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The Implementation of Real Options Theory for Economic Evaluation in Oil and Gas Field Project: Case Studies in Indonesia

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Abstract

Conventional Net Present Value (NPV) is one of the very simple and popular methods that is used for a valuation of projects and for decision making regarding investments in planning of a field development. Conventional NPV analysis involves the estimation of an investment's worth by applying a risk-adjusted discount rate to expected net cash flows derived by applying an expected price case to expected output at that price.

However, there are some important aspects which are not taken into account by the conventional NPV in many types of projects valuation. One of them is managerial flexibilities. Options that are derived from them are commonly called "real options" which is associated with project uncertainties. Binomial Method with risk-neutral probabilities is used to approximate them, associated with the changes in the value of a project over time. There are three methods that will be used to solve the binomial problem. The Cox, Ross, and Rubenstein (CRR), Jarrow-Rudd, and Tian method

This study shows how real options theory can be applied for valuation of an oil and gas field development in Indonesia by following the Indonesian PSC (Production Sharing Contract). In this field, there are options which can be taken into account such as investing to enhance production, drilling certain number of wells, waiting, or shutting down the field (abandon).

Keywords: Real Options

INTRODUCTION

Every oil and gas project which is going to be explored in Indonesia must have a well-planned for its development this kind of plan is commonly known as Plan of Development (POD). POD contains a deep evaluation from an integrated process including geological and geophysical analysis, study of drilling and production, reservoir management, reservoir simulation in reference to the development scenarios, and financial analysis. The financial analysis of a POD project includes evaluation of each investment scenario that may be applied, and it is made to obtain the maximum income or revenue with the consideration of market and technical condition.

It is a common knowledge that oil and gas field developments are the projects with both high risks and costs, and not to mention they are also influenced by high uncertainties. These things play a big role in decision making analysis in the field plan of development, there are many uncertainties but in this particular study only two basic uncertainties that will be taken into account. The first is market uncertainties which are generally affected by external factors such as the fluctuation of oil price or the change of interest rate and the second is technical uncertainties which come from internal factors like the exact original oil or gas in place, production performance, etc.

Besides uncertainties, flexibilities also play an important role in the decision making in field plan of development. It can come from any opportunities or alternatives at any time as long as the project is still ongoing. The alternatives could be the options to invest certain amount of money in the projects like work over job, infill drilling, adding some compressors in gas field particularly, delaying the investment or abandoning at any particular time during the project's contract. These kinds of flexibilities are called Real Options. Unlike the common traditional Net Present Value method, Real Options theory can take the risks which caused by the uncertainties and the flexibilities themselves taken into account for the decision making in the development of the field.

The real options theory in petroleum industry was first introduced by Paddock, Siegel and Smith [8]. They started a research using options theory to study the value of an offshore lease and the development investment timing. The Paddock, Siegel and Smith approach is the most popular real options model for upstream petroleum applications. It extended financial option theory by developing a methodology for the valuation of real asset: an offshore petroleum lease by combining option pricing technique with a model of equilibrium in the market for petroleum reserves.

The valuation of oil field investment using option pricing theory was also published by Lehman [6]. It also illustrates the shortcomings of traditional approach to investment analysis as well as dynamic programming and offers option pricing as the alternative analytic technique. In 1996, Dickens and Lohrenz examined the validity of using option pricing theory methods to value oil and gas assets by comparing the value of discounted cash flow and option pricing methods for an actual Gulf of Mexico oil well [3].

Brandão et al. suggested an approach of the real options valuation problems by using binomial decision trees by modifying the traditional decision tree analysis methods with risk-neutral probabilities to approximate the uncertainty associated with the changes in value of the project over time. This model will be used in this study as it offers simpler and more intuitive solutions for practical purposes [1].

The real options textbook of Pacheco & Vellasco analyzed the investment models for oil and natural resources industry and the several methods to approximate the solution of real options valuation problems [9].

The world is characterized by change, uncertainty and competitive interactions between projects and companies, and establishes that management can make future decisions in response to changing circumstances all of aspects above are the assumption of the methodology of the real option [7]. The future is considered to have full of alternatives and options that can add value in the majority of cases.

The real options method applies financial options theory to quantify the value of management flexibilities in a world of uncertainties [10].

METHODS

In a POD project, real options are used in the decision-making process for managing risk and opportunities which are the source of uncertainties. The real options theory in petroleum industry was first introduced by Paddock, Siegel and Smith in 1987 in the format of option pricing for project evaluation. The parameters to be considered in real options are analogized to the financial options.

The available options in petroleum industry in this case gas field development project can be variative depending on technical and market condition. But, in general they can be categorized as follow.

1. The options to expand the project by putting additional investment in response to positive market condition (e.g. higher oil/gas price).
2. The options to wait by postponing additional investment or deferring investment for a period of time, or in general changing schedule of project investment until the market condition are more favorable.
3. The options to suspend operations temporarily or the options to resume operations after a temporary shutdown.
4. The options to resume operations after a temporary shutdown.
5. The options to abandon the field (or some operating wells) which is no longer economical.

The main objective behind the application of real option theory of a petroleum field development is related to capturing the flexibilities value available at the time of making strategic investments.

