Optimizing Crude Oil Sales from Strategic Petroleum Reserves in Asia

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Abstract

A joint oil stockpiling facility no more than 3 days sailing from its key markets would be ideally positioned as a Strategic Petroleum Reserve for net importing nations during times of crisis and tight markets. At other times, the facility would have additional value in its capacity to provide an excellent central location for the sale of spot crude for a crude oil marketing company or major producing company. At the same time, the sale of crude oil options to Asian markets can provide a secure and reliable source of supply during times of volatility and enhance a major producing company's market share in the region. Spot crude oil and product sales from a joint oil stockpiling facility would be able reach tight markets in a few days, and in fact would be available for pick-up in variable quantities that are appropriate for specific market disruptions. As a result, the sale of spot crude oil spread options would have the potential to address sporadic and unanticipated increases in demand without adding undue downward pressure to regional oil prices. The case study develops a model to price the sale of crude oil spread options to China from a hypothetical joint oil stockpiling facility in Northeast Asia over a 15-year period from 2016 to 2030.

Contents

Contribution of this paper to the literature
This study contributes to existing literature by illustrating a commercially attractive way to enhance the value of Strategic Petroleum Reserves and joint oil stockpiling reserves in Northeast Asia during times of transition and volatility on global oil markets.

1. Introduction

In this paper, joint oil stockpiling (JOS) refers to a commercial arrangement whereby crude oil, owned and commercially traded by an exporting country, is stored in an importing country in exchange for priority drawdown by the host country in the event of an emergency. It can thus be classified as both commercial and strategic storage (Doshi & Sammy, 2017).

The use of joint stockpiling agreements for commercial purposes, and projects involving the leasing of parts of national strategic storage facilities have been gaining popularity with major crude oil producing and trading companies since 2006 (Kilduff, 2015). These, in turn, have been used to create regional hubs or distribution centers in the race to capture market share in oil-consuming markets located a long distance from major suppliers as outlined in "Joint Oil Stockpiling between Middle East Exporters and Northeast Asian importers," (Doshi & Sammy, 2017) .To cite some examples: On Jan. 25, 2017, India signed a deal with the Abu Dhabi National Oil Company (ADNOC) to store the latter's crude in a 5.86 MMbbl underground oil storage facility in Mangalore - part of India's SPR. According to Sultan Ahmed Al Jabar, United Arab Emirates (UAE) Minister of State and ADNOC CEO, "We will utilize the Mangalore Facility to not only build on our existing business relationships across India but also to explore new downstream opportunities for ADNOC's expanding range of refined and petrochemical products." Verma (2017) ADNOC has a similar agreement to store up to 6.29 million barrels (1 million kiloliters) at the Kiire oil terminal in southern Japan at no cost (Reuters, 2017). Finally, Iraqi state-oil marketer SOMO is contemplating the construction of storage facilities in South Korea in an attempt to increase sales to Asia (Rasheed, 2018).

The SPR requirements have also contributed to proliferation of such agreements. Under the terms of an agreement reached in March 2001, all members of the IEA are committed to maintaining a crude oil reserve equal to 90 days of net oil imports. The terms of the SPR vary across nations, and the situation is slightly different in Japan and South Korea. In Japan, the SPR is composed of three different types of stockpiles, state-controlled reserves, private reserves of petroleum held in accordance with the Petroleum Stockpiling Law and private reserves of petroleum products. In South Korea, refiners, specific distributors, and importers are obligated to hold 40-60 days of their daily imports, and sales of refined products based on a lagged 12-month average.

Sales of spread options from regional joint stockpiling facilities have the potential to enhance MOC's market share of local and nearby markets. The case study develops a model to price the sale of crude oil spread options to China from a hypothetical joint oil stockpiling facility in Northeast Asia over a 15-year period from 2016 to 2030.

One of the examples of a JOC in Northeast Asia is the Okinawa facility. It is one of six private bases selected by Japan's Ministry of Economy, Trade, and Industry (METI) to facilitate the strategic drawdown of national reserves. In an early stage or pre-emergency, approximately 20 MMbbl of oil will be drawn down from several national and private sector bases.

The METI order clearly defines the use of a market mechanism to distribute the oil, which will be executed by competitive bidding to successful competitors. The sales bidding is expected to be completed within 13 days of the METI Ministerial Order requesting the drawdown of national reserves in case of an emergency (JNOC, 2001). Contracts are awarded to successful bidders over the next seven days of the process. The response schedule is as follows:

- Day 1: METI decides to draw down national reserves.
- Day 1-13: A Notice of Sale is issued
- Day 14-20: Contracts are awarded to successful bidders.
- Day 21-28: The facility prepares to start drawdown.
- Day 21: Crude oil is delivered by tanker to the successful bidder(s) (JNOC, 2001).

