An economic analysis of China’s domestic crude oil supply policies

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ABSTRACT

China’s domestic oil production has lagged the growth in domestic oil consumption since the beginning of the 21st century, leading to a growing reliance on imports. In response, the Chinese government has introduced a number of policies, including import license constraints, to support domestic suppliers. In an effort to measure the economic impact of these policies we develop a short-run equilibrium model of China’s wholesale oil and gas market at the provincial scale. We construct counterfactual scenarios that suggest that relaxing policies that prioritize domestic production in 2016, when the average price of Chinese oil imports was US$42 per barrel (bbl), could have increased China’s import demand by 0.29 million barrels per day (MMbbl/d). This results in a substitution of 9% of China’s domestic production in 2016, and a reduction of US $2.8 billion in crude supply costs including transportation as the imported oil has more direct access to the country’s pipeline network, compared to the displaced domestic production. In addition, rising import prices since mid-2017 may provide a window of opportunity for Chinese policymakers to proceed with further deregulation of the domestic oil sector, as the short-term impact on domestic producers is reduced.

1. Introduction

China’s demand for crude oil has more than doubled since 2000, driven by rapid economic growth, industrialization and increasing exports of refined petroleum products, mainly to other Asian markets. The growth in demand for crude significantly outpaced domestic supply, which rose 23% over the same period (CEIC Data 2018). As shown in Figure 1, the gap in the crude oil balance has been filled by the increasing reliance on imports that approached 70% of the country’s demand in 2016 (ITC Trade Map (ITC) 2018). In conjunction with the displacement of a large percentage of imports by the United States (U.S.), prompted by the boom in U.S. shale output, China overtook the U.S. as the world’s biggest crude oil importer in 2017 (U.S. Energy Information Administration (EIA) 2018a).

The Chinese government has been pursuing several strategies to secure its oil supply base, including diversifying the sources of international supplies; securing controlling stakes in foreign exploration and production assets, investing in pipeline and storage (midstream) infrastructure projects; and increasing its strategic petroleum reserve at times of lower oil prices, particularly between 2015 and 2017.

Policies targeting higher output in the domestic oil industry, such as intensifying oil exploration in China, developing the country’s vast unconventional hydrocarbon reserves and building a more extensive national pipeline network have not, however, resulted in any significant oil output growth to date. Aging conventional production assets, rising marginal production costs and the complex geology of China’s unconventional oil and gas resources have restricted domestic producer’s response to the oil supply challenge.

The problems facing China’s growing energy supply challenges go beyond physical and geological constraints. Market structure issues and regulatory barriers, have also come into play. The dominance of three state-owned national oil companies (NOCs) companies and the slow pace of reforms further complicate growth and development of China’s upstream sector. In response to the rapid growth in imports, a number of direct and indirect protectionist policies have been introduced in order to support the competitiveness of domestic producers. These include import licensing restrictions, limited third-party access to pipeline and port infrastructure and other market access barriers. Specific barriers and their impacts can be difficult to distinguish due to variance in interpretation and actual enforcement of relevant policies. However, the cumulative impact of these policies cannot be disregarded, particularly with respect to the distortion the domestic oil market, especially when oil prices are perceived as low.
The challenges for China’s upstream oil sector, as domestic energy needs continue to grow, give rise to protectionist policies. The aim of this study is to quantify the cumulative effect of government policies that prioritize domestic supplies from China’s NOCs. This includes the impact on total supply costs and China’s demand for crude oil from the international market. Can the preservation of domestic oil resources, based on the relative cost of domestic production versus imports, contribute to China’s long-term energy supply security? What are the potential consequences for domestic oil industry players if local consumers are given unrestricted access to global oil markets? Understanding the potential magnitude of such policy consequences could help the Chinese authorities design policy and also help market participants develop their corporate strategies.

We develop a short-run equilibrium model of the wholesale oil and gas market at the provincial scale. To our knowledge this is the first analysis that attempts to measure the economic impact of the government’s crude supply policies, in aggregate, using an equilibrium model. The remainder of this paper is structured as follows. Section 2 provides an overview of China’s oil market structure, the recent development of trade institutions, and policies. Section 3 describes the structure of the oil supply model. Section 4 describes the scenario design and presents the corresponding analysis. Section 5 provides the concluding remarks.

1.1. China’s crude oil market

The purpose of this section is to provide a context behind the introduction of protectionist policies as a response to the stress on China’s domestic oil supplies. Both resource development and regulatory issues are explored as contributing factors. We also discuss China’s efforts to further reform its domestic market and advance its role in global oil trade. This sets the stage for the main question asked in this study: what is the cost of these protectionist policies for China’s economy and its impact on market participants?

Addressing the shifts in China’s oil supply balance and its energy security concerns has been a priority among both policymakers and analysts. The policy response has focused on securing oil imports from a diversified range of suppliers and acquiring control over foreign oil resources through investments in upstream assets and midstream infrastructure in other countries.

Despite China’s efforts to stimulate its production at home, there has been no significant output increase. Domestic production has actually been in decline since 2015 (U.S. Energy Information Administration (EIA) 2018a). Analysts cite aging conventional assets, the need to develop new technology to address challenging geological conditions, limited access to water, high market concentration levels and the insufficient pace of reform as some of the major problems facing the Chinese upstream sector.