One of important advantages of the real option theory is that they help to protect the totality of investment profit, by decreasing potential losses since once again it can accommodate the uncertainties by considering the managerial flexibilities.

Financial option is the basic of the development of real options thinking because both models deal with valuation of the right but not the obligation to make a decision in response to uncertainties.

Financial options have been in place in capital markets for over a century and many experts tackled with the problem of accurately valuing them. A major breakthrough in financial options valuation was realized in 1973 when Black, Scholes, and Merton introduced their Noble-prize-winning formula for European financial options valuation. Although the Black-Scholes formula created considerable insight in the financial markets, its naive application to real options is still problematic.

Most investments in oil or gas field development have a cash flow pattern similar to financial options. A call option in capital markets gives its holder the right to acquire a stock for a fixed predetermined price. The holder can exercise his right to acquire the stock before the option expires. This financial instrument protects its holder from stock price falls during a certain time period. A similar cash flow pattern is when a company acquires a license to develop a block within a period of time, for example five years. The company can immediately explore the block or wait for higher oil or gas prices when such a project is more profitable. If the company does not exercise its right to explore the block within the license period, the license will expire. These similarities propose a situation where the lessons learned in valuation of financial options can be successfully applied to valuation of real options.

When uncertainties are taken into account, the value of real option can be calculated by using numerical methods such as finite difference method to solve model which is in form of partial differential equation, binomial trees method, or by the use of statistical simulation techniques like Monte Carlo simulation and Stochastic Dynamic Programming.

a. Binomial Method

In this particular case of study, binomial method is the one that has been chosen to be used for valuing the real option. This method uses the stochastic process for solving the valuation model that has been made before. There are two common form that can be utilized by the binomial methods the first one is binomial tree and the second one is binomial lattice (Figure 1). This method is also usually used for the stocks movement in financial options.

It can be observed that a binomial lattice is way simpler than binomial tree which forms the probability tree with the binary chance branches. Binomial Lattice is unique because the value resulting from moving up and then down has the equal chance to the value of moving down then up. Thus, this probability tree is recombining since there are some paths with the same outcome value, which significantly reduce the number of nodes.

Where S is the current market price of the asset at t = 0 which can change to Su or Sd after a particular additional time (Δt) while u represents the up-movement factor and d represents the down movement factor. The p and (1-p) are the probability of both upward or downward moves.

In this particular study, there are three methods which proposed to determine the three key parameters above (p, u, and d). With these three parameters, the binomial tree which chosen to be used to value the real option can be calculated.

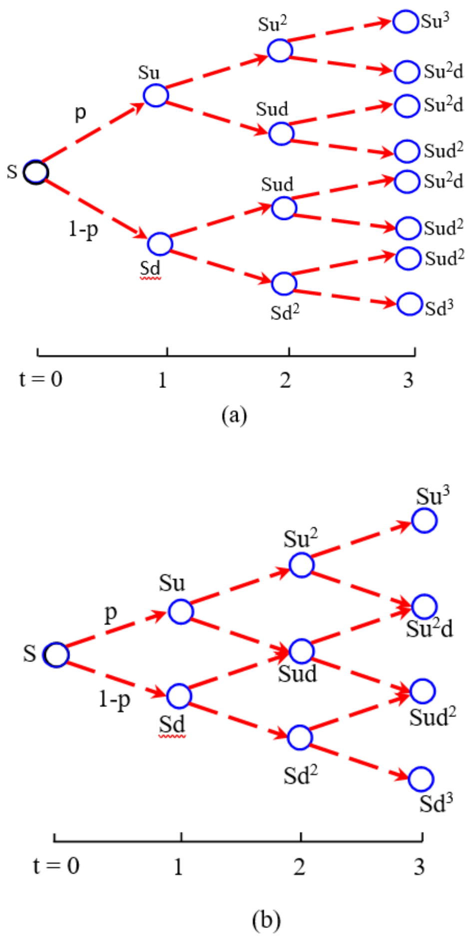

Figure 1: Binomial methods: (a) Binomial Tree (b) Binomial Lattice (After Brandao et.al., 2005)

b. Cox, Ross, Rubenstein (CRR) Method

To determine specifically the three parameters of the binomial model, three equations are required. Two of these equations are obtained from the expectation that over a very small period of time the binomial model should behave in the same way as an asset in a risk neutral world. This leads to the equation that can be seen below.

$$pu + (1 - p)d = e^{r\Delta t} \quad (1)$$

The equation above is known as matching return equation which ensures that over the small period of time Δt the expected return of the binomial model matches the expected return in a risk-neutral world, and the equation below which is called the matching variance

$$pu^2 + (1 - p)d^2 - (e^{r\Delta r})^2 = \sigma^2 \Delta t \quad (2)$$

which ensures that the variance matches.

The last equation was first proposed (Cox, Ross and Rubenstein, 1979). The equation can be seen as follow.

$$u = 1/d \quad (3)$$

By rearranging the three equations before, the up-movement factor *u*, and the down movement factor *d*, for interval time of Δt can be determined as follow

$$u = e^{\sigma\sqrt{\Delta t}} \quad (4)$$

$$d = e^{-\sigma\sqrt{\Delta t}} \quad (5)$$

The σ is the volatility if the underlying asset, in financial case this parameter is related to the stock price volatility, but in this case this parameter represents the project volatility. It can be approximated from volatility of gas price or by using Monte Carlo simulation from the expected cash flow.

