مركـــز الملـــك عبـــدالله للدراســـات والبحـوث البتروليـــة
King Abdullah Petroleum Studies and Research Center

Securing New Markets in Asia: The Value of Strategic Spot Crude Oil Sales to Teapot Refiners

Jennifer Considine, Kang Wu, Abdullah Aldayel

June 2019

Doi: 10.30573/KS--2019-DP79

Acknowledgments

The authors are thankful to Lester Hunt, Fred Joutz, Fatih Karanfil, Anwar Gasim and Olivier Durand for their comments and suggestions and to participants at the 2nd International Conference on Energy, Finance Macroeconomy (held in Montpellier, France, Oct 24-26, 2018). The authors would also like to thank Chay Allen, Eloise Logan and James Bourne for their editorial guidance and Abu Rumel for his help with the text. The authors accept sole responsibility for any errors and omissions. The views expressed in this paper are the authors' and do not necessarily represent the views of their affiliated institutions.

About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

This publication is also available in Arabic.

Legal Notice

Key Points

In the race to secure customers on competitive world oil markets, many oil producers are looking to China as a promising source of increased market share. The task of securing new customers in China can be challenging, as most of China's recent growth in oil demand has come from 'teapot refiners' who have been less predictable, and more like the 'wild west,' than China's national oil companies. Teapot refiners tend to be more focused on short-term profits than long-term relationships. They have also been subjected to strict government guidelines on capacity expansions, and more recently a clampdown on the illegal trade of crude import quotas. The situation has been complicated further by the recent enforcement of tax laws and strict quality controls.

Strategic spot sales from joint stockpiling facilities to Asia and Chinese teapot refiners show promise as a means for producers to increase their market shares in the region. But at what price? This study examines the potential implications of spot sales from a hypothetical joint stockpiling facility located close to China, similar to that in Okinawa, Japan, for a major producing nation in the context of a bigger market penetration of teapot refineries. The analysis will be conducted in light of the potential implications of these sales for major oil companies subject to strict production quotas, and existing term and long-term contracts.

This study applies a valuation model developed by KAPSARC (Considine et al. 2019) to Chinese teapot refineries, to determine the potential value of spot crude oil sales from a strategically located joint stockpiling facility that aims to capture market share. Our analysis follows a combination of net present value (NPV) analysis and a strategic options approach. Given (i) crude oil production costs, (ii) transportation costs, (iii) assumed quantities of different gravities heavy medium and light crude oil and (iv) a base case or reference value of existing term and long-term crude oil sales of $3.52 billion. The assumptions underlying the reference case are described in detail in Considine et al. (2019).

It develops a theoretical framework in which demographic and economic factors such as price and income can be seen to jointly determine industrial energy consumption. We select the population aged between 15-64 as the demographic variable. For a robustness check, we also consider those aged 15 and over in the analysis.

- Adding the optionality of strategic spot oil sales has the potential to increase the expected net present value (XNPV) gross revenue earnings before interest, tax, depreciation and amortization (EBITDA) of the joint stockpiling facility via spot sales by an expected $156.94, a significant 4.5%. We assume a 2.5% discount rate which is well in line with contemporary interest rates in the United Arab Emirates and Qatar (Deposit 2018).

- Strategic spot oil sales to the teapot refineries increase the minimum XNPV of gross revenue via spot sales by around $530 million, thereby reducing the risk, or downside of the facility significantly.

- The upside potential is considerable. As well as the benefits of solidifying regional relationships and the potential for producers to capture long-term market share, there is a 5% probability that strategic spot oil sales could increase the gross income of the pre-existing facility by $830.89 million.

Key Points

These results show that the model plays well in the scenario where a major Middle Eastern producing company makes a series of strategic sales of various gravities of spot crudes to Chinese teapot refineries in Shandong Province from a joint stockpiling facility in Okinawa. The results are further analyzed for a number of different scenarios, showing the effects of increased spot oil sales on crude oil prices and the demand for long-term contracts. In the base or reference case, we assume that the increase in spot oil sales does not affect term prices or demand for term contracts. The results of the study clearly demonstrate a positive NPV for the reference case.

Note: Chinese teapot refiners use the straight-run fuel oil, the residue left after crude oil has been distilled, as a feedstock for their plants because it is less expensive than crude and has been subject to lower taxes (Aizhu and Meng 2018). The crude mix assumption reflects the balanced diversification of China's crude oil import portfolio: "By 2010, China's oil import portfolio became remarkably diversified in terms of sulfur contents, thanks to the ongoing large-scale addition of desulfurization capacity." (Kim 2016)

In the first alternative scenario, we assume the increased sales of spot crude to China results in a permanent 2.5% reduction in world oil prices. Our results show that a reduction in regional prices and increased sales in the region lead to higher crude oil revenues. In the second alternative scenario, it is assumed that increased spot oil sales to China lead to an increase in world oil prices. While the pricing dynamics in this scenario are slightly more complex, the net effect on revenues from increased market share in the region is expected to be positive. Negative impacts, if any, can be easily offset by an increase in light crude oil sales to teapot refineries. At the same time, an increase in global oil prices leads to an increase in the demand for long-term contracts in China, thus positively impacting crude oil revenues.

The teapot refineries can improve their credit rating through merging and forming conglomerates, thereby facilitating the term contracts which require a credit line of $1 billion (Downs 2017). This is happening now but will take some time to be fully functional. MEPs could also find creative ways to enter the Chinese teapot refinery market. Selling spot cargos from conveniently located joint stockpiling sites in Northeast Asia, particularly Japan and South Korea, is one way to move in this direction and is the focus of this paper. The assumptions underlying the valuation model are outlined in detail in Considine et al. (2019).

The potential fair market value of these strategic spot sales can be estimated by calculating how much a market player would pay to secure the right to purchase crude oil supplies from the primary producer at market prices from the same location as the joint stockpiling facility. That value, in turn, will depend on the price of competing crude oil supplies from around the world and can be estimated as a simple European spread option. The value can be realized by the MEP either by selling the option over the counter in the form of bilateral agreements directly to the teapot refiners and other customers, or through actual spot sales.

This study's model results show there are clear benefits to be derived from the strategic sale of spot crude to Chinese teapot refineries. This is true for several scenarios concerning the impact of the increase in spot oil sales on term crude oil prices and the demand for long-term contracts. While the pricing dynamics can be complex, the net effect on revenues from increased spot oil sales in the region is expected to be positive. Negative impacts, if any, can be easily offset by an increase in light crude oil sales to teapot refineries. Our results show an increase in strategic spot oil sales during periods of increasing global oil prices can lead to an increase in demand for long-term contracts in China, thus yielding positive long-term implications for crude oil revenues.

Introduction

Strategic spot sales to Asia and Chinese teapot refiners show promise as a means to increase market share in the region. But at what price? Is it reasonable to assume that increased sales of spot crude oil to a region will have no implications for world oil prices and the demand for long-term contracts? This study examines the potential implications of spot sales from a hypothetical joint stockpiling facility located close to China for a major producing company located in the Middle East in the context of a bigger market penetration of teapot refineries. The analysis will be conducted in light of the potential implications of these sales for the major producing company that is subject to strict production quotas.

Reference scenario: no impact

In the reference case, the strategic sale of crude oil to Chinese teapot refiners is assumed to have no impact on either world oil prices or existing term contracts. This is a realistic proposition: Existing production quotas on Middle Eastern producing companies (MEP) means the total quantity of crude oil produced and released onto world oil markets will be unchanged. The implications, if any, of increased spot sales to the region are likely to be a short-term reduction in local oil prices, and changes in the future demand for long-term contracts. Under this neutral scenario, or base case, the cost and benefits analysis of spot crude sales from the joint stockpiling facilities will be determined solely by the strategic options valuation model developed in the recent KAPSARC study by Considine et al. (2019).

Alternative Scenario 1: negative impact

In the first alternative scenario, the sale of spot crude to China results in a reduction in both world oil prices

The Okinawa joint oil stockpiling facility

The facility is located no more than three days sailing from key markets in China and is ideally positioned as a strategic petroleum reserve for International Energy Agency (IEA) member countries during times of crises and tight markets. The facility has additional value in its capacity to provide an excellent central location for the sale of spot crude to Chinese teapot refineries. Crude deliveries can reach tight markets in a few days and can be available for pickup in quantities appropriate for specific market disruptions. As a result, spot sales and the sales of call options on crude oil have the potential to address sporadic and unanticipated increases in demand without adding sustained, downward pressure on regional oil prices, or term contracts.

Major oil companies (MOCs) can deliver crude oil supplies as needed to the hypothetical joint oil stockpiling facility, as they can easily replenish their stocks with daily and weekly deliveries from very large crude carriers (VLCCs). Assuming 16-inch diameter pipes capable of moving 75,000 barrels (bbl) of crude an hour, it can take 40 hours to offload a 3 million barrel (MMbbl) capacity supertanker (Maslowski 2011). Note: MOCs often own a fleet of VLCCs and, if not, can get excellent terms on time charter deals (Considine et al. 2019).

and the prices of MEP term contracts to China. In this scenario, the increase in spot oil sales fulfills some extra-pent up demand, and the incremental volumes result in a slight reduction in world oil prices. We assume a 2.5% reduction in global and term oil prices and assess the impact on the value of spot oil sales to the teapot refiners.

Alternative Scenario 2: positive impact

In this scenario, spot deals not only open up new markets but also lead to more term contracts in the region. The additional volumes displace competing crude from Russia and other competitors, leading to more long-term term contracts for the MEP. For comparison, we assume a 2.5% increase in oil prices for term contracts for MEPs' sour crudes and assess the results. Under this scenario, the net effects of selling spot crudes to Chinese teapot refineries from the joint stockpiling facility at Okinawa are enhanced by additional benefits derived from increases in crude oil prices and volumes of term sales.

It is important to note that the Middle Eastern producing company is subject to production quotas, not sales quotas. As a result, the increased spot sales do not necessarily have to come at the expense of fewer long term contracts — or a reduction in long term contracts in the region, so long as the production constraints are not violated.

Spot sales from strategically placed joint stockpiling facilities can enhance a major oil company's market share in Asia. This paper utilizes a valuation methodology developed by Considine et al. (2019) to determine the potential value of spot sales from these facilities, under the assumptions outlined in the three scenarios listed above, from the perspective of an MEP.

The main body of this paper is organized as follows: The first section documents the rise of the teapot refiners, with special attention given to the flow of oil across the Chinese border, and the rising levels of crude oil imports and exports of petroleum products. The second section examines the proposition that the rise of spot crude oil sales to China has come at the expense of long-term and short-term contracts. A quantitative analysis supports the proposition that this is not a foregone conclusion, suggesting that the use of spot sales to increase market share does not necessarily come at the expense of existing term contracts.

The third section outlines the project assumptions underlying the base or reference case.

The potential incremental value of the strategic spot sales is quantified in the fourth section. These first four sections form the basis of the analysis for the reference case and assume that the spot sales of crude oil have no impact on world oil prices, the official Saudi selling price, and the sale of short-term and long-term contracts to existing customers.

Note: Technically there is no official Saudi selling price but an official pricing differential, or pricing formula that is announced in advance of the actual sales date. The pricing formula used to price crude oil sales to Asia was changed in October 2018: "Under the new terms, Saudi Aramco's official selling price for October will be based on the average settlement prices for the DME December Oman contract and the December Dubai cash price assessed by Platts, both of which are set in October." (Tan 2018)

The final section identifies several variables as potential sources of uncertainty that can change the model results significantly. These are selected for sensitivity analysis and modeled in terms of appropriate probability distribution functions.
A sensitivity analysis is performed using Monte

Carlo simulation and stepwise multiple regression, to determine the regression coefficients of the exogenous variables. This section examines the implications of the first and second scenarios — where increased spot sales have negative and positive implications for world oil prices, respectively. Finally, the results are reported in the conclusion, which also outlines potential areas for further research.

The Appendices provide further detail on the project model and assumptions. These are as follows:

Appendix A: Teapot refineries

Appendix B: Sensitivity analysis and Monte Carlo simulations

Appendix C: Estimating the relationship between Chinese long-term contracts, the spot price of Brent, and the rise of the teapot refineries

The History and Current Status of Crude Imports and Crude Oil Runs From Chinese Teapot Refiners

The target market for the MEPs is China's Shandong Province, where most Chinese teapot refineries are concentrated. China has a very large refining sector and is the world's top crude oil importer. The teapot refineries in China are owned by local governments and independent private players outside the four major national oil companies (NOCs), and they play an important role both in refining and importing. The four NOCs are the China National Petroleum Corporation (CNPC) and its publicly listed company PetroChina, Sinopec and its listed company Sinopec Corp., China National Offshore Oil Corporation (CNOOC) and its listed company CNOOC Ltd, and Sinochem. At the start of 2017, China had a crude distillation capacity of 14.5 million barrels per day (MMbbl/d). The combined installed capacity of the above four NOCs and their affiliated joint ventures accounted for about three quarters of the total. The residual, approximately one quarter, or nearly 3.7 MMbbl/d, is in the hands of teapot refineries (Wu and Brown 2017) (See Figure 1 and Table 1).

Chinese teapot refineries have a long and fascinating history. Two decades ago they were small in size. For nearly a decade after China's major reorganization of its oil and gas industry in 1998, the teapot refineries had a difficult time, with the government

Figure 1. Chinese teapot refineries.

Sources: Bloomberg; KAPSARC 2018.

cracking down on small refineries and promoting the dominance of NOCs (Wu 2012). However, as China's oil demand surged from 2005 onward, Chinese teapot refineries found ways to flourish.

The surge of teapot refineries has been relentless, despite continuous restrictions by the central government. A new era began for them when Chinese President Xi Jinping assumed power in 2013. The Chinese government started incorporating the teapot refineries into the country's oil and refining system, giving them a share of the market through legislation (Downs 2017). A policy allowing Chinese teapot refineries to buy spot crude on the world oil market was implemented in late 2015, following a couple of years of preparation, leading to the increasing share of teapot refineries in China's crude oil imports.

Table 1. Select independent refiners' import quotas (million tonnes per annum).

