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King Abdullah Petroleum Studies and Research Center

The Value of Spot Sales to a Producing Country Subject to Production Quotas

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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.

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Key Points

This paper presents a methodology for the valuation of strategic crude oil stockpiling used for tactical spot sales from the perspective of major oil producing companies facing production quotas.

Over the past few years, a growing surplus of lighter crude and shale oil have led to fierce competition and elevated volatility in global oil markets. In this environment, oil companies that are constrained by strict production quotas find it challenging to maintain profits. Tactical spot oil sales offer a possible solution: by diverting a portion of their output to be held in storage, producers can increase their flexibility to tap spot markets while leaving the total volume of production and sales constant.

This study applies a valuation model developed by KAPSARC to quantify the potential value of spot crude oil sales from strategically located stockpiling facilities. We employ a combination of net present value (NPV) analysis and a real-options approach, which is described in detail in Considine et al. (2019). Our base case analyzes a hypothetical joint stockpiling facility located approximately three days' sailing from key markets in Northeast Asia, with sales of 3 million barrels of crude oil. For this scenario, tactical spot sales increases its value by over 6%, a significant gain.

Based on these results, we then examine the effects of increased spot oil sales on crude prices and the demand for term and long-term contracts under several different scenarios. In the base case, we assume that the increase in spot oil sales from a major producing company has no effect on oil prices or demand for term contracts. In this scenario, the use of the strategic facility shows clear potential to increase the company's profitability.

In the first alternative scenario, we assume the increase in spot oil sales to Northeast Asia results in a 10% reduction in world oil prices. This triggers a drop in regional prices and, in turn, a rise in regional demand, thus yielding positive implications for crude oil revenues. In the second alternative scenario, we assume increased spot oil sales lead to a 10% rise in world oil prices. While the pricing dynamics in this scenario are more complex, the net effects on revenue are expected to be positive for the oil producer in question.

Summary

In recent years, global oil markets have experienced intensified competition driven by growing surpluses of lighter crude and shale oil. As their margins have shrunk, many producers have increased output in order to boost revenue, adding to the oversupply. Meanwhile, global market dynamics have been upended, with many predicting that the United States will become the primary swing supplier of crude oil (Morse 2018). This atmosphere is particularly challenging for those major oil companies subject to strict production quotas, as they seek to maximize profitability while maintaining constant levels of crude oil production and sales.

One promising strategy for quota-restricted producers is to utilize strategically placed crude oil stockpiles for tactical spot sales. To estimate the value of this approach for a hypothetical scenario, we deploy the 'real options' valuation model developed in Considine et al. (2019). The methodology combines net present value, options pricing and stochastic modeling techniques.

The potential incremental value of tactical spot sales can be estimated by calculating how much a market participant would pay to secure the right to purchase — which can be viewed as a financial option — spot oil supplies at market prices from the location of 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.

This case study illustrates that an oil producer can increase both revenue and market share via tactical spot oil sales from a storage facility located close to key markets in Northeast Asia. Additional advantages to these spot oil sales include a reduction in trading risk, increased flexibility to accommodate the needs of valued customers, and greater price transparency.

Introduction

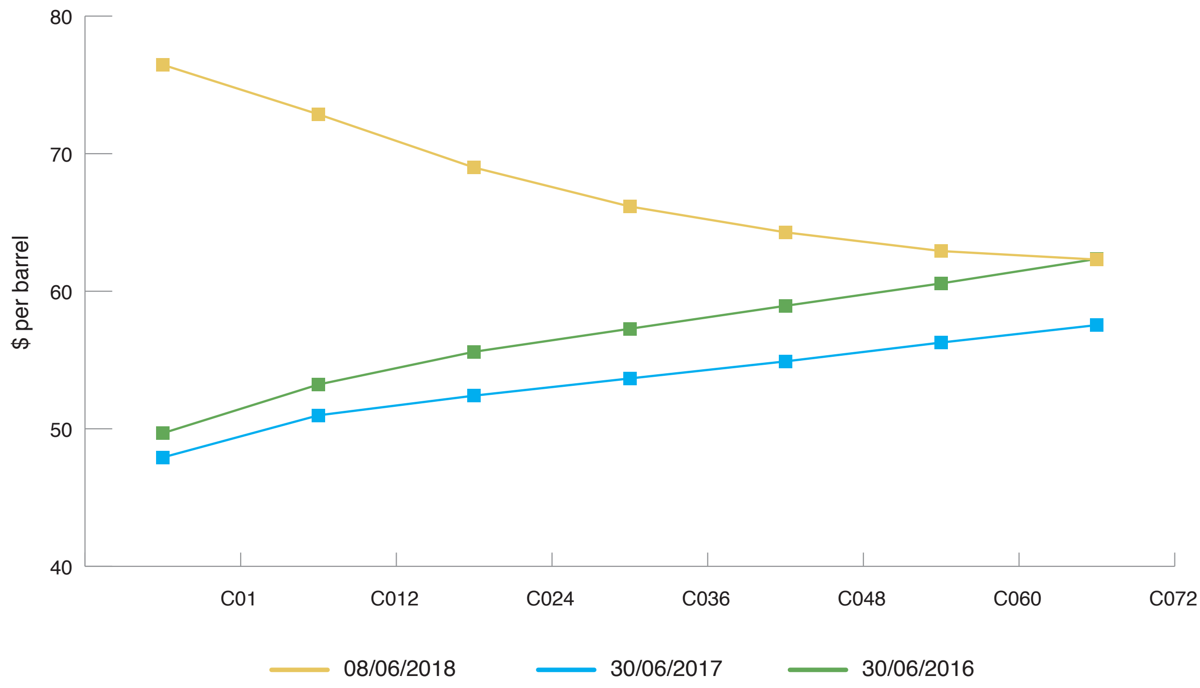
Over the past few years, rising interest rates and increased supplies of lighter crude and shale oil have led to fierce competition on world oil markets. At the same time, the recent shift in the term-structure of oil markets from steep contango to backwardation has sharply reduced storage costs and erased the usual economic incentives to hold inventories (see Figure 1) (Sheppard and Hume 2018b). When the market is in backwardation the futures price is less than the spot price, so that it does not pay to hold inventories. The demand for storage falls, and the price of storage (storage costs) falls with it.

