Cost of Natural Gas in Eastern Chinese Markets: Implications for LNG Imports

BY YUE WANG AND ZHEN ZHU

China is the third largest consumer of natural gas in the world, behind the U.S. and Russia. As the country switches to cleaner energy to reduce air pollution and lower carbon emissions, natural gas consumption has increased significantly. For 2017, gas consumption surged due to the 'coal-to-gas' policy in the northern region and industrial consumption increase. Severe natural gas shortages have occurred in China this winter; even major gas production provinces such as Sichuan and Inner Mongolia have undergone gas shortages. Consequently, liquefied natural gas (LNG) imports have surged to a record high to more than 38 million tons, almost a 50% increase compared to that of 2016, making China the second biggest importer in the world behind Japan.

Even though Chinese gas consumption has increased dramatically, it is expected that the consumption will increase substantially more. According to China's clean heating plan for the northern region, the share of clean heating will reach 70% by 2021, replacing 150 million tons of coal.[1] To achieve this target, China will need more gas to replace coal, and gas consumption will likely to keep rising in the future.

As a result of shale revolution, natural gas production in the United States has risen dramatically during the past a few years. Several LNG export projects have been proposed and some projects are already under construction. Energy cooperation between the U.S. and China seems unavoidable in the future. For LNG exporters targeting the Chinese market, an important question would be whether LNG is competitive or not compared to China's own domestic production and other imports, especially given the fact that the Chinese government has unveiled a series of natural gas reforms to create a market-oriented pricing mechanism. Unfortunately, the system has not been established yet and it is extremely difficult to obtain natural gas price information at this time. There are several issues. One is that there is no gas price reference point in China. Second, the gas pricing mechanism is not transparent and public price information is usually not available. This article addresses the issues by estimating the costs of domestic gas and pipeline-imported gas transported to the Chinese eastern coastal markets. Given the fact that the relevant data is usually classified, it is nearly impossible to find direct cost information about gas production and prices in China. We explore a variety of sources to shed light on the issue.

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See footnotes at end of text.

Natural gas consumption and production in China

Natural gas consumption in China has been rising continuously for the past 16 years; however, the growth rate slowed down in the past few years (see Figure 1). In 2017, due to the implementation of 'coal to gas' policy in the northern region, gas consumption has most likely increased remarkably, with a double-digit growth rate since 2014.

Figure 2 shows that Chinese domestic gas production accounted for about 2/3 of the gas supply with the rest coming through pipeline and LNG imports. Figure 3 shows that the domestic production of natural gas has undergone a steady growth for the past 17

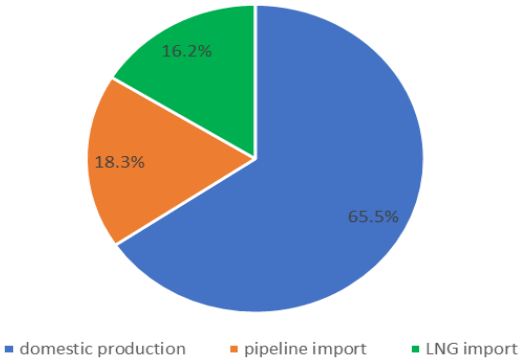

Figure 2: Source of China's natural gas supply (2016)
Source: National Bureau of Statistics (PRC)

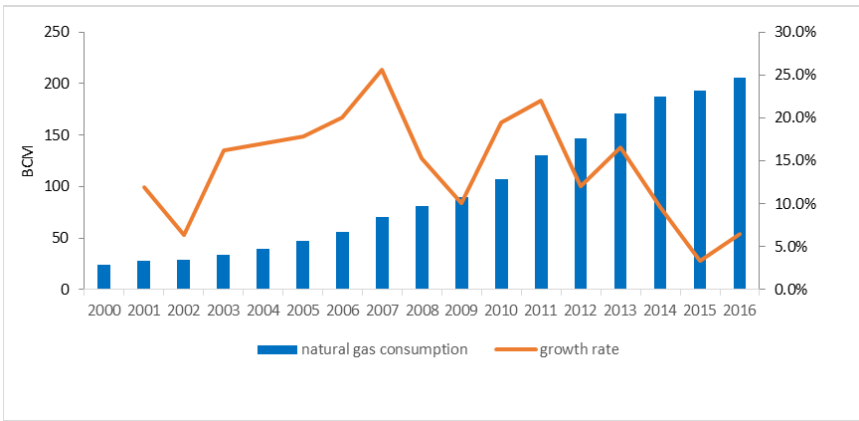

Figure 1: Natural gas consumption in China (2001-2016)
Source: National Bureau of Statistics (PRC)