Location	Status	Refinery Name Operator	Capacity BBl/day	End 2016 quotas	End 2017 quotas
Yanan, CNSX, CN	Operational	Yan'an RefinerYanchang Petroleum Group Co Ltd	160,000	2.4	1.2
China	Operational	Yulin Capacity Yanchang Petroleum Group Co Ltd	160,000	3.6	0
Ningxia, CN	Operational	Baota RefineryBaota Petrochemical Group Co Ltd	150,411	6.2	0.5
Dongying, CNSD, CN	Operational	Huaxing RefineShandong Huaxing Petrochemical Grou	140,384	2.2	2.1
Liaoning, CN	Operational	Panjin RefineryPanjin Northern Asphalt Co Ltd	140,384	7	5.7
Hebei, CN	Operational	Xinhai RefineryHebei Xinhai Chemical Group Co Ltd	120,329	0	1.9
Henan, CN	Operational	Yongmei Coal HYongmei Coal Group Co Ltd	120,000	0	2.2
Zibo, CNSD, CN	Operational	Jincheng RefinShandong Jincheng Petrochemical Gro	118,323	0	1.5
Zibo, CNSD, CN	Operational	Huifeng RefineShandong Huifeng Petroleum Chemica	116,318	4.2	1.7
Weifang, CN	Operational	Hongrun RefineSinochem Hongrun Petrochemical Co L	114,312	5.3	5.1
Dongying, CNSD, CN	Operational	Tianhong RefinShandong Tianhong Chemical Co Ltd	100,274	4.4	3.8
Dongying, CN	Operational	Yatong RefinerDongying Yatong Petrochemical Co Ltd	80,219	3.4	2
Binzhou, CNSD, CN	Operational	Chambroad RefShandong Chambroad Petrochemicals	70,192	3.3	0.8
Gangkou, CN	Operational	Gangkou RefineRizhao Landbridge Gangkou Petrochem	70,192	1.8	1.8

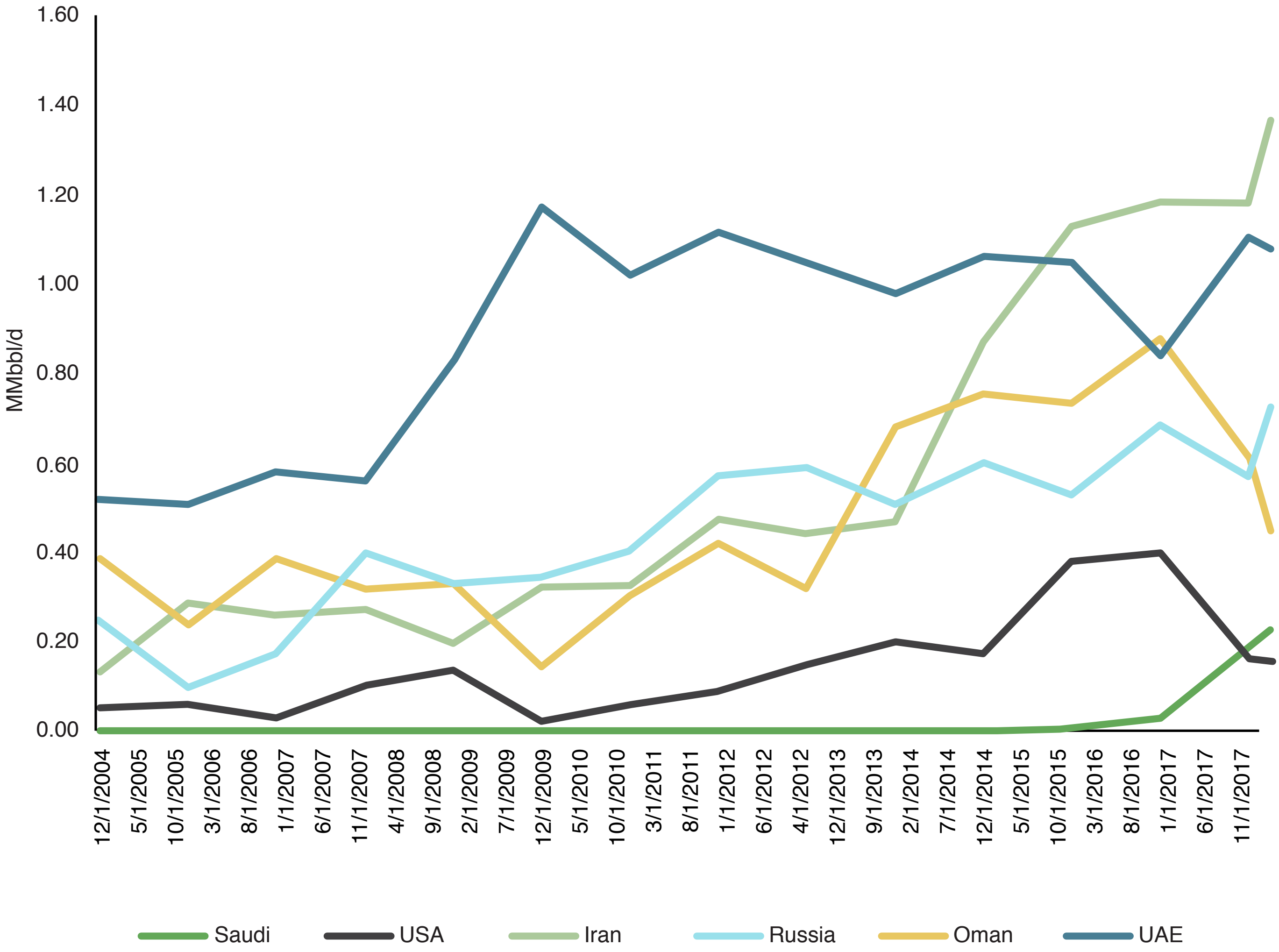
Location	Status	Refinery Name Operator	Capacity BBl/day	End 2016 quotas	End 2017 quotas
Dongying, CN	Operational	Lijin Refinery CLiJin Petrochemical Plant Co Ltd	70,192	3.5	3.1
Dongying, CNSD, CN	Operational	Qicheng RefineShandong Qicheng Petroleum Chemica	70,192	0	1.6
Haiyou, CN	Operational	Haiyou RefinerShandong Haiyou Petrochemical Group	70,192	3.2	0.4
Dezhou, CNSD, CN	Operational	Hengyuan RefinShandong Hengyuan Petrochemical Co	70,192	3.5	1.8
Dongying, CNSD, CN	Operational	Dongfang RefinShandong Dongfang Hualong Industry	60,164	0	3
Dongying, CNSD, CN	Operational	Kenli Refinery Shandong Kenli Petrochemical Group C	60,164	2.5	2.2
Weifang, CNSD, CN	Operational	Luqing RefineryShandong Shouguang Luqing Petroche	60,164	2.6	2.2
Heze, CNSD, CN	Operational	Shengshi RefinShandong Yuhuang Chemical Co Ltd	60,164	2.5	1.3
Binzhou, CNSD, CN	Operational	Zhonghai RefinShandong Zhonghai Fine Chemical Co	46,126	0	1.9
Dongying, CNSD, CN	Operational	Shengxing RefiShandong Haihua Shengxing Chemical	44,121	0	2.2
Haiyue, CN	Operational	Haiyue RefinerShandong Haiyue Chemical Co Ltd	20,055	0	2.1
Dongming, CN	Operational	Dongming RefinShandong Dongming Petrochemical Gr	10,027	7.5	6.6
Qingyuan, CN	Operational	Qingyuan RefinShandong Qingyuan Petrochemical Co	3,786	4	2
Total			**11,902,730.2**	**73.1**	**60.7**

Sources: Bloomberg; Oxford Institute for Energy Studies 2018.

China and the United States (U.S.) are the largest two crude oil importers in the world. In December 2016, China imported 8.6 MMbbl/d of crude oil, up by 10% from December 2015. In December 2017, Chinese imports fell slightly to 7.9 MMbbl/d, rising to 8.07 MMbbl/d in March 2018 (Bloomberg 2018; GACC 2017). After years of Saudi Arabia being the largest crude oil exporter to China, it lost that spot to Russia in 2015 and was behind both Russia and Angola during the first eight months of 2017. The U.S., Iran and Russia have been gaining market share steadily over the past few years (Figure 2).

Chinese teapot refineries have contributed significantly to surging imports in recent years after the government granted them import permits in 2015. In 2015, the volume of their imports was very low. By August 1, 2017, as many as 29 teapot

Figure 2. Chinese crude imports by country.



Sources: General Administration of China Customs; Bloomberg 2018.

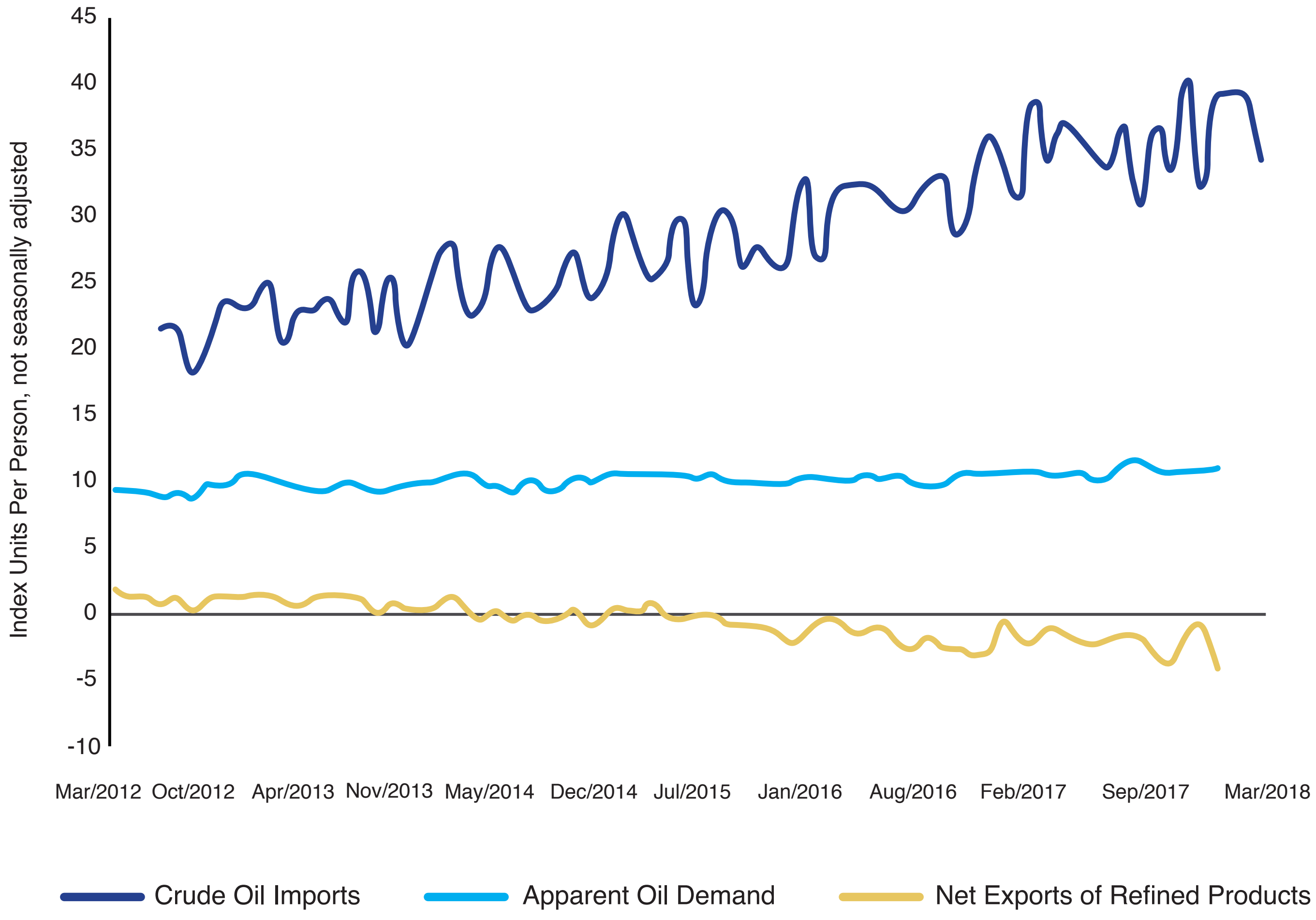
refineries had been granted crude import permits, importing an annualized total of over 1.9 MMbbl/d (China OGP 2017). Chinese teapot refineries imported some 2 MMbbl/d of crude oil during the first half of 2017, doubling the volume from the same period in 2016 (Downs 2017).

Figure 3 illustrates the flow of crude oil supplies across the borders of China. The level of crude oil imports shown in dark blue is clearly rising faster than the level of domestic crude oil demand shown in light blue. The level of net exports, that is exports minus imports of petroleum crude oil, has been falling steadily since 2016 (Gilbert 2017).

Saudi Aramco has long been working with the state trading companies of China's NOCs, namely Unipec for Sinopec, Chinaoil for PetroChina and Sinochem, on term contracts only. Saudi Aramco has little exposure to Chinese teapot refineries, as the latter still have difficulties qualifying themselves as trusted crude buyers for term contracts. At present, the major crude oil exporters to Chinese teapot refineries include Russia, Angola, Venezuela, Brazil,

The History and Current Status of Crude Imports and Crude Oil Runs From Chinese Teapot Refiners

Figure 3. Tracking teapot refiners.



Source: Bloomberg 2018.

Malaysia, Oman, the Democratic Republic of Congo, Iraq, the United Kingdom and Gabon, among others.

Chinese teapot refineries are here to stay and continue to grow. It is a segment of the global oil market that the MEPs cannot ignore. There are at least three strategies that companies can take advantage of to penetrate this growing segment of the Chinese oil market. The first is establishing a partnership between the teapot refineries and Chinese NOCs. This has progressed only slowly. The second is forming an alliance or merging with teapot refineries to be one of a few conglomerates so as to better qualify as importers of crude oil in the global market and sign term contracts. The teapot refineries can improve their credit rating through merging and forming conglomerates, thereby facilitating the term contracts which require a credit line of $1 billion (Downs 2017). This is happening right now but will take some time to be fully functional. MEPs could also find creative ways to enter the Chinese teapot refinery market. Selling spot cargos from conveniently located joint stockpiling sites in Northeast Asia, particularly Japan and South Korea, is one way to move in this direction and is the focus of this paper.