The approximation of project volatility can be made based on the volatility of gas price with two assumptions. The first one is the project is highly sensitive to the gas price and the second one is the gas price follows the Geometric Brownian Motion (log-normally distributed). Thus, the historical data of gas price can be used to calculate the gas price volatility just like the calculation of financial stock volatility which can be assumed as the project volatility. This approximation can be used by assuming that the gas price volatility obtained represents overall volatility along the interval time chosen. So, volatility can be formulated as follow.

$$var\left[\ln\left(\frac{S(t+\Delta t)}{S(t)}\right)\right] = \sigma^2 \Delta t \quad (6)$$

Where $S(t+\Delta t)$ is the stock price at $t = t+\Delta t$ and $S(t)$ represents the stock price at time *t* while log-normal of price ratio refers to return value of the price. Thus Eq. II.11 can be used for real options valuation of POD project when stock price is replaced by gas price.

The movement of stock price could be an increase or a decrease with the probability *p* and 1- *p* respectively. Thus, the probability of having up movement, *p* can be defined as follow.

$$p = \frac{e^{r\Delta t} - d}{u - d} \quad (7)$$

The r refers to the risk-free rate and the probability of moving downward is $1-p$.

c. Jarrow-Rudd (Equal Probability) Method

Jarrow and Rudd proposed the binomial model which is often well-known by equal-probability model. Like the CRR method, equal probability model also needs three equations to solve the binomial.

The two equations above (II.6 and II.7) which are used in the CRR method to match both return and variance are also used in this method. Since there are three unknowns in the binomial model (p, u and d) a third equation is required to calculate the unique values. (Jarrow-Rudd, 1982)

$$p = 1/2 \tag{8}$$

With that equation, it can be assumed that there is an equal probability of the asset price increasing or falling.

By rearranging the three equations before, the up-movement factor u, and the down movement factor d, for interval time of Δt can be determined as follow.

$$u = e^{r\Delta t}\left(1 + \sqrt{e^{\sigma^2 \Delta t} - 1}\right) \tag{9}$$

$$d = e^{r\Delta t}\left(1 - \sqrt{e^{\sigma^2 \Delta t} - 1}\right) \tag{10}$$

d. Tian Method

Tian proposed the third method that can be used to solve the binomial model. He constructed his model with almost the same two early assumptions which was proposed by CRR. Just as same as the previous two methods, Tian also makes the third equation to find the three key parameters to solve the binomial model.

Cox, Ross and Rubenstein considered a recombining tree with $u=1/d$ (CRR, 1979) and Jarrow-Rudd proposed the equal probability $p=1/2$ (Jarrow-Rudd, 1982), but Tian matched the first three moments of the binomial model to the first three moments of a lognormal distribution. Hence the three equations used are

$$pu + (1-p) = e^{r\Delta t} \tag{11}$$

$$pu^2 + (1-p)d^2 = (e^{r\Delta t})^2 e^{\sigma^2 \Delta t} \tag{12}$$

$$pu^3 + (1-p)d^3 = (e^{r\Delta t})^3 \left(e^{\sigma^2 \Delta t}\right)^3 \tag{13}$$

Those three equations can lead to the parameters,

$$p = \frac{e^{r\Delta t} - d}{u - d} \tag{14}$$

$$u = 0.5 e^{r\Delta t} v\left(v + 1 + \sqrt{v^2 + 2v - 3}\right) \tag{15}$$

$$d = 0.5 e^{r\Delta t} v\left(v + 1 - \sqrt{v^2 + 2v - 3}\right) \tag{16}$$

$$v = e^{\sigma^2 \Delta t} \tag{17}$$

e. Real Options Valuation with Binomial Method

The binomial lattice is used as modified decision tree analysis to determine the value of real options. Decision tree can be used to model the managerial flexibilities in discrete time by generating a tree with decision nodes representing the flexibilities to maximize the project value. The presence of the managerial flexibilities at each decision nodes changes the expected future cash flow, thereby alternating risk of the project.

After three key parameters has been determined, then the first binomial form of dynamic project value can be constructed.

$$V_i^{\,u} = (V_{i-1} - V_{i-1} \times \delta_{i-1})\, u \tag{18}$$

$$V_i^{\,d} = (V_{i-1} - V_{i-1} \times \delta_{i-1}) d \tag{19}$$

Where V_i refers to the dynamic project value at t_i, where the u and d represent the up and down state values. V_{i-1} is the value of the project at the previous time. The δ_{i-1} refers to the payout ratio of static cash flow which is calculated by dividing cash flow at time t_i to the expected present value (PV) of at time t_i.

Present Value (PV) can be calculated from the economic analysis of Plan Of Development based on the cash flow. This calculation includes the discount rate but without the presence of managerial flexibilities and uncertainties. The formula of Present Value (PV) can be stated as shown below (Brandão et al, 2005).

$$\overline{PV_\iota} = \sum_{i=t}^{n} \frac{\bar{C_\iota}}{(1+\mu)^{i-t}} \tag{20}$$

Ci represents the cash flow at time t_i and μ represents the estimated risk-adjusted discount rate and the payout ratio can be stated as follow

$$\delta_i = \bar{C_\iota}/\overline{PV_\iota} \tag{21}$$

The dynamic cash flow represents the up and down movement in the form of binomial lattice then can be made based on the Vi which is shown at the equation (II.16 and II.17) by using forward method (Brandão et al, 2005).

$$C_{i,j} = \delta_i \times V_{i,j} \tag{22}$$

The i and j describe the state of cash flow in the lattice t_i, while i becomes to the counter of upward movement and j for downward movement.