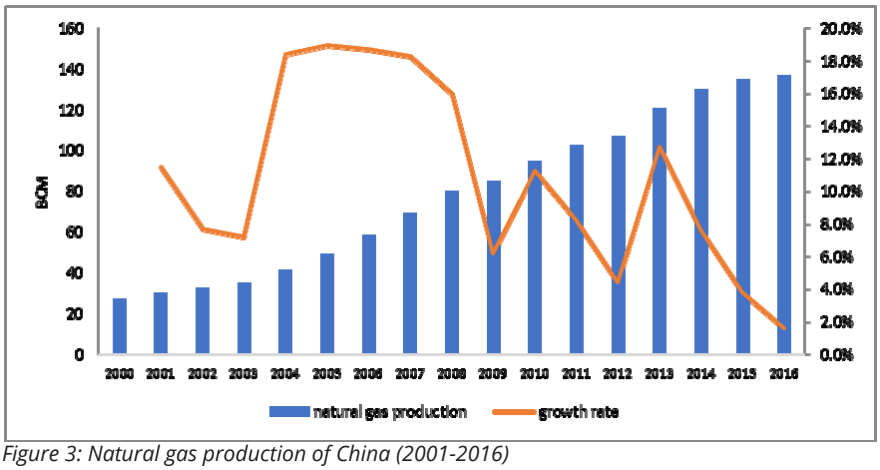

Figure 3: Natural gas production of China (2001-2016)
Source: National Bureau of Statistics (PRC)

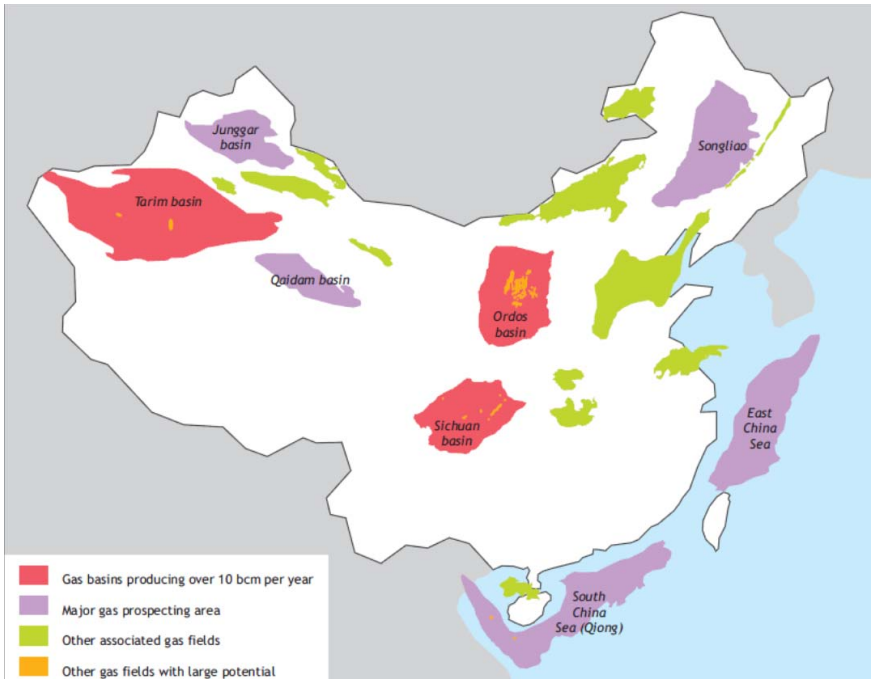

Figure 4: Map of China's Gas Basins
Source: International Energy Agency

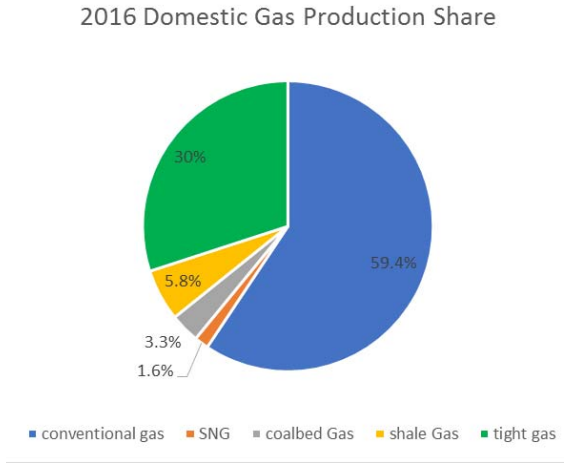

Figure 5: Domestic production by source[2] (2016)

years. Production in 2016 was almost 5 times that for 2000. However, since 2005, the annual gas production growth rate has slowed down significantly with only 1.6% production growth for 2016.