With crude prices in steep backwardation, the oil storage trade has been solidly 'out of the money' for over a year, meaning that the once lucrative strategy of buying spot oil to store and sell forward is no longer profitable. The value of storage plummeted in 2017 and 2018, with Louisiana Offshore Oil Port (LOOP) storage futures crashing to as low as $0.02 per barrel from highs of $1.85 per barrel in April 2016 (CME Group 2018).

In response to stiffer competition and shrinking margins, the United States (U.S.) and major trading houses have increased volumes to maintain revenue. In March 2018 Glencore traded an average of 6 million barrels per day (MMb/d), 500,000 barrels per day over 2017 levels. Mecuria's oil trade reached 2.43 MMb/d in 2017, 330,000 barrels per day more than in 2016 (Sheppard and Hume 2018a).

Meanwhile, the global oil production landscape is rapidly evolving, and some believe the U.S. appears positioned to become the swing supplier of crude oil (Morse 2018). Major oil producing companies that are subject to strict production quotas are searching for alternative means of competition and are hoping to increase profits while maintaining constant levels of crude oil production and sales.

Figure 1. Brent futures curve.



Source: Bloomberg.

Case Studies: Strategic Spot Oil Sales From the Middle East to Asia

Traditionally, the Kingdom of Saudi Arabia has traded only term contracts to restricted destinations. Once the cargos have reached their destination, they are not allowed to be resold to another customer or refinery. More recently, Saudi Aramco has begun to enter into the spot market for crude oil. A number of these transactions have been conducted from the strategic stockpiles in Okinawa.

Saudi Aramco is planning a significant expansion of its trading business. According to Ibrahim Al-Buainain, CEO of Saudi Aramco Products Trading Company, the firm will begin to purchase and sell non-Saudi crude. The company will also place crude oil marketing and refined-product trading under the same management team in an effort to prepare for an initial public offering of Saudi Aramco (Dipaola 2017).

The first spot sale of Saudi crude to a small, independent refinery in China — a 'teapot refinery' — was reported in April 2016. The 730,000 barrel delivery of Arab Heavy to the Chambroad refinery in Shandong province was priced at the official Saudi Aramco selling price.

According to S&P Global Platts, Saudi Arabia has been actively selling four grades of crude oil (Arab Extra Light, Arab Light, Arab Medium and Arab Heavy) from the leased facilities at Okinawa (Kumagai 2017b). These sales have included shipments to: (i) the Petron refinery in the Philippines in March 2017, (ii) the JX Nippon Oil & Energy refinery, of 2 million barrels, and (iii) the S-Oil South Korea, of 1 million barrels.

Initial results from these spot sales are promising. According to calculations by Platts analysts, Saudi Arabia's share of crude oil imports to Japan averaged 1.29 MMb/d for the six months from January to July 2017, increasing the Kingdom's share of Japanese imports by 40% compared with the 35.2% reported a year earlier. Saudi Arabia was the only Middle Eastern supplier to increase its share of the Japanese market during this time (Kumagai 2017a). This case illustrates the potential for a major crude oil producer to increase both revenue and market share via spot oil sales from a storage facility located close to key markets in Northeast Asia.

Tactical spot oil sales can also reduce trading risk, increase flexibility to accommodate customer demand, and improve price transparency. In the past, Middle East sour grades would have been purchased well over three months in advance of delivery, with transactions occurring a full two months before the crude is loaded onto the cargo ship, and allowing for approximately 30 days of shipping time (Kumagai 2017b). The storage facility in Okinawa changes these dynamics, giving Saudi Aramco the option to sell spot shipments from a much shorter distance. This not only makes delivery faster and less costly, but it also means that smaller shipments are more cost-effective than at longer distances. As a result of this greater flexibility, it also becomes easier to find alternative customers in the region when trade problems occur (Zhou 2016).

Complex Middle East pricing formulas result in crude prices being reported in the UAE and Dubai a full month after loading, and a month before loading in Iran, Saudi Arabia and Iraq. As a result, many buyers in Asia prefer the spot markets of the U.S. and Europe, which offer easy access to competitive cargos and transparent pricing arrangements. Factoring in shipping time, the prices of spot purchases from the U.S. and the North Sea can be locked in roughly two months ahead of delivery (Serene 2017, 2018).

To cite another example, in July 2016, the National Iranian Oil Company (NIOC) sold 2 million barrels of Heavy Iranian crude to Trafigura, which used the supertanker Olympic Target to sell this oil to teapot refiners in China's Shandong province. As reported by the Iran Daily, Trafigura helped to mitigate credit risk and logistics problems associated with the smaller non-state buyers in China: "No single teapot could absorb a VLCC (very large crude carrier) cargo. Without a crude storage operation in China, it is hard for NIOC to see into teapots." (Iran Daily 2017)

The above cases exemplify the ongoing shift of the Middle East's oil producing countries away from term contracts and into spot sales as they adjust to evolving global market dynamics. As spot crude oils sales from the U.S., Europe and Africa increase, this trend is expected to continue. Tactical spot oil sales are proving to be a useful tool in the battle for market share on competitive crude oil markets. This study examines the potential value of spot crude oil sales, given three possible scenarios concerning the implications of the incremental sales on global oil prices.

Base-case scenario: no impact

In our base case, tactical sales of crude oil to Asian markets are assumed to have no impact on either world oil prices or term contracts. This is hardly an unrealistic proposition: existing production quotas will remain in place, and accordingly there will be no change in the global quantity of crude oil produced. As long as total output stays flat, any impact on prices is likely to be short-term and localized, causing only regional decreases in spot prices, and reductions in future demand for long-term contracts. Under this neutral scenario, the cost and benefits analysis of spot crude sales from the joint stockpiling facilities will be determined solely by the quantitative valuation model utilized in the analysis.

Alternative scenario 1: negative impact

In this first alternative scenario, the increased spot crude sales to Asian markets depresses both the volumes and prices of the major oil producer's term contracts in the region. We assume a 10% reduction in term oil prices and assess the degree to which this is offset by the value of the tactical spot sales. We also provide a brief discussion of the potential implications for the volume of term contracts.

Alternative scenario 2: positive impact

As illustrated by the case studies, it is possible that spot sales not only tap new markets, but also lead to increased demand for term contracts. In this case, the additional volumes displace competing crude from Russia and other competitors, leading to a rise in term contract sales for the major producing company. We therefore assume a 10% increase in the oil price of term contracts and assess the results. Under this scenario, the net effects of spot sales to buyers in Asia from the strategically located stockpiles are enhanced by additional benefits derived from increases in both regional crude oil prices and volumes of term sales.