Backward method then is used to re-calculate the project value by considering the flexibilities. The project value without exercising real options can be calculated as

$$V_{i,j} = C_{i,j} + \left[e^{-r\Delta t}(p\, V_{i+1,j} \; + (1-p)\, V_{i,j+1})\right] \tag{23}$$

And if the flexibilities to employ the available options are taken into account at a particular time t_i. Thus, at that time when the option is employed, the project value can be calculated as follow.

$$V_{j,i} = \max\,\{value\ of\ option\ 1;\ option\ 2; ..; option\ N\} \tag{24}$$

MATERIALS

a. Oil Field

The data is obtained from a mature oil field in the region of South Sumatera in Indonesia which has been operated since 1931. This field consists of seven layers of sandstone with 130 wells including 12 active wells and 118 inactive wells. The inactive wells consist of 98 suspended wells and 14 plug & abandon wells.

In this case study, the POFD schedule made in 2014 will be reviewed by considering best practice and field condition and also by accommodating the market condition and its predicted changes in the future. The re-evaluation will be started at 2016 condition, by assuming that the 2014 and 2015 has going well based on the scheduled Scenario 4, where 3 additional infill drilling wells and 4 workovers had been made each year.

Based on reservoir, geology, geophysics study and also production optimization, there are some possible alternatives can be employed for developing Field-X. They can be summarized in the following scenarios.

1. Scenario 1: Base case

   Base case scenario is the scenario in which there's no changes made in the field, the oil is produced only from currently active production wells along the project life. In this scenario, there are 7 active wells (as per May 2013).

2. Scenario 2: Infill drilling (ID)

   In this scenario, additional of 8 wells in total need to be drilled in addition to the existing production wells. The locations of these additional wells were chosen based on geology and geophysics study and technical field consideration in order to obtain optimum production.

3. Scenario 3: Workover (WO)

   The production is expected to increase by doing work over to 15 existing wells by either re-opening potential existing wells or re-perforating to other potential layers based on reservoir simulation results.

4. Scenario 4: Infill Drilling + Workover

   This development scenario combines infill drilling and workover to produce even more increase in the oil production of the field.

5. Scenario 5: Infill Drilling + Workover + Injection

   In this scenario, in addition to the additional development wells of infill drilling and workover wells, 2 injection wells are also taken into account. Those injection wells are already drilled in 2014 and being used as water disposal and pressure maintenance wells ever since. Water injection rate is 1500 BWPD.

6. Scenario 6: Abandonment

   This scenario is related to the project expansion, where some unproductive and uneconomical development wells may be closed or abandoned if the value becomes no longer economical.

Figure 2 shows the gas production rate and cumulative for each scenario. For oil field case, the binomial lattice method would be conducted for evaluating project values.

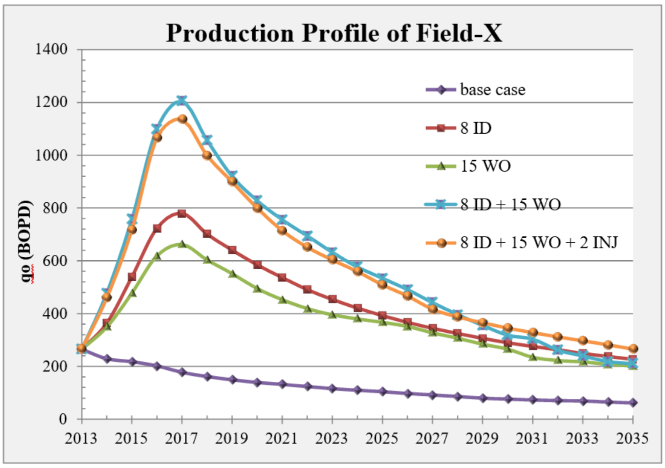

Figure 2: Oil Production Rate Forecast

b. Gas Field

The gas field is located in the Natuna Sea, 486 km northeast of Singapore and 1,247 km north of Jakarta. This field covers almost 2,00 square kilometers in two separate blocks. The PSC contains oil and gas fields which are operated from four platforms with six subsea tie-backs. The contract for the block recently entered a renewal phase and will be effective until 2028.

Sales gas produced in this field is currently coming from the A, B, C and D fields. It is processed at the C platform before being shipped via the undersea pipeline of the West Natuna transportation System (WNTS).

The available alternatives to further develop this field are all based on geology, reservoir, geophysics study and production optimization simulation. Thus, these following scenarios can be made.

1. Scenario 1: Base case

   Base case or waiting scenario is the scenario which there is no changes made in the field. The gas is only produced with the maximum of 200 psi on the surface so the there is a limit of a potential gas flow for each well.