Nothing is guaranteed: While Chinese teapot refiners have successfully navigated all of the regulatory challenges facing the industry to date, their ensured success and growth are not guaranteed. A new period of radical reform in China's domestic oil industry could result in the decline of the teapot refineries through competition, or diktat, though there is currently no sign of this happening any time soon. There are pros and cons to the three strategies that the MEPs can use to increase market share with teapot refineries. While a thorough discussion of these is beyond the scope of this analysis, the first — teaming up with the teapots and Chinese NOCs, and merging and/or forming a conglomerate with the teapots — will take a considerable amount of time. The third method, spot sales to the teapots, can be achieved immediately and with fewer long-term consequences should regulation of the industry take a sudden adverse turn.

Chronology of events: The rise of the Chinese teapot refineries

Early history: 1960s-1970s

- The teapot refineries are built as small facilities, typically near oilfields or ports in China. Approximately 70% are located in Shandong province.

Early history: 1990s-2014

- The reform of China's NOCs in the late 1990s leads to the forced closure of teapot refineries.
- From 1995 to 2014, the number of teapot refineries falls by over 50%.
- Teapot refineries are restricted to run on a mix of domestic crude and various middle distillates such as fuel oil from the NOCs.
- In 2014, Xi Jinping begins to contemplate a different approach, favoring the teapot refineries.

2015

- China allows teapot refiners to start processing imported crude oil, with a number of refiners allowed to import crude directly.
- Eleven refiners are given permits to import 987,000 bbl/d of crude.
- The government shuts down crude oil distillation units with a capacity of under 40,000 bbl/d, in an effort to upgrade the industry's efficiency.
- Teapot refiners are encouraged to close inefficient crude distillation units in return for additional crude import quotas (Zhou and Jaipuriyar 2018).
- Utilization rates at China's independent refiners average 41.4%.

2016

- Nineteen independent refiners are allowed to import 1.5 MMbbl/d of crude (Raval and Hume 2017).
  - China's crude imports rise by 10% to 8.55 MMbbl/d in December 2016 (Figure 1).
  - Utilization rates at China's independent refiners average 52.5%.

Independent refiners are permitted to export refined products and are given export quotas.

Saudi Arabia ships two cargos to Longkou in China, including a 730,000 bbl cargo on the Aframax Alyarmouk from the Okinawa terminal in Japan in May. These are the first shipments to teapot refineries (Kumagai 2016).

Eight refiners promise to shut 418,000 bbl/d of capacity and receive 494,000 bbl/d of import quotas.

Numerous reports of illegal trade in quotas and tax evasion.

2017

The government clamps down on exports by independent refiners who are given no quotas to control excessive operating rates and improve air quality.

- Thirty-two independent refiners are allowed to import 2.04 MMbbl/d of crude.
- Independent refiners promise to shut down 1.24 MMbbl/d of capacity (Zhou and Jaipuriyar 2018).

The government puts in place more stringent checks and balances to ensure that all criteria are met before awarding import quotas.

China's National Development and Reform Commission (NDRC) announces that it will halt new crude import quota applications from existing refineries, effective from May 5, to control imports and capacity expansions (Zhou and Jaipuriyar 2018).

New refining projects are approved. These include a 301,000 bbl/d refinery by the independent company Xuyang Petrochemical and a 321,000 bbl/d plant by the independent company Shenghong Petrochemical. A 301,000 bbl/d joint project between state-owned Norinco and Saudi Aramco is reinstated (Zhou and Jaipuriyar 2018).

- China's crude imports reach levels as high as 8.43 MMbbl/d, and oil products exports increase by over 7% from 2016 levels.
- Shandong teapot refineries crude feedstock reaches 1,821 bbl/d from January to October 2017, a 22.1% increase over the 1,491 bbl/d reported from January to October 2016 (Xiu 2017).
- The processing rates at independent refiners reach as high as 60.2% in 2017.

A new nationwide mandate to expand the mandatory use of E10 fuel — a gasoline containing 10% ethanol — is expanded from 11 trial provinces to the whole of China by 2020 (Paraskova 2018a).

The independent non-state refineries are given permits to import 2.86 MMbbl/d of crude in 2018, a 55% increase over the 1.84 MMbbl/d permitted in 2017.

Environmental and safety checks are strengthened. In Shandong, 10 key independent refiners with a combined capacity of 400,000 bbl/d are forced to prolong maintenance, and several small refiners suspend operations.

- The refinery throughput rates reach levels as low as 10.71 bbl/d, as state firms and independent refineries compete for market share in a loose market with high levels of inventories (Paraskova 2017).

In October, 20 central government bodies draft a memorandum of understanding to tighten the monitoring of the sector, hoping to stop tax avoidance and the illegal trade in quotas (Meidan 2017).

2018

The government eases controls on crude imports and product exports, though independent refiners are not yet given export quotas.

The government turns an environment-protection fee collected from companies into an environment tax, effective January 1.

The State Administration of Taxation announces tighter regulations effective March 1, to enforce collection of a $38 per barrel ($0.24 per liter) gasoline consumption tax and a $29 per barrel ($0.18 per liter) tax on diesel, in an effort to stop tax avoidance (Paraskova 2018b).

The NDRC unveils measures to punish refiners that fail to meet the government's capacity expansions, and environmental and safety guidelines. Punishments include the outright closures of capacities under 40,000 bbl/d, and the closures of illegal expansions and refiners that are found to be flouting the guidelines.

Chinese teapot refiners prepare to obtain permits to blend ethanol to comply with the nationwide mandate.

The increase in import quotas leads to a visible build up and surge in floating storage at Shandong import terminals in early April (Kayrros 2018).

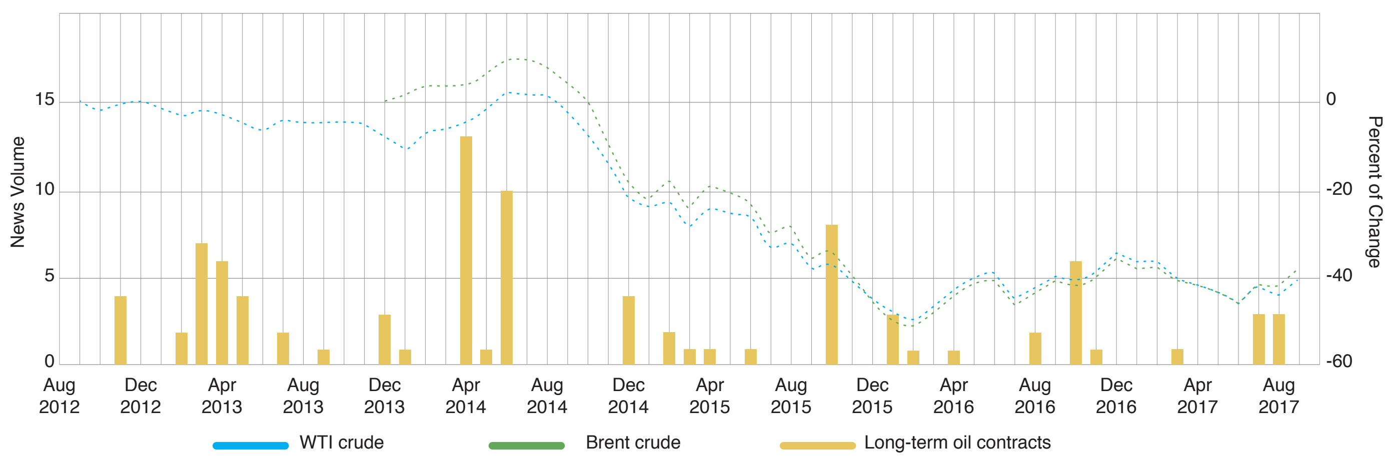
The Relationship Between Spot Oil Prices, Term Contracts, and the Rise of Chinese Teapot Refineries

There is no readily available detailed and accurate information on the exact size of the spot market and bilateral agreements for spot and term sales. However, a close examination of publicly available data suggests that the demand for and supply of long-term contracts versus spot contracts rises and falls with world oil prices. When prices are high, crude oil producers prefer to lock customers in. Customers, on the other hand, tend to prefer spot markets when prices are low and falling. This interaction between buyers and sellers results in an increase in the number of long-term contracts when crude oil prices are rising.

According to publicly available sources, the size of the spot market has risen steadily since the early 1980s. A number of industry analysts, including Daniel Yergin of Cambridge Energy Research Associates, estimate the size of the spot market to have been 10% of all physical crude oil sales in 1979, rising to over 50% in 1982 (Kaminska 2017). By 2007, these volumes are believed to have fallen to only 35-40% of total physical crude oil sales. More recently, over the past three years, independent traders and commodity houses have expanded their volumes significantly, by well over 65%, with volumes traded by Vitol, Glencore and Trafigura reaching 17 MMbbl of crude oil and petroleum products a day, a 70% increase over the 10 MMbbl/d in 2014. When volumes from Gunvor and Mercuria are included, total volumes reach levels as high as 22 MMbbl/d, 67% of the 32.83 MMbbl produced by OPEC in August 2017 (Hume and Sheppard 2017).

While the exact nature of the contractual agreements — spot or term — is unavailable for the volumes in question, there is 'hearsay' evidence of the rise in spot and independent market transactions during periods of 'low' and falling oil prices. Figure 4 presents the results of a Factiva search for "long-term oil contracts" plotted against Brent and West Texas Intermediate (WTI) spot crude oil prices. The primary y-axis measures the volume of news containing the phrase "long-term oil contracts," and

Figure 4. Factiva analysis: Number of news stories, reports and documents on Chinese long-term crude oil contracts vs. the European Brent and WTI spot price (FOB).

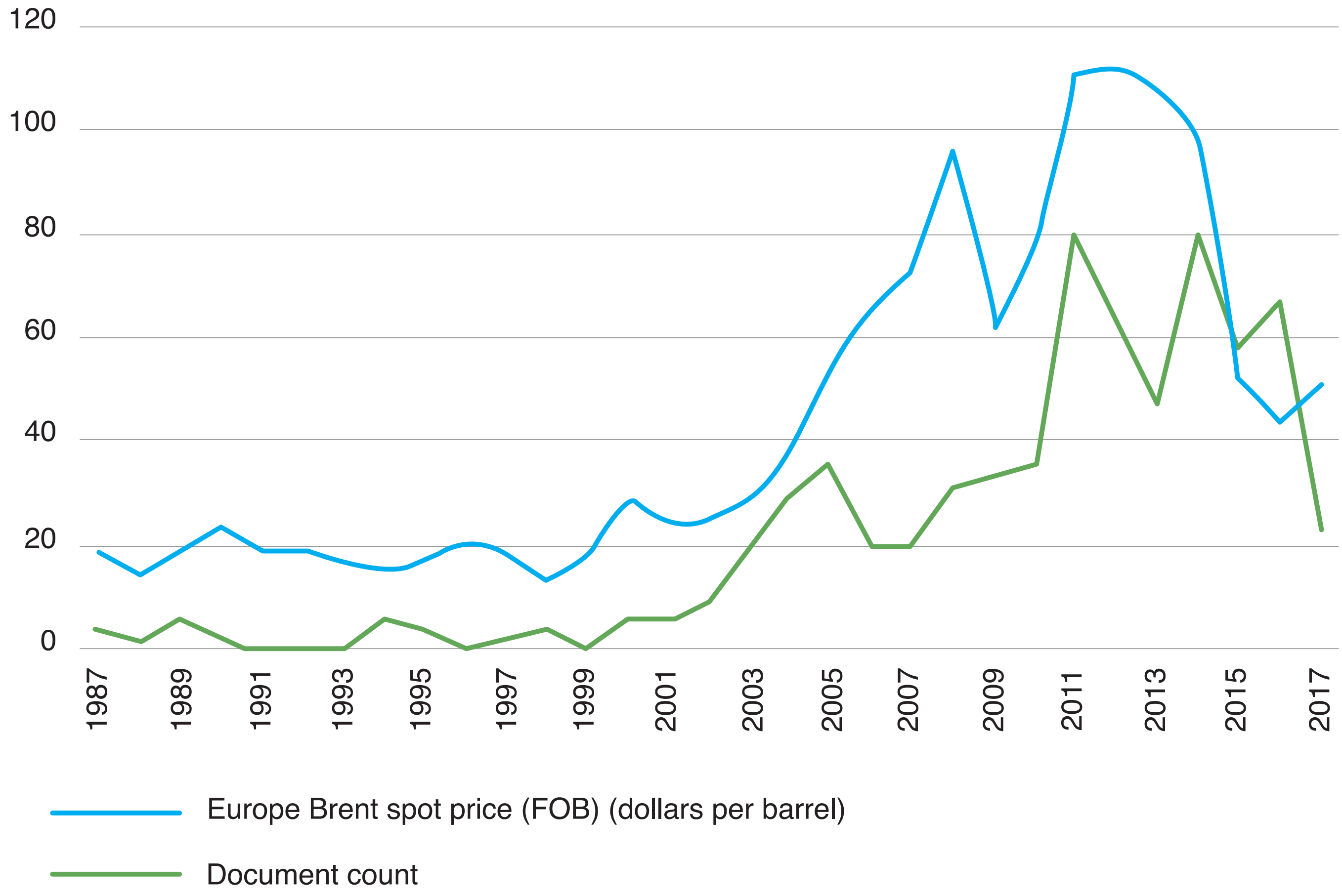


Sources: KAPSARC and Factiva.

the secondary y-axis — on the right-hand side of the chart — displays the percentage change in world oil prices. Unsurprisingly, the volume of news stories and industry talk about long-term contracts tends to increase when analysts suspect an upward change in the direction of price movements and when prices are rising.

The results are even more compelling when long-term contracts in China are considered. Figure 5 displays the results of a Factiva search for "China long-term oil contracts." The chart provides visual evidence that the volume of news and industry reports relating to 'new' long-term contracts increases when world oil prices rise. This supposition is supported by quantitative analysis. A simple regression analysis on the number of documents and reports counted by Factiva's analysis, and the spot price for European Brent on a free on board (FOB) basis suggests that each percentage increase in spot crude oil prices results in a 0.61 increase in the number of news reports and documents citing Chinese long-term crude oil contracts.