This paper develops a methodology to estimate the potential value of spot sales from strategically placed storage facilities in Asia, from the perspective of a major crude oil producing company that is subject to strict production sanctions, under the assumptions outlined in the three scenarios listed above.

The main body of this paper is organized as follows: The first section outlines the assumptions underlying the base case. The second section introduces the central problem of how to estimate the incremental value of spot crude oil sales from a strategically located stockpile. It explains how this can be quantified in terms of a simple European spread option. In the third section, sensitivity analysis and Monte Carlo simulation are conducted to identify potential sources of uncertainty that can impact the output of the spread option model. Finally, the concluding section summarizes the results and outlines areas for further research.

Project Assumptions: Base Case NPV of Spot Crude Oil Sales From a Storage Facility Located Close to Asian Markets

Adjustments by a major producing company (MPC) to its spot sales strategies can impact regional and global crude oil prices and the company's existing and future volumes of term oil sales. Therefore, the starting point of this analysis is to set a well-defined 'base case.' This section outlines the assumptions underlying the base case net present value (NPV) of spot crude oil sales from a storage facility located close to major markets in Northeast Asia from the perspective of a Middle Eastern MPC that is subject to a production quota.

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

1. The main port of transit for the Middle East crude is assumed to be located more than 25 sailing days away from key markets in Asia, such as Qingdao, China.

2. The MPC can store approximately 6.2 million barrels of crude oil free of charge throughout the project lifetime.

3. In exchange for providing free storage, the owner of the storage facility gets a priority claim on the oil stocks in case of emergency.

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

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 major producing company (MPC) perspective, 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.

Combining the above, with half the base storage capacity of 6.2 million barrels designated as strategic reserves, 3.1 million barrels remain for commercial use. Adjusting this for 0.99% slippage, about 3.07 million barrels will be available at any time to the MPC for spot sales. (Slippage is due to leaks and errors in the physical drawdown procedure.)

Given crude oil production costs of US$3 per barrel, transportation costs from the Middle Eastern MPC to the strategically located storage facility of $1.65 per barrel, and spot crude oil sales free on board (FOB) at the joint oil stockpiling (JOS) facility of 33.3% of the available tanker capacity of Arabian Medium, 33.3% of Arabian Heavy and 33.3% of Arabian Light crude, the project yields an expected XNPV of $3.43 billion at a 2.5% discount rate (see Table 1, and Appendix D). Note: XNPV is a slight variation on net present value (NPV) that is used when the incoming cash flows occur at irregular intervals, such as spot sales.

Project Assumptions: Base Case NPV of Spot Crude Oil Sales from a Storage Facility Located Close to Asian Markets

Table 1. Base case NPV.

		2016	2017	2018	2019	2020	2030	XNPV
Physical quantities (million barrels [MMb/d])								
Storage capacity		6.20	6.20	6.20	6.20	6.20	6.20	
Required strategic oil		3.19	3.19	3.19	3.19	3.19	3.19	
Slippage								
Percentage of strategic oil required	0.99							
Physical quantities (MMb/d)	52%							
Storage capacity		6.13	6.13	6.13	6.13	6.13	6.13	
Required strategic oil		3.16	3.16	3.16	3.16	3.16	3.16	
Contract revenue								
Crude oil futures DUBAI ICE		$83.82	$83.82	$83.82	$83.82	$83.82	$83.82	
Arab Light		$84.94	$84.94	$84.94	$84.94	$84.94	$84.94	
Volume of Arab Light		0.99	0.99	0.99	0.99	0.99	0.99	
Assumed % of Arab Light	33%							
Arab Medium		$83.43	$83.43	$83.43	$83.43	$83.43	$83.43	
Volume of Arab Medium		0.99	0.99	0.99	0.99	0.99	0.99	
Assumed % of Arab Medium	33%							
Arab Heavy		$81.21	$81.21	$81.21	$81.21	$81.21	$81.21	
Volume of Arab Heavy		0.99	0.99	0.99	0.99	0.99	0.99	
Assumed % of Arab Heavy	33%							
Total revenue								
Spot sales revenue AL $ million		$84.41	$84.41	$84.41	$84.41	$84.41	$84.41	
Spot sales revenue AM $ million		$82.66	$82.66	$82.66	$82.66	$82.66	$82.66	
Spot sales revenue AH $ million		$80.47	$80.47	$80.47	$80.47	$80.47	$80.47	
Total revenue		$247.54	$247.54	$247.54	$247.54	$247.54	$247.54	$3,711.67
Inflation								
Costs of crude oil supplies	2.5%							
Production costs per barrel		$9.67	$9.91	$10.16	$10.41	$10.67	$13.66	
Transportation cost from Middle East to Asia	3.25	$4.95	$5.08	$5.20	$5.34	$5.47	$7.00	
Operating expenses	1.67							

		2016	2017	2018	2019	2020	2030	XNPV
Operating		$0.52	$0.53	$0.54	$0.55	$0.57	$0.73	
Other	0.52	$0.50	$0.51	$0.53	$0.54	$0.55	$0.71	
Total operating expenses	0.50	$15.64	$16.03	$16.43	$16.84	$17.26	$22.10	
Gross income EBITDA		$231.90	$231.51	$231.11	$230.70	$230.28	$225.44	$3,431.34
Optionality. Call options total revenue								
Revenue from spot sales of Arab Light $/b		10.34	10.34	10.34	10.34	10.34	10.34	
Revenue from spot sales of Arab Medium $/b	33%	0.00	0.00	0.00	0.00	0.00	0.00	
Revenue from spot sales of Arab Heavy $/b	33%	0.95	0.95	0.95	0.95	0.95	0.95	
Percentage of storage capacity	33%	3.07	3.07	3.07	3.07	3.07	3.07	
Total revenue from options ($ million)	50%	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$169.42
Alternative optionality total revenue								
Total value of option		$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	
Intrinsic value of SPR		$231.90	$231.51	$231.11	$230.70	$230.28	$225.44	
Option Value = Total value of option plus intrinsic value		$243.20	$242.81	$242.41	$242.00	$241.57	$236.74	$3,600.75
Net present value		$232.77	$461.58	$685.52	$904.70	$1,119.22	$3,026.29	

Source: KAPSARC.

