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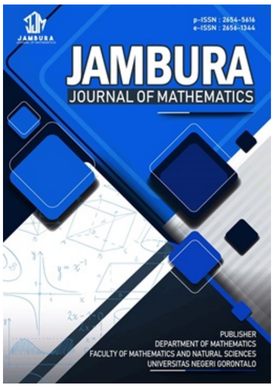

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Research Article

Using Real Options and Geometric Brownian Motion Methods to Evaluate Petroleum Projects in Indonesia

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ABSTRACT. *There are several methods for evaluating the value of a project. The most commonly used method is the Discounted Cash Flows (DCF) method which is more practical in its use. However, the DCF method still has several weaknesses, including not paying attention to the flexibility of the manager's decision-making when the project is carried out. The Real Options method enhances this by offering more flexible and varied models. This study uses Benninga's version of the binomial method to evaluate the value of petroleum projects with the characteristics of existing companies in Indonesia. In this study, oil prices are assumed to move following the Geometric Brownian Motion (GBM) model which is commonly used in modeling the movement of a fluctuating price. In addition, the author also modifies the binomial model by including expansion options, divestment options and a combination of both. The results of this study show that the more options that managers can choose in decision-making, the greater the opportunity for the company to optimize profits and minimize losses.*

1. Introduction

Indonesia's oil production continues to increase. Based on data reported by Global Fire Power [1], Indonesia is ranked 21st in the world's largest oil-producing countries in 2024 with a total production of 845 thousand barrels of oil per day. The ranking has increased from the previous year which ranked 24th with a total production of 775 thousand barrels of oil per day. This data is supported by SKK Migas statement which states that in 2024 there will be 15 companies that will increase production capacity by 41,922 barrels of oil per day [2]. Some of these data show that petroleum projects in Indonesia are projects that are still being taken into account, even encouraged to continue to increase from year to year. Thus, investment in oil projects in Indonesia is still an issue that receives attention from investors.

One of the important things to optimize the investment value of a project is good investment planning. To achieve this, an investment manager must have a method that can be used as a basis for decision-making. The Valuation Method is very important in planning the investment of a project. There are several methods that are usually used as the basis for decision-making by an investment manager. The Discounted Cash Flows (DCF) method is one of the most widely used methods of valuing project value. This is because the DCF method is very practical and easy to use [3, 4]. However, the DCF method still has weaknesses compared to other methods. Among the disadvantages of the DCF method is that it cannot take into account the possibilities that occur while the project is in progress, so that these possibilities affect decision-making. In other words, one of the disadvantages of the DCF method is that it does not take into account the flexibility of the project, making it less suitable if used as a high-risk and long-term valuation method [5].

To perfect the weaknesses of the DCF method, researchers used Real Options method which takes into account the flexibility of decision-making for a manager while the project is in progress [6]. The real options method was first introduced by Myers who said that in valuation of project value there are two main things. The two main things are present value of expected cash flow and growth opportunities of project when it is carried out [7]. In practice, the real options method adopts options pricing method of stock prices in the financial industry. There are several methods that are usually used, including the Black-Scholes Real Options method [8], the Binomial Real Options method [9, 10], Trinomial Real Options method [11, 12], and Quadrinomial Real Options method [13].

One of the methods of real options that is quite easy and often used is the binomial method. The binomial method was first introduced by Cox [14] who is often known as the CRR (Cox, Ross, & Rubinson) binomial method. Initially, the binomial method was only used in determining price of stock options in financial world. However, over time, binomial methods with their various versions are also used to evaluate the value of projects on real options. Several previous studies have used binomial method as a project value valuation. Among them are Brandao [9] who pioneered the use of standard binomial methods to evaluate the value of petroleum projects, Jalaludin [6] applied binomial real options method by paying attention to learning options to estimate value of biotechnology projects, Yeh [15] applied the binomial method to estimate the value of real estate projects, Danylyshyn [16] has used the Binomial Real Options method in

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project investment management which aims to minimize risk, Liu [17] has used the binomial model for real options valuation in calculating the optimal subsidies for renewable energy investment in China, Abad [18] has implemented Binomial Real Options method to manage technical debt in requirements engineering, Loncar [19] has used the Binomial Real Options method on renewable energy projects in Serbia, and others.

To evaluate the investment plan of petroleum projects with more precise results, the application of real options method alone is not enough. There is a special parameter in petroleum projects that need to be modeled precisely, namely stochastic oil price movements. Oil price movements have uncertainty and high risks when the information provided is incomplete. Therefore, it is necessary to choose the right model to represent the movement of oil prices. Among the model used by previous researcher is the Geometric Brownian Motion (GBM) model. The result of Postali's research [20] have shown that the GBM model is a good proxy for modeling oil price movements.

The aim of this study is to develop a valuation method for petroleum project investment plans with a case study on the characteristics of petroleum projects in Indonesia. The valuation method developed in this study is Benninga's version [21] of the Binomial Real Options combined with the Geometric Brownian Motion (GBM) model. The reason for using the GBM model on real options as a valuation of the investment value of petroleum projects is because the GBM is one of the best methods to represent stochastic oil price movements as evidenced by the results of Postali's research [20]. The merger of the two models to form a new model is expected to predict the price movement and market value of petroleum projects in such a way that it is close to the actual value. In addition, another novelty in this study is that there is a scheme of expansion options and divestment options that provide flexibility for managers.

2. Methods

The methods used in this research are the Real Options Valuation method with the Benninga Version Binomial model and the Geometric Brownian Motion (GBM) model.

2.1. Geometric Brownian Motion Model

In this study, Geometric Brownian Motion (GBM) is used to model oil price movements. According to Sidarto [22], stock price movements are defined as Geometric Brownian Motion (GBM) which was first proposed by Robert Brown in 1827 and then perfected by Albert Einstein (1905).

Suppose the interval $[0,\ t]$ is divided into n sub-intervals of equal length, with width $\frac{t}{n}$ and $t_i = i\delta t$ so that the asset price model is obtained as follows:

$$\frac{S(t_{i+1}) - S(t_i)}{S(t_i)} = \mu\delta t + \sigma\sqrt{\delta t}Y_i, \quad Y_i \sim N(0,1),$$

$$S(t_{i+1}) = S(t_i) + \mu\delta t S(t_i) + \sigma\sqrt{\delta t}Y_i\, S(t_i),$$

with $\mu > 0,\ \sigma \geq 0$ and $Y_0,\ Y_1, Y_2,\ \ldots\ iid,\ \sim N(0,1)$, so that

$$S(t_{i+1}) = (1 + \mu\delta t + \ \sigma\sqrt{\delta t}Y_i)\, S(t_i).$$

Consequently,

$$S(t) = S_0 \prod_{i=0}^{n=1} (1 + \mu\delta t + \ \sigma\sqrt{\delta