According to the U.S. Energy Information Administration (EIA), China holds the 13th largest proven conventional oil reserves in the world, with 25.62 billion barrels (bbl) (U.S. Energy Information Administration (EIA) 2018b). China’s unconventional proven oil reserves, including heavy and extra-heavy oil, oil sands, tight oil and kerogen oil, are also among the largest in the world, adding another 13 billion bbl (Wang et al. 2015). Attempts to intensify exploration, develop the extensive unconventional hydrocarbon reserves and speed up the construction of inter-regional pipeline networks have not yet contributed enough to additional production. China’s conventional onshore and shallow water oil production mainly comes from just a few large mature fields,
notably Daqing, Shengli and Liaohe. Output at these fields in 2016 dropped by 9.5% compared to the previous year (Oil Price 2017).

China’s unconventional oil production is also unlikely to increase significantly in the near future because of geological, technological and economic constraints. Chinese shale oil resources tend to be heavier than those in the U.S., being waxier and containing a smaller share of condensates (Gordon et al. 2014). In addition, the shale oil reserves in China’s major basins, e.g., Tarim and Junggar, lie deep underground in hard geological formations, making their extraction process capital-, energy- and technology-intensive. Also, the remote location of these two basins – in the country’s western provinces, a long distance from major demand centers and existing infrastructure – further undermines the economics of their development.

China’s oil market and regulatory environment have also not been conducive to boosting domestic oil production. Market participants are either unable or unwilling to accumulate sufficient capital to increase investments in exploration and production. China’s upstream sector is highly concentrated and dominated by the country’s three big NOCs; China National Petroleum Corporation (CNPC), China Petroleum & Chemical Corporation (Sinopec), and China National Offshore Oil Corporation (CNOOC) responsible for offshore development. CNPC accounts for about 54% of domestic oil production, most of the remaining domestic onshore fields (19 percent) are operated by Sinopec, CNOOC’s production accounts for 20%, while private companies account for the remaining 7%. These statistics have been compiled using data from a subscription to the IHS Markit Vantage database in 2018. Foreign oil companies’ participation is restricted to production sharing contracts with designated NOCs, providing only limited access to the development of conventional hydrocarbon resources.

China’s midstream is also dominated by the three NOCs. CNPC owns or operates more than 70% of the country’s oil pipelines, and Sinopec has access to more crude oil import terminals than other market participants (analysis compiled using a subscription to the IHS EDIN database). Although privately-owned companies can engage in crude oil storage, trading and importation, their market access is effectively restricted by the need to obtain business permits and import licenses from the Ministry of Commerce, as well as by the import quotas and other administrative barriers imposed on non-state-owned enterprises.

Despite their market dominance, the profits and cash flows of NOCs’, as well as private companies, are negatively affected by certain sectoral regulations that apply in China. These include state-controlled pricing mechanisms for refined petroleum products and some segments of the natural gas market. While China’s domestic crude oil prices have been in relative alignment with the global market since the late 1990s, the domestic pricing mechanisms for petroleum products are still not entirely market-based. The prices shift based on a 10-working day moving average and are subject to ad hoc interventions from the government. The management of retail prices for gasoline and diesel is still in the hands of the regulators.

These regulatory and structural hurdles will likely factor into preventing China from reaching its ambitious oil and energy policy targets. Under Beijing’s 13th Five Year Plan, China is scheduled to produce 200 MMmt of crude oil by 2020 – requiring a reversal of the current output downward trend. The plan also foresees China adding 5 billion mt of proven oil reserves as well as making significant progress in the exploration and development of unconventional oil resources (National Development and Reform Commission (NDRC) 2016). The country also has a target for energy self-sufficiency to exceed 80% by 2020 (National Energy Administration (NEA) 2016).

Given China’s supply challenges, especially in domestic resource development, protectionist policies can be viewed as an immediate tool to help reach specific targets. However, these measures are unlikely to be sustainable in the long term. Strong oil demand projections will further shift the country’s supply balance towards imports. The 13th Five Year Plan for Petroleum Development forecasted overall oil consumption of 590 MMmt by 2020 (National Development and Reform Commission (NDRC) 2016). However, several analysts and industry participants have predicted higher numbers: for example, CNPC expected domestic crude oil demand to hit 600 MMmt in 2018 (S&P Global Platts 2018a) and a ceiling of 690 MMmt by 2030 (Reuters 2017). Other factors that will likely contribute to continued oil demand growth include the projected intensified building of China’s strategic petroleum reserve, which is targeted to reach 500 MMbbl, or the equivalent of 90 days of net imports, by 2020, and the development of more commercial oil storage facilities (S&P Global Platts 2018b).

A growing reliance on crude imports and continued integration into foreign trade, investment, finance and international energy governance will require better alignment of China’s domestic regulations with its strategic targets, as well as with domestic and global market drivers. The emergence of Singapore-based Chinese trading houses and their dominance on the Dubai Mercantile Exchange (DME), and more recently the launch of crude oil futures contracts on the Shanghai International Energy Exchange (INE) in
March 2018, demonstrate efforts by China to strengthen its role in the global oil market. The INE contracts are based on medium sour crude oil similar to Dubai and Oman crude markers. The shortest term INE contract emerged as the third most traded oil futures contract globally in 2018 with a 16% market share, overtaking the volume for similar contracts traded on the DME (Nikkei 2018). However, the INE contract still tracks the better-known and more liquid Brent and West Texas Intermediate (WTI) benchmarks and is unlikely to become a regional benchmark for refineries in the near future. So far the INE crude futures contract is being used primarily by local speculators, and has yet to attract major international players (Reuters 2018b). The success of the contract depends not only on the ability to attract a sufficiently large pool of traders and provide the necessary tools to manage price volatility, but also on a predictable and non-adverse policy environment (Till 2014).