Gas production in China is relatively concentrated geographically. For example, in 2014, production in the Ordos basin reached 42.6 BCM, and production in Sichuan basin and Tarim basin was more than 25 BCM each. The total production from these three basins accounted for 74.5% of all domestic production. In 2016, the largest ten gas fields contributed 51% of all domestic production, and all these fields are located in these three basins (Sichuan Basin, Ordos Basin and Tarim Basin). See Figure 4.

Figure 5 shows with respect to the source of domestic production, conventional gas, which includes tight gas by Chinese definition, still plays a dominant role, despite that the Chinese government has enacted policies to stimulate unconventional gas production.

Gas supply cost at reference cities

In China, a majority of domestically produced and pipeline imported gas is from the western region. Long-distance transportation is usually required to transport gas to the coastal markets. For foreign LNG exporters, the costs of gas at Chinese coastal markets would be an important factor in determining whether LNG is competitive or not. For reference, three eastern Chinese cities, Guangzhou, Shanghai and Beijing, are used to represent southern, central and northern markets to address this question. See Figure 6 for location of the reference cities and transportation pipelines. The cost of gas at a reference city is the sum of the production cost and transportation fee[3].

Cost of domestic conventional gas transported to reference cities

Chinese gas production cost information is difficulty to obtain, if not impossible. With respect to cost information for conventional gas production, we could not find official cost information except that the average cost of domestic onshore conventional gas (around $6/1000ft3 (1.4 RMB/m3 or $5.56/

MMBtu from a research institution[4], and 0.883 RMB/m3 ($3.5/MMBtu for production cost of CNPC[5]). It is worth noting that before 2013, the ex-factory benchmark price (or first station price) for different gas fields were set by the NDRC (National Development and Reform Commission (PRC)) with a cost-plus method, which included wellhead cost, purification fee and applicable taxes and margins (Sergey Paltsev, 2015). After 2013, a city gate price was set with the netback method, which is linked to fuel oil and LPG. For this article, the average ex-factory prices of industrial use, city gas and residential use[6] for 2010 were used as a benchmark; and the costs of conventional gas at reference city gates (Guangzhou, Shanghai and Beijing) are calculated by adding the transportation cost to the ex-factory price. See Table 1.

Figure 6: Selected Chinese natural gas infrastructure
Source: International Energy Agency

Cost of tight gas transported to reference cities

Located in the north of Ordos basin, the Sulige gas field is the largest gas field by production. In 2014, the production of that field accounted for over 65% of all tight gas production in China (Yang Zhen, 2016); therefore, the Sulige gas field is used as representative for tight gas production in China.

	Sichuan-Chongqing gas fields (RMB/m3)	Changqing gas fields[8] (RMB/m3)	Xinjiang gas fields (RMB/m^3)
05/2010 (average ex-factory price or first station price)	**1.402**	**1.25**	**1.065**

Table 1: NDRC natural gas prices for different gas fields[7]

A sweet block (M-block) has been studied for economic evaluation (Yang Zhen, 2016). Yang found that for a gas price of 1.26 RMB/m3 ($5.01/MMBtu) at the Changqing field, the after-tax IRR for existing wells would be only 1.6%, which is far below the cost of capital. For the future wells of the M-Block, the after-tax IRR will be -6.1%, with a net cash flow of -5.05 billion RMB. To get a reasonable after-tax IRR, the gas price at the Yulin city gate (near Sulige gas field) should be around 1.60 RMB/m3 ($6.36/MMBtu). Thus we use the economically feasible city gate price of 1.68 RMB/m3 ($6.68/MMBtu), which will generate an IRR of 8% for the sweet M block, to calculate the costs at the city gate of Guangzhou, Shanghai and Beijing.

Transportation costs from Sulige to Shanghai, Guangzhou and Beijing are 0.583 RMB/m3 ($2.32/MMBtu), 0.675 RMB/m3 ($2.68/MMBtu) and 0.285 RMB/m3 ($1.13/MMBtu), respectively. Therefore, the total costs for Sulige tight gas to reach these city gates are 2.263 RMB/m3 ($8.99/MMBtu), 2.355 RMB/m3 ($9.36/MMBtu) and 1.965 RMB/m3 ($7.81/MMBtu) accordingly.