This paper is organized as follows.

The second section, "Materials and Methods" outlines the assumptions underlying the sale of spread options and formulates the problem in terms of a simple European spread option.

The third section shows estimation of the relationship between benchmark Dubai Crude and the three main Saudi Arabian export crude grades, the relationship between Brent and Saudi Arabian crudes, and potential incremental value of spot sales from the hypothetical JOS facility. The main underlying assumption of these sections is that the spot sales of crude oil have no impact on world oil prices and that the sale of oil under short-term and long-term contracts to existing customers is unaffected.

The results are reported in the "Results and Conclusion" section, which outlines some possible areas for further research.

Finally, the project model is laid out in detail in the Appendix.

2. Material and Methods

2.1. Project Assumptions

The reference or base case value of crude oil options from the leased facilities of a hypothetical JOS facility is calculated from the perspective of a MOC located a long distance away from potentially lucrative market centers. For the purpose of this analysis, the MPT for a major supplier is located more than 25 days' sailing from key markets in Northeast Asia, such as the Chinese port of Qingdao which services a number of China's teapot refiners (Phua & Jean, 2016).

The four assumptions underlying the valuation model can be listed as follows:
1: The major producing company, MOC, can store approximately 6.2 MMbbl of crude oil free of charge throughout the project lifetime.

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

3: The storage facility owner can claim the crude oil storage at the JOS as quasi-government inventory so that about 50 percent of the oil is counted as part of their national strategic crude oil reserves.[i] (Reuters, 2016).

4: The value of utilizing a JOS storage facility for commercial purposes derives primarily from its proximity to key markets in Asia (three-days' sailing at average speeds permits the sale of spot crude from the JOS to buyers in the region). From the NOC perspective, this adds considerable value as the voyage from a major oil export port to, for example, Qingdao, China, takes well over 25 days – too long for profitable spot sales to the area.

2.2. Hypothetical Terms of Operation

Under the terms of our hypothetical agreement, the volumes of crude oil supplies are held in storage by the MOC and can be used to supply Asian customers on a term basis, for term sales or long-term deals signed months in advance. Their use for spot sales during times of high oil prices is relatively new and adds considerable value to any such 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 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 at the end of the year as they struggle to meet the provincial government's crude oil import targets (Platts, 2016).

2.3. Data Inputs

In our hypothetical case study, a regionally sited JOS (on the island of Okinawa, Japan) provides storage facilities for 6.2 MMbbl crude and refined oil products. Assuming 50 percent of these volumes are reserved for strategic stockpiles, with 0.99 percent slippage, about 3 MMbbl can be used for spot sales to Asian markets (any potential slippage is due to leaks and errors in the physical drawdown procedure). This value is a conservative minimum approximation. Any major oil producing, or marketing company will have the capacity to send VLCCs carrying up to as much as 2.1 MMbbl each and even ULCCs carrying up to 3 MMbbl each, rotating between a major port in close proximity to the supply source and a JOS.

Assuming crude oil production costs of $3/bbl, transportation costs from MPT to JOS of $1.65/bbl and a sale of 100 percent Arabian Medium crude, the gross income from these sales, at current oil prices, is approximately $98 million per annum, yielding a NPV of $1.45 billion at a 2.5 percent discount rate (see Table 1).

Arabian Medium is – as the name suggests – the main medium gravity grade crude exported by Saudi Arabia. For physical spot sales it, and most other regional crudes, is priced at a differential to the regional crude benchmark, Dubai, as assessed by the United States (U.S.)-based price reporting agency Platts, a division of S&P Global (Platts, 2018).

Table 1 lists the assumptions underlying these projections for sales of Arabian Medium export crude on a FOB basis at MPT, no taxes, or operating expenses for the facility, free lease of crude oil storage, 50 percent strategic oil requirements and spot sales of 3 MMbbl per year from a regional JOS facility.

We used the futures curve for benchmark Dubai crude to estimate the futures curves for the three main grades of Saudi Arabian export crudes (CME Group, 2016). Specifically, the relationship between Arabian Medium and Dubai Mo01 was estimated by simple two variable regression analyses. The results of these analyses are presented in Table 2.

Note: Dubai is the regional crude benchmark, Arabian Light, Medium and Heavy are Saudi Arabia's three main export grades. Mo01 refers to the current month until two days (not business days) before the end of the month (Platts, 2018).

We construct a base case scenario in which we assume 50 percent of the storage facility's crude oil capacity is available for sale on the spot market once per annum. We also assume that there is a 21–28-day period required between a ministerial order for strategic drawdown and delivery, and a 24-day vessel journey from MPT to Qingdao port and other similar markets in Northeast Asia. Under these assumptions, there is ample opportunity to make more than one trip per year. Many such trips could be made per year without disrupting the crude oil supplies available for strategic purposes.