Chinese policymakers remain keen to reform the country’s energy sector. Relevant strategic plans emphasize the need to rely more on market drivers, facilitate market access and competition and strengthen the supervision of the relevant state-owned monopolies or oligopolies. The reform plan for the oil and gas industry, officially called Several Opinions on Deepening Oil and Gas Sector Reform, announced in 2017, outlined measures aimed at deregulating and creating a competitive landscape in the sector (Xinhua 2017). The plan proposed that NOCs divest most of their non-core assets, reduce their social commitments and collaborate more with private companies across the oil supply chain, including previously-restricted domestic exploration and production sectors. The 2017 reform proposal also called for a transition to market-based pricing in both pipeline transportation and sales of refined products, with the government’s role reduced to interventions in cases of large price fluctuations (Xinhua 2017).

These reform initiatives, although necessary for the long-term development of the Chinese energy sector in general and for the oil industry in particular, might cause short-term disruptions, as consumers become exposed to the marginal costs and as all direct or indirect market access barriers are lifted. Such disruptions can have a big impact not only on the domestic oil market but also on global markets, given China’s growing role in the global economy and in energy trading.

The 2018–2019 trade dispute between China and the U.S. and the re-imposition of U.S. sanctions on Iran could further complicate China’s domestic reform efforts. Concerns that the Chinese government will introduce tariffs on imports of U.S. crude plus pressure from the U.S. administration to limit oil imports from Iran, led to a rapid decline in imports from Iran and the U.S. by Chinese buyers in the second half of 2018 (Bloomberg 2018; Reuters 2018a). The impact of elevated political tensions on oil markets may call for supplementing domestic sectoral reforms with import diversification and regional collaboration strategies. Qi and Yang (2018) have shown the benefits of the latter approach, using an optimization tool to investigate oil supply risks for East Asian importers.

2. A model of China’s oil and gas market

2.1. Model description

To explore the effects of China’s current import regulations, we construct a short-run costs minimization model that represents the annual supply of oil and gas to the Chinese market at the provincial scale. It is built as an extension of the natural gas equilibrium model subject to regional price controls developed by Rioux et al. (2018). The model is structured as a single year, short-run static optimization problem, subject to fixed provincial demand levels, considering only existing production and inter-provincial oil pipeline capacities, with no new investment factored-in. However, annualized capital development costs are included for incremental production from mature fields, required to offset the natural decline in the fields’ output.

With respect to modeling oil production, the model design is similar to the petroleum supply chain optimization problem developed by Jiao et al. (2010). Their model covers a range of activities across the supply chain, including refining and petrochemicals, which are not included in our model. However, Jiao does not account for capacity constraints, whereas our model captures existing pipeline network capacities. We use a transshipment model to represent explicit flows by pipeline, rail and truck from origin to destination, including connections between neighboring provinces.

Our pipeline transshipment model is similar to that developed by Zuying et al. (2014). Their model applies a higher spatial resolution to identify optimal supply pathways only within China’s Eastern pipeline network, whereas our model covers all of the provinces in mainland China. The authors use the tool to investigate inefficiencies in China’s existing crude flows. In our study, the transportation model accounts for how transportation costs and constraints can reduce the competitiveness of domestic production. For example, remote producers with limited access to cheaper pipeline transport (versus long-haul rail or truck) may be
less competitive than imports with access to more developed coastal pipeline networks.

Furthermore, our model tracks the ownership of upstream and midstream assets by China’s three big oil-producing NOCs, originally used to capture third-party access restrictions on Chinese pipelines. Crude imports by pipeline and by seaborne tanker are permitted. We also set a maximum level on imports by seaborne vessels to capture import licensing and other market access constraints. A complete description of the oil supply model is provided in Appendix 1.

For a more detailed analysis of the factors that underline China’s oil import trade, see the empirical analysis by Shao et al. (2017). With respect to other efforts to model policies targeting Chinese oil imports, including a thorough review of related studies, see Chen et al. (2017). The authors use a game theoretic approach to analyze import and export quota mechanisms, considering relationships between various agents, including NOCs, independent refineries, and other consumers. While the authors look at the impact of different import quota policies, our study looks more generally at the aggregate impact of all policies on the competitiveness of Chinese suppliers, including those that do no target imports directly.

### 2.2. Model calibration

We calibrate our model of China’s domestic oil and gas supply to market conditions observed in 2016. This calendar year was chosen as the most recent 12-month period for which all necessary statistical data was available. In addition, 2016 saw the lowest average international crude oil prices since 2004, providing a good reference year for the potential impact of national policies aimed at prioritizing domestic production.

We use metric tonnes (mt) in the calibration and analysis of China’s domestic oil production, as it is the standard unit of measurement used in the Chinese government’s oil statistics. Conversion to barrels is done if the corresponding gravity of the oil is available in the calibration data and tracked by the model. Note that we track crude shipments as metric tonnes, but not density. This is an area where the model could be improved, such as including a regional refining model with constraints on the gravity of crude used as feedstock, or other characteristics (e.g. sulfur content).