Figure 5. Factiva analysis: Number of news stories, reports and documents on Chinese long-term crude oil contracts vs. the European Brent spot price (FOB).



Sources: Document count analysis by Factiva; Brent Oil prices (EIA 2017).

The Relationship Between Spot Oil Prices, Term Contracts, and the Rise of Chinese Teapot Refineries

It is interesting to note that the analysis does not support the proposition that the rise of spot purchases by teapot refineries has had a negative effect on the demand for long-term contracts during the period under consideration. There also appears to have been more than enough oil to satisfy demand. The Chinese government created what has amounted to a "new country's worth of oil imports" when it announced in 2015 that Chinese teapot refineries would be permitted to buy spot crude on the world oil market, a privilege that had previously only been extended to the state-owned oil companies (Downs 2017). The inclusion of a dummy variable accounting for the rise of the teapot refineries in our regression suggests that the number of long-term contract announcements has increased significantly since 2015. Appendix C reports the results of the regression analysis.

While the rise of spot sales to teapot refineries does not appear to have had any effect on the number of news stories on Chinese long-term contracts, its effects on actual contracts, shorter-term contracts, and future demand are uncertain. What has changed is the composition of Chinese crude oil imports. In 2016, Russia became the top supplier of crude oil to China, displacing Saudi Arabia for the first time since 2007 (Downs 2017). Strategic spot sales to teapot refiners can be used as part of a strategy to expand the list of trusted customers and to win back market share.

Not all of Russia's increase in its share of Chinese crude oil imports was due to its marketing efforts. Saudi Arabia reduced its total exports from 2,750.9 million barrels in 2016 to 2,620.4 million barrels in 2017, while Russia increased its total exports from 2,008.4 million barrels to 2,031.8 million barrels over the same period. While Saudi Arabia reduced its total oil exports, it increased its exports to China from 373.8 to 382.6 million barrels, thereby increasing China's share of its total exports from 13.59% to 14.6% (BP 2017).

Project Assumptions: The Reference Case NPV of Spot Crude Oil Sales to Teapot Refineries From a Joint Stockpiling Facility in Asia

An analysis of spot crude oil sales from an MEP should take into account the implications, if any, of regional, or global, crude oil prices and of the MEP's existing volume of term oil sales. As a result, the analysis must be conducted relative to a well-defined 'base case' or starting positon. This section defines the assumptions underlying the starting position for this analysis. To be precise, it outlines the assumptions underlying the base case reference NPV of spot crude oil sales from a storage facility located close to several Chinese teapot refineries from the perspective of a major MEP subject to a strict production quota.

Note: The number of spot oil sales from Middle East producing countries to Chinese teapot refineries has been rising steadily since 2016. On April 25, 2016, Reuters reported what might well be the first crude oil cargo of spot sales from Saudi Aramco to an independent Chinese refinery. The 730,000 barrel cargo was lifted from Okinawa, in Japan, and shipped to Shandong Chambroad Petrochemicals Co., a teapot refiner (Chen 2016).

Following the methodology utilized in Considine et al. (2019) the primary assumptions underlying the calculation of the base or reference case NPV are as follows:

1. The main port of transit for Middle East crude (Ras Tanura [RT]) is located more than 25 sailing days away from key markets in Asia, such as in Qingdao, China. The joint oil stockpiling facility, similar to Okinawa, is located near to the teapot refineries, only three sailing days away from Qingdao.

2. The MEP can store approximately 6.2 MMbbl of crude oil free of charge throughout the project's lifetime.

3. In return for the free use of storage facilities, the owner gets a priority claim on the oil stocks in case of an emergency.

4. The storage facility owner can claim the crude oil storage as quasi-government inventory so that about 50% of the oil stored is counted as part of their national strategic crude oil reserves (Reuters 2016).

5. The value of utilizing the joint storage facilities for commercial purposes derives primarily from its proximity to key markets in Asia. A three-day sailing trip permits the sale of spot crude to the area. From the perspective of the MEP, this adds considerable value as the voyage from a major oil export port to Qingdao takes well over 25 days and would be prohibitively long for spot sales to the area. For further details on the project assumptions see Considine et al. (2019).

6. The commercial portion of the storage can be cycled (injections and withdrawals of all 'commercial storage') at least six times a year.

Project Assumptions: The Reference Case NPV of Spot Crude Oil Sales to Teapot Refineries From a Joint Stockpiling Facility in Asia

Under the terms of our hypothetical agreement, the volumes of crude oil supplies held in storage by the MEP can be used to supply Asian customers on a term basis, for term sales or long-term deals signed months in advance. The use of storage for spot sales from the MEP during times of high oil prices is relatively new and adds considerable value to the joint storage agreement. Concerning the effects of an increased supply of crude on the crude oil price, the study assumes liquid forward and futures markets, so that all of these operations can be completed and hedged at the market prices at the time of execution. Finally, a number of factors leading to tight markets and supply and demand shocks can contribute to a sudden and short-term increase in spot prices in Asia. For example, independent refiners in China are often caught short, struggling for supply at the end of the year as they try to meet the provincial government's crude oil import targets (Platts 2016).

Tabel 2. NPV of spot crude oil sales to teapot refineries.

		2018	2019	2020	2031	2032	XNPV
Physical quantities million barrels							
Storage capacity		6.20	6.20	6.20	6.20	6.20	
Required strategic oil		3.10	3.10	3.10	3.10	3.10	
Slippage	0.99						
Percent of strategic oil required	50%						
Physical quantities million barrels							
Storage capacity		6.13	6.13	6.13	6.13	6.13	
Required strategic oil		3.07	3.07	3.07	3.07	3.07	
Contract revenue							
Crude oil futures Dubai		$83.82	$83.82	$83.82	$83.82	$83.82	
Arab Light		$84.94	$84.94	$84.94	$84.94	$84.94	
Volume of Arab Light	33%	1.02	1.02	1.02	1.02	1.02	
Assumed % of Arab Light							
Arab Medium		$83.43	$83.43	$83.43	$83.43	$83.43	
Volume of Arab Medium	33%	1.02	1.02	1.02	1.02	1.02	
Assumed % of Arab Medium							
Arab Heavy		$81.21	$81.21	$81.21	$81.21	$81.21	
Volume of Arab Heavy	33%	1.02	1.02	1.02	1.02	1.02	
Assumed % of Arab Heavy							

Project Assumptions: The Reference Case NPV of Spot Crude Oil Sales to Teapot Refineries From a Joint Stockpiling Facility in Asia

		2018	2019	2020	2031	2032	XNPV
Total revenue							
Spot sales revenue AL $million		$87.02	$87.02	$87.02	$87.02	$87.02	
Spot sales revenue AM $million		$85.22	$85.22	$85.22	$85.22	$85.22	
Spot sales revenue AL $million		$82.95	$82.95	$82.95	$82.95	$82.95	
Total revenue		$255.19	$255.19	$255.19	$255.19	$255.19	$3,826.46
Inflation	2.5%						
Costs of crude oil supplies							
Crude oil supplies							
Production costs per barrel							
Production costs per barrel	3.50	$10.74	$11.00	$11.28	$14.80	$15.17	
Transportation cost from RT to Okinawa	1.67	$5.11	$5.23	$5.37	$7.04	$7.22	
Operating expenses							
Operating	0.52	$0.52	$0.53	$0.54	$0.71	$0.73	
Other	0.50	$0.50	$0.51	$0.53	$0.69	$0.71	
Facilities	$-	$-	$-	$-	$-	$-	
Total operating expenses		$16.86	$17.28	$17.71	$23.24	$23.82	
Gross income: EBITDA		$238.34	$237.91	$237.48	$231.95	$231.37	$3,524.28
NPV		**$233.66**	**$462.34**	**$686.12**	**$2,850.54**	**$3,022.45**	
Optionality call options total revenue							
Revenue from spot sales of Arab Light $/bbl	30%	9.58	9.58	9.58	9.58	9.58	
Revenue from spot sales of Arab Medium $/bbl	40%	0.01	0.01	0.01	0.01	0.01	
Revenue from Spot Sales of Arab Heavy $/bbl	30%	0.88	0.88	0.88	0.88	0.88	
Percent of storage capacity	50%	3.07	3.07	3.07	3.07	3.07	
Total revenue from options $ million		**$10.47**	**$10.47**	**$10.47**	**$10.47**	**$10.47**	**$156.94**
Alternative optionality total revenue							
Total value of option		$10.47	$10.47	$10.47	$10.47	$10.47	
Intrinsic value of SPR		$238.34	$237.91	$237.48	$231.95	$231.37	
Option value = total value of option plus intrinsic value		$248.80	$248.38	$247.95	$242.42	$241.84	
Gross income: EBITDA		$248.80	$248.38	$247.95	$242.42	$241.84	$3,681.22
NPV		**$243.92**	**$482.66**	**$716.31**	**$2,977.25**	**$3,156.94**	

Note: Values for 2021-2029 are not reported for the sake of brevity but are available from the authors on request. The definition of XNPV is provided in Appendix B.
Source: KAPSARC calculations.

Project Assumptions: The Reference Case NPV of Spot Crude Oil Sales to Teapot Refineries From a Joint Stockpiling Facility in Asia

In this case study, the joint storage facility can accommodate 6.2 MMbbl of crude and oil products. Assuming 50% of these volumes are reserved for strategic stockpiles, and slippage of 1%, about 3.07 MMbbl can be used for spot crude oil sales to Asian markets (potential slippage is due to leaks and errors in the physical drawdown procedure).

The project yields an expected value for gross income earnings before interest, tax, depreciation and amortization (EBITDA) expected net present value (XNPV) of approximately $3.5 billion at a 2.5% discount rate. This is with crude oil production costs of $3.50/bbl, transportation costs from the MEP to the strategically located storage facility of $1.67/bbl and assumed spot crude oil sales FOB at Okinawa of 40% of the available capacity of Arabian Medium, 30% of Arabian Heavy and 30% of Arabian Light crude.

Table 2 illustrates the assumptions underlying these projections, including the free lease of crude oil storage, 50% strategic oil requirements and sales of 3.07 MMbbl per year.

Crude oil feedstock for Chinese teapot refiners is assumed to be equally allocated between three types of Arabian crude oil: heavy, medium and light. This is a valid assumption, as the mix of crude oil employed by the teapot refiners varies significantly according to market conditions. The mix has included Russian ESPO with a sulfur content of 0.62%, Venezuelan Tia Juana Heavy with 2.66% sulfur, and a number of diverse crude grades from Saudi Arabia, Africa, and Latin America (Tan 2016).

The futures curve for Dubai crude was used to estimate the futures curves for Arabian crudes (CME Group 2016). The relationship between Arabian Medium and Dubai Mo01 was estimated by two variable regression analyses. The relationship between Brent and the minimum price of light, medium and heavy crudes from competing areas was estimated using a similar method. The formulas for the minimum price of light, medium, and heavy crudes, and the results of these regressions are described in detail in Considine et al. (2019).

The Potential Value of Spot Oil Sales to Teapot Refineries From a Joint Stockpiling Leasing Agreement: A ‘Spread Option’

The potential incremental or fair market value of the strategic spot oil sales can be estimated by calculating how much a market player (consumer or customer) would pay to secure the right to purchase crude oil from the MEP at the strategically located stockpile (Carmona and Durrleman 2003). That value, in turn, will depend on the price of crude oil from competitors around the world and can be estimated as a simple European spread option.

Potential customers for this option include trading companies, refiners and shipping companies that are interested in hedging their shipping costs. They also include refiners hoping to lock in a lower price for their spot oil sales and hedge their transportation costs from the joint oil stockpiling facility to Quingdao. The position can also be layered on synthetically by speculative traders, such as Vitoil or Mercuria, and hedged on the Intercontinental Exchange (ICE) and the New York Mercantile Exchange (NYMEX).

The price p, or the fair market value of the European spread option, is given by the following equation, which is derived in detail in Appendix B.

$$p = e^{-rT} \iint (s_2 - s_1 - K)^+ f_T(s_1 s_2) d_{s_1} d_{s_2}$$

1-7:

Where:

1. K = The exercise price level: The cost of freight to transport crude from the storage facility to a major Asian market such as Qingdao.
2. T = The expiration date: The option is expected to expire two months after the value or settlement date.
3. $S_1(0)$ = The price of crude FOB at Qingdao port.
4. $S_2(0)$ = The price of Middle Eastern crude of comparable API FOB at the storage facility at time t.
5. r = The short-term risk-free interest rate.

The price of Arabian Heavy, Medium and Light (Platts 2016) plus the cost of sea transportation from the MEP to the strategically located storage facility of approximately $1.67/bbl is derived from KAPSARC calculations, with the distance calculated using the website www.sea-distance.org, and the cost estimated using the KAPSARC Global Trade Oil Model.

The study assumes that the transportation costs from the joint oil stockpiling facility to Qingdao are constant at 82 cents per barrel. As a result, it is possible to use the transportation cost as the exercise price. In an alternative formulation, the transportation costs can be added to the value of S2, and the exercise price can be set equal to zero. All of the asset prices here are quoted as free on board (FOB) so that the cost of delivering the goods to the FOB port is included, but the customer is responsible for shipping the goods from that point to the final destination.

Note: All the costs of getting to the final destination might be included in an alternative formulation of the option, including detailed interest costs on any borrowed funds, and transportation costs to the specific teapot refiners. It should be noted that the potential purchasers of the option, the refiners or customers, might prefer the simpler version outlined above. They might also prefer to handle those details themselves, as they might have their own fleet of boats and service providers, thereby enabling them to secure a lower cost and a higher value for the options. A trader fabricating the synthetic position can simply ignore these details, and use a combination of call and put options to simulate the position (Delany 2017).

A detailed listing of the inputs or exogenous variables used in this analysis is presented in Considine et al. (2019). The solution to the above equation, which is the price or fair market value of the option calculated for three separate grades of crude are:

1. Arabian Light vs. Minimum Light grade = $1.14/bbl

2. Arabian Medium vs. Minimum Medium grade = $0.00078/bbl

3. Arabian Heavy vs. Minimum Heavy grade = $0.10/bbl

The very low estimate of the value for the Arabian Medium vs. Minimum Medium grade arises from the prices used at the time of the estimation. The spot price for Arabian Medium was higher than the price of competing crudes, illustrating the fierce competition for market share in the region at that time.