The futures curve for Dubai crude was used to estimate the futures curves for Arabian crudes (CME Group 2016). Specifically, the relationship between Arabian Medium and Dubai Mo01 was measured by a simple two variable regression analysis (see Appendix A). Similarly, the relationships between Brent and the minimum price of light, medium and heavy crudes from competing areas were estimated by simple two variable regression analysis (see Appendix C).

The Incremental Value of Spot Crude Oil Sales: A Spread Option

The potential incremental value of the tactical spot oil sales can be estimated by calculating how much a buyer would pay to secure the right to purchase crude oil from the MPC's strategically located stockpile at market prices (Carmona 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.

The price p, or equivalently the fair market value of the European spread option, is given by the following equation, which is derived in detail in Equations 1-7 in Appendix B:

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

Where:

1. K = the exercise price level (defined here as the cost of freight to transport crude from the storage facility to a major Asian market).

2. T = the expiration date (defined here as 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 (American Petroleum Institute) gravity FOB at the storage facility at time t.

5. r = The short-term risk-free interest rate.

The prices of Arabian Heavy, Medium and Light (Platts) plus the cost of sea transportation from the MPC to the strategically located storage facility of approximately $1.65 per barrel (as estimated by KAPSARC calculations, with the distance calculated using sea-distance.org and the cost of sea transportation estimated using the KAPSARC Global Trade Oil Model).

A detailed listing of the inputs or exogenous variables used in this analysis is presented in Appendices B and C. Given these assumptions, the above equation yields option prices for the three grades of crude of:

1. Arabian Light vs. Minimum Light Grade = $1.14 per barrel.

2. Arabian Medium vs Minimum Medium Grade = $0.00 per barrel.

3. Arabian Heavy vs. Minimum Heavy Grade = $0.10 per barrel.

Note: The zero fair market value for the Arabian Medium versus the minimum medium grade arises from the spot prices at the time of estimation. At that time, the spot price for Arabian Medium was significantly higher than the price of competing crudes.

As shown in Table 1, adding the options value increases the expected XNPV of the project by $220 million — well over 6% — to an expected XNPV of about $3.65 billion. A comparison of the results of our analysis with and without additional options value of strategic crude oil sales is shown in Table D1 of Appendix D. As might have been expected, adding the optionality increases the minimum XNPV of gross revenue via spot sales from $469 million to $1.54 billion, thereby reducing the risk, or downside of the project significantly.

Sensitivity Analysis and Monte Carlo Simulations

The sensitivity analysis below employs stochastic modeling techniques to quantify geopolitical, fiscal and other risks that can have a significant impact on volatile crude oil markets. A description of the mathematical models and estimation techniques is provided in Appendix D.

The following variables were selected for sensitivity analysis:

1. Amount of crude oil held as strategic reserves.
2. Discount rate.
3. Slippage.
4. Production costs per barrel.
5. Transportation costs from the MPC to the storage facility.
6. Brent futures.
7. Dubai futures.

To examine the effects of economic uncertainty on the value of the tactical spot sales, a sensitivity analysis was performed using stepwise regression (Draper 1966). The results and the estimated regression coefficients are presented in Table 2, and Figures 2 and 3. The analysis indicates that the variable with the greatest impact on NPV is the forward curve for Dubai crude; a $1 increase in the price of Dubai crude raises the value from the crude sales FOB at Qingdao by approximately $46 million.

The second most important variable is the amount of oil reserved at all times for alternative purposes, such as the fulfillment of term, and long-term contracts and emergency drawdown. A 1% increase in the amount of oil that must remain in storage reduces the gross income — earnings before income, after tax (EBITDA) — plus the options value by over $7.5 million (see Table 2).

Table 2. Sensitivity analysis.

Sensitivity analysis for gross income EBIT assuming no optionality

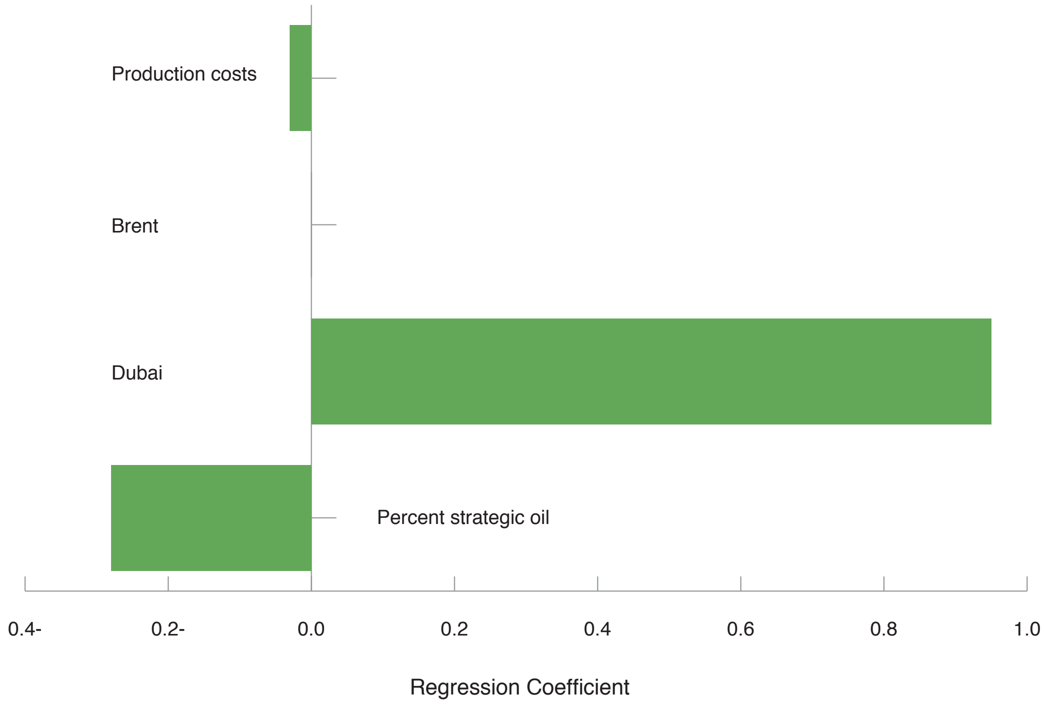
Variable	Standard deviation	Regression coefficient value	Coefficient in Original Units
Output variable			
Gross income EBIT	1,261.41		
Input variables			
Percentage strategic oil	4.91%	-0.28	(7,197.75)
Dubai	25.7	0.95	46.63
Brent	26.17		-
Production costs	3.25	-0.03	(11.64)