We calibrate the model to the oil and gas production and demand levels reported in 2016 in China’s official provincial balance sheets (CEIC Data 2018). See Table 1 for a breakdown of provincial supply and demand. The model includes detailed provincial production cost profiles and inter-provincial transportation costs by pipeline and land based tankers (truck and rail).

Production levels, marginal cost curves, gas-to-oil ratios and capital development costs have been calibrated using data compiled from the IHS Markit Vantage upstream database, covering more than 1,200 Chinese oil and gas assets. We represent domestic production by ownership, China’s three big upstream midstream NOCs (CNPC, CNOOC and Sinopec) and aggregated independent producers, and by geographic location, i.e., 32 regions including the 30 provinces listed in Table 1, and two offshore production areas, Bozhong basin in Beihai Bay and Xihu sag off the coast of Zhejiang. We include imports by pipeline from Central Asia, Russia and Myanmar, and seaborne tanker imports at every coastal province in eastern and southern China. Oil production and imports are reported in MMmt and gas production in billion cubic meters (bcm). Production costs are reported in U.S. dollars per metric tonne (US$/mt) for oil and dollars per thousand cubic meters (US$/Mcm) for gas.

As a short-run optimization, the model does not include investments in new fields or new pipeline capacity but allows for capital development costs associated with incremental output from mature fields. Incremental production is set as a percentage of the total output of the mature field, typically between 10% and 20%. This percentage is calculated using data from the natural decline of fields when they receive no new capital expenditure. This provides an estimate of incremental output that can be achieved through additional development. All capital costs are discounted for the remaining years of production of the field, applying a depreciation rate of 10 percent for the purchase of plant, machinery and equipment in China (Ernst & Young (EY) 2016).

Domestic transportation modes include oil and natural gas pipelines, as well as tanker shipments by rail and truck for crude and liquefied natural gas (LNG). Land-based tanker shipments are associated with higher transportation costs when pipelines are unavailable or fully utilized. Oil and gas pipeline, liquefaction and regasification capacities were compiled using a subscription to the IHS Markit EDIN midstream database. We assume unconstrained land-based tanker shipments between adjacent provinces and estimate average transportation costs and other parameters, listed in Table A2 (Appendix 2).

Finally, we calibrate international prices for oil and gas imports by pipeline and via seaborne tanker. Average tanker import prices are set to US$306/mt for oil (about US$42/bbl), based on a weighted average of non-pipeline Chinese import prices in 2016 (ITC Trade Map (ITC) 2018; World Bank 2018). The same sources were used to calculate an average pipeline
Table 1. China hydrocarbons: supply and demand, by province, in 2016.

| Region          | Oil (MMmt) | Gas (bcm) | Oil (MMmt) | Gas (bcm) | Oil (MMmt) | Gas (bcm) |
|-----------------|------------|-----------|------------|-----------|------------|-----------|
| Anhui           | 0.02       | 0.00      | 5.39       | 4.31      | -5.37      | -4.31     |
| Beijing         | 0.00       | 0.00      | 8.21       | 17.72     | -8.21      | -17.72    |
| Chongqing       | 0.01       | 3.19      | 0.00       | 9.87      | 0.01       | -6.68     |
| Fujian          | 0.00       | 0.00      | 20.89      | 5.36      | -20.89     | -5.36     |
| Gansu           | 0.89       | 0.03      | 13.67      | 2.89      | -12.78     | -2.86     |
| Guangdong       | 13.04      | 3.32      | 50.44      | 14.07     | -37.40     | -10.75    |
| Guangxi         | 0.04       | 0.00      | 13.4       | 1.39      | -13.36     | -1.39     |
| Guizhou         | 0.00       | 0.52      | 0.00       | 1.87      | 0.00       | -1.35     |
| Hainan          | 2.65       | 3.52      | 11.19      | 4.54      | -8.54      | -1.02     |
| Hebei           | 15.26      | 1.07      | 17.62      | 7.56      | -2.36      | -6.49     |
| Heilongjiang    | 35.63      | 2.92      | 22.1       | 4.2       | 13.73      | -1.28     |
| Henan           | 2.78       | 0.46      | 7.07       | 10.14     | -4.29      | -9.68     |
| Hubei           | 1.03       | 0.12      | 12.4       | 4.54      | -11.37     | -4.42     |
| Hunan           | 0.00       | 0.00      | 8.42       | 3.03      | -8.42      | -3.03     |
| Inner Mongolia  | 2.32       | 21.19     | 4.20       | 3.67      | -1.88      | 17.52     |
| Jiangsu         | 1.44       | 0.24      | 40.92      | 18.77     | -39.48     | -18.53    |
| Jiangxi         | 0.00       | 0.00      | 7.26       | 2.06      | -7.26      | -2.06     |
| Jinlin          | 4.05       | 2.14      | 10.51      | 2.34      | -6.46      | -0.20     |
| Liaoning        | 9.57       | 2.01      | 70.57      | 5.44      | -61.00     | -3.43     |
| Ningxia         | 0.07       | 0.00      | 5.76       | 2.34      | -5.69      | -2.34     |
| Qinghai         | 1.96       | 6.57      | 1.49       | 5.1       | 0.47       | 1.47      |
| Shaanxi         | 24.04      | 9.63      | 18.24      | 9.06      | 5.80       | 0.57      |
| Shandong        | 41.68      | 1.21      | 102.03     | 10.66     | -60.35     | -9.45     |
| Shanghai        | 0.00       | 0.00      | 24.74      | 8.7       | -24.74     | -8.70     |
| Shanxi          | 8.53       | 11.44     | 9.15       | 7.65      | -0.62      | 3.79      |
| Sichuan         | 0.15       | 23.57     | 9.03       | 18.99     | -8.88      | 4.58      |
| Tianjin         | 3.54       | 0.27      | 14.34      | 0.00      | -10.80     | 0.27      |
| Xinjiang        | 26.99      | 33.28     | 24.53      | 14.56     | 2.46       | 18.72     |
| Yunnan          | 0.00       | 0.00      | 0.00       | 0.85      | 0.00       | -0.85     |
| Zhejiang        | 0.11       | 0.45      | 26.67      | 9.31      | -26.56     | -8.86     |
| **Total**       | **196.00** | **127.16**| **560.24** | **210.99**| **-364.24**| **-83.83**|