As Table 2 shows, adding the options value increases the XNPV of the project by $157 million — well over 4% — to an XNPV of about $3.68 billion.

Sensitivity Analysis and Monte Carlo Simulations

Geopolitical and fiscal risks have the capacity to change the results of this analysis significantly. The key economic variables subject to commodity and transaction risks in the case of spot oil sales to Chinese teapot refineries include the grade of crude oil to be exported (heavy, medium or light), the amount of crude oil required to be maintained in the joint stockpiling facility at all times for strategic purposes, commodity prices, costs and the project discount rate. The following variables were selected for sensitivity analysis:

1. The gravity of the crude oil to be exported (heavy, medium or light).
2. The amount of crude oil required in the facility at all times for strategic purposes.
3. The project discount rate.
4. Slippage.
5. The production costs per barrel.
6. The transportation costs from RT to Okinawa.
7. Brent futures.
8. Dubai futures.

Probability density functions for these variables were estimated using historical data series and are described in detail in Appendix B (equations B1 and B2). The Monte Carlo simulations were performed utilizing a Mersenne Twister random number generator and a Latin hypercube sampling methodology.

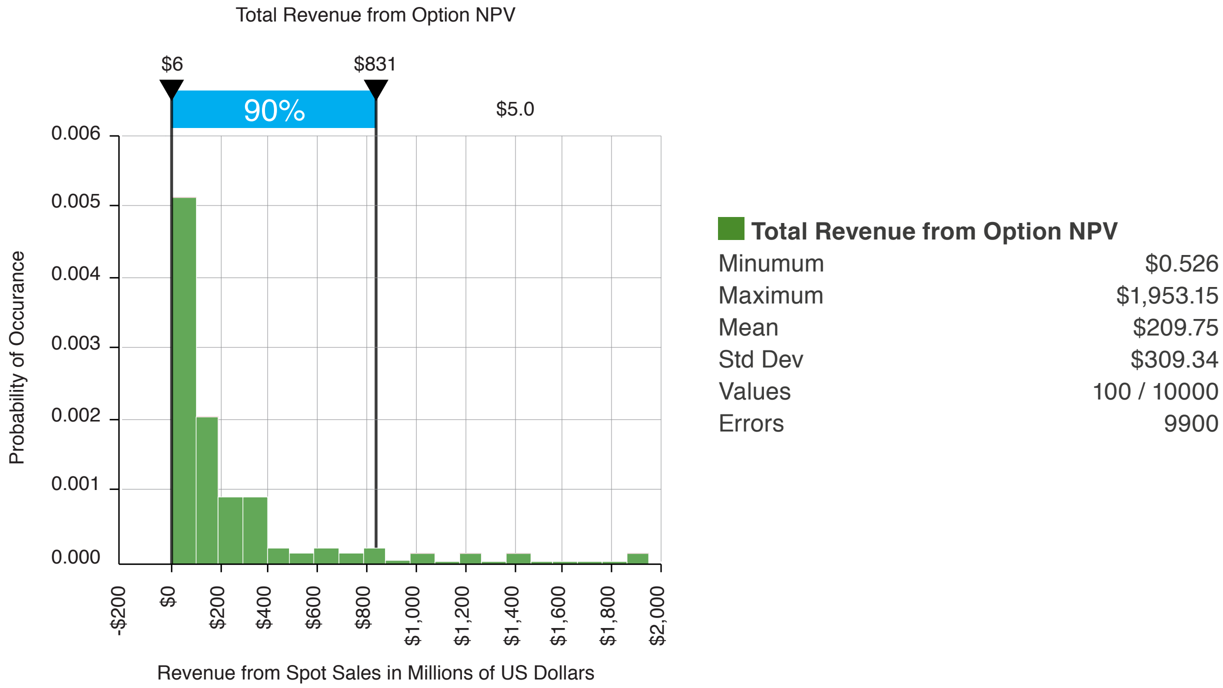
The results of the sensitivity analysis are summarized as follows. The potential value of the spot oil sales from the strategic stockpiling facility is equal to the XNPV of the reference case plus the XNPV of the options value shown in Table 2. Given crude oil production costs of $3.5/bbl, transportation costs from RT to Okinawa of $1.67/bbl and assumed spot crude oil sales FOB at Okinawa of 40% Arabian Medium, 30% Arabian Heavy and 30% Arabian Light crude, the project 'base' or reference case assumptions are an XNPV of $3.52 billion at a 2.5% discount rate.

Adding the optionality of spot oil sales has the potential to increase the XNPV gross revenue EBITDA of the project via spot sales by an expected $156.94, or 4.5%, to $3.68 billion.

Figure 6 illustrates the probability distribution of the potential gross revenue stream XNPV EBITDA of the option for spot sales, given the uncertainty of world oil markets and the probability distributions of the variables listed above (XNPV is defined in Appendix B).

Table B1 of Appendix B shows a comparison of the results of our analysis with and without the additional options value of strategic crude oil sales. As might have been expected, adding the optionality increases the minimum XNPV of the gross revenue via spot sales from $279.59 million to $938.05 million, thereby reducing the risk, or downside of the project significantly. The upside potential is considerable: There is a 5% probability that strategic spot oil sales could increase the gross income of the pre-existing project by an average of $830.89 million (Table 3).

Figure 6. Probability distribution of potential revenue streams from spot oil sales.



Sources: KAPSARC estimates; @Risk (Palisade).

Tabel 3. Gross income: EBITDA from strategic spot oil sales (million US$).

Statistics		**Percentile**	
Minimum	$0.53	5%	$5.66
Maximum	$1,953.15	10%	$11.24
Mean	$156.94	20%	$22.63
Std Dev	$309.34	30%	$45.80
Variance	95690.6282	40%	$72.55
Skewness	3.177837835	50%	$97.88
Kurtosis	15.37999068	55%	$122.35
Median	$97.88	60%	$136.32
Mode	$22.54	65%	$170.08
Left X	$5.66	70%	$195.77
Left P	5%	75%	$245.85
Right X	$830.89	80%	$296.65
Right P	95%	85%	$358.63
Diff X	$825.23	90%	$449.65
Diff P	90%	95%	$830.89

Sources: KAPSARC calculations; Monte Carlo simulations estimated using @Risk (Palisade).

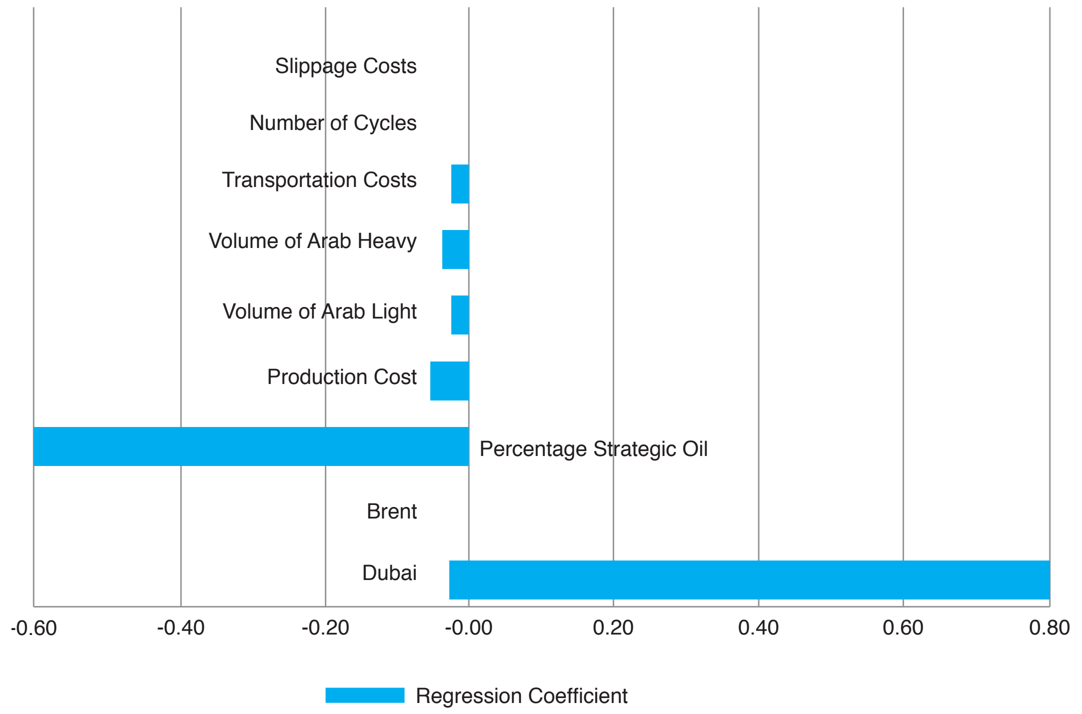
A sensitivity analysis was performed to illustrate the effects of economic uncertainty on the value of the incremental spot oil sales using stepwise multiple regression, to estimate the regression coefficients of the exogenous variables (Draper 1966). The results of this regression and the estimated regression coefficients are presented in Table 4, and figures 7 and 8.

The first variable to be considered is the amount of strategic oil supplies required to remain in the storage tanks at all times for emergency drawdown. A 1% increase in the amount of oil that must remain in storage reduces the gross income EBITDA plus the options value by well over $78 million.

The implications for gross income EBITDA for the project assumptions – the reference case level of straightforward term sales from the Okinawa storage facility — is significant. Even without the additional optionality offered by the ability to secure safe supplies of MEP crude at market prices, a 1% reduction in the amount of oil reserved for strategic purposes raises the expected income from the base case, or reference case, assumptions by more than $71 million.

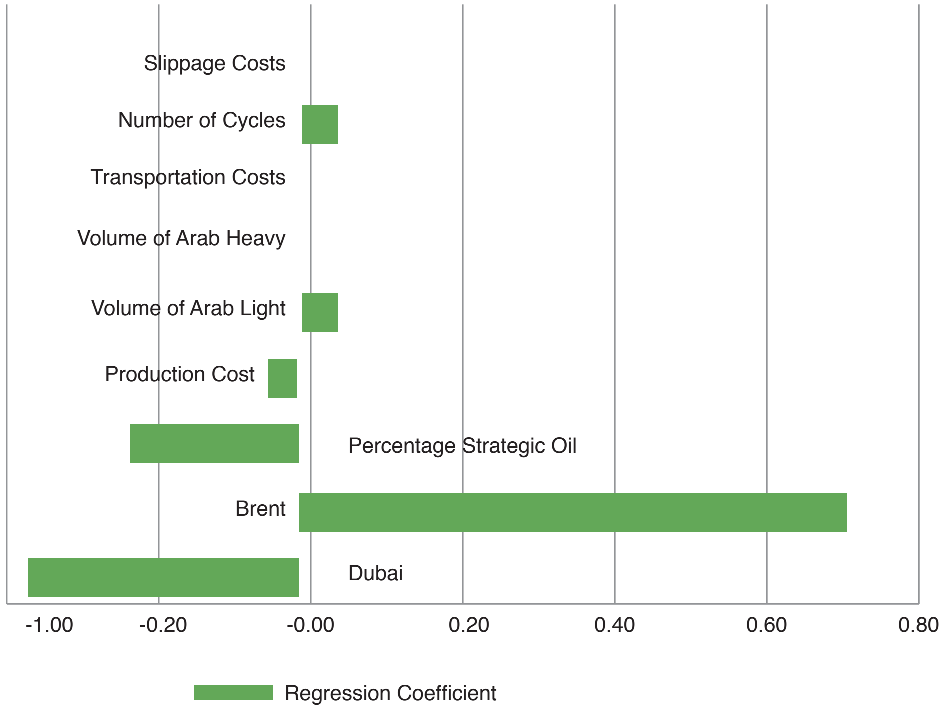
The next variable to be considered is the gravity of the crude oil sold. A 1% increase in the volume of light crude sold (approximately 31,000 barrels per strategic cycle) increases the value of the strategic crude oil sales FOB at Qingdao by approximately $1.25 million. A shift from medium-gravity crude to the heavy grades has the opposite effect, reducing the value of strategic sales by $1.25 million. A $1 increase in transportation costs (RT to Qingdao) and crude oil production costs reduces the project's value by over $92 million and $66 million, respectively.

Figure 7. Regression coefficient sensitivity analysis for gross income, assuming no optionality from strategic spot sales.



Sources: KAPSARC calculations; Monte Carlo simulations estimated using @Risk (Palisade).

Figure 8. Regression coefficient sensitivity analysis for gross income plus options value from spot sales.



Sources: KAPSARC calculations; Monte Carlo simulations estimated using @Risk (Palisade).

Another important variable is the forward curve for Dubai crude. Unsurprisingly, a $1 increase in the price of Dubai increases the value of the reference or base case without the additional optionality of strategic spot oil sales by approximately $47.50 million (Table 4).

The regression coefficients for gross income plus the options value of the strategic oil sales to teapot refineries depends on the spread, or difference, between spot prices for crude oil FOB at Okinawa and the minimum price of competing crudes FOB at Qingdao (Figure 2). In this case, it is the relative movement in prices that determine the ‘market’ value placed on the ability to reserve the right to purchase Arabian crude at spot prices at a future date in order to hedge or protect against sudden adverse price movements. Unsurprisingly, an increase in the price of Brent relative to Dubai adds significant value to the spot oil sales from the strategic joint stockpiling facility at Okinawa.

Holding everything else constant:

A $1.00 increase in the price of Brent M1 increases the XNPV of gross revenues EBITDA plus the options value by $100 million.

A $1.00 reduction in the price of Dubai increases the XNPV of the facility by $56 million.

Adding an extra cycle: Increasing the number of times the commercial volume of crude oil can be completely withdrawn from inventory and sold on the spot market by one cycle increases the gross income EBITDA by approximately $36.25 million.

Increasing the volume of light crude sold by 1% (approximately 31,000 barrels per strategic cycle) increases the gross income EBITDA plus the options value by $9.06 million. This suggests that there is considerable value to be derived from shifting strategic sales of spot crudes to lighter crudes when the market permits.

Tabel 4. Sensitivity analysis for gross income.