Sensitivity analysis for gross income EBIT plus real options value

Variable	Standard deviation	Regression coefficient value	Coefficient in Original Units
Output variable			
Gross income EBIT	1,187.82		
Input variables			
Percentage strategic oil	4.91%	-0.31	(7,504.06)
Dubai	25.7	-1.74	(80.42)
Brent	26.17	2.67	121.19
Production costs	3.25	-0.02	(7.31)

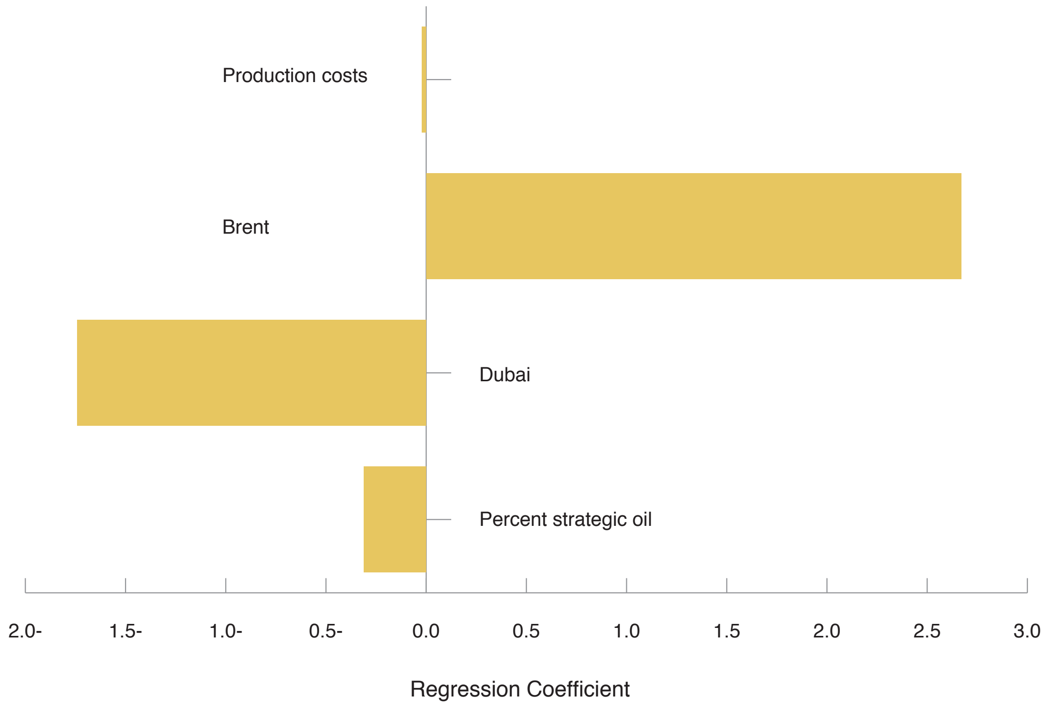
Source: KAPSARC.

Figure 2. Regression coefficient (sensitivity analysis for gross income assuming no optionality).



Source: KAPSARC.

Figure 3. Regression coefficient (sensitivity analysis for gross income plus real options value).



Source: KAPSARC.

The regression coefficients for gross income plus the options value depend on the spread between spot prices for Arabian crudes FOB at the strategic storage facility and the minimum price of competing crudes FOB at Qingdao (see Figure 2). 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 the JOS. Holding everything else constant:

> A $1 increase in the price of Brent M1 increases the XNPV of EBIT plus the options value by $121 million.

> A $1 reduction in the price of Dubai increases the expected XNPV of the facility by $80 million.

For the purpose of this analysis, the expected value of the incremental spot oil sales reflect what a buyer would pay to the MPC today — over and above the transportation costs — to reserve the right to buy spot crude for delivery at a future date.

So far, the analysis has assumed, as its base case, that the increased spot sales to Asian markets will have no impact on either term prices or volume of term contracts held by the MPC. The two alternative scenarios discussed below analyze the impact of a reduction and an increase in oil prices.

Alternative scenario 1: Spot oil sales result in a 10% reduction in world oil prices

In the first alternative scenario, the increase in spot crude sales to Asia results in a permanent 10% reduction in world oil prices (i.e., both Brent and Dubai crude fall by 10% at the same time). As term oil sales are priced at the official selling price, which is tied directly to Dubai crude by a precise pricing formula, there are direct implications for the future trajectory of gross revenues from crude oil sales.

A $1 reduction in the price of Dubai crude cuts the base case FOB Qingdao revenue by approximately $46 million (see Table 2).

A 10% reduction in world oil prices causes a $213 million drop in gross income over the project's lifetime, based on the June 30, 2017 price of $46.34 per barrel for Dubai crude (Quandi 2017). However, this may be an overestimate. The MPC could easily take measures to hedge against the price reduction well in advance of the announcement of spot oil sales.

The implications for future term and long-term contracts are less clear. Given strict MPC production quotas, there will be no impact on total crude oil production. Nevertheless, changes in the timing and distribution of spot sales may impact regional crude prices. Most importantly, the prices of Brent and competing crudes could shift relative to Dubai and Arabian crudes FOB at the JOS. This would have significant implications for the spread options value, which depends on the difference between spot prices for Arabian crudes FOB at the storage facility and the minimum price of competing crudes FOB at Qingdao (see Figure 2). As before, a $1 increase in the price of Brent M1 (relative to Dubai) increases the XNPV of the project by $121 million, while a $1 reduction in the price of Dubai (relative to Brent) increases it by $80 million. The effects of the Dubai price movement are realized through the pricing mechanisms for the official prices for Arabian crude. In both cases, the effect on the total XNPV of gross oil revenues — existing sales plus the incremental spot oil sales — is positive.

It is important to note the slight discrepancy between the pricing dynamics of a reduction in the price of Dubai relative to Brent, and an increase in the price of Brent. The asymmetry is due to the implications of the pricing dynamics for competitors in the region, and the ease of transport from areas such as North America and Europe to Asia. An increase in the price of Brent relative to Dubai would result in a diversion of crude oil supplies currently flowing from Brent markets to Asia back to European markets. This, in turn, would mean fewer long distance competitors headed to the region and a higher value for tactical spot sales. Similarly, a reduction in the price of Dubai relative to Brent reflects an oversupply in the Middle East, resulting in increased competition for Asian markets, and a slightly lower value of tactical sales to Northeast Asia from the strategic facility in question.