Source: CEIC Data (2018). Data does not include Tibet, Hong Kong, Macau and Taiwan.

Import price of US$288/mt from Central Asia. To address the impact of international crude prices on the economics of China’s domestic oil production we run several counterfactual scenarios with a range of import prices, described in detail in the following section.

3. Scenario design and analysis

To assess the impact of national policies on China’s domestic crude production we first build two scenarios, a baseline scenario to replicate the market conditions in 2016, and a counterfactual open market scenario, also for 2016. Both scenarios are short-run, minimizing total supply costs using existing upstream and midstream infrastructure. First, we run the baseline with pipeline contracts from Russia and Central Asia fixed to 2016 levels, and seaborne tanker imports from the rest of the world, capped at levels reported by ITC (see Table A2). In the open market scenario, we allow for additional waterborne tanker imports from the international market as a substitute for uneconomic domestic supplies. We only relax tanker imports and keep pipeline contracts fixed to 2016 levels, under the assumption that pipeline imports are less flexible in the short term.

To assess the sensitivity of our simulation to import prices we run additional counterfactual scenarios changing the average crude import price used in the open market scenario: US$30/bbl, US$40/bbl, US$50/bbl, US$60/bbl, US$70/bbl, US$80/bbl and US$100/bbl (or US $221/mt, US$367/mt, US$441/mt, US$515/mt, US$588/mt, and US$736/mt). In all of these scenarios the natural gas market is calibrated to 2016 market conditions, including price caps on pipeline deliveries to city gate consumers as presented in Rioux et al. (2018).

3.1. The open market scenario

The results from the baseline and open market scenarios are listed in Table 2, including total oil production in million metric tonnes (MMmt), spare capacity (based on domestic oil fields reported to be operational in 2016), import quantities, and costs broken down by production, imports and transportation.

We find that liberalization of crude oil imports, i.e., removing licensing and other indirect constraints limiting buyers’ access to imported crude, would have significant implications for the domestic Chinese market. Under the conditions observed in 2016, domestic crude oil output would decline by 17.8 MMmt, or 8.9%,
these constraints were removed. The average gravity of the displaced production is 6 barrels/mt, or about 0.29 million barrels per day of equivalent imports.

Under the open market scenario domestic production costs decline by US$7.9 billion, equivalent to 27.1% of China’s overall oil production costs in 2016. These savings are partially offset by increased import costs, providing a total reduction of US$2.8 billion, or 1.7%, of total supply costs.

To illustrate how 8.9% of domestic production can account for 27.1% of production costs we plot China’s domestic supply curve for the baseline and open market scenarios in Figure 2. The last 0.4 MMbbl/day shows a steep incline in China’s oil production costs in the baseline scenario. The curve includes operating and capital development costs without transportation costs. Units have been converted to million barrels per day (MMbbl/d) using the specific gravity of crude reported for each asset reported in the IHS Vantage database.

In Figure 3, we show the location of China’s domestic production cuts under the open market scenario by asset ownership and location. It shows how the potential impact of import liberalization varies significantly by region and company. The output declines are found across the country but are primarily concentrated in Northeast China (Heilongjiang and Liaoning provinces) and in the west China (Shaanxi and Xinjiang), where crude oil is the most expensive to produce and/or difficult to deliver to consumers. CNPC, China’s biggest NOC, has the largest share of decline in production, at about 75% of the total. If these declines occurred as a result of government reforms, China’s NOCs would be concerned about the potential impact on their supply chains and provincial authorities would have to address the effects of a decline in oil production on regional gross domestic product, tax revenues and employment. Given these factors, the disproportionately large impact of potential reforms at both company and provincial levels might impede the liberalization of the domestic oil market.

The results indicate that certain segments of Chinese domestic oil production are potentially vulnerable to competition from seaborne imports. They can also come under pressure from pipeline imports, which are fixed in our scenarios to existing pipeline contracts. The imported quantities via pipelines from Russia, Kazakhstan and Myanmar in 2016, at 38.9 MMmt, were significantly lower than the nominal capacity of these import routes at 30 MMmt (doubled since the second branch from Russia to China opened at the beginning of 2018), 20 MMmt and 22 MMmt respectively (the Myanmar line was completed in 2014 but first crude did not flow until May 2017). Moreover, the pipeline import delivery nodes from Russia and Kazakhstan are located in the regions of China with the least economically competitive domestic production assets – the northeast and far west China.