2. Scenario 2: Lowering pressure (70 psi)

   Gas production can be increased if the pressure is lowered. However, the pressure in the surface must be capable enough of flowing the gas, since the gas cannot be saved in the storage tank like oils. Thus, the investment that must be done in order to increase the production by lowering the pressure is adding some compressors at the surface facilities.

In this scenario there are two compressors are added which put in the two different platforms, B and C. These compressors have the capability of lowering the pressure up to 70 psi.

3. Scenario 3: Lowering pressure (0 psi)

   This scenario is basically the same as scenario 2, the difference is only at the capability of the compressors, which in this scenario the pressure can be lowered until 0 psi. This scenario is definitely costlier than the previous one, since the compressors used in scenario 3 are more powerful.

4. Scenario 4: Abandonment/divest

   Each gas well in this field has its economic value. This value is calculated based on the capability of producing the gas and the operational cost. If the operational cost is bigger than the revenue gets from its production, then this well should be closes. If the entire field cannot produce enough gas to cover the operational cost, then the field should be abandoned or divested.

Figure 3 shows the gas production rate and cumulative for each scenario. For gas field case, 3 (three) methods would be conducted to evaluate project values.

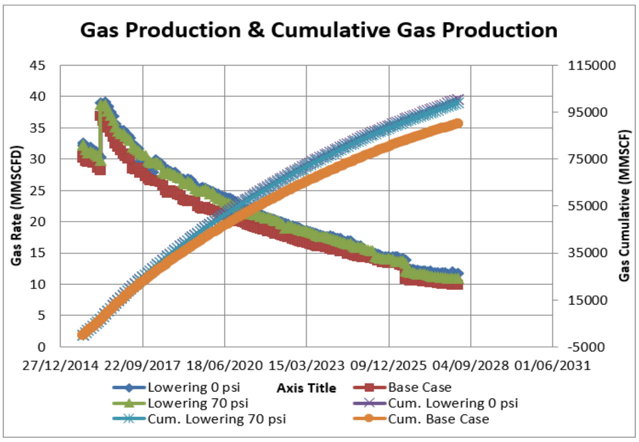

Figure 3: Gas Production Forecast

RESULTS AND DISCUSSION

a. Oil Field

Conventional NPV

The calculations of NPV and IRR were made by using Indonesia PSC regulation. The oil price is assumed as following Figure 4. The evaluation results using conventional NPV method are shown in Table 1.

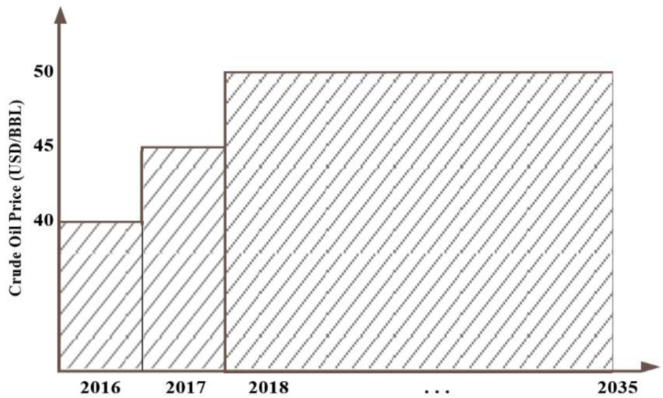

Figure 4: Oil Price assumption

Table 1: Conventional Economic Evaluation of Oil Field

Economic Indicator	Scenario 1 Base case	Scenario 2 Infill Drilling	Scenario 3 Workover	Scenario 4 ID + WO	Scenario 5 ID + WO + INJ
Total Investment (MUS$)	0	21,665.10	10,500.00	32,165.10	32,165.10
Contractor NPV@10% (MUS$)	6,918	17,677.48	16,962.91	28,390.70	26,558.55
IRR (%)	112%	52%	232%	71%	63%
Pay Out Time (Year)	0.69	3.26	1.73	2.96	3.07
Indonesia NPV@10% (MUS$)	14,159	28,295.73	26,063.63	44,764.53	42,179.80

Economic analysis results by conventional NPV method show that Scenario 4 (8 infill drilling and 15 workover wells) give the highest revenue for both contractor and government. With 10 % of discount factor, contractor NPV of expanding project with scenario 4 is around US$ 28.39 million and government NPV is US$ 44.76 million. So, the chosen scenario (by using conventional NPV method) was Scenario 4.

Real Options Approach

The annual project volatility (σ) can be approximated from crude oil price volatility by assuming that market change is mainly affected by crude oil price volatility. Data used for volatility calculation is Europe Brent Oil Price monthly data since January 2013 up to January 2016 (*Source: U.S. Energy Information Administration;* https://www.eia.gov/). Project volatility calculation results are as shown in Table 2.

Table 2: Project Volatility Calculation Result of Oil Field Case

Variance	0.0085
Std. Deviation	0.0923
1/Δt	0.0278
Volatility (σ)	**55.38%**
Up-movement factor	**1.74**
Down-movement factor	**0.57**
Probability of moving up	**0.41**
Probability of moving down	**0.59**

Binomial lattice form of PV (Figure 5) is constructed to represent dynamic project value by using forward steps and utilizing all calculated parameters above.

Dynamic project values at the end of project life are the same as dynamic cash flow at that time. Thus, by using Equation 23 of backward steps we can re-calculate project value without any options employment for each year along project life. Then for the years in which the available alternatives or options is about to be employed, the value will be replaced with the value of the options.