Alternative scenario 2: Spot oil prices result in a 10% increase in world oil prices

The second alternative scenario assumes that increased spot crude sales to Asia cause a permanent 10% increase in world oil prices. A $1 increase in the price of Dubai increases the value from the crude sales FOB at Qingdao by approximately $46 million (see Table 2). Given Dubai crude oil prices of $46.34 per barrel, a 10% rise in world oil prices would increase the gross income from spot crude oil sales by $213 million over the project's lifetime (Quandi 2017).

Once again, the increase in spot sales to Asia has the potential to increase the price of Dubai relative to Brent (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 reduction in the price of Brent M1 (relative to Dubai) reduces the XNPV of gross revenues EBIT plus the options value by $121 million. A $1 increase in the price of Dubai (relative to Brent) reduces the expected XNPV of the facility by $80 million. In both cases, the reduction in the options value is offset by the positive increase in the value from the spot oil sales due to higher prices in the region.

Conclusion

The ability to conduct tactical spot sales from a strategically placed storage facility represents a potential way for crude oil producers to increase profitability, which can be especially beneficial for those that are subject to strict production quotas. The valuation method developed in this case study can be applied to a number of other facilities in different strategic locations and different gravities of crude oil and oil products, and will be effective under all types of market conditions.

To cite two examples: Saudi Arabia has been actively selling four grades of crude oil from leased facilities in Okinawa, Japan, including a 1 million barrel shipment to S-Oil South Korea. The National Iranian Oil Company sold a 2 million barrel spot cargo of Iranian Heavy to Trafigura, which in turn sold it to teapot refiners in eastern Shandong Province.

Our case study shows that tactical spot sales from a strategically located stockpile close to Asian markets can have significant value. This is true for a comprehensive range of different assumptions and scenarios concerning future oil prices. The base-case scenario assumes no impact on regional or global prices, or on the prices or volumes of term contracts by the MPC. This is primarily the result of strict production quotas, which mean that no volume is added to the global oil market.

The benefits are greater in the first alternative scenario, which assumes increased spot sales lead to a 10% reduction in world oil prices, and hence the prices under term contracts for the MPC in question. This is unlikely but possible as increased spot sales to the region have the potential to affect the relative prices of Dubai and Brent crudes, thereby increasing the spread options value of the spot oil sales. The demand for term sales, at a reduced regional price, is expected to increase.

For the second alternative scenario, under which increased spot sales to the region result in a 10% increase in world oil prices, the benefits are reduced but do not disappear. In this case, the relationship between regional crude oil prices and the volume of term contracts is more complicated, but the total revenues from sales by the MPC are unlikely to be affected adversely.

In the final analysis, given the existence of binding production quotas, there will be no lasting implications for world oil prices due to the diversion of sales to Asia. The addition of new customers, and competitively priced strategic assets, has the potential to expand market share and revenues for years to come.

This analysis indicates considerable potential for further study, including:

1. Stochastic optimization techniques designed to maximize the value of incremental crude oil sales through an optimal mix of heavy, medium and light crudes.

2. Stochastic optimization techniques designed to forecast the potential value of the sale of spot crudes, and their corresponding gravities, to selected markets in several regions including North America, Latin America, Asia and Europe.

3. Further sensitivity analysis investigating the effects of changes in relevant costs, including for tanker and rail transportation, crude oil production, and storage.

Appendices

Appendix A. Estimating the relationship between Dubai and Saudi crudes.

The futures curve for Dubai crude was used to estimate the futures curves for Saudi crudes (CME Group 2016). Specifically, the relationship between Arabian Light, Medium and Heavy crudes and Dubai Mo01 was estimated by simple two variable regression analysis. The results of this analysis are presented in Table A1 (Platts 2016a).

Table A1. Regression results.

Regression equation						
Arab Light = - 2.62482437 + 1.04466961 Dubai Mo01						
Multiple regression for Arab Light **Summary**	**Multiple R**	**R-Square**	**Adjusted R-square**	**Std. err. of estimate**	**Rows ignored**	**Outliers**
	0.9988	0.9977	0.9977	1.469644856		
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-Value**	
Explained	1	779305.7339	779305.7339	360813.7453	< 0.0001	
Unexplained	838	1809.959331	2.159856003			
Regression table	**Coefficient**	**Standard error**	**t-Value**	**p-Value**	**Confidence interval 95%**	
					Lower	Upper
Constant	-2.624824375	0.139083278	-18.87232173	< 0.0001	-2.897816878	-2.351831872
Dubai Mo01	1.044669609	0.001739152	600.6777383	< 0.0001	1.041256004	1.048083214

Regression equation						
Arab Medium + (Dubai+Oman)/2 = - 3.63390492 + 1.03867596 Dubai Mo01						
Multiple regression for Arab Medium + (Dubai+Oman)/2 **Summary**	**Multiple R**	**R-Square**	**Adjusted R-square**	**Std. err. of estimate**	**Rows ignored**	**Outliers**
	0.9984	0.9968	0.9968	1.724515299		
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-Value**	
Explained	1	766770.2355	766770.2355	257828.6312	< 0.0001	
Unexplained	835	2483.250769	2.973953017			
Regression table	**Coefficient**	**Standard error**	**t-Value**	**p-Value**	**Confidence interval 95%**	
					Lower	Upper
Constant	-3.633904924	0.16334807	-22.24639025	< 0.0001	-3.954526	-3.313283847
Dubai Mo01	1.038675962	0.002045571	507.7682849	< 0.0001	1.034660897	1.042691027

Regression equation						
Arab Heavy + (Dubai+Oman)/2 = - 4.58852152 + 1.0236342 Dubai Mo01						
Multiple regression for Arab Heavy + (Dubai+Oman)/2 **Summary**	**Multiple R**	**R-Square**	**Adjusted R-square**	**Std. err. of estimate**	**Rows ignored**	**Outliers**
	0.9982	0.9964	0.9964	1.804711746		

ANOVA table	Degrees of freedom	Sum of squares	Mean of squares	F	p-Value
Explained	1	744722.8206	744722.8206	228654.0889	< 0.0001
Unexplained	835	2719.582047	3.256984488		

Regression table	Coefficient	Standard error	t-Value	p-Value	Confidence interval 95%	
					Lower	Upper
Constant	-4.588521516	0.17094437	-26.84219148	< 0.0001	-4.924052678	-4.252990354
Dubai Mo01	1.023634203	0.002140698	478.1778842	< 0.0001	1.019432423	1.027835984

Sources: Internal KAPSARC estimates; Platts; CME Group; estimated using Palisade StatTools.