Sensitivity analysis for gross income EBITDA assuming no optionality

Variable	Standard deviation	Regression coefficient value	Coefficient in original units
Output variable			
Gross income EBITDA	1,526.27		
Input variables			
Dubai	25.70	0.80	$47.50
Brent	26.17		
Percent strategic oil	0.12	-0.57	-$71.75
Production costs	0.69	-0.03	-$66.09
Volume of Arab Light	0.12	0.01	$1.26
Volume of Arab Heavy	0.12	-0.01	-$1.26
Transportation costs	0.07	0.00	$91.95
Number of cycles	3.46		
Slippage costs	0.69		

Sensitivity analysis for gross income EBITDA plus optionality

Variable	Standard deviation	Regression coefficient value	Coefficient in original units
Output variable			
Gross income EBITDA	1,526.27		
Input variables			
Dubai	25.70	0.80	$47.50
Brent	26.17		
Percent strategic oil	0.12	-0.57	-$71.75
Production costs	0.69	-0.03	-$66.09
Volume of Arab Light	0.12	0.01	$1.26
Volume of Arab Heavy	0.12	-0.01	-$1.26
Transportation costs	0.07	0.00	$91.95
Number of cycles	3.46		
Slippage costs	0.69		

Sources: KAPSARC calculations; Monte Carlo simulations estimated using @Risk (Palisade).

Alternative Scenario 1: Spot oil sales result in a 2.5% reduction in world oil prices

In Alternative Scenario 1, the assumption is that the increase in the sale of spot crude to China results in a permanent 2.5% reduction in the prices of Brent and Dubai crude. Given spot oil sales are priced at the official Middle Eastern selling price, which is tied directly to Dubai crude, a reduction in the price of Dubai crude has direct implications for the future trajectory of gross revenues from crude oil sales. The analysis assumes an oil price elasticity of 0.11, implying an exogenous increase in the global crude oil supply of approximately 275,000 bbl/d in spot oil sales to teapot refiners (Kilian and Murphy 2014; Caldara, Cavallo, and Lacoviello 2016; Board of Governors of the Federal Reserve System et al. 2016).

A $1 reduction in the price of Dubai crude reduces the value from the reference case, or base case, assumption crude sales FOB at Qingdao by approximately $47.5 million (see Table 4). With Dubai crude oil prices reported at $71.14 per barrel on August 12, 2018, a 2.5% reduction in world oil prices would reduce the gross income EBITDA from spot crude oil sales by $85 million over the project's lifetime (Oil Price 2018). This figure may be an overestimate. A major crude oil producer anticipating a reduction in crude oil prices could easily take measures to hedge against this well in advance of the announcement of spot oil sales.

The negative effects of a reduction in world oil prices from increased supply can be mitigated by an increase in the volume of light crudes sold to teapot refineries. Increasing the volume of light crude sold by 1% (approximately 31,000 bbl per strategic cycle) increases the gross income EBITDA by $9.06 million. This suggests that there is considerable value to be derived from shifting strategic sales of spot crudes to teapot refineries to lighter crudes when market conditions are favorable. Indeed, the glut of diesel on Chinese markets in September 2016 led several teapot refineries to search for sweeter cargoes of lower-sulfur crude with high gasoline yields from Africa and Russia (ESPO) (Mathonniere 2016).

The implications for existing, future term and long-term contracts are not as transparent. There will be no change in total crude oil production if existing production quotas persist. The diversion of crude oil supplies to Asia may result in an effective increase in the price of Brent (and competing crudes) relative to Dubai and the 'official' or spot prices for Arabian crudes FOB at Okinawa. These relative changes will have significant implications for the options value of spot oil sales, which depends on the spread – or difference – between spot prices for Arabian crudes FOB at Okinawa and the minimum price of competing crudes FOB at Qingdao (see Figure 2).

As mentioned above, a $1.00 increase in the price of Brent M1 (relative to Dubai) increases the XNPV of gross revenues EBITDA plus the options value by $100 million. With Brent currently trading at levels as high as $72.57 (Bloomberg 2018), a 2.5% increase in the price of Brent would increase the XNPV of gross revenues EBITDA plus the options value by $181 million. Alternatively, a 2.5% reduction in the price of Dubai crude (relative to Brent) increases the XNPV of the facility by $99.5 million. The effects of the Dubai crude price movement are realized through the pricing mechanisms for the official prices of Arabian crude. In both cases, the increase in the XNPV of gross oil revenues — existing sales plus the incremental spot oil sales — is positive.

Alternative Scenario 2: Spot oil sales Result in a 2.5% Increase in World Oil Prices

Alternative Scenario 2 assumes that the sale of spot crude to China results in a permanent 2.5% increase in world oil prices. A $1 increase in the price of Dubai crude increases the value of the crude sales FOB at Qingdao by approximately $47.5 million (see Table 4). With Dubai crude oil prices reported at $71.14 per barrel on August 12, 2018, a 2.5% increase in world oil prices would increase the gross income EBITDA from the reference case term oil sales by $85 million over the project's lifetime (Oil Price 2018).

Once again, binding production quotas should result in no increase in global production, and world oil prices should remain constant over the longer term. In the short run, the increase in spot sales to the region has the potential to result in a future increase in the relative price of Dubai crude, or an effective reduction in the price of Brent relative to Dubai. This would likely be the result of a displacement of spot crude oil sales from alternative suppliers, such as Russia. A $1.00 increase in the price of Brent M1 (relative to Dubai) increases the XNPV of gross revenues EBITDA plus the options value by $100 million. Similarly, a $1 increase in the price of Dubai crude (relative to Brent) reduces the XNPV of the facility by $56 million.

These potential losses can be partially offset by either:

(i) An increase in long-term term contracts to the region. As mentioned previously, each dollar increase in Brent crude oil results in a 0.61 increase in the number of news reports and documents citing Chinese long-term crude oil contracts.

(ii) An increase in the volume of spot sales of lighter crude oil to teapot refiners.

In the final analysis, regardless of the market conditions, a strategic deployment of spot oil sales to Chinese teapot refiners, taking the gravity of the crude oil sales into account, could potentially add considerable value to a major Middle Eastern producing company with existing term and long-term contracts in the region.

Conclusion

The ability to conduct spot sales from a strategically placed storage facility to capture market share in new and emerging markets, such as the Chinese teapot refineries, represents a potential source of value to crude oil producers and marketers. That value can be estimated for a variety of facilities and under a number of different market conditions using the valuation method developed in this case study. The potential value from these strategic spot sales will depend on several factors, including the volatility of crude oil prices, the gravities of crude targeted, and the proximity of alternative suppliers.

A joint stockpiling facility located close to the teapot refiners in China holds substantially more value than a simple net present value calculation would suggest, given its potential for numerous sales of crude oil. The potential fair market value of spot oil sales from the joint oil storage facility depends on the price of crude oil from global competitors; it can be estimated as a simple European spread option.

Our analysis follows the methodology presented in Considine et al. (2019). Given (i) crude oil production costs of $3.5/bbl barrel, (ii) transportation costs from RT to Okinawa of $1.67/bbl, (iii) assumed spot crude oil sales FOB at Okinawa of 40% Arabian Medium, 30% Arabian Heavy and 30% Arabian Light crude, and (iv) a base case or reference value of existing crude term and long-term crude oil sales of $3.52 billion.

> Adding the optionality of strategic spot oil sales has the potential to increase the XNPV gross revenue EBITDA of the project via spot sales by an expected $156.94 million, a significant 4.5%.

> The amount of strategic oil supplies required to remain in storage tanks at all times, in case of an emergency drawdown, is the variable with the most impact on the net present value of spot oil sales.

> The next most important variable is the gravity of the crude oil sold. A 1% increase in the volume of light spot oil sales (approximately 31,000 barrels per strategic cycle) increases the value of the project by approximately $1.25 million.

> A shift from medium gravity crude to the heavy grades has the opposite effect, reducing the value of strategic sales by $1.25 million.

> A $1 increase in transportation costs (RT to Qingdao) and crude oil production costs reduces the project's value by over $92 million and $66 million, respectively.

> Another important variable is the forward curve for Dubai crude. Unsurprisingly, a $1 increase in the price of Dubai increases the value of the reference or base case assumptions by approximately $47.50 million.

The value of strategic spot oil sales to teapot refineries depends on the spread – or difference – between spot prices for crude oil FOB at Okinawa and the minimum price of competing crudes FOB at Qingdao (Figure 2). It is the relative movement in prices that determines the 'market' value placed on the ability to reserve the right to purchase Middle Eastern crude at spot prices at a future date, in order to hedge or protect against sudden adverse price movements. An increase in the price of Brent relative to Dubai crude adds significant value to the spot oil sales from the strategic joint stockpiling facility at Okinawa.

Holding everything else constant:

> A $1.00 increase in the price of Brent M1 increases the XNPV of gross revenues EBITDA plus the options value by $100 million.

A $1.00 reduction in the price of Dubai crude increases the XNPV of the facility by $56 million.

Adding an extra cycle, so increasing the number of times the commercial volume of crude oil can be completely withdrawn from inventory and sold on the spot market by one, increases the gross income EBITDA by approximately $36.25 million.

Increasing the volume of light crude sold by 1% (approximately 31,000 barrels per strategic cycle) increases the gross income by $9.06 million.

The analysis suggests that there is considerable value to be derived from shifting strategic sales of spot crudes to lighter crudes when the market permits.

Our case study shows clear benefits to the MEP from the strategic sale of spot crude to Chinese teapot refineries located in Shandong province. This is true for a comprehensive range of different assumptions and scenarios concerning future oil prices, and the impact of additional 'spot' volumes on regional and global crude oil prices. In the reference or base case scenario, spot prices generated by such sales are assumed to have no impact on either the term prices or volumes of term contracts. This is primarily the result of the assumption that the MEP is subject to strict production quotas.

The benefits are reinforced under the alternative scenario which assumes that increased spot sales to the region lead to a 2.5% reduction in world oil prices, and hence a reduction in the prices under term and long-term contracts for the MEP. While this result may be counterintuitive, it is not unlikely. In this case, increased spot sales to the region have the potential to affect the relative price of regional crude (Dubai) relative to Brent, thereby increasing the options value of the spot oil sales, which depend on the spread or difference between spot prices for Arabian crude oil and competing crudes.

In the final scenario, the increased spot sales to the region are assumed to result in a 2.5% increase in world oil prices and the price of term contracts. In this case, the relationship between regional crude oil prices and the volume of term contracts is slightly more complicated, but on balance, the total revenues from sales by the MEP are unlikely to be affected adversely. Any negative effects can be easily mitigated through the sale of lighter crude oil grades to teapot refineries.

In the final analysis, if existing production quotas persist, there will be no lasting implications for world oil prices due to the diversion of sales to the Asia Pacific Region. New customers and competitively priced strategic assets makes it possible for MEPs to expand their market shares and revenues for years to come.

Given the framework and model construction, there is considerable potential for further study and analysis, including:

1. Stochastic optimization techniques designed to maximize the options value through the choice of an optimal mix of heavy, medium and light crudes.
2. Stochastic optimization techniques designed to forecast the potential value from the sale of spot crudes, and its corresponding gravities, to selected markets in North America, Latin America, Asia and Europe.
3. Further sensitivity analysis investigating the effects of changes in tanker and rail transportation costs, crude oil production costs and storage charges.

Appendix A: National and Teapot Refineries

Select independent refiners' import quotas					
		Million tonnes per annum			
Location	Status	Refinery Name Operator	Capacity BBl/day	End 2016 quotas	End 2017 quotas
Huizhou, CN	Operational	CNOOC HuizhouChina National Offshore Oil Corp	441,205		
Dalian, CN	Operational	PetroChina DalPetroChina Co Ltd	411,123		
Guangzhou, CN	Operational	Sinopec GuangzChina Petrochemical Corp	314,860		
Quanzhou, CN	Operational	Sinopec QuanzhChina Petroleum & Chemical Corp	280,767		
Tianjin, CN	Operational	PetroChina RosChina National Petroleum Corp	261,069		
Gaoqiao, CN	Operational	Sinopec GaoqiaChina Petroleum & Chemical Corp	260,712		
China	Operational	PetroChina YunPetroChina Co Ltd	260,712		
Qinnanqu, CN	Operational	PetroChina GuaPetroChina Co Ltd	240,658		
Qingdao, CN	Operational	Sinopec QingdaChina Petroleum & Chemical Corp	240,658		
Mawei, CN	Operational	Sinochem QuanSinochem International Corp	240,000		
Beijing, CN	Operational	PetroChina FusPetroChina Co Ltd	230,630		
Lanzhou, CN	Operational	PetroChina LanPetroChina Co Ltd	210,575		
Nanjing city, CN	Operational	Sinopec NanjinChina Petroleum & Chemical Corp	210,000		
China	Operational	PetroChina UruPetroChina Co Ltd	200,548		
Dalian, CN	Operational	PetroChina DalPetroChina Co Ltd	200,548		
Liaoyang, CN	Operational	Liaoyang PetroChina National Petroleum Corp	200,548		
North China, CN	Operational	North China ReChina National Petroleum Corp	200,548		
Jilin, CN	Operational	PetroChina JiliPetroChina Co Ltd	200,548		
Pengzhouxiang, CN	Operational	PetroChina SichPetroChina Co Ltd	200,548		
Beijing, CN	Operational	Sinopec BeijingChina Petroleum & Chemical Corp	200,548		
Ningbo Daxie, CN	Operational	Ningbo Daxie PChina National Offshore Oil Corp	166,455		
Anqing, CN	Operational	Sinopec AnqingChina Petrochemical Corp	160,438		
Yueyang, CN	Operational	Sinopec YueyanChina Petrochemical Corp	160,438		
Heze, CNSD, CN	Operational	Dongming RefinShandong Dongming Petrochemical Gr	160,438		
Jinan City, CNSD, CN	Operational	Sinopec Jinan CChina Petrochemical Corp	160,438		
Luoyang, CN	Operational	Sinopec LuoyanChina Petroleum & Chemical Corp	160,438		
Shijiazhuang, CN	Operational	Sinopec ShijiazChina Petroleum & Chemical Corp	160,438		
Yanan, CNSX, CN	Operational	Yan'an RefinerYanchang Petroleum Group Co Ltd	160,000	2.4	1.2
China	Operational	Yulin Capacity Yanchang Petroleum Group Co Ltd	160,000	3.6	0
Ningxia, CN	Operational	Baota RefineryBaota Petrochemical Group Co Ltd	150,411	6.2	0.5
Liaoning province, CN	Operational	Petrochina JinzPetroChina Co Ltd	150,411		