The assumption that the reference level of crude oil sales of 3 MMbbl per year is a very conservative estimate. Clearly, given the capacity to make numerous deliveries of crude oil to JOS per year to replenish the required volume of strategic oil inventories, the facility holds substantially more capacity for short-term sales than the base value presented in Table 1.

2.4. The Value of a Spread Option on Spot Crude Oil Sales from Joint Stockpiles

Spread options derive their value from the difference in prices between two or more assets. They are generally traded over the counter rather than on an exchange. In commodity markets spread options are often based on the difference in asset prices between two or more locations, points on the calendar, grades or quality of the energy source and inputs vs. outputs in the production process, such as spark spreads and crack spreads (Carmona & Durrleman, 2003). This example is based on location spread or the difference between crude oil prices in two different locations.

The fair value of the spread call option reflects the fair market value of the right, but not the corresponding obligation, to purchase spot crude from the MOC, FOB at JOS, for final delivery in Asian markets (e.g., Qingdao) at a given exercise price at a future date. The exercise, or strike, price is the cost of transporting the crude oil between JOS and Qingdao at some future date, t.

Table-1. NPV of Spot Crude Oil Sales from JOS.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Physical Quantities Million Barrels															
Storage Capacity	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20
Required Strategic Oil	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
Slippage	99%														
Percent of Strategic Oil Required	50%														
Physical Quantities Million Barrels															
Storage Capacity	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13
Required Strategic Oil	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
Contract Revenue															
Crude Oil Futures DUBAI	$ 48.66	$ 46.96	$ 50.22	$ 52.43	$ 53.59	$ 41.31	$ 41.31	$ 41.31	$ 41.31	$ 41.31	$ 41.31	$ 41.31	$ 41.31	$ 41.31	$ 41.31
Arab Light Futures	$ 48.21	$ 46.43	$ 49.84	$ 52.14	$ 53.36	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53
Volume of Arab Light	0% -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assumed % of Arab Light															
Arab Medium Futures	$46.90	$45.14	$48.53	$50.82	$52.03	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27
Volume of Arab Medium	100% $ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07
Assumed % of Arab Medium															
Arab Heavy Futures	$ 45.22	$ 43.48	$ 46.82	$ 49.08	$ 50.27	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69
Volume of Arab Heavy	0% -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assumed % of Arab Heavy															
Total Revenue															
Spot Sales Revenue AL $Million	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Spot Sales Revenue AM $Million	$ 143.88	$ 138.47	$ 148.85	$ 155.89	$ 159.60	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46
Spot Sales Revenue AL $Million	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Revenue	$ 143.88	$ 138.47	$ 148.85	$ 155.89	$ 159.60	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46	$ 120.46
Inflation	2.5%														
Costs of Crude Oil Supplies															
Crude Oil Supplies															
Production Costs per Barrel															
Production Costs per Barrel	3.00 $ 9.20	$ 9.43	$ 9.67	$ 9.91	$ 10.16	$ 10.41	$ 10.67	$ 10.94	$ 11.21	$ 11.49	$ 11.78	$ 12.07	$ 12.38	$ 12.69	$ 13.00
Transportation Cost from Ras Tanura to Okinawa	1.65 $ 5.06	$ 5.19	$ 5.32	$ 5.45	$ 5.59	$ 5.73	$ 5.87	$ 6.02	$ 6.17	$ 6.32	$ 6.48	$ 6.64	$ 6.81	$ 6.98	$ 7.15
Operating Expenses															
Operating	0.50 $ 0.50	$ 0.51	$ 0.53	$ 0.54	$ 0.55	$ 0.57	$ 0.58	$ 0.59	$ 0.61	$ 0.62	$ 0.64	$ 0.66	$ 0.67	$ 0.69	$ 0.71

Other	0.50 $ 0.50	$ 0.51	$ 0.53	$ 0.54	$ 0.55	$ 0.57	$ 0.58	$ 0.59	$ 0.61	$ 0.62	$ 0.64	$ 0.66	$ 0.67	$ 0.69	$ 0.71
Total Operating Expenses	$ 15.26	$ 15.65	$ 16.04	$ 16.44	$ 16.85	$ 17.27	$ 17.70	$ 18.14	$ 18.60	$ 19.06	$ 19.54	$ 20.03	$ 20.53	$ 21.04	$ 21.57
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Gross Income Without Option Value: EBITDA	$ 128.61	$ 122.82	$ 132.81	$ 139.45	$ 142.75	$ 103.19	$ 102.76	$ 102.32	$ 101.86	$ 101.40	$ 100.92	$ 100.43	$ 99.93	$ 99.42	$ 98.89
NPV	$ 126.09	$ 244.14	$ 369.30	$ 498.13	$ 627.42	$ 719.05	$ 808.51	$ 895.84	$ 981.07	$ 1,064.26	$ 1,145.42	$ 1,224.61	$ 1,301.87	$ 1,377.21	$ 1,450.69