The re-evaluation is conducted to determine the best scheduling of development plan, allowing some adjustments to be made during project life. Available options are the options to wait or pending the additional investment (stay with on-going scenario), options to expand the project by infill drilling, workover or the combination of them, and the options to abandon development wells if it is not profitable. In this case, decision of which options should be chosen are based on their values, those resulting on the highest value will the normally choose to maximize overall project value.

Based on the real options valuation, it is known that best option to be employed in 2016 is adding 4 workover and then adding 2 infill drilling + 3 workover in 2017 (Table 3 and Table 4). Thus, by replacing the project values in column 2016 and 2017 of Figure 5 with those highlighted values of Table 3 and Table 4, the overall project present value after real options valuation is US$ 13.26 million. Complete dynamic project value that may be obtained after employing such scheduled can be seen in Figure 6.

Table 3: Value of Each Options for 2016 Column in Dynamic Project Value After Options Employment in MMUS$

Scenario	WAIT	2ID	4WO	2ID+4WO	2ID + 4WO + INJ	AB of 2ID+4WO
Row 1	84.55	83.70	85.57	83.07	82.94	82.67
Row 2	27.96	27.11	28.99	26.48	26.35	26.08
Row 3	9.27	8.42	10.29	7.78	7.66	7.39
Row 4	3.10	2.25	4.12	1.61	1.48	1.21

Table 4: Value of Each Options for 2017 Column in Dynamic Project Value After Options Employment in MMUS$

Scenario	WAIT	2ID	2ID+3WO	2ID + 3WO +INJ	AB of 2ID+3WO
Row 1	165.34	165.05	165.39	165.24	163.77
Row 2	54.62	54.34	54.67	54.53	53.05
Row 3	18.04	17.76	18.10	17.95	16.47
Row 4	5.96	5.68	6.01	5.87	4.39
Row 5	1.97	1.69	2.02	1.88	0.40

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
12.3	21.5	38.8	84.5	165.3	220.6	300.6	417.1	582.0	814.2	1,143	1,604	2,239	3,092	4,220	5,706	7,630	10,055	12,994	15,867	18,605	19,520	15,778
	7.1	12.8	27.9	54.6	72.9	99.3	137.8	192.2	269.0	377.4	529.7	739.5	1,022	1,394	1,885	2,521	3,322	4,293	5,242	6,146	6,448	5,212
		4.2	9.2	18.0	24.1	32.8	45.5	63.5	88.9	124.7	175.0	244.3	337.5	460.5	622.7	832.7	1,097	1,418	1,732	2,030	2,130	1,722
			3.0	6.0	8.0	10.8	15.0	21.0	29.4	41.2	57.8	80.7	111.5	152.1	205.7	275.1	362.5	468.5	572.0	670.7	703.7	568.8
				2.0	2.6	3.6	5.0	6.9	9.7	13.6	19.1	26.7	36.8	50.3	68.0	90.9	119.8	154.8	189.0	221.6	232.5	187.9
					0.9	1.2	1.6	2.3	3.2	4.5	6.3	8.8	12.2	16.6	22.5	30.0	39.6	51.1	62.4	73.2	76.8	62.1
						0.4	0.5	0.8	1.1	1.5	2.1	2.9	4.0	5.5	7.4	9.9	13.1	16.9	20.6	24.2	25.4	20.5
							0.2	0.2	0.3	0.5	0.7	1.0	1.3	1.8	2.5	3.3	4.3	5.6	6.8	8.0	8.4	6.8
								0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.8	1.1	1.4	1.8	2.3	2.6	2.8	2.2
									0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	0.9	0.7
										0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.2
											0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
														0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
															0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
																0.0	0.0	0.0	0.0	0.0	0.0	0.0
																	0.0	0.0	0.0	0.0	0.0	0.0
																		0.0	0.0	0.0	0.0	0.0
																			0.0	0.0	0.0	0.0
																				0.0	0.0	0.0
																					0.0	0.0
																						0.0

Figure 5: Dynamic Project Present Value of On-Going POFD Project of Oil Field-X before the option is employed (Million US$)

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
13.26	22.4	39.8	85.6	165.4	220.6	300.6	417.1	582.0	814.2	1143	1604	2239	3092	4220	5706	7630	10055	12994	15867	18605	19520	15778
	8.1	13.8	29.0	54.7	72.9	99.3	137.8	192.2	269.0	377.4	529.7	739.5	1022	1394	1885	2521	3322	4293	5242	6146	6448	5212
		5.3	10.3	18.1	24.1	32.8	45.5	63.5	88.9	124.7	175.0	244.3	337.5	460.5	622.7	832.7	1097	1418	1732	2030	2130	1722
			4.1	6.0	8.0	10.8	15.0	21.0	29.4	41.2	57.8	80.7	111.5	152.1	205.7	275.1	362.5	468.5	572.0	670.7	703.7	568.8
				2.0	2.6	3.6	5.0	6.9	9.7	13.6	19.1	26.7	36.8	50.3	68.0	90.9	119.8	154.8	189.0	221.6	232.5	187.9
					0.9	1.2	1.6	2.3	3.2	4.5	6.3	8.8	12.2	16.6	22.5	30.0	39.6	51.1	62.4	73.2	76.8	62.1
						0.4	0.5	0.8	1.1	1.5	2.1	2.9	4.0	5.5	7.4	9.9	13.1	16.9	20.6	24.2	25.4	20.5
							0.2	0.2	0.3	0.5	0.7	1.0	1.3	1.8	2.5	3.3	4.3	5.6	6.8	8.0	8.4	6.8
								0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.8	1.1	1.4	1.8	2.3	2.6	2.8	2.2
									0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	0.9	0.7
										0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.2
											0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
														0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
															0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
																0.0	0.0	0.0	0.0	0.0	0.0	0.0
																	0.0	0.0	0.0	0.0	0.0	0.0
																		0.0	0.0	0.0	0.0	0.0
																			0.0	0.0	0.0	0.0
																				0.0	0.0	0.0
																					0.0	0.0
																						0.0