Note: Std. err. = standard error.

Appendix B. The spread option mathematical model.

Following the methodology utilized in Considine et al. (2019), the spread option is calculated using the following assumptions:

1. Type of exercise right: European.
2. Exercise price: cost to transport the crude oil from the strategic stockpile to Qingdao $0.82 per barrel.
3. Expiration date (T): two months after the value or settlement date.
4. S1(0) = the compound price index computed from the aggregation of a number of other financial instruments, reflecting the minimum price at time t=0 of all competing crudes FOB at Qingdao port.
    a. The minimum light grade is the Platts daily price of ESPO Mo01 FOB Qingdao port at time t=0.
    b. The minimum medium grade is the minimum of the Platts daily price of Dubai Mo01 and Castilla Blend FOB at Qingdao port at time t=0.
    c. The minimum heavy grade is the minimum of the Platts daily price of Cold Lake Blend Hardisty Canada, Kern River, and Western Canadian Select (WCS) Hardisty Canada FOB at Qingdao port at time t=0.
5. S2(0) = The price of Saudi Aramco crude of comparable API FOB the strategic stockpile at time t=0.
    a. The price of Arabian Light FOB at the JOS at time t=0.
    b. The price of Arabian Medium FOB at the JOS at time t=0.
    c. The price of Arabian Heavy FOB at the JOS at time t=0.
6. r = 2.5%.
7. The correlation coefficients between the various crude oil prices.

Notes:

(i) The minimum light grade is the Platts daily price of ESPO Mo01 FOB at Qingdao port at time t=0, based on the price of ESPO FOB Kozimoto (Platts) plus the cost of sea transportation to Qingdao of approximately $0.87 per barrel. This was estimated by KAPSARC, with the distance calculated using sea-distance.org, and the cost estimated using the KAPSARC Global Trade Oil Model.

(ii) The minimum medium grade is the minimum of the Platts daily price of Dubai Mo01 and Castilla Blend FOB at Qingdao port at time t=0. This is based on KAPSARC calculations and estimates of the cost of sea transportation to Qingdao, using the KAPSARC Global Trade Oil Model and distances provided by sea-distance.org, of approximately $1.64 per barrel for Dubai Mo01 and $2.12 per barrel for Castilla Blend FOB Colombia.

(iii) The minimum heavy grade is the minimum of the Platts daily price of Cold Lake Blend Hardisty Canada, Kern River, and WCS Hardisty Canada FOB at Qingdao port at time t=0. This is based on the minimum price of three crudes at any given time: (a) Kern River plus the cost of transportation to San Francisco port by pipeline of $1.39 per barrel, plus KAPSARC calculations of the cost of sea transportation to Qingdao of approximately of $1.35 per barrel, and (b) Cold Lake Blend and WCS Hardisty Canada plus the cost of transportation to a California port by pipeline of approximately $12.65 per barrel plus KAPSARC calculations of the cost of sea transportation to Qingdao of approximately $4.33 per barrel, and

(iv) The price of Arabian crude of comparable API FOB at the strategic storage facility at time t. The three prices are for Arabian Heavy, Medium and Light crude (Platts) plus $1.65 per barrel for sea transportation. This was estimated by KAPSARC using the KAPSARC Global Trade Oil Model and distances provided by sea-distance.org.

Table B1. Canadian Pacific (CP) - Rates Hardisty to the United States Gulf Coast (USGC) (Nov 16, 2016).

Classification	Loading fee US$/car	Loading fee US$ per barrel	Manifest train US$/car	Manifest train US$ per barrel	Unit train US$/car	Unit train US$ per barrel	Unloading fee USGC (US$/car)	Unloading fee USGC (US$ per barrel)	Brokerage fees (US$/car)	Brokerage fees (US$ per barrel)	Total per car	Total per barrel
Hazardous	$1,020.00	$1.50	$8,700.00	$12.79	-	-	$1,020.00	$1.50	$34.00	$0.05	$10,774.00	$15.84
Hazardous	$1,020.00	$1.50	-	-	$6,501.00	$9.56	$1,020.00	$1.50	$34.00	$0.05	$8,591.00	$12.61
Non Hazardous	$1,020.00	$1.50	$6,960.00	$10.24	-	-	$1,020.00	$1.50	$34.00	$0.05	$9,034.00	$13.29
Non Hazardous	$1,020.00	$1.50	-	-	$5,568.00	$8.19	$1,020.00	$1.50	$34.00	$0.05	$7,642.00	$11.24

Source: Personal interviews, Diamond A Ventures, Simba Industrial Transload (November 17, 2016).

Note: Hazardous regulated material (crude and liquefied petroleum gases [LPGs]) classification = heavy crudes and LPGS; non-hazardous non-regulated material = medium/lighter crudes classified as fuel oils (Lloydminster crudes); crude cars = ~680-720 barrels per car. ~10% minimum of heavy crude is diluent; crude manifest trains are trains that haul between 1-70 crude cars. Crude unit trains haul ~100 crude cars. Super unit trains haul 120+ crude cars - limited # of facilities that can take them. UniFest Trains are typically manifest trains leaving a destination that drop off cargo and pick up additional crude cars to become unit trains or can (for some reason) achieve unit train rates.

Appendix C. Estimating the relationship between Brent and Middle Eastern crudes.

As mentioned above, the futures curve for Brent crude was used to estimate the futures curves for the minimum price of crude delivered FOB at Qingdao (CME Group 2016). Specifically, the relationships between Brent and the minimum price of light, medium and heavy crudes from competing areas were estimated by simple two variable regression analysis. The results of this analysis are presented in Table C1 (Platts 2016a).

Table C1. Regression results.