In short, the potential incremental value of sales of spot crude spread options, in this case Arabian Medium, from JOS, can be valued as the fair value of a spread call option between two points:

1. Crude deliveries FOB JOS at time t
2. Crude deliveries FOB to Qingdao port, China at time t

    Note: The distance from the study's JOS in Naha Okinawa, Japan to Qingdao, China is approximately 736 nautical miles and takes just over three days to complete at an average speed of 10 knots (Sea- distances.org and the KAPSARC Global Trade Oil Model).

    The Appendix specifies the mathematical model for a spread option and provides more detail. However, in summary, the project assumptions specifying the terms of the option are:

1. Type of exercise right: European
2. Exercise price level: the cost of freight to transport the crude oil from JOS to Qingdao.
3. Expiration date: two months

    The call spread option is in the black if the cost of transporting a competing crude to Qingdao minus the price of Arabian Medium FOB JOS is greater than the cost of transporting the crude from JOS to Qingdao. The option is out of the money when the cost of getting a competing crude to Qingdao minus the price of Arabian Medium FOB JOS is less than or equal to the cost of transporting the crude from JOS to Qingdao.

Table-2. Regression results (Saudi / Dubai crudes).

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**		
	0.9988	0.9977	0.9977	1.469645		
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-value**	
Explained	1	779305.7	779305.7	360813.7	< 0.0001	
Unexplained	838	1809.959	2.159856			
Regression table	**Coefficient**	**Standard error**	**t-value**	**p-value**	**Confidence interval 95%**	
					Lower	**Upper**
Constant	-2.62482	0.139083	-18.8723	< 0.0001	-2.89782	-2.35183
Dubai Mo01	1.04467	0.001739	600.6777	< 0.0001	1.041256	1.048083
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**		
	0.9984	0.9968	0.9968	1.724515		
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-value**	
Explained	1	766770.2	766770.2	257828.6	< 0.0001	
Unexplained	835	2483.251	2.973953			
Regression table	**Coefficient**	**Standard error**	**t-value**	**p-value**	**Confidence interval 95%**	
					Lower	**Upper**
Constant	-3.6339	0.163348	-22.2464	< 0.0001	-3.95453	-3.31328
Dubai Mo01	1.038676	0.002046	507.7683	< 0.0001	1.034661	1.042691
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**		
	0.9982	0.9964	0.9964	1.804712		
ANOVA Table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-value**	
Explained	1	744722.8	744722.8	228654.1	< 0.0001	
Unexplained	835	2719.582	3.256984			
Regression Table	**Coefficient**	**Standard error**	**t-value**	**p-value**	**Confidence interval 95%**	
					Lower	**Upper**
Constant	-4.58852	0.170944	-26.8422	< 0.0001	-4.92405	-4.25299
Dubai Mo01	1.023634	0.002141	478.1779	< 0.0001	1.019432	1.027836

Once estimated the option's fair market value will give an excellent approximation of the value of the transportation between JOS and Qingdao. Or equivalently, the option's value reflects the amount of money a market player would pay to a MOC today – over and above the transportation costs – to reserve the right to buy spot crude for delivery at a future date.

Unsurprisingly, given the volatility of crude oil prices, the level of competition for market share in Asia can be significant and includes a number of shipments from distances exceeding 20 sailing days. To cite one example, China imported crude oil from the U.S. and Canada, including 213,705 bbl transported from the San Francisco area in April 2015 (Bloomberg Staff, 2015). Since that time, Chinese imports from the U.S. have continued to increase, exceeding 8 MMbbl of U.S. light crude in February 2017 (Traywick & Sheela, 2017).

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

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

Where:
1. K = The exercise price level: The cost of freight to transport crude from JOS to 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 MOC crude of comparable API FOB JOS at time t. (The American Petroleum Industry gravity (API gravity) is the standard measure of how light or heavy a petroleum liquid is when compared to water.)
5. r = The short-term risk-free interest rate.
    Note: The spot price of Arabian Heavy, Medium and Light (as assessed by Platts) plus the cost of sea transportation from MPT to JOS of approximately \$1.65/bbl was estimated using Sea-distances.org, and the KAPSARC Global Trade Oil Model with the total cost estimated using the KAPSARC Global Trade Oil Model (Al-Kathiri, Yazeed, Tilak, & Frederic, 2017)

3. Calculations

3.1. Estimating the Relationship between Benchmark Dubai Crude and the Three Main Saudi Arabian Export Crude Grades

The futures curve for Dubai crude was used to estimate the futures curves for Arabian crudes (CME Group, 2016; Platts, 2016). Specifically, the relationship between Arabian Light, Medium and Heavy crudes, and Dubai Mo01 was estimated by simple two variable regression analyses. Table 2 presents the results of these analyses.