Figure 6: Dynamic Project Present Value of On-Going POFD Project of Oil Field-X after the option is employed (Million US$)

b. Gas Field

<u>*Conventional NPV*</u>

The calculations of NPV and IRR were made by using Indonesia PSC regulation. The gas price was assumed US$ 9 /MMBTU. The economic evaluation results using conventional NPV method are shown in Table 5.

Table 5: Conventional Economic Evaluation of Gas Field

Economic Indicator	Scenario 1 Base case
Total Investment (MUS$)	180,000
Contractor NPV@10% (MUS$)	112,793
IRR (%)	42%
Pay Out Time (Year)	2.76
Indonesia NPV@10% (MUS$)	230,608

<u>*Real Options Approach*</u>

The project volatility (σ) is obtained by using the approximation from gas price volatility. This approximation is done with the assumption of market change is highly affected by gas price volatility. The data used for this calculation is Indonesia Natural Gas Price monthly data since March 2013 until January 2016 (*Source:* http://www.indexmundi.com). Table 6 shows the project volatility calculation results.

Table 6: Project Volatility Calculation Result of Gas Field Case

Variance	0.0045
Std. Deviation	0.07
1/Δt	0.04
Volatility (σ)	**40%**
Up-movement factor	**1.49**
Down-movement factor	**0.67**
Probability of moving up	**0.46**
Probability of moving down	**0.54**

An assessment will be conducted in 2017 to evaluate whether it is feasible to put an additional investment in the project based on market and technical consideration.

As has been stated before there are 3 (three) available options in general, the first one is option to wait (no additional investment), the second one is put an additional investment (2 different compressors specification), and the last one is abandonment. The gas price is assumed to be $9/MMBTU in 2017.

The figures and tables below (Figure 7 – 9, Table 7 – 9) show the expected value for each option for 3 (three) methods.

2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	1	2	3	4	5	6	7	8	9	10	11	12	13
130.9	195.7	212.5	228.3	278.3	332.6	381.0	422.9	433.7	511.9	580.5	617.7	584.6	415.3
	87.4	94.9	102.6	125.0	149.4	171.2	190.0	194.9	230.0	260.9	277.5	262.7	186.6
		42.1	46.1	56.2	67.2	76.9	85.4	87.6	103.4	117.2	124.7	118.0	83.9
			20.7	25.2	30.2	34.6	38.4	39.3	46.4	52.7	56.0	53.0	37.7
				11.3	13.6	15.5	17.2	17.7	20.9	23.7	25.2	23.8	16.9
					6.1	7.0	7.7	7.9	9.4	10.6	11.3	10.7	7.6
						3.1	3.5	3.6	4.2	4.8	5.1	4.8	3.4
							1.6	1.6	1.9	2.1	2.3	2.2	1.5
								0.7	0.9	1.0	1.0	1.0	0.7
									0.4	0.4	0.5	0.4	0.3
										0.2	0.2	0.2	0.1
											0.1	0.1	0.1
												0.0	0.0
													0.0

**) All values in MMUS$*
= Year
= Number of year
= Project value after option

Figure 7: Binomial form of dynamic project present value After options employment in 2017 (CRR method)

2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	1	2	3	4	5	6	7	8	9	10	11	12	13
130.9	195.4	211.7	227.1	276.3	329.7	376.9	417.7	427.5	503.8	570.3	605.7	572.3	405.8
	79.9	86.6	93.5	113.8	135.8	155.2	172.0	176.1	207.5	234.9	249.5	235.7	167.2
		35.1	38.5	46.9	55.9	63.9	70.9	72.5	85.5	96.8	102.8	97.1	68.8
			15.9	19.3	23.0	26.3	29.2	29.9	35.2	39.9	42.3	40.0	28.4
				8.0	9.5	10.8	12.0	12.3	14.5	16.4	17.4	16.5	11.7
					3.9	4.5	5.0	5.1	6.0	6.8	7.2	6.8	4.8
						1.8	2.0	2.1	2.5	2.8	3.0	2.8	2.0
							0.8	0.9	1.0	1.1	1.2	1.2	0.8
								0.4	0.4	0.5	0.5	0.5	0.3
									0.2	0.2	0.2	0.2	0.1
										0.1	0.1	0.1	0.1
											0.0	0.0	0.0
												0.0	0.0
													0.0