Cost of shale gas transported to Shanghai

Even though China has one of the largest shale gas reserves in the world and the Chinese government has enacted favorable policies in the past years to promote shale gas production, there are still various obstacles for shale gas development. Currently, all the shale gas is produced in the Sichuan basin, where the terrain is rough and population density is high. In addition, the geological situation of Sichuan basin is more complex compared to that of the United States. For example, over half of the shale gas reserve is more than 3500m deep, and cannot be extracted economically today (Dong Dazhong, 2014). The average cost of a shale gas well in China[9] is 50 million RMB (7.5 million USD) to 100 million RMB (15 million

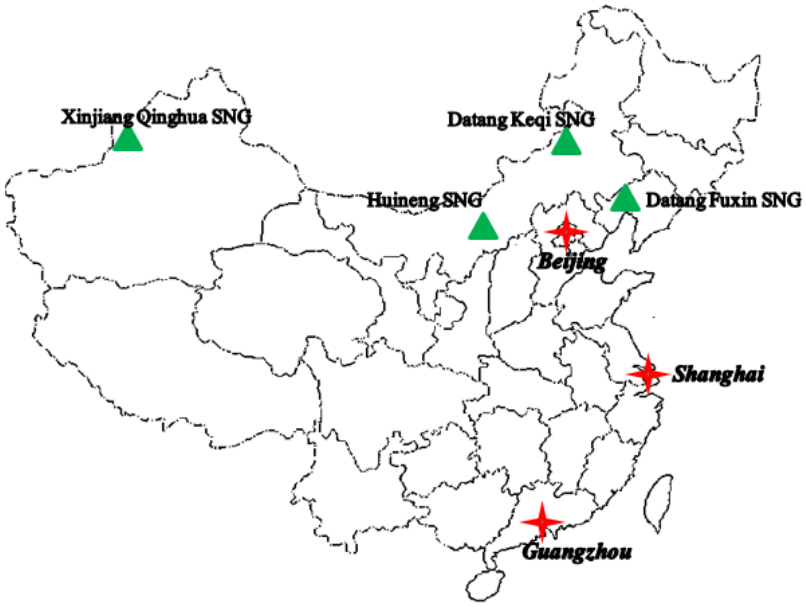

Figure 7: SNG projects in China

USD), which is much higher than that of the United States. Due to these disadvantages, the Chinese government subsidized the shale gas industry. The subsidy is 0.3 RMB/m3 ($1.19/MMBtu) from 2016 to 2018, and will be 0.2 RMB/m3 ($0.79/MMBtu) for 2019 and 2020[10].

Shale gas extraction was expensive in the past. For example, in 2014, the wellhead cost of shale gas in the Fuling gas field (Sichuan Basin) ranged from $11.2/MMBtu to $21.1/MMBtu[11]. According to Sinopec, shale gas development could not break even without 0.4 RMB/m3 ($1.59/MMBtu) subsidy in 2014[12]. It's hard to say whether the current cost is still as high as that, given the fact that for the Weiyuan block of CNPC, the drilling cost has been lowered from 130 million RMB ($19.7 million USD) to about 50 million RMB ($7.6 million USD) in 2017[13].

One thing worth noting is that, in 2011, when China launched the first tender for shale gas exploration, 6 companies competed for 4 blocks. In 2012, the second tender was launched and 16 bid-winning companies obtained rights to explore 19 blocks. However, it was 5 years later when the third tender was launched due to technological challenges, higher exploration costs and environmental issues[14]. The challenges faced in the shale gas development can also be corroborated with the fact that in 2015, ConocoPhillips retreated from China's shale gas development. One year later, in 2016, Shell also stopped its shale gas development in the Sichuan Basin.

Due to very limited information about the progress of shale gas development in China, the cost of $11.2/MMBtu was used to calculate the production cost of shale gas for the Shanghai city gate. The pipeline network owned by Sinopec was used as the basis to calculate the transportation fee. The cost of transportation to Shanghai is 0.6342 RMB/m3 ($2.52/MMBtu). Therefore, the cost of shale gas at the Shanghai city gate is estimated to be $13.72/MMBtu.

Cost of synthetic natural gas (SNG) transported to the reference cities

The Chinese government promoted the development of synthetic natural gas (SNG) as a source of gas supply. Currently, there are 3 SNG projects that are already in production, and they all located in either Xinjiang or Inner Mongolia (see Figure 7).

Due to the fact that gate prices of natural gas in these two provinces are the lowest in China, these three projects all face profit challenges. For the Datang Keqi SNG project located in Inner Mongolia, the initial settlement price with CNPC[15] was 2.75 RMB/m3 ($10.9/MMBtu), which could generate a profit of about 0.7 - 0.8 RMB/m3 ($2.8/MMBtu - $3.2/MMBtu) with the government's subsidy of 0.2 RMB/m3 ($0.8/MMBtu). The production cost of Datang Keqi SNG is estimated to be in a range of 2.15 RMB/m3 ($8.54/MMBtu) to 2.25RMB/m3 ($8.94/MMBtu), which can be corroborated by a report[16]stating the cost of Datang Keqi SNG being around 2.2RMB/m3 ($8.74/MMBtu). As for the Xinjiang Qinghua SNG project, the first-stage production capacity is 1.375 BCM/year, with a production cost of 1.6 RMB/m3 ($6.36/MMBtu). The other project, Inner Mongolia Huineng[17], whose first stage was completed in November 2011, has a production capacity of 0.4 BCM/year with a production cost of SNG of 3.4 RMB/m3 ($13.5/MMBtu). For this project, even when the second stage is completed, the cost would still be as high as 2.3 RMB/m3 ($9.14/MMBtu), which is substantially higher than the benchmark city gate price of Inner Mongolia (1.24RMB/m3 or $4.93/MMBtu). After having been put into production for more than 2 years, all three projects generated negative returns.

