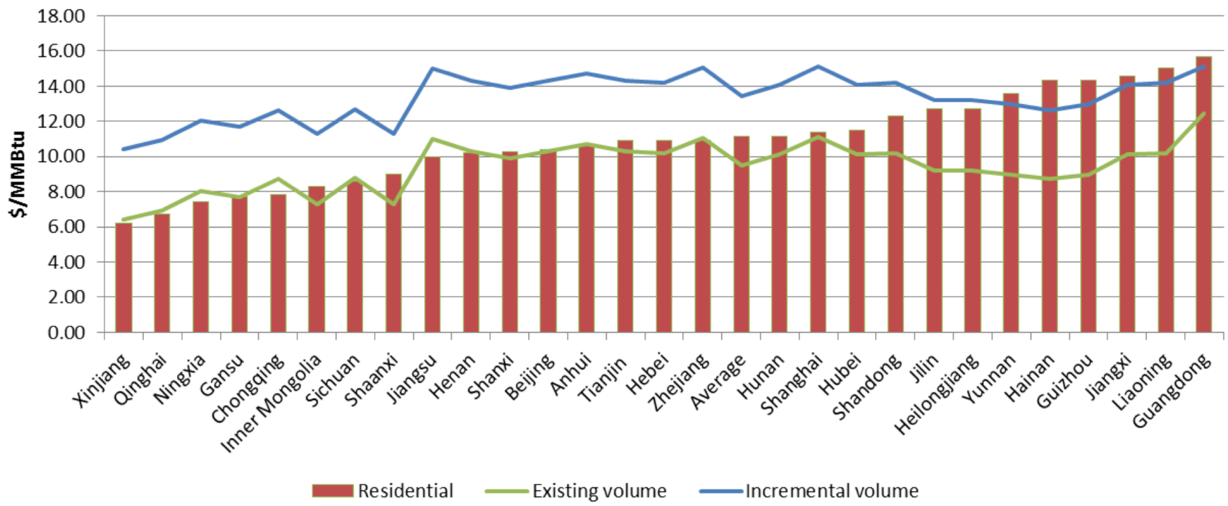


Figure 16. Natural gas prices for the residential sector during the first adjustment period. Data Source: CNPC (2014), NDRC (2013).

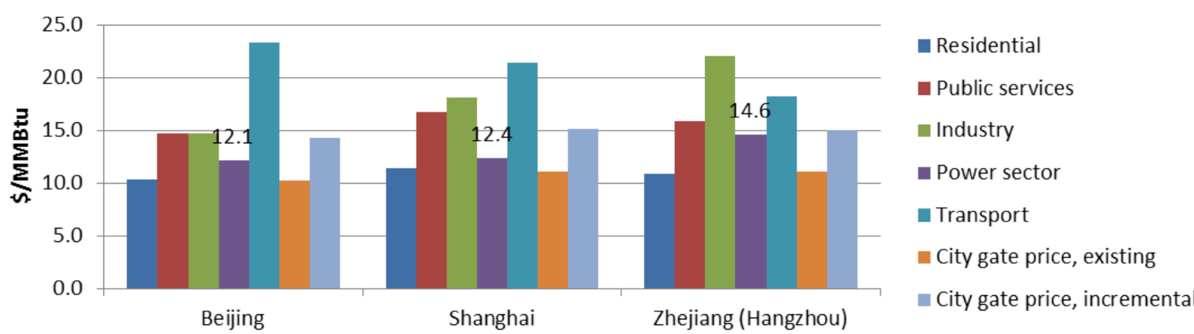


Figure 17. End user gas prices in Beijing, Shanghai and Zhejiang in the first adjustment period. Data Source: CNPC (2014), NDRC (2013).

provinces. Local governments often provide subsidy for the space-heating in households, as well as for power generation that contributes to a local air pollution control. In this context, the profitability of the Power sector depends heavily on subsidy from the local governments. Based on natural gas prices (shown in Figure 17 as 12.10 $/MMBtu for Beijing) and electricity price (also regulated by the China's central government), we estimate that in Beijing the gas-fired combined heat and power plant (CHP) takes a loss of 0.11 yuan for each kilowatt hour (kWh) of energy supply due to the increased gas price associated with the new pricing approach[10].

4.4 Limitations of the Current Pricing Reform

China's natural gas pricing program has been successful in terms of addressing the major deficiencies of the old pricing regime and has made substantial progress toward establishing a

[10] The estimate is obtained with the following assumptions: Fuel cost accounts for 70% of the production cost for a typical gas fired CHP in China (Ji *et al.*, 2013), 1 cubic meter of natural gas generates 5 kWh electricity. Electricity price for gas-fired CHP in Beijing is 0.65 yuan/kWh (BMCDR, 2014).

market-based pricing system. It has encouraged producers and importers to provide additional supplies of natural gas. Where the old pricing scheme largely ignored that both supply and demand have their impact on price formulation, the new pricing approach created a link with international prices of imported fuel oil and LPG. However, though the new pricing approach reflects market pricing principles to a larger extent, the reform has its limitations. It is still not a true market system, where prices are constantly determined based on the interaction of supply and demand.