Another factor that somewhat alleviates the impact of a liberalized imports regime, under our baseline scenario, is an improved oil transportation pattern. On the inter-provincial scale, the growth in seaborne tanker imports corresponds to a significant increase in pipeline shipments of more than 100 percent, at 25.5 billion mt-kilometers (mt-km) (i.e. the product of quantity and distance transported), with an associated decline in less efficient internal land-based tanker shipments of 34% (27.9 billion mt-km).

### Table 2. Key quantity and cost indicators under the modeling scenarios.

|                     | Reference | Open market | Difference |
|---------------------|-----------|-------------|------------|
| Production, MMmt    | 199.5     | 181.7       | −8.9%      |
| Spare capacity, MMmt| 0.1       | 17.9        | -          |
| Pipeline imports, MMmt| 19.6       | 19.6        | 0.0%       |
| Tanker imports (sea), MMmt| 361.1 | 379.0       | 5.0%       |
| Pipeline shipment, billion mt-km | 19.9 | 45.4       | 128.5%     |
| Tanker shipment (land), billion mt-km | 82.0 | 54.1 | −34.0% |
| Production costs, (US$ billion) | 29.1 | 21.2 | −27.1% |
| Import costs, (US$ billion) | 116.3 | 121.7 | 4.7% |
| Transport costs, (US$ billion) | 0.5 | 0.4 | −16.4% |
| Total oil supply costs, (US$ billion) | 145.9 | 143.4 | −1.7% |
| Total gas supply costs, (US$ billion) | 24.2 | 23.8 | −1.4% |
| **Total costs, (US$ billion)** | **170.0** | **167.2** | **−1.7%** |

Source: KAPSARC research

![Figure 2](https://example.com/figure2.png)

**Figure 2.** Supply curves for domestic production, before transportation, in each scenario.

Source: KAPSARC
This suggests that a majority of the production decline occurs in regions with limited access to pipeline infrastructure, where road and rail tanker shipments are needed to deliver oil to consumers. With an increase in seaborne tanker imports under the open market scenario, more oil is directed into existing pipeline networks through well connected coastal regions. However, if the existing oil pipeline infrastructure cannot be fully and efficiently utilized due to restrictive pricing mechanisms or inefficient third-party access, domestic oil production would be further disadvantaged.

3.2. Sensitivity analysis

Next, we assess the sensitivity of our major indicators of the Chinese oil industry to the crude import price assumption. Table 3 shows the production, spare capacity, seaborne tanker imports, oil supply costs and total supply costs (including natural gas) in the open market scenario under different price assumptions for oil imported through China’s coastal provinces.

The amount of spare capacity is sensitive to the import price at or near the initial assumption of around US$42/bbl (US$306/mt). The spare capacity increases to 25.6 MMmt, or about 0.42 MMbbl/d, when reducing the price to US$30/bbl, while raising the price to US$50/bbl decreases the spare capacity by about half – to 9 MMmt or about 0.15 MMbbl/d. Further increases in the import price have a smaller impact on domestic production, indicating that even near peak 2018 prices, of around US$80/bbl, about 6.6 MMmt (0.11 MMbbl/d) of China’s 2016 oil output would be uneconomic, at an additional cost of US$1.1 billion versus sourcing cheaper imports.

By late 2018, crude prices had fallen back to roughly 2016 levels after sustained increases that started in the second half of 2017. This can complicate the assessment of how reform initiatives would affect China’s domestic oil producers in the short run. However, even at the oil import prices pertaining in late 2018, which were higher than the 2016 average, the short-term impact on domestic producers will likely be less pronounced. This provides a window of opportunity for Chinese policymakers to proceed with further deregulating the country’s oil sector and to lift protectionist policies to support the sustainable long-term development of the country’s domestic oil industry.

4. Conclusions

Our estimations indicate that, despite significant reforms undertaken since the last major liberalization of the Chinese economy in the late 1990s and increasing integration into global oil markets, China’s domestic oil sector is still negatively affected by the policies that directly or

| Scenario                  | Crude import price (US$/bbl) |
|---------------------------|------------------------------|
|                           | 30  | 42  | 50  | 60  | 70  | 80  | 100 |
| Open market scenario      |     |     |     |     |     |     |     |
| Production, MMmt          | 174.0 | 181.7 | 190.6 | 192.1 | 192.5 | 193.0 | 193.5 |
| Spare capacity, MMmt      | 25.6  | 17.9  | 9.0  | 7.5  | 7.1  | 6.6  | 6.1  |
| Tanker imports (sea), MMmt| 402.0 | 379.0 | 370.2 | 368.6 | 368.3 | 367.8 | 367.2 |
| Oil costs, US$ billion    | 109.8 | 143.4 | 165.6 | 192.5 | 219.7 | 246.7 | 300.4 |
| Total costs, US$ billion  | 133.9 | 167.2 | 189.5 | 216.4 | 243.5 | 270.6 | 324.3 |
| Baseline scenario         |     |     |     |     |     |     |     |
| Total costs, US$ billion  | 139.4 | 170.0 | 192.0 | 218.6 | 245.0 | 271.6 | 324.6 |
| Difference, US$ billion   | 5.4  | 2.8  | 2.5  | 2.3  | 1.5  | 1.1  | 0.3  |

Source: KAPSARC Research
implicitly restrict market access to non-state-owned players. The resulting market structure and regulatory environment prioritize production from a number of economically uncompetitive, high-cost mature domestic oil assets. However, this interferes with the regional and national supply-demand equilibrium and impedes the optimal allocation of capital in the upstream oil and fuel transportation sectors, which leads to increased system costs and undermines the long-term competitiveness of the country’s oil industry.