For this article, we use Datang Keqi and Xinjiang Qinghua SNG projects as the benchmark to calculate the costs of synthetic natural gas transported to Beijing, Shanghai

and Guangzhou city gates. For the Datang Keqi project, the initial settlement price 2.75 RMB/m3 ($10.93/MMBtu) is used to calculate the cost at the Beijing city gate. The project is located about 400 km north of Beijing. An exclusive pipeline was built for the project, which is linked to the pipeline network of CNPC to reach Beijing. The length of the pipeline is 320 km to Bakeshiyin station (northeast of Beijing), and the unit cost is 0.9787 RMB/(1000m3*km)[18]. For the Xinjiang Qinghua SNG project, the production cost of 1.6 RMB/m3 ($6.36/MMBtu) was used. The distance to the eastern coastal market is much further compared to that of Datang Keqi.

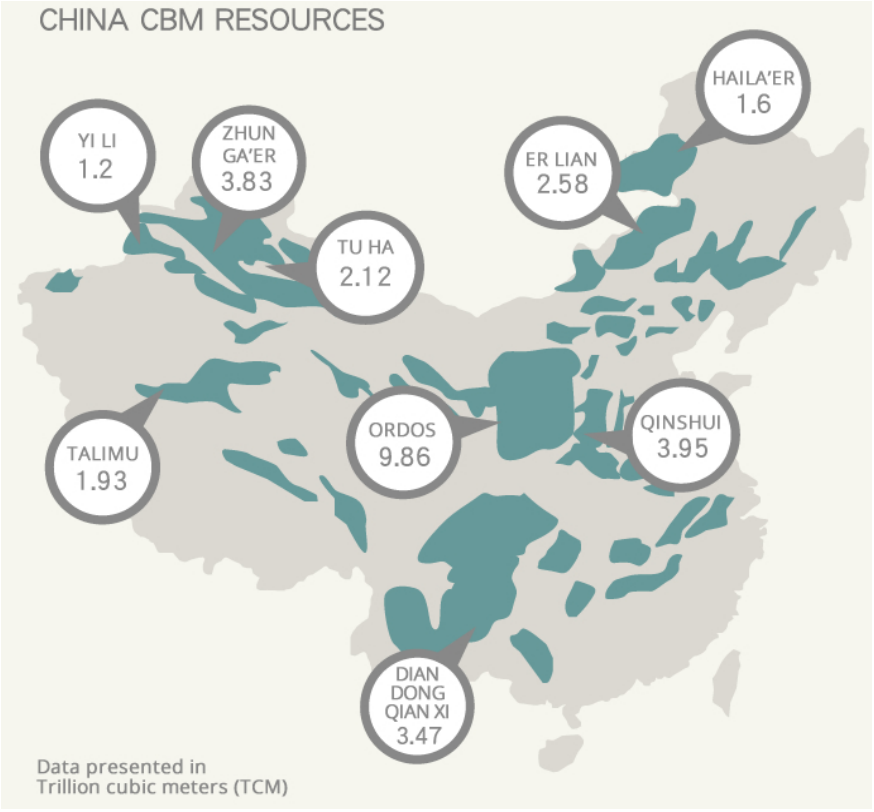

Figure 8: China coalbed gas resources
Source: Sino Oil and Gas

Cost of coalbed gas transported to Shanghai

China has a coalbed gas (also known as coalbed methane or CBM) reserve of 36,800 BCM with a depth less than 2000 meters deep. Currently, two industry bases were established in the Qinshui basin (Shanxi Province) and Ordos basin. In 2014, the total amount of coalbed gas produced in these two basins accounted for 94.6% of all coalbed gas production in China (Mu Fuyuan, 2015).

In the past, the Chinese government has set an ambitious target for coalbed gas. For example, the 12th 5-year plan for natural gas development has set the coalbed gas production for 2015 to be 16 BCM. However, actual production for 2015 was only 4.4 BCM. The 13th 5-year plan has lowered the coal bed gas production target to 10 BCM.