Currently, prices in the new mechanism are established on a starting date, but with no clear indication of an ending date. There is also no clear information on the rules and conditions under which the ex-plant and city gate prices will change in response to the traded prices of imported fuel oil and LPG. Government authorities provide the city gate prices, but they do not list the data sources used for the prices of imported fuel oil, LPG, or transmission tariff. Understanding the exact rules of the price formulation and the duration of the period for which each new price is set would help natural gas producers and users make sound economic decisions that will increase the economic welfare of China. Currently, the reform still focuses on producers and importers, while end user prices are controlled by local authorities. A true market reform would allow flexibility in price formulation at all levels. The Industry sector and the Power & Heating sector are the two largest drivers of China's natural gas consumption growth, but they appear to benefit little from the new reform initiative. The Transportation sector is in a similar situation. As the pricing reform largely ignores demand-side dynamics, it may be problematic to expand natural gas use in industry and transportation to achieve the government objective of increasing natural gas in China's energy mix.

The new initiative also fails in correcting price distortions and squeezing out cross-subsidies. The natural gas prices in China's Industry and Power sectors are higher than in the Residential sector, while supply costs in the Residential sector are often the highest. In the liberalized markets of developed countries Residential end user prices are usually among the highest. The reform has ignored such distortions between the costs and the resulting prices. It also does little to encourage competition, which would lower the price levels. In China, the three state-owned oil and gas companies dominate natural gas supply; in order to create an efficient natural gas market in China, it is important that private companies have the same rights as state-owned companies in terms of the access to natural gas pipelines, LNG facilities, and gas storage facilities.

As for future reform directions, the following issues are important to consider:

More transparent gas pricing system and correction of price distortions. China's natural gas pricing is still heavily regulated, and the system lacks transparency. Clarity for the rules and conditions under which the city gate prices respond to changes in the international oil market price would create the foundation for a movement to a complete market-based pricing system. It is also important to start deregulating the distribution market to correct the price distortions in the retail markets.

Encourage competition in natural gas production and distribution. Competition often leads to a more efficient allocation of resources and ultimately to lower prices. PetroChina, Sinopec, and

CNOOC contribute about 90% of China's natural gas supply. They also own major pipeline infrastructure. To become more efficient, regulations are needed to secure equal access for private companies to capital, pipeline and distributional infrastructure. Shale gas production in the United States shows the importance of these small and independent companies in the fast development of new production.

Address the market failure barrier to natural gas by internalizing the environmental externalities of coal. Establishing a complete market-based natural gas pricing system is important, but most likely would not be enough to substantially increase the contribution of natural gas in China's energy mix. Natural gas has a relative environmental benefit compared to coal, but prices do not reflect additional costs related to health and environmental effects of energy use, so natural gas is more expensive than coal. A recent study shows that a substantial substitution of natural gas for coal could take place when a coal resource tax and/or carbon tax is introduced (Zhang *et al.*, 2015). Coal use must be reduced for China to reach its goal of peaking carbon emissions by 2030 (China Daily, 2014). Substituting coal with natural gas offers such an option, and introduction of incentives (e.g., by carbon tax or cap-and-trade system) is an efficient mechanism to mitigate emissions (Paltsev *et al.*, 2015).

5. CONCLUSIONS

China's top leadership made decisions to deepen its reform at the Party's Third Plenary in 2014, emphasizing the decisive role of the market in resources allocation (Xinhua Net, 2015). A market-oriented natural gas pricing reform is in line with China's national reform policy. NDRC's natural gas pricing reform aims at establishing a market-based natural gas pricing system, ultimately increasing the contribution of natural gas in China's energy supply mix. This increase will most likely rely both on domestic production and imports. Despite the large resource estimates[11], China's experience with shale gas production so far has not provided the same results as the "shale gas revolution" in the United States. In addition to geological, land ownership and water issues, natural gas prices and infrastructure developments are among the limiting factors. With successful resolution of these issues, China has the potential to become a major natural gas producer by mid-century (Paltsev *et al.*, 2013). A successful price reform will also help in finding the right balance of import infrastructure development (both pipeline and LNG) and domestic production.

Experiences of the US, where natural gas prices are determined by interaction of supply and demand, and the EU, where the regions are segmented and some prices are still linked to oil, offer an illustration of the relative efficiencies of the gas pricing mechanisms and benefits of moving to a more complete market system. A complete natural gas pricing reform in China would allow natural gas producers and importers to provide adequate amounts of natural gas and eliminate shortages. Competition will push producers to be more efficient, thereby providing a greater value for the scarce resource. At the same time, careful market design and pacing of the

[11] EIA (2013) estimated shale resources to be around 30,000 bcm in China and around 20,000 bcm in the US.

reform is needed to minimize the potential negative effects, such as monopolistic power and impacts on consumers from different income groups.

The new natural gas pricing regime in China has a better predictability and transparency compared with the old pricing regime. It has a strong connection with the international fuel oil market and LPG prices. To minimize potential political opposition during the new regime implementation, the government adopted a two-tier pricing approach for the period of transition. Because it focuses mostly on the supply side, the current reform falls short of establishing a truly market-based pricing system. Among the major limitations of the current reform is a failure to address the issues at the level of local distribution and retail prices. It also has created biased incentives and favors the large natural gas suppliers. An immediate step for improving the new pricing approach would be to set transparent rules and conditions under which the city gate natural gas prices would adjust automatically in response to changes in international oil and gas market prices. For long-term development, the Chinese government should investigate pathways for moving to a complete market-based natural gas pricing system. This will establish a better resource allocation system and result in an increased welfare of China.

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