Our open market scenario quantifies the effects of these distortions based on market conditions in 2016. We find that removing market access barriers would displace 17.9 MMmt, or 8.9 percent, of inefficient domestic output, primarily located in China’s Northeast, with seaborne tanker imports. Together with optimized transportation logistics, this would bring China’s oil supply costs down by US$2.8 billion per year, equivalent to 1.7% of the country’s annual oil supply costs in 2016.

The potential impact of deregulation on local production and imports could be greater still, as the simulations performed in this study are based on the most efficient utilization of existing transport infrastructure. In reality, however, this assumption may be challenged by a lack of market-based pricing mechanisms and restrictions on third-party access to that infrastructure. This would induce refineries, which are primarily located in China’s eastern and southern coastal provinces, to further increase their reliance on seaborne crude imports. The opposite is the case for the country’s inland refineries, which have no direct access to ports and pipelines. Higher utilization levels of import terminals and pipeline capacities also pose a threat to less cost-efficient domestic crude oil production.

Our findings suggest that — under current economic conditions — the removal of China’s restrictions on purchases of foreign crude would create a significant shift in China’s domestic oil supply logistics as seaborne imports to coastal provinces would increase. This would also have significant implications for the global oil market, as Chinese crude imports could exceed current projections.

On the other hand, the observed sensitivity of uneconomic domestic output to global crude prices implies that for the price levels reported at the time of writing (late 2018), domestic production would be more competitive than reported in our open market scenario. If 2016 market conditions were replicated under the US $80/bbl price assumption, deregulation would result in a decrease of only 6.6 MMmt of domestic oil production (or additions to the spare capacity) in China.

Despite trade tensions with the U.S. and renewed Iran sanctions, oil market conditions at the time of writing provide Chinese policymakers with a good opportunity to proceed with more oil sector reforms, without having a significant short-term negative impact on the country’s energy security and self-sufficiency targets. In the long run, such measures would likely benefit the country’s energy security by helping to establish a more efficient and resilient domestic oil producing sector, and providing a stronger basis for China’s international energy integration and governance initiatives.

We have presented a short-term perspective of reforming China’s oil industry using a standard optimization model. Future research efforts could focus on the long-term effects of reforming China’s oil industry, incorporating investments and retirements in the upstream (oil production), as well as in the midstream (pipeline infrastructure). A dynamic modeling framework would require linking with an international oil market outlook and could investigate possible impacts of domestic reforms on the global market. Future efforts could also extend the representation of the midstream sector and the characterization of crude qualities. Such a tool could be used to investigate connections between refinery stocks, reforms to China domestic upstream market, and China’s demand for crude, differentiated by quality.

The successful implementation of China’s proposed oil sector liberalization program is also contingent on the buy-in of key stakeholders. In this regard, potential direct and indirect consequences of the reforms, including short- and long-term impacts on existing supply chains, as well as regional economic, fiscal and employment indicators, should be evaluated not only on the macro and country scale but also at the corporate and provincial levels.

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Appendices

Appendix 1. KAPSAC Energy Model (KEM) of China oil model description

We develop an optimization problem, where the suppliers of crude oil coordinate to minimize total supply costs. This problem is an extension of the natural gas module developed for the KAPSARC Energy Model of China (KEM China) by Rioux et al. (2018). A mixed complementarity problem (MCP) approach was used in the original gas module to capture the economic impacts of price caps applied to some segments of China’s wholesale natural gas market. Because China’s crude oil prices are deregulated, we formulate the supplier’s problem as a standard linear program (LP) in equation block (1). The LP is built using the general algebraic modeling system (GAMS), and the extended mathematical programming (EMP) framework is used to convert it into the equivalent linear complementarity problem (LCP), and combine it with the MCP formulation of the regulated gas sector. Table A1 lists all sets, variables and coefficients used in the model.

The variables of the suppliers’ problem include the production $q_{irs}$, by company $i$ in each region $r$ from source $s$ with unique production cost $CP_{irs}$, the transportation $t_{jrr'}w$ by company $i$ by pipeline or land based tanker ($w$) owned by company $j$ connecting regions $r$ to $r'$, imports $imp_{irw}$ and final delivery $d_{ir}$ to each region by each corporation. The suppliers’ objective function (1) is to minimize the aggregate costs of all companies, including the marginal cost of production $\sum_{irw} CP_{irs}q_{irs}$, the cost of transportation $\sum_{jrr'w} CT_{jrr'w}t_{jrr'w}$, and imports $\sum_{irw} t_{irw}imp_{irw}$ subject to constraints (1.1) to (1.6).