The coalbed gas industry faces many challenges such as low reserve grade and lack of proper technique. Beside technological difficulties, these coalbed gas producers also lack pipeline connection to existing trunk lines. The specialized transportation line can be expensive. For instance, the unit cost of the transportation line from Qinshui coalbed gas to Boai of Henan province is 3.5047 RMB/(1000m3*km), which is more than thirteen times higher than that of the east section of the West-East transportation line[19].

For a cost estimate, Qinshui coalbed gas project is used as reference to calculate the cost of coalbed gas transported to Shanghai. The main transportation line is from Qinshui gas station to Shanghai via West-East Pipeline A for a distance of 1081.14 km. As the unit cost is 0.2429 RMB/(1000m3*km), the total transportation cost amounts to 0.2626 RMB/m3 ($1.04/MMBtu).

Figure 9: West-East Gas pipeline of China
Source: World Iron & Steel

Year	Average Brent oil price($/bbl)	Average import price (RMB/m³)
2011	111.26	2.08
2012	111.63	2.46
2013	108.56	2.17
2014	98.97	2.17
2015	52.32	1.64
2016	43.64	1.17

Table 2: Annual Brent oil price and imported gas price in Xinjiang
Source: EIA, Urumqi Customs District

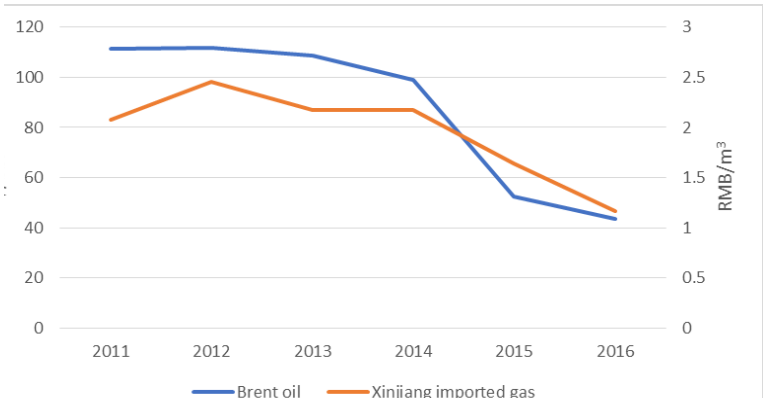

Figure 10: Prices of Brent oil and Xinjiang imported gas

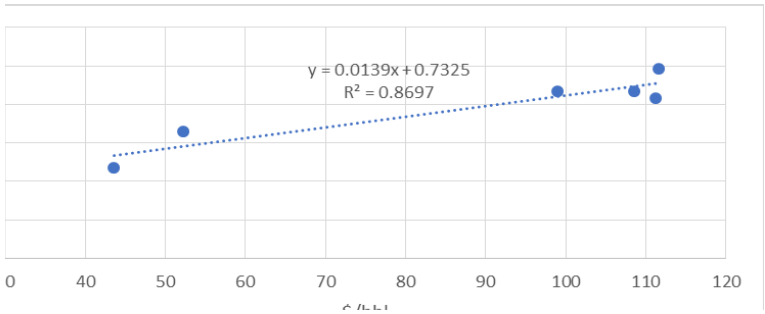

Figure 11: A regression analysis of Brent oil price and Xinjiang imported gas price