Select independent refiners' import quotas

		Million tonnes per annum			
Location	**Status**	**Refinery Name Operator**	**Capacity BBl/ day**	**End 2016 quotas**	**End 2017 quotas**
Dongying, CNSD, CN	Operational	Huaxing RefineShandong Huaxing Petrochemical Grou	140,384	2.2	2.1
Liaoning, CN	Operational	Panjin RefineryPanjin Northern Asphalt Co Ltd	140,384	7	5.7
Huludao City, CN	Operational	PetroChina JinxPetroChina Co Ltd	140,384		
Beihai, CN	Operational	Sinopec BeihaiChina Petrochemical Corp	130,356		
Jiujiang, CNJI, CN	Operational	Sinopec JiujianChina Petrochemical Corp	130,356		
Weifang, CNSD, CN	Operational	Changyi RefineShandong Changyi PetroChemical Co L	120,329		
Hebei, CN	Operational	Xinhai RefineryHebei Xinhai Chemical Group Co Ltd	120,329	0	1.9
Henan, CN	Operational	Yongmei Coal HYongmei Coal Group Co Ltd	120,000	0	2.2
Zibo, CNSD, CN	Operational	Jincheng RefinShandong Jincheng Petrochemical Gro	118,323	0	1.5
Zibo, CNSD, CN	Operational	Huifeng RefineShandong Huifeng Petroleum Chemica	116,318	4.2	1.7
Dongying, CNSD, CN	Operational	Wantong RefineShandong Wantong Petrochemical Grou	116,318		
Weifang, CN	Operational	Hongrun RefineSinochem Hongrun Petrochemical Co L	114,312	5.3	5.1
Daqing City, CN	Operational	PetroChina DaqPetroChina Co Ltd	110,301		
Binzhou, CN	Operational	Binzhou RefineChina Offshore Bitumen Co Ltd	100,274		
North Huajin, CN	Operational	CNHCI RefineryNorth Huajin Chemical Industries Co	100,274		
Ningxia, CN	Operational	Ningxia PetrocChina National Petroleum Corp	100,274		
Changqing, CN	Operational	PetroChina ChaPetroChina Co Ltd	100,274		
Dagang, CN	Operational	PetroChina Dag	100,274		
Qingdao, CN	Operational	Qingdao RefineChina Petrochemical Corp	100,274		
Dongying, CNSD, CN	Operational	Tianhong RefinShandong Tianhong Chemical Co Ltd	100,274	4.4	3.8
Dongxing, CN	Operational	Dongxing RefinChina Petrochemical Corp	100,274		
Yinchuan, CN	Operational	PetroChina YinPetroChina Co Ltd	100,000		
Yueyang, CN	Operational	Sinopec YueyanChina Petroleum & Chemical Corp	100,000		
Taizhou, CN	Operational	Taizhou RefineChina National Offshore Oil Corp	90,247		
Harbin, CN	Operational	Harbin PetrochChina National Petroleum Corp	90,247		
Yanchuan, CN	Operational	YongPing RefinYanchang Petroleum Group Co Ltd	90,000		
Dongying, CN	Operational	Hualian RefinerDongying Hualian Petroleum & Chemic	80,219		
Dongying, CN	Operational	Yatong RefinerDongying Yatong Petrochemical Co Ltd	80,219	3.4	2
Qingyang, CN	Operational	Qingyang PetroChina National Petroleum Corp	74,203		

Sources: Energy Aspects; Bloomberg.

Appendix A: National and Teapot Refineries

Select independent refiners' import quotas					
		Million tonnes per annum			
Location	**Status**	**Refinery Name Operator**	**Capacity BBl/day**	**End 2016 quo-tas**	**End 2017 quo-tas**
Binzhou, CNSD, CN	Operational	Chambroad RefShandong Chambroad Petrochemicals	70,192	3.3	0.8
Cangzhou, CN	Operational	Sinopec CangzhChina Petrochemical Corp	70,192		
Gangkou, CN	Operational	Gangkou RefineRizhao Landbridge Gangkou Petrochem	70,192	1.8	1.8
Dongying, CN	Operational	Lijin Refinery CLiJin Petrochemical Plant Co Ltd	70,192	3.5	3.1
Dongying, CNSD, CN	Operational	Qicheng RefineShandong Qicheng Petroleum Chemica	70,192	0	1.6
Haiyou, CN	Operational	Haiyou RefinerShandong Haiyou Petrochemical Group	70,192	3.2	0.4
Dezhou, CNSD, CN	Operational	Hengyuan RefinShandong Hengyuan Petrochemical Co	70,192	3.5	1.8
Dongying, CN	Operational	Zhenghe RefineZhenghe Group Co Ltd	70,192		
Binzhou, CNSD, CN	Operational	Binyang RefineShandong Binhua Binyang Combustion	64,175		
Dongying, CNSD, CN	Operational	Dongfang RefinShandong Dongfang Hualong Industry	60,164	0	3
Dongying, CNSD, CN	Operational	Kenli Refinery Shandong Kenli Petrochemical Group C	60,164	2.5	2.2
Weifang, CNSD, CN	Operational	Luqing RefineryShandong Shouguang Luqing Petroche	60,164	2.6	2.2
Heze, CNSD, CN	Operational	Shengshi RefinShandong Yuhuang Chemical Co Ltd	60,164	2.5	1.3
Fanfgyu, CN	Operational	Fangyu RefinerShandong Fangyu Lubricating Oil Co Ltd	52,142		
Qingyishan, CN	Operational	Qingyishan RefShandong Qingyishan Petrochemical T	52,142		
Yumen, CN	Operational	Yumen RefinerChina National Petroleum Corp	50,137		
Weifang, CNSD, CN	Operational	Haihua RefinerShandong Haihua Group Co Ltd	48,132		
Rizhao, CNSD, CN	Operational	Shtar Refinery Shandong Shtar Science & Technology	46,126		
Binzhou, CNSD, CN	Operational	Zhonghai RefinShandong Zhonghai Fine Chemical Co	46,126	0	1.9
Dongying, CN	Operational	Keli Refinery CDongying Keli Chemical Co Ltd	44,121		
Fuyu, CN	Operational	Fuyu Refinery Shandong Fuyu Chemical Co Ltd	44,121		
Dongying, CNSD, CN	Operational	Shengxing RefiShandong Haihua Shengxing Chemical	44,121	0	2.2
Xintai, CN	Operational	Xintai RefineryZibo Xintai Petrochemical Co Ltd	44,121		
Baling, CN	Operational	Sinopec BalingChina Petrochemical Corp	40,110		
Weifang, CN	Operational	Lianmeng RefinShouguang Lianmeng Petrochemical C	40,110		
Qingjiang, CN	Operational	Qingjiang RefinChina Petrochemical Corp	40,110		
Xi'an, CN	Operational	Xi'an Refinery China Petrochemical Corp	40,110		
Dongying, CNSD, CN	Operational	Hengrunde RefShandong Hengrunde Petrifaction Co L	34,093		
Qingdao, CN	Operational	Anbang RefinerQingdao Anbang Refining & Chemical	32,088		
Daqing, CN	Operational	Daqing RefinerChina National Chemical Corp	30,082		
Dongying, CN	Operational	CNOOC RefineryChina National Offshore Oil Corp	30,082		
Golmud, CN	Operational	Golmud RefinerChina National Petroleum Corp	30,082		

Select independent refiners' import quotas					
		Million tonnes per annum			
Location	**Status**	**Refinery Name Operator**	**Capacity BBl/day**	**End 2016 quo-tas**	**End 2017 quo-tas**
Kinshi, CN	Operational	Kinshi RefineryShandong Kinshi Bitumen Co Ltd	30,082		
Taizhou, CN	Operational	Taizhou RefineChina Petrochemical Corp	30,082		
Binzhou, CNSD, CN	Operational	Tianhong RefinShandong Tianhong Chemical Co Ltd	30,082		
Tianjin, CN	Operational	Tianjin RefinerChina National Chemical Corp	26,071		
Eastar, CN	Operational	Eastar RefineryDongying Eastar Group Chemical Co Ltd	24,066		
Haiyue, CN	Operational	Haiyue RefinerShandong Haiyue Chemical Co Ltd	20,055	0	2.1
Yuanrun, CN	Operational	Yuanrun RefineShandong Yuanrun Petrochemical Co L	20,055		
Zhanjiang, CN	Operational	Zhanjiang BranChina National Offshore Oil Corp	16,044		
Qiwangda, CN	Operational	Qiwangda RefinShandong Qiwangda Petrochemical Co	15,145		
Hongyuan, CN	Operational	Hongyuan RefinGaoqing Hongyuan Petrochemical Co L	14,038		
Shenyang, CN	Operational	Shenyang RefinChina National Chemical Corp	14,038		
Nanchong, CN	Operational	Nanchong RefinChina National Petroleum Corp	14,009		
Dongming, CN	Operational	Dongming RefinShandong Dongming Petrochemical Gr	10,027	7.5	6.6
Jinan, CN	Operational	Jinan Refinery China National Chemical Corp	10,027		
Sichuan, CN	Operational	Sichuan RefineChina National Offshore Oil Corp	10,027		
Zepu, CN	Operational	Zepu Refinery China National Petroleum Corp	10,027		
Zhongyuan, CN	Operational	Zhongyuan RefChina Petrochemical Corp	9,466		
Shida, CN	Operational	Shida RefineryShandong Shida Technology Petrochem	8,022		
Dongying, CNSD, CN	Operational	Yikun RefineryShandong Yikun Chemical Co Ltd	8,022		
Hangzhou, CN	Operational	Hangzhou RefinChina Petrochemical Corp	7,573		
Huaxiang, CN	Operational	Huaxiang RefinShandong Huaxing Petrochemical Grou	7,573		
Changcheng, CN	Operational	Changcheng ReJinan Changcheng Refining Co Ltd	6,016		
Haoqing, CN	Operational	Haoqing RefineDonying Haoqing Petrochemical Co Ltd	6,016		
Huasheng, CN	Operational	Huasheng RefinShandong Huasheng Petrochemical Co	6,016		
Guangyuan, CN	Operational	Guangyuan RefLijin Guangyuan Bitumen Co Ltd	4,011		
Qingyuan, CN	Operational	Qingyuan RefinShandong Qingyuan Petrochemical Co	3,786	4	2
Yangzhou, CN	Operational	Yangzhou RefinChina Petrochemical Corp	3,408		
Dongying, CN	Operational	Mingyuan RefinDongying Mingyuan Chemical Co Ltd	2,005		
Guangzhou City, CN	Operational	Sinopec GuangzChina Petroleum & Chemical Corp As	288		
Total			**11,902,730.2**	**73.1**	**60.7**

Sources: Energy Aspects; Bloomberg.

Appendix B: Sensitivity Analysis and Monte Carlo Simulations

As shown in Considine et al. (2019), the use of stochastic modeling and Monte Carlo simulation to accommodate risks and uncertainties in crude oil projects is well documented (Nahmias 2016; Ellefsen 2008). Nischal (2010) employs stochastic modeling and Monte Carlo simulation to model a crude oil dispatch plan from a process plant in India. Kleindorfer (2013) uses Monte Carlo simulation to minimize commodity procurement risks through hedging tools designed to limit exposure to unanticipated movements in exchange rates and commodity prices.

As mentioned previously in the case of spot oil sales to Chinese teapot refineries, the key economic variables subject to commodity and transaction risks include the grade of crude oil exported (heavy, medium or light), the amount of crude oil required to be maintained in the joint stockpiling facility at all times for strategic purposes, commodity prices, costs and the project discount rate. The following variables were selected for sensitivity analysis:

1. The gravity of the crude oil exported (heavy, medium or light).

2. The amount of crude oil required in the facility at all times for strategic purposes.

3. The project discount rate.

4. Slippage.

5. Production costs per barrel.

6. Transportation costs from Ras Tanura to Okinawa.

7. Brent futures.

8. Dubai futures.

Uniform probability distributions were estimated for assumptions 1-6, and their resulting probability distributions are listed below:

1. The volume of light crude oil to be sold on the spot market ~ U (0.09,0.51)

2. The volume of heavy crude oil to be sold on the spot market ~ U (0.09,0.51)

3. Amount of strategic oil ~ U (0.29,0.71)

4. Slippage ~ U(0.981,0.998)

5. Discount rate ~ U(0.04,0.26)

6. Production costs per barrel ~ U(2.42,4.58)

7. Transportation costs Ras Tanura to Okinawa ~ U (1.55,1.78)

8. Operating costs ~ U (0.4,0.63)

Where X has a continuous uniform distribution:

$$X \backsim U(a,b) \qquad (B1)$$

and a = the endpoint of the left interval

b = the endpoint of the right interval

Daily estimates of historical futures prices were used to estimate the probability distributions of Brent and Dubai crude, using Platt's estimates of Brent M1 and Dubai Mo01 from Jan. 1, 2008 to Aug. 3, 2016 (Platts 2016). A number of probability distributions were fitted to the data, and the 'best fit' was determined using the Anderson-Darling test statistic, calculated as the average square distance between the empirical cumulative distribution function, and the fitted function, with special attention to the tails (Law 2001; Palisade 2012).

The resulting distributions are Kumaraswamy, which is perhaps unsurprising given the nature of Platt's data gathering and its connection with the distributions used in the field of hydrology, specifically the estimation of reservoir yield and storage distribution (Fletcher 1996; Aloui 2015; Javanshiri 2015).

Dubai Mo01 ~ Kw (2.3305,2.4455,16.038,141.55)

Brent M1 ~ Kw(2.0125,2.2961,24.798,146.45)

Where X has a continuous uniform distribution:

B2 $X \sim Kw(\alpha,\beta,\gamma,\delta)$

and α = shape parameter

β = shape parameter

γ = defined minimum

δ = defined maximum

The distributions were correlated using the 0.999 correlation coefficient estimated with historical data from Platts: Jan. 1, 2008 to Aug. 3, 2016.

Given the discounted net present value model presented in Table 2, Monte Carlo simulations were performed utilizing the probability distributions listed above, a Mersenne Twister random number generator (Matsumoto 1998), and Latin Hypercube sampling methodology (Mckay 1979). Table B1 presents the results of the Monte Carlo Simulation for gross income EBITDA with and without the options value.