Regression equation						
Min Cold Lake WCS Kern @ Qingdao = 3.3559321 + 0.82043253 Brent M1						
Multiple regression for Min Cold Lake WCS Kern @ Qingdao **Summary**	**Multiple R**	**R-Square**	**Adjusted R-square**	**Std. err. of estimate**	**Rows ignored**	**Outliers**
	0.9509	0.9043	0.9042	7.226804401	2	0
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-Value**	
Explained	1	1062343.708	1062343.708	20341.00699	< 0.0001	
Unexplained	2153	112444.0891	52.22670186			
Regression table	**Coefficient**	**Standard error**	**t-Value**	**p-Value**	**Confidence interval 95%**	
					Lower	Upper
Constant	3.355932099	0.526632549	6.372435777	< 0.0001	2.323170681	4.388693517
Brent M1	0.820432528	0.0057525	142.6219022	< 0.0001	0.809151493	0.831713563

Regression equation						
Min Castilla Dubai @ Qiingdao = - 4.57309702 + 0.95367646 Brent M1						
Multiple regression for min Castilla Dubai @ Qiingdao **Summary**	**Multiple R**	**R-Square**	**Adjusted R-square**	**Std. err. of estimate**	**Rows ignored**	**Outliers**
	0.9915	0.9830	0.9830	3.390663442	2	0

ANOVA table	Degrees of freedom	Sum of squares	Mean of squares	F	p-Value
Explained	1	1435428.057	1435428.057	124856.7606	< 0.0001
Unexplained	2153	24752.17674	11.49659858		

Regression table	Coefficient	Standard error	t-Value	p-Value	Confidence interval 95%	
					Lower	Upper
Constant	-4.573097022	0.247084829	-18.5082064	< 0.0001	-5.057646788	-4.088547255
Brent M1	0.953676456	0.002698951	353.3507615	< 0.0001	0.948383633	0.958969278

Regression equation						
ESPO @ Qingdao = 0.03872019 + 1.00762764 Brent M1						
Multiple regression for ESPO @ Qingdao **Summary**	**Multiple R**	**R-Square**	**Adjusted R-square**	**Std. err. of estimate**	**Rows ignored**	**Outliers**
	0.9973	0.9946	0.9946	1.962826097	505	0

ANOVA table	Degrees of freedom	Sum of squares	Mean of squares	F	p-Value
Explained	1	1167486.89	1167486.89	303031.9115	< 0.0001
Unexplained	1650	6356.932375	3.852686288		

Regression table	Coefficient	Standard error	t-Value	p-Value	Confidence interval 95%	
					Lower	Upper
Constant	0.038720188	0.170790147	0.226712073	0.8207	-0.296268078	0.373708455
Brent M1	1.007627638	0.001830442	550.4833436	< 0.0001	1.004037405	1.011217872

Sources: Internal KAPSARC estimates; Platts; CME Group; estimated using Palisade StatTools.

Note: Std. err. = standard error.

Appendix D. Sensitivity analysis and Monte Carlo simulations.

For the JOS storage facility, the key economic variables subject to commodity and transaction risks include the amount of crude oil required to be maintained in the facility at all times for strategic purposes, commodity prices, costs and the project discount rate. The following variables were selected for sensitivity analysis:

1. Amount of crude oil held as strategic reserves
2. Discount rate
3. Slippage
4. Production costs per barrel
5. Transportation costs from the MPC to the storage facility
6. Brent futures
7. Dubai futures

Uniform probability distributions were estimated for assumptions 1-5 as follow:

1. Amount of strategic reserves ~U (0.43,0.6)
2. Discount rate ~U (0.04,0.26)
3. Slippage: ~U (0.981,0.998)
4. Production costs ~U (0.4,0.63)
5. Transportation costs Rass Tanura to JOS ~ U (1.55,1.78)

Where X has a continuous uniform distribution:

$$X \backsim U(a,b) \quad (9)$$

a = the endpoint of the left interval; and

b = the endpoint of the right interval

Platts price estimates for Brent M1 and Dubai Mo01 from Jan. 1, 2008 to Aug. 3, 2016 were used to estimate the probability distributions of the respective crude prices (Platts 2016a). Several probability distributions were fitted to the data, and the 'best fit' was determined using the Anderson-Darling test, 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 results are double-bounded Kumaraswamy distributions, which is perhaps not surprising given the nature of Platts' data gathering and connection with the distributions use in the field of hydrology, specifically the estimation of reservoir yield and storage distribution (Fletcher 1996; Aloui 2015; Javanshiri 2015).

1) Brent M1∽Kw (2.3305,2.4455,16.038,141.55)

2) Dubai Mo01∽Kw (2.0125,2.2961,24.798,146.45)

Where X has a continuous uniform distribution:

10 $$X \backsim Kw(\alpha, \beta, \gamma, \delta)$$

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 the historical data from Platts.

Given the discounted net present value (NPV) 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). The results of the Monte Carlo simulation are presented in Table D1.

If the cash flows are not necessarily periodic, the XNPV can be calculated for the project according to the following formula:

8 $$XNPV = \sum_{i=0}^{T} \frac{P_i}{(1+r_t)^{\frac{d_i-d_0}{365}}}$$

Where:

P_i= the i^{th} payment

d_i= the i^{th} payment date

d_0= 0^{th} payment date

Table D1. Value of strategic spot oil sales summary statistics.

Total XNPV of gross revenue from spot sales

Statistics		Percentile	
Minimum	$468.67	5%	$1,380.05
Maximum	$7,015.29	10%	$1,702.69
Mean	$3,433.09	15%	$2,045.84
Std. dev.	1261.40538	20%	$2,353.64
Variance	1591143.53	25%	$2,499.77
Skewness	0.10	30%	$2,679.02
Kurtosis	2.57	35%	$2,934.93
Median	$3,422.43	40%	$3,077.60
Mode	$3,012.82	45%	$3,258.20

Total XNPV of gross revenue from spot sales plus option value

Statistics		Percentile	
Minimum	$1,544.37	5%	$1,896.43
Maximum	$7,158.99	10%	$2,115.75
Mean	$3,654.38	15%	$2,301.57
Std. dev.	1187.819807	20%	$2,554.76
Variance	1410915.90	25%	$2,708.58
Skewness	0.40	30%	$2,859.29
Kurtosis	2.51	35%	$3,056.21
Median	$3,558.48	40%	$3,222.59
Mode	$3,954.46	45%	$3,420.96

Sources: Internal KAPSARC calculations; Monte Carlo simulations; estimated using Risk Palisade.

Note: Std. dev. = standard deviation.

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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's 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.

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