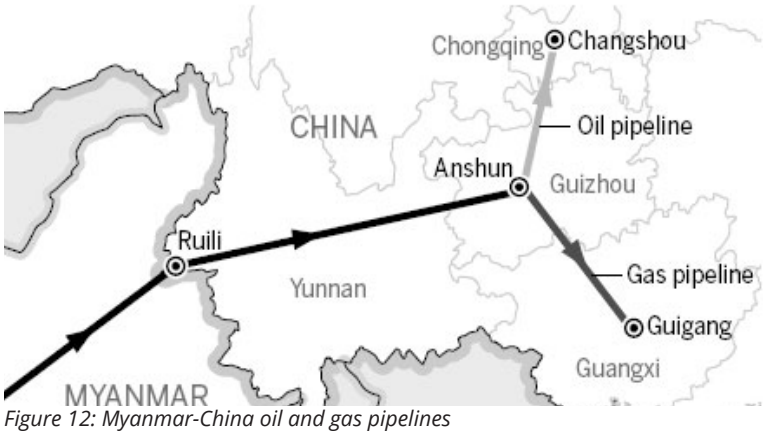

Figure 12: Myanmar-China oil and gas pipelines
Source: China Daily

Currently, the Chinese government subsidizes the coalbed gas production at 0.3 RMB/m3 ($1.19/MMBtu). According to Opsteel,[20] the cost of coalbed production is around 2 RMB/m3 ($7.95/MMBtu). Lingfeng (Lingfeng, 2017), in a study of premium reserves, showed that for an ex-factory price of 1.25 RMB/m3 ($4.97/MMBtu), the after-tax IRR will be 2.9%, which is far below the benchmark IRR of 8%. With an ex-factory price of 1.25 RMB/m3 ($4.97/MMBtu), the project needs a 0.77 RMB/m3 ($3.06/MMBtu) subsidy to achieve 8% IRR. Thus the cost of Qinshui coalbed gas is estimated to be 2 RMB/m3 ($7.95/MMBtu), and the total cost of Qinshui coalbed gas at Shanghai city gate is estimated as 2.2626 RMB/m3 ($8.99/MMBtu).

Cost of Central Asia and Myanmar imported gas transported to reference cities

CNPC is the only pipeline gas importer in China. However, due to the high cost of imported gas and low city gate price, CNPC has been losing money for years. For gas imported from Central Asia, a long-distance transportation is required to reach the Chinese border city Horgos. The pipeline then runs several thousand kilometers to arrive at the eastern coastal market. See Figure 9. The total pipeline length is 4901 km from Horgos to Gangzhou.

It is not clear how the imported gas price is determined at Horgos customs. However, it is suggested that the gas price is linked to the oil price (Chen, 2014). The imported gas price and annual Brent oil price from 2012 to 2016 are shown in Table 2 and plotted in Figure 10. It appears that there is a tight connection between these two prices and the regression line in Figure 11 confirms such a relationship.

China started to import natural gas from Myanmar in 2013. The import amount in 2016 reached 2.86 million tons (approximately 3.89 BCM), accounting for 10% of all the pipeline imports of natural gas. The gas supply is mainly from Myanmar's offshore gas field Shwe, which has a daily production of about 500 MMcf, and around 80% of the production is transported to China[21].

Figure 12 shows the Myanmar-China oil and gas pipeline. The transportation distance between Ruili of Yunnan province and Guigang of Guangxi province is 1727 km. The unit transportation cost is 0.4109 RMB/(1000m3*km). For simplicity, Guangzhou is used as the reference city to calculate the cost of Myanmar imported gas transported

to the southeastern coastal market of China[22].

Figure 13 plots the Brent oil price along with the Myanmar imported gas price. Again, it is not clear what kind of pricing mechanism was applied for natural gas imported from Myanmar, except that He (He Chunlei, 2014) stated that the price of natural gas import from Myanmar was linked to the oil price. Figure 14 provides some preliminary evidence supporting He (2014) based on regression analysis of Myanmar imported gas price on Brent oil price.

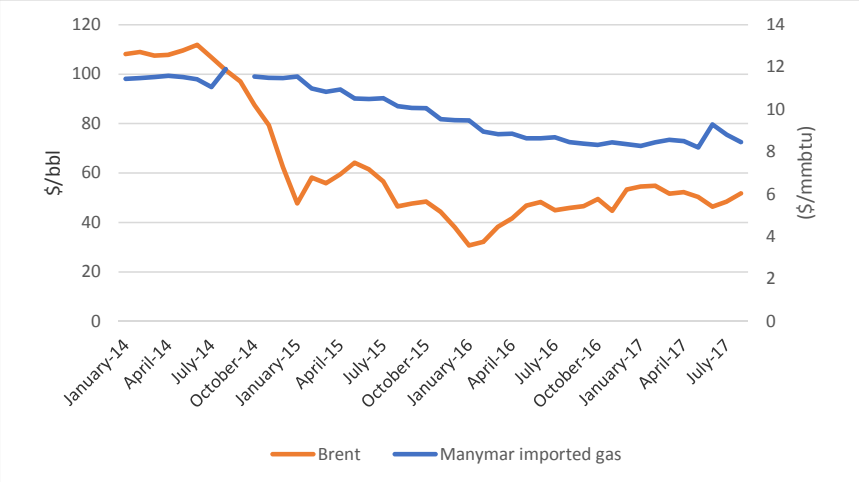

Figure 13 Brent oil price and Myanmar imported gas price
Source: China Customs and China-nengyuan.com