Table B1. Value of strategic optionality summary statistics.

Gross income: EBIDTA without the optionality			
Statistics		**Percentile**	
Minimum	$279.59	5%	$1,259.77
Maximum	$8,623.66	10%	$1,620.14
Mean	$3,524.28	15%	$1,929.10
Std. dev.	$1,526.27	20%	$2,165.79
Variance	2329502.753	25%	$2,370.66
Skewness	0.406278373	30%	$2,584.08
Kurtosis	2.650714542	35%	$2,788.46
Median	$3,384.36	40%	$2,988.65
Mwode	$3,117.25	45%	$3,175.51
Left X	$1,259.77	50%	$3,384.36
Left P	5%	55%	$3,580.09
Right X	$6,263.98	60%	$3,792.33
Right P	95%	65%	$4,031.16
Diff X	$5,004.20	70%	$4,270.41
Diff P	90%	75%	$4,543.28

Appendix B: Sensitivity Analysis and Monte Carlo Simulations

Table B1. Value of strategic optionality summary statistics.

Gross income: EBIDTA with the optionality			
Statistics		**Percentile**	
Minimum	$938.05	5%	$1,419.27
Maximum	$7,655.10	10%	$1,856.22
Mean	$3,681.22	15%	$2,032.44
Std. dev.	$1,569.59	20%	$2,324.21
Variance	2463615.839	25%	$2,483.76
Skewness	0.454917948	30%	$2,727.54
Kurtosis	2.567410032	35%	$2,840.44
Median	$3,532.11	40%	$2,934.30
Mode	$2,064.61	45%	$3,233.13
Left X	$1,419.27	50%	$3,532.11
Left P	5%	55%	$3,729.46
Right X	$6,387.63	60%	$3,903.44
Right P	95%	65%	$4,082.01
Diff X	$4,968.35	70%	$4,334.70
Diff P	90%	75%	$4,936.82

Sources: KAPSARC calculations; Monte Carlo simulations. Estimated using @Risk (Palisade).

Calculation of XNPV for non-periodic cash flows

When cash flows are not necessarily periodic, as is the case for the incremental spot sale provided here, the XNPV can be calculated for the project as follows:

Where:

$$XNPV = \sum_{i=0}^{T} \frac{P_i}{(1+r_t)^{\frac{d_i - d_0}{365}}}$$

P^i= the i^{th} payment

d_i= the i^{th} payment date

d_0= 0^{th} payment date

Note: The XNPV uses actual dates to determine the timing of cash flows, thus providing a more accurate result when cash flows are sporadic. As a result, although the cash flows in this example would appear to be regular, there is no cost to using XNPV in this example. In fact, there is considerable benefit in using it as it draws the reader's attention to the fact that cash flows from spot sales can easily be sporadic and would then require the use of the XNPV formula (Blackwood 2017).

Appendix C: Estimating the Relationship Between Chinese Long-Term Contracts, the Spot Price of Brent, and the Rise of the Teapot Refineries

As mentioned above, the relationship between Chinese long-term contracts, the spot price of Brent, and the rise of the teapot refineries was estimated by a simple three variable regression analysis on the number of documents and reports counted by Factiva analysis, the spot price for European Brent (FOB), and a dummy variable accounting for the rise of the teapot refineries between 2015-17. Table C1 presents the results of this analysis.

Table C1. Regression results: Chinese long-term contracts vs the spot price of Brent.

Gross income: EBIDTA with the optionality						
Multiple regression for documents	**"Multiple R"**	**R-square**	**"Adjusted R-square"**	**"Std. err. of estimate"**		
Summary						
	0.8882	0.7889	0.7738	11.81882529		
	"Degrees of Freedom"	"Sum of Squares"	"Mean of Squares"	F	p-Value	
ANOVA Table						
Explained	2	14615.60452	7307.80226	52.31643736	< 0.0001	
Unexplained	28	3911.169674	139.6846312			
	Coefficient	"Standard Error"	t-Value	p-Value	Confidence Interval 95%	
Regression Table					Lower	Upper
Constant	-7.871220217	3.677934236	-2.140119891	0.0412	-15.40512697	-0.337313461
Europe Brent Spot Price FOB (Dollars per Barrel)	0.615855885	0.06591885	9.342636923	< 0.0001	0.480827241	0.750884529
Date > = 2015	26.97244476	7.186709342	3.753100824	0.0008	12.25113801	41.6937515

Note: Brent was chosen as a benchmark for this analysis, due to an increasing number of crude oil contracts using dated Brent as a reference price since 2008. This trend was primarily due to a decline in production from major crude oil fields in Asia traditionally used as benchmarks, including Malaysia Tapis crude, and Indonesian Minas and Duri (Giaever-Enger and Booth 2008).

References

Aizhu, Chen, and Meng Meng. 2018. "China's independent refiners embrace old friend fuel oil as taxes, rising crude, bite margins." *Reuters*, May 23. https://www.reuters.com/article/us-china-oil-tax-independents-idUSKCN1IO17S

Blackwood, Neale. 2017. "Get More Accurate Results with Excel's XNPV Function." March. https://www.intheblack.com/articles/2017/03/01/accurate-excel-xnpv-function

Bloomberg. 2018. "Energy - Bloomberg." August 13. https://www.bloomberg.com/energy.

Board of Governors of the Federal Reserve System, Dario Caldara, Michele Cavallo, and Matteo Iacoviello. 2016. "Oil Price Elasticities and Oil Price Fluctuations." *International Finance Discussion Papers* 2016 (1173): 1–59. https://doi.org/10.17016/IFDP.2016.1173

BP. 2017. "BP Statistical Review of World Energy 2017." https://www.bp.com/content/dam/bp-country/de_ch/PDF/bp-statistical-review-of-world-energy-2017-full-report.pdf

Caldara, Dario, Michele Cavallo, and Matteo Iacoviello. 2016. "Oil Price Elasticities and Oil Price fluctuations." EIA Workshop (September): 15.

Chen, Aizhu. 2016. "UPDATE 1-Aramco in first spot crude sale to Chinese teapot refiner." *Reuters*, April 25. https://af.reuters.com/article/commoditiesNews/idAFL3N17S2UT.

Considine, Jennifer, Kang Wu, Ziyad Al-Fawzan, and Sammy Six. 2019. "Placing a Value on Spot Sales from a Joint Oil Stockpiling Facility." KAPSARC discussion paper.

Delany, Gary. 2017. "Suit Yourself: Don't Ignore Flexibility of Synthetic Option Strategies." TradingFloor.com, February 28. https://www.tradingfloor.com/posts/suit-yourself-dont-ignore-flexibility-of-synthetic-ption-strategies-8496762

Deposit. 2018. "Middle East Interest Rates - Compare Middle East and GCC Bank Rates." June 2018. https://middle-east.deposits.org/

Downs, Erica. 2017. *The Rise of China's Independent Refineries*. New York: Center on Global Energy Policy, School of International and Public Policies, Columbia University.

Energy Information Administration (EIA). 2017. "Spot Prices for Crude Oil and Petroleum Products." October 4. https://www.eia.gov/dnav/pet/PET_PRI_SPT_S1_M.htm

GACC. 2017. "Statistics - GACC." 2017. http://english.customs.gov.cn/Statistics/Statistics?ColumnId=7

Giaever-Enger, Thomas, and Daniel Booth. 2008. "Dated Brent as a solution to pricing of crude oil in Asia," October. https://www.platts.com/IM.Platts.Content/InsightAnalysis/IndustrySolutionPapers/datedbrentasia.pdf

Gilbert, Bert. 2017. "Storm in a Teapot: Smaller China Refiners Shake up World Markets." *Bloomberg Professional Services*, April 24. https://www.bloomberg.com/professional/blog/storm-teapot-smaller-china-refiners-shake-world-markets/

Hume, Neil, and David Sheppard. 2017. "Oil trading surge strengthens grip of big commodity houses." *Financial Times*, March 26. https://www.ft.com content/1f12b950-1085-11e7-a88c-50ba212dce4d

Kaminska, Izabella. 2013. "The decline of the oil spot market?" *Financial Times*, April 24. Accessed October 1, 2017. http://ftalphaville.ft.com/2013/04/24/1469422/the-decline-of-the-oil-spot-market/

Kayrros. 2018. "Why Is Oil Building Up Along China's Coast?" May 3. https://medium.com/@kayrros/why-is-oil-building-up-along-chinas-coast-ad50e1d13c89

Kilian, Lutz, and Daniel P. Murphy. 2014. "The Role of Inventories and Speculative Trading in the Global Market for Crude Oil: Speculation in Oil Markets." *Journal of Applied Econometrics* 29 (3): 454–78. https://doi.org/10.1002/jae.2322

Kumagai, Takeo. 2016. "Saudis Ship from Okinawa to China, Japan." Platts Oilgram News, July 15. https://pmc.platts.com/Article.aspx?nl=Oilgram%20News&id=b6fbbbfe-fd08-44de-b9ba-8d6062fd754b

Mathonniere, Julien. 2016. "Sweet and Sour Crude Expectations on Chinese 'Teapots' Tax Crackdown." September 13. https://www.linkedin.com/pulse/sweet-sour-crude-expectations-chinese-teapots-tax-julien-mathonni%C3%A8re/

Meidan, Michal. 2017. "China's Independent Refiners: A New Force Shaping Global Oil Markets." Oxford Institute for Energy Studies. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/05/Chinas-Independent-Refiners-A-New-Force-Shaping-Global-Oil-Markets-OIES-Energy-Insight.pdf

OilPrice.com. 2018. "Oil Price Charts." Accessed August 12, 2018. https://oilprice.com/oil-price-charts.

Paraskova, Tsvetana. 2017. "China's Refinery Run Rates At 10-Month Low." OilPrice.com, August 14. https://oilprice.com/Latest-Energy-News/World-News/Chinas-Refineries-Run-Rates-At-10-Month-Low.html

———. 2018a. "Chinese 'Teapot' Oil Refiners Prepare For Ethanol Blending." OilPrice.com, March 20. https://oilprice.com/Latest-Energy-News/World-News/Chinese-Teapot-Oil-Refiners-Prepare-For-Ethanol-Blending.html

———. 2018b. "China's Oil Demand Could Take A Big Hit." OilPrice.com, June 13. https://oilprice.com/Energy/Energy-General/Chinas-Oil-Demand-Could-Take-A-Big-Hit.html

Raval, Anjli, and Neil Hume. 2017. "China's 'teapot' oil refiners feel the heat as competition grows." *Financial Times*, September 27. https://www.ft.com/content/5a78b594-a365-11e7-9e4f-7f5e6a7c98a2

Tan, Florence. 2016. "Russian ESPO crude falls out of favour with China teapot refiners." *Reuters*, May 13. https://www.reuters.com/article/russia-china-oil-idUSL3N17W3NJ

———. 2018. "Saudi plans first change in Asia crude oil price formula in decades, to use DME Oman." *Reuters*, July 4. https://www.reuters.com/article/us-saudi-asia-oil-prices-idUSKBN1JU1MK

Xiu, Daisy. 2017. "Shandong Independent Refineries Boost Oil Product Sales in October." Platts Oilgram News, November 13. https://pmc.platts.com/Article.aspx?nl=Oilgram%20News&id=714a6a96-56cc-4e78-bd9d-01009a1954a7

Zhou, Oceana, and Mriganka Jaipuriyar. 2018. "FACTBOX: China's Recent Refining Sector Policy Timeline." S&P Global Platts Market Center, February.

Notes

Notes

About the Author

Jennifer Considine

Jennifer is a visiting researcher at KAPSARC and a senior research fellow at the Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP) in Dundee, Scotland. She has led a number of research projects involving options pricing, real options valuations of physical assets including electricity generation facilities, storage companies, and natural gas pipelines and contracts, risk management and hedging techniques, and trading strategies for a variety of commodities including natural gas, electricity and crude oil.

Kang Wu

Kang is a former program director for Markets and Industrial Development at KAPSARC, with many years of energy research and consulting experience. His ongoing research covers a variety of issues related to economic, energy (particularly oil and gas) and environmental developments in China and the rest of the Asia-Pacific region. Kang speaks at international conferences, forums, workshops and training programs, and his research has been cited by international media, including Time magazine, the Wall Street Journal, New York Times, Asian Wall Street Journal, International Herald Tribune, Far Eastern Economic Review, Financial Times, Reuters, Voice of America, BBC and CNBC, among others. In 2003, Kang testified before the U.S.-China Economic and Security Review Commission on Capitol Hill in Washington, D.C. on the impact of China's energy sector and market developments on the rest of the world. He is the author and co-author of numerous company studies, journal articles, research papers, project reports, books, chapters and other publications.

Abdullah Aldayel

Abdullah is a research analyst in the Markets and Industrial Development program, with a focus on oil markets and energy policies. Previously, he completed an internship at Halliburton's research and development center in Dhahran, Saudi Arabia.

About the Project

This project intends to assess how the concept of energy security and energy security strategies of suppliers and consumers have evolved following the recent shifts in the global energy markets and balances, and the implications and potential directions of this evolution. The project is focused on the countries of the Gulf Cooperation Council and Northeast Asia and their inter-regional collaboration, with a special emphasis on Saudi Arabia and China. Besides conventional energy security dimensions, we plan to address the following research propositions: How can the magnitude of the changes in energy security be verified and quantified? Are the current energy export/import portfolios of the countries in focus optimal, considering existing and potential risks and diversification costs? Is there a subtle shift from energy security to enterprise and competition?

The goal of this research project is to study the other side of the coin — the security of oil demand from the net-exporters perspective. How do large oil exporters trade off risk and rewards in ensuring the security of demand? In the first phase of this research project, a comparative static model of global oil trade is developed to empirically measure the impacts of alternative crude oil market shares across segmented markets; to assess the strategic choice national oil companies (NOCs) have in valuing alternative sales market portfolios in the context of the trade-off along the risk-reward frontier; and to compare international oil company behavior as a benchmark for NOCs.

KAPSARC

مركز الملك عبدالله للدراسات والبحوث البترولية

King Abdullah Petroleum Studies and Research Center

www.kapsarc.org