The companies must meet a fixed demand for crude $D_r$ in (1.1), with each unit of production bound by the available capacity $E_{irs}$ in (1.2). Constraint (1.3) describes the supply balance between model regions, where for each company $i$ the total production plus imports (from available regions $r'$) and transportation (times the transportation yield $Y_{r'w}$) into region $r$ must be greater than the transportation, leaving $r$ plus the final distribution by each company. The transportation constraint for inter-regional pipeline capacity $F_{jrr'}$ owned by company $j$ is defined in (1.4), while existing pipeline import contracts $CN_{irw}$ are set as a lower bound in (1.5). The final constraint (1.6) sets the maximum amount of aggregate seaborne tanker imports from coastal regions $r'$ as $CL$. The coefficient represents policies implemented by the Chinese government to protect domestic producers.

$$\begin{align*}
\text{min } z &= \sum_{irs} CP_{irs}q_{irs} + \sum_{jrr'w} CT_{jrr'w}t_{jrr'w} \\
&+ \sum_{irw} t_{irw}imp_{irw} \\
\text{s.t.} \\
\sum_{s} q_{irs} &\geq D_r \quad \forall ir \quad (1.1) \\
q_{irs} &\leq E_{irs} \quad \forall irs \quad (1.2) \\
\sum_{s} q_{irs} + \sum_{w} imp_{irw}(r)w + \sum_{r'} t_{jrr'w}Y_{r'w} &\geq \sum_{r'} t_{jrr'w} + d_{ir} \quad \forall ir \quad (1.3) \\
\sum_{r'} t_{jrr'w} &\leq F_{jrr'} \quad \forall irr', w = pipe \quad (1.4) \\
imp_{irw} &\geq CN_{irw} \quad \forall r'(r), w = pipe \quad (1.5) \\
\sum_{r'} imp_{irw} &\leq CL \quad \forall w = tank \quad (1.6) \\
d_{ir} &\geq 0, q_{irs} \geq 0, imp_{irw} \geq 0, t_{jrr'w} \geq 0
\end{align*}$$

Table A1. Sets, variables and parameters used in the model.

| Sets | | Variables | Cost coefficients and other parameters |
|------|---|---|---|
| $i, j$ | Companies operating in the oil market | $d_{ir}$ Crude oil delivered by company $i$ in region $r$ | $CL$ Aggregate import contract licenses for coastal imports by maritime tanker |
| $r, r'$ | Model regions. $r'(r)$ is all import regions, $r'(r)$ only coastal regions with maritime import capacity | $t_{jrr'w}$ Transportation by company $i$ on infrastructure owned by company $j$ from $r$ to $r'$ by mode $w$ | $CN_{irw}$ Contracts for imported oil purchased by company $i$ in region $r$ for pipeline imports |
| $s$ | Regional production differentiated by marginal production costs (supply steps) | $imp_{irw}$ Quantity of oil imported by company $i$, in region $r$ | $CP_{irs}$ Marginal cost of production for company $i$ in region $r$ for supply step $s$. Includes annualized development costs for incremental production. |
| $w$ | Transportation mode (pipe, tank) | $q_{irs}$ Natural gas production by company $i$, in $r$, from supply step $s$ | $CT_{jrr'w}$ Variable transportation cost from $r$ to $r'$ for gas type $w$ |
| $D_r$ | Fixed oil demand in region $r$ | | $D_r$ Fixed oil demand in region $r$ |
| $F_{jrr'}$ | Production capacity by company $i$, in region $r$, and supply step $s$ | | $F_{jrr'}$ Production capacity owned by company $j$ from region $r$ to $r'$ for pipelines |
| $l_{irw}$ | Import price in region $r$ by mode $w$ | | $t_{irw}$ Import price in region $r$ by mode $w$ |
| $Y_{r'w}$ | Transportation yield by mode $w$ | | $Y_{r'w}$ Transportation yield by mode $w$ |
## Appendix 2. Model calibration

### Table A2. Variable costs, yields and other model calibration coefficients.

| Natural gas parameters                        | Value\(^a\)                  | Reference                              |
|-----------------------------------------------|-------------------------------|----------------------------------------|
| Pipeline transport cost                       | US$0.00210/Mcm-km             | Rioux et al. (2018)                    |
| Pipeline losses                               | 0.002%/km                     | Rioux et al. (2018)                    |
| LNG transportation (truck)                   | US$0.0118/Mcm-km              | Rioux et al. (2018)                    |
| Regasification cost                           | US$12/Mcm                     | NERA (2014) (Southeast Asia)           |
| Regasification yield                          | 98.6%                         | Egging et al. (2010)                   |
| Liquefaction cost                             | US$10/Mcm                     | NERA (2014) (Southeast Asia)           |
| Liquefaction yield                            | 88%                           | Egging et al. (2010)                   |
| Pipeline imports in 2016                      | 38.9 bcm                      | ITC Trade Map (ITC) (2018), KAPSARC Analysis |
| Tanker imports in 2016                        | 36.2 bcm                      |                                        |
| Pipeline import price (Central Asian imports) | US$179/Mcm                    |                                        |
| Tanker import price                           | US$315/Mcm                    |                                        |

**Oil parameters**

| Pipeline transport costs (rail)                | US$0.0025/mt-km               | KAPSARC Analysis                      |
| Pipeline imports in 2016                      | 20.5 MMmt                     | ITC Trade Map (ITC) (2018), KAPSARC Analysis |
| Tanker imports in 2016                         | 360.4 MMmt                    |                                        |
| Pipeline import price (Central Asian imports) | US$288/MMmt                   |                                        |
| Tanker import price                            | US$306/mt                     |                                        |

\(^a\) Natural gas units are thousand cubic meters (Mcm), thousand cubic meter kilometers (Mcm-km), and billion cubic meters (bcm). Oil units are metric tonnes (mt), metric tonne-kilometers (mt-km) and million metric tonnes (MMmt).