3.2. Estimating the Relationship between Brent and Saudi Arabian Crudes

We used the futures curve for benchmark Brent crude to estimate the futures curves for the minimum price of crude delivered FOB at Qingdao (CME Group, 2016). Specifically, the relationship between Brent and the minimum price of Saudi Arabian export grades of Light, Medium, and Heavy crudes was estimated by a simple two-variable regression analysis. The results are presented in Table 3 (Platts, 2016).

3.3. Potential Incremental Value of Spot Sales from the Hypothetical JOS Facility

Given the following assumptions:
1. Type of exercise right: European
2. Exercise price level: Cost of freight to transport the crude oil from JOS to Qingdao is \$0.82/bbl.
3. Expiration date T: The option is expected to expire two months after the value or settlement date.
4. $S_1(0)$ = The compound price index computed from the aggregation of several other financial instruments reflecting the minimum price at time t of all competing crudes FOB to China's Qingdao port.
a. The minimum light grade is the Platts daily price of ESPO Mo01 FOB Qingdao port at time 0.
b. The minimum medium grade is the minimum of the Platts daily price of Dubai Mo01 and Castilla Blend FOB Qingdao port at time 0.
c. 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 Qingdao port at time 0.
5. $S_2(0)$ = The price of MOC crude of comparable API FOB JOS at time t.
a. The price of Arabian Light FOB JOS at time t-0.
b. The price of Arabian Medium FOB JOS at time t=0.
c. The price of Arabian Heavy FOB JOS at time t=0.
6. r = 2.5 percent
7. The forward curves for Brent and Dubai at time t=0.
8. Six sales of options per year.
9. The correlation coefficients between the various crude prices.
    Table 4 lists the fair market annual options values for incremental spot oil sales from the JOS facility.

The options value of the JOS facility is equal to the NPV of the reference case, plus the options value calculated in Table 4. Assuming crude oil production costs of \$3/bbl, transportation costs from MPT to JOS of \$1.65/bbl and assumed spot sales FOB JOS of 33 percent of the available capacity of Arabian Medium, 33 percent of Arabian Heavy and 33 percent of Arabian Light crude, the gross revenue from these sales is approximately \$94 million per annum. This yields an NPV of \$1.61 billion at a 2.5 percent discount rate (see Table 5).

Table-3. Regression results (Brent / Saudi crudes)

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**		
	0.9509	0.9043	0.9042	7.226804		
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-value**	
Explained	1	1062344	1062344	20341.01	< 0.0001	
Unexplained	2153	112444.1	52.2267			
Regression table	**Coefficient**	**Standard error**	**t-value**	**p-value**	**Confidence interval 95%**	
					Lower	**Upper**
Constant	3.355932	0.526633	6.372436	< 0.0001	2.323171	4.388694
Brent M1	0.820433	0.005753	142.6219	< 0.0001	0.809151	0.831714
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**		
	0.9915	0.9830	0.9830	3.390663		
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-value**	
Explained	1	1435428	1435428	124856.8	< 0.0001	
Unexplained	2153	24752.18	11.4966			
	Coefficient	**Standard error**	**t-value**	**p-value**	**Confidence interval 95%**	
Regression table					Lower	Upper
Constant	-4.5731	0.247085	-18.5082	< 0.0001	-5.05765	-4.08855
Brent M1	0.953676	0.002699	353.3508	< 0.0001	0.948384	0.958969
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**		
	0.9973	0.9946	0.9946	1.962826		
ANOVA table	**Degrees of freedom**	**Sum of squares**	**Mean of squares**	**F**	**p-value**	
Explained	1	1167487	1167487	303031.9	< 0.0001	
Unexplained	1650	6356.932	3.852686			
	Coefficient	**Standard error**	**t-value**	**p-value**	**Confidence interval 95%**	
Regression table					Lower	Upper
Constant	0.03872	0.17079	0.226712	0.8207	-0.29627	0.373708
Brent M1	1.007628	0.00183	550.4833	< 0.0001	1.004037	1.011218

Adding the options value increases this value significantly, to approximately $118 million per annum. If the cash flows are not necessarily periodic, the XNPV can be calculated for the project and equals approximately $1.775 billion over the 15 years from 2016 to 2030.

(1) $XNPV = \sum_{i=1}^{N} \dfrac{P_i}{\left((1+r)^{\frac{d_i-d_1}{365}}\right)}$

Where: d_i = the i'*th* payment

d_1 = the 0'*th* payment

P_i = the i'*th* payment

d_i = the i'*th* payment

Table–4. Real options value.

Arab Light vs Minimum Light Composite		Arab Medium vs Minimum Medium Composite	Arab Heavy vs Minimum Heavy Composite
Asset 1 = S1(0)	$ 84.94	$ 83.43	$ 81.21
Asset 2 = S2(0)	$ 87.39	$ 78.10	$ 74.48
Exercise price	$ 0.820	0.82	0.82
Expiry date	12–Aug–2018	12–Aug–2018	12–Aug–2018
Value (settlement) date	12–Jun–2018	12–Jun–2018	12–Jun–2018
Volatility of asset 1	52.27%	57.27%	60.46%
Volatility of asset 2	49.11%	58.99%	51.16%
Interest rate – annual – Actual/365	2.50%	2.50%	2.50%
Correlation Coefficient	0.998	0.995	0.970
Fair Value of Option	$ 1.73	$ 0.0008	$ 0.16
Delta of asset 1	$ (0.85)	$ (0.0017)	$ (0.07)
Delta of asset 2	$ 0.86	$ 0.0018	$ 0.08
Capacity Available	2.98	2.98	2.98
Fair Value of Real Option	$ 1.7348	$ 0.0008	$ 0.16
Volume of Arab Crude Traded	0.99	0.99	0.99
Fraction of time traded	6.00	6.00	6.00
Option Value $ Millions			$ 0.95
	$ 10.34	$ 0.00	

4. Results and Conclusion

Given the assumptions outlined in this case study, the solution to the equation (1), which is the price or fair market value of the option calculated for three separate grades of crude, is:

1. Arabian Light vs. Minimum Light Grade = $1.14/bbl.
2. Arabian Medium vs. Minimum Medium Grade = $0.00.
3. Arabian Heavy vs. Minimum Heavy Grade = $0.10.

Note: The zero fair market value for Arabian Medium versus the Minimum Medium Grade arises from the spot prices at the time of estimation using the most recent data for 2016. At mid-year 2016 the spot price for Arabian Medium was $46.90/bbl, significantly higher than the minimum price of competing crudes, which averaged $41.83/bbl.

In short, given market conditions at the time of valuation, the most value to be derived from the sale of Arabian Medium crude arises from competition with lighter grades, specifically Arabian Light 34 API versus Russian ESPO 34.8 API plus transportation costs from the Russian far-east port of Kozmino to Qingdao. Given market conditions at the time of estimation, spot sales to this area were highly desirable, and market participants were willing to pay a premium of up to $1.14/bbl simply to reserve the right to purchase Arabian Light at market prices FOB JOS for delivery two months from the settlement date.

The capacity to use the JOS storage facility to sell spread options presents considerable potential value to a MOC. That value can be estimated utilizing the spread options model presented in detail in Sections 1-3 of this paper. Given the framework and model construction there is considerable potential for further study and analysis, including:

1. Stochastic Optimization techniques designed to maximize the real options value through the choice of an optimal mix of Heavy, Medium and Light Crude.
2. Stochastic Optimization techniques designed to forecast the sale of spot crudes, and corresponding gravities, to select markets in North America, Latin America, Asia, and Europe.
3. Further sensitivity analysis investigating the effects of changes in transportation costs, production costs, VLCC, freight, rail, and storage charges.

Table-5. NPV estimations.

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	XNPV
Physical quantities million barrels																
Storage capacity	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	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	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	
Slippage	0.99															
Percent of strategic oil required	52%															
Physical quantities million barrels																
Storage capacity	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	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	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	
Contract revenue																
Crude oil futures Dubai ICE	$48.656	$46.9586	$50.2169	$52.4257	$53.5922	$41.3070	$41.3070	$41.3070	$41.3070	$41.3070	$41.3070	$41.3070	$41.3070	$41.3070	$41.3070	
Arab Light	$ 48.21	$ 46.43	$ 49.84	$ 52.14	$ 53.36	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	$ 40.53	
Volume of Arab Light	33% $ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	
Assumed % of Arab Light																
Arab Medium	$ 46.90	$ 45.14	$ 48.53	$ 50.82	$ 52.03	$ 39.27	$ 39.27	$ 39.27	$ 39.27	$ 39.27	$ 39.27	$ 39.27	$ 39.27	$ 39.27	$ 39.27	
Volume of Arab Medium	33% $0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	$0.99	
Assumed % of Arab Medium																
Arab Heavy	$ 45.22	$ 43.48	$ 46.82	$ 49.08	$ 50.27	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	$ 37.69	
Volume of Arab Heavy	33% $ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	$ 0.99	
Assumed % of Arab Heavy																
Total revenue																
Spot sales revenue AL $million	$ 47.81	$ 46.05	$ 49.43	$ 51.72	$ 52.92	$ 40.20	$ 40.20	$ 40.20	$ 40.20	$ 40.20	$ 40.20	$ 40.20	$ 40.20	$ 40.20	$ 40.20	
Spot sales revenue AM $million	$ 46.52	$ 44.77	$ 48.13	$ 50.40	$ 51.60	$ 38.95	$ 38.95	$ 38.95	$ 38.95	$ 38.95	$ 38.95	$ 38.95	$ 38.95	$ 38.95	$ 38.95	
Spot sales revenue AL $million	$ 44.85	$ 43.12	$ 46.43	$ 48.67	$ 49.86	$ 37.39	$ 37.39	$ 37.39	$ 37.39	$ 37.39	$ 37.39	$ 37.39	$ 37.39	$ 37.39	$ 37.39	
Total revenue	$ 139.18	$ 133.95	$ 143.99	$ 150.79	$ 154.39	$ 116.53	$ 116.53	$ 116.53	$ 116.53	$ 116.53	$ 116.53	$ 116.53	$ 116.53	$ 116.53	$ 116.53	$ 1,886.74
Inflation	2.50%															
Costs of crude oil supplies																
Crude oil supplies																
Production costs per barrel	$3.25															
Production costs	9.67	9.91	10.16	10.41	10.67	10.94	11.21	11.49	11.78	12.08	12.38	12.69	13.01	13.33	13.66	
Transportation cost from MPT to JOS (At 1.67/Bbl)	$ 4.97	$ 5.09	$ 5.22	$ 5.35	$ 5.48	$ 5.62	$ 5.76	$ 5.91	$ 6.05	$ 6.21	$ 6.36	$ 6.52	$ 6.68	$ 6.85	$ 7.02	
Operating expenses																
Operating	52% $ 0.52	$ 0.53	$ 0.55	$ 0.56	$ 0.57	$ 0.59	$ 0.60	$ 0.62	$ 0.63	$ 0.65	$ 0.67	$ 0.68	$ 0.70	$ 0.72	$ 0.73	
Other	$ 0.50	$ 0.51	$ 0.53	$ 0.54	$ 0.55	$ 0.57	$ 0.58	$ 0.59	$ 0.61	$ 0.62	$ 0.64	$ 0.66	$ 0.67	$ 0.69	$ 0.71	
Facilities	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
Total operating expenses	$ 15.66	$ 16.05	$ 16.45	$ 16.86	$ 17.28	$ 17.72	$ 18.16	$ 18.61	$ 19.08	$ 19.56	$ 20.04	$ 20.55	$ 21.06	$ 21.59	$ 22.13	
Gross income without option value: EBITDA	$ 123.52	$ 117.90	$ 127.53	$ 133.93	$ 137.10	$ 98.81	$ 98.37	$ 97.92	$ 97.45	$ 96.97	$ 96.49	$ 95.98	$ 95.47	$ 94.94	$ 94.40	$ 1,606.09
NPV	$ 123.52	$ 241.41	$ 368.95	$ 502.88	$ 639.98	$ 738.79	$ 837.17	$ 935.08	$ 1,032.53	$ 1,129.51	$ 1,225.99	$ 1,321.98	$ 1,417.45	$ 1,512.39	$ 1,606.80	
Optionality. Spread options ROV Options Premium	m															
Revenue from spot sales of Arab Light $/bbl	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	$ 10.34	
Revenue from spot sales of Arab Medium $/bbl	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00	
Revenue from spot sales of Arab Heavy $/bbl	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	$ 0.95	
Percent of storage capacity 50%	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	$ 3.07	

Total revenue from strategic options $ million	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$11.30	$169.40
Incremental value of strategic option	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	$ 11.30	
Intrinsic value of spot oil sales from JOS	$ 123.52	$ 117.90	$ 127.53	$ 133.93	$ 137.10	$ 98.81	$ 98.37	$ 97.92	$ 97.45	$ 96.97	$ 96.49	$ 95.98	$ 95.47	$ 94.94	$ 94.40	
Gross income: EBITDA	$ 134.82	$ 129.19	$ 138.83	$ 145.23	$ 148.40	$ 110.11	$ 109.67	$ 109.22	$ 108.75	$ 108.27	$ 107.78	$ 107.28	$ 106.77	$ 106.24	$ 105.70	$ 1,775.49
Gross income: EBITDA	$ 134.82	$ 129.19	$ 138.83	$ 145.23	$ 148.40	$ 110.11	$ 109.67	$ 109.22	$ 108.75	$ 108.27	$ 107.78	$ 107.28	$ 106.77	$ 106.24	$ 105.70	$ 1,775.49
NPV	$ 134.82	$ 264.01	$ 402.84	$ 548.07	$ 696.47	$ 806.59	$ 916.26	$ 1,025.47	$ 1,134.22	$ 1,242.49	$ 1,350.28	$ 1,457.56	$ 1,564.33	$ 1,670.57	$ 1,776.28	

Abbreviations:
- FOB – free on board
- IEA – International Energy Agency
- JOS – joint oil stockpiling
- METI – Ministry of Economy, Trade, and Industry
- MPT – main point of transit
- MOC – major oil company
- SPR – strategic petroleum reserves
- ULCC – ultra large crude carriers
- VLCC – very large crude carriers

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Appendix: The Mathematical Model: A "Spread Option"

For the sake of simplicity, the analysis was restricted to the case of a simple European Style spread option between two underlying assets. American options are considerably more difficult to value than European style options because they can be exercised at any time before the expiry date. The analysis can be extended to the American Style spread options between more than one asset, or even a basket or portfolio of assets (Borovkova, Permana, & Van Der Weide, 2012). Alternatively, Natarajan (2007) examines the pricing process for a class of multi-asset European options based on a piecewise linear convex payoff in asset prices. Both of these methodologies have the capacity to add value to the analysis and are recommended as an area of future research.

Given the compound price index $S_1 = \{S_1(t)\}_{t \geq 0}$ and, underlying asset price $S_2 = \{S_2(t)\}_{t \geq 0}$, the spread will be the difference between the two instruments.

(1) $$S(t) = S_2(t) - S_1(t), t \geq 0$$

Where:

$S_1(t)$ = The compound price index computed from the aggregation of a number of crude oil prices reflecting the minimum price at time t of all competing crudes FOB China Qingdao port.

$S_2(t)$ = The price of Arabian Medium FOB JOS at time t.

A player is said to be buying the spread, if he purchases S_2 and sells S_1. He will make a profit on the transaction if the minimum price that he receives from selling crude FOB Qingdao port minus the costs of purchasing the crude – Arabian Medium FOB JOS – is greater than the exercise price, which is defined as the cost of transportation from JOS to Qingdao.

The purpose of this section is to calculate the "price" of a simple European call option on the spread between S_1 and S_2. That is the fair market value of the right to purchase the spread, at a fixed exercise, or strike price, which has been set equal to the cost of transportation from JOS to Qingdao. As mentioned above, European call options differ from their American cousins as they can only be exercised at expiry date T. They are defined by the date of expiry, the strike or exercise price and the value of the underlying instruments. (The American option can be exercised at any date prior to expiry, and as a result is considerably more difficult to calculate.)

The payoff of the spread option is given as:

2 $\qquad (S(T) - K)^+ = (S(T) - K)1_{\{S(T)>K\}}$

Where:

S(T) is defined in Equation #1

T = The expiry date of the option.

K = The strike or exercise price of the option. In this case the exercise price is equal to the cost of transportation from JOS to Qingdao

Following Black and Scholes (1973) and Merton (1973) the price of the European call option p(t,x) at time t, when S(t) = x is given by the solution to the backward parabolic PDE:

3 $\qquad \partial_t p(t,x) + \frac{1}{2}\sigma^2 x^2 \partial_{xx}^2 p(t,x) + rx\partial_x p(t,x) - rp(t,x) = 0$

$\qquad$ *and terminal condition*: $p(T,x) = (x - K)^+$

Where:

r = the short-term risk free interest rate.

σ = The volatility of the underlying asset

When S(T) has a log-normal distribution:

4 $\qquad p = E\{e^{-rt}(S(T) - K)^+\}$

This can be solved explicitly for p given values for S(0), T, r and K

5 $\qquad p = S(0)\emptyset(d_1) - Ke^{-rt}\emptyset(d_2)$

Where

$$d_1 = \frac{\ln(\frac{S(0)e^{-rt}}{K})}{\sigma\sqrt{T}} + \frac{1}{2}\sigma\sqrt{T} \quad and \quad d_2 = d_1 - \sigma\sqrt{T}$$

$\emptyset(x)$*is the cumulative distribution function for the standard normal distribution with mean zero, and standard deviation of* $1, N(0,1)$

The spread option is the difference between a European call option on asset 1 and a European put option on asset 2, with identical maturity T, and strike price K. It is given by the risk neutral expectation: (Valdo Durrleman, 2003)

6 $\qquad p = e^{-rt}E\{(S_2(T) - S_1(T) - K)^+\}$

At expiry T:

7 $\qquad p = e^{-rT}\iint(s_2 - s_1 - K)^+ f_T(s_1 s_2)d_{s_1}d_{s_2}$

The solution to the double integral described in equation 6 is obtained numerically, using Monte Carlo Simulation (Rubinstein, 1994), (Garman, 1992).