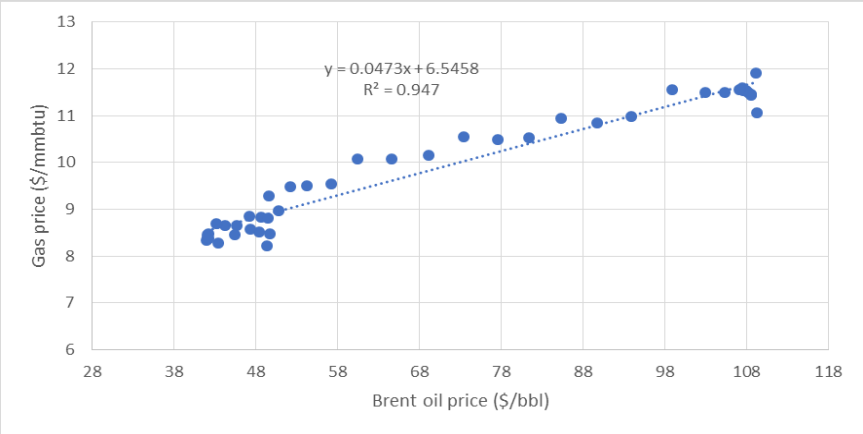

Figure 14. Relation between average twelve-month Brent oil price and Myanmar imported gas price

Summary of gas prices for reference cities

After adding the transportation cost, which is calculated by multiplying the unit transportation fee by the transportation distance, the costs of gas from different sources at the reference cities are shown in Table 3:

Conventional gas from the Ordos basin and Tarim Basin is cheaper compared to gas from other sources; and it can be transported to coastal markets with costs lower than $8/MMBtu. However, it is cautioned that our study uses the 2010 ex-factory price of gas for conventional gas. It is likely that cost of production has increased. For example, from 2011 to 2015, the production cost of CNPC[23] had risen from 0.631 RMB/m3 ($2.51/MMBtu) to 0.883 RMB/m3 ($3.51/MMBtu). In addition, the remaining conventional resource has a low grade and therefore the cost of exploration will probably increase[24]. All of these suggest that the costs at reference cities may be higher than our estimated costs.

	Conventional					SNG			Pipeline import	
	Sichuan Basin	Ordos Basin	Tarim Basin	Tight gas	Shale gas	Datang Keqi	Xinjiang Qinghua	Coalbed gas	Central Asia	Myanmar
Beijing		6.12	6.58	7.81		12.71	8.91		8.74	
Shanghai	8.09	7.28	6.88	8.99	13.72		10.15	8.99	9.98	
Guangzhou		7.67	7.68	9.36			9.97		9.8	13.07

Table 3: Costs of gas transported to reference cities ($/MMBtu)

In calculating tight gas and coalbed gas cost, we have applied the economic analyses of sweet blocks; thus, our estimates should be lower than the actual costs of tight gas and coalbed gas at reference city gates.

The costs of pipeline imported gas are based on Brent oil price of $60/bbl. For natural gas imported from Central Asia, the costs are estimated to be around $10/MMBtu at the Shanghai and Guangzhou city gates. The gas imported from Myanmar is more expensive than that imported from Central Asia. If the oil price is higher than $60/Bbl, then the costs will be higher than our estimated costs in the coastal markets.

The delivery cost of U.S. LNG to China

The U.S. export of LNG to China increased substantially in the last couple of years and the upward trend is expected to continue

given the increased demand from China and still relatively low gas price in the U.S. For LNG exporters targeting the Chinese market, the delivery cost of LNG compared to the gas costs at reference city gates would be important in determining whether LNG is competitive or not. As there are always risks associated with the LNG value chain, from exploration to shipping and marketing, it is difficult to ascertain the delivery cost of LNG. One report mentioned that U.S. LNG can be shipped to Tokyo for a fixed price of $8/MMBtu[25]. Since the distance between Tokyo and the coastal region of China is relatively short compared to the shipping distance between the United States and East Asia, it is reasonable to infer that the $8 delivery cost can also be applied to the coastal market of China.

The economic viability of U.S. LNG exports to Asia and Europe was examined by Ripple (Ripple, 2016), who found that under the terms of the BG contract and low day rate shipping costs, U.S. LNG can be delivered to Tokyo at a cost of $5.6/MMBtu. Assume the regasification cost to be $0.35/MMBtu, then the gas cost out of the regasification facilities would be $5.95/MMBtu. Ignoring the transportation between LNG processing plant and city gate, it is reasonable to assume the cost at the reference city gates to be around $6.00/MMBtu, which is lower than the cost of Chinese domestically produced gas and pipeline imported gas.

In general, the U.S. LNG can be cost competitive in China's coastal market, especially compared to domestically-produced unconventional gas and imported gas from both Central Asia and Myanmar.

Footnotes

[1] National Development and Reform Commission (PRC). 2017. Clean Heating Planning for the Northern Region of China (2017-2021).

[2] Source: 2017 China Natural Gas Development Report, Sinopec and authors' estimation based on CNPC Environmental Protection Report.

[3] In June 2017, Chinese NOCs released their cost information about trunk line transportation, which can be found on the website of CNPC, Sinopec and CNOOC.

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