**) All values in MMUS$*
= Year
= Number of year
= Project value after option

Figure 8: Binomial form of dynamic project present value After options employment in 2017 (Equal Probability method)

2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	1	2	3	4	5	6	7	8	9	10	11	12	13
130.9	245.0	332.9	446.5	680.6	1017.3	1457.1	2022.9	2594.2	3829.5	5431.1	7226.5	8553.4	7598.8
	106.6	145.0	195.2	297.6	444.8	637.2	884.6	1134.4	1674.6	2374.9	3160.0	3740.2	3322.8
		62.8	85.4	130.1	194.5	278.6	386.8	496.0	732.3	1038.5	1381.8	1635.5	1453.0
			37.3	56.9	85.1	121.8	169.1	216.9	320.2	454.1	604.2	715.2	635.4
				24.9	37.2	53.3	74.0	94.8	140.0	198.6	264.2	312.7	277.8
					16.3	23.3	32.3	41.5	61.2	86.8	115.5	136.8	121.5
						10.2	14.1	18.1	26.8	38.0	50.5	59.8	53.1
							6.2	7.9	11.7	16.6	22.1	26.1	23.2
								3.5	5.1	7.3	9.7	11.4	10.2
									2.2	3.2	4.2	5.0	4.4
										1.4	1.8	2.2	1.9
											0.8	1.0	0.8
												0.4	0.4
													0.2

**) All values in MMUS$*
= Year
= Number of year
= Project value after option

Figure 9: Binomial form of dynamic project present value After options employment in 2017 (Tian method)

Table 7: Value of each option in 2017 column after options employment (CRR method)

Row	Wait	Abandonment	Adding Compressors (70 psig)	Adding Compressors (0 psig)
1	196.25	59.50	209.91	212.48
2	88.18	35.71	93.88	94.92
3	39.62	25.01	41.74	42.10

**) All values in MMUS$*

Table 8: Value of each option in 2017 column after options employment (Equal Probability method)

Row	Wait	Abandonment	Adding Compressors (70 psig)	Adding Compressors (0 psig)
1	195.55	59.35	209.16	211.72
2	80.54	34.02	85.68	86.62
3	33.17	23.59	34.82	35.09

**) All values in MMUS$*

The option which results the highest value to the project will then be chosen in order to get the maximum of overall project value. The tables above show how these kinds of options can change the value of the project for each method. Table 10 shows the option values of each method in 2015. All of the methods give same option values, i.e. 6.8 MMUS$.

Table 9: Value of each option in 2017 column after options employment (Tian method)

Row	Wait	Abandonment	Adding Compressors (70 psig)	Adding Compressors (0 psig)
1	306.9	83.9	328.7	332.9
2	134.2	45.8	143.3	145.0
3	58.7	29.2	62.2	62.8

**) All values in MMUS$*

Table 10: Option Value in 2015

	CRR	Jarrow-Rudd	Tian
Project value before options employment	124.09	124.09	124.09
Project value after options employment	130.92	130.92	130.92
Option value	**6.84**	**6.84**	**6.84**

**) All values in MMUS$*

The gas price sensitivity analysis is also conducted in this study. Different gas prices would lead to different decision to make. Table 11 shows the result the sensitivity analysis for each method.

Table 11: Sensitivity analysis of gas price towards the chosen option for each method

Gas Price (US$/MMBTU)	CRR Method	Equal Probability Method	Tian Method
12	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
11.5	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
11	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
10.5	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
10	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
9.5	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
9	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
8.5	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
8	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
7.5	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
7	Adding Compressors (0 psig)	Adding Compressors (0 psig)	Adding Compressors (0 psig)
6.5	Adding Compressors (0 psig)/Abandonment	Adding Compressors (70 psig) Abandonment	Adding Compressors (0 psig)
6	Adding Compressors (0 psig)/Abandonment	Adding Compressors (0 psig)/(70psig)/Abandonment	Adding Compressors (0 psig)

Gas Price (US$/MMBTU)	CRR Method	Equal Probability Method	Tian Method
5.5	Adding Compressors (0 psig)/Abandonment	Adding Compressors (0 psig)/Abandonment	Adding Compressors (0 psig)/Abandonment
5	Abandonment/Compressor (0psig)	Abandonment/Compressor (0 psig)	Abandonment/Compressor (0 psig)
4.5	Abandonment	Abandonment	Abandonment

It shows clearly that when the gas price is high enough the option of putting an additional investment such as adding some compressors (0 psig) has the highest value and on the contrary, when the gas price falls quite steeply the option which has the highest value is to abandon the field or divest. The option to wait is never happened in this particular case study, even in the three different methods. This happened barely because the cost that needed to add some investment is not quite significant compare to the additional revenue which caused by the increment of the gas production.

CONCLUSION

The Real Option Theory is applicable to the oil and gas industry. The conventional NPV method is tend to under-assess the value of the project, since it could not accommodate the flexibilities of managing investment which is hold by the managerial at any time during the project life. Real Option Theory can prevent the under-assessed project value because it can mitigate the technical or market uncertainties by utilizing the managerial flexibilities.

NOMENCLATURE

NPV	=	Net Present Value
ID	=	Infill Drilling
WO	=	Workover
INJ	=	Injection well
PV	=	Present Value
AB	=	Well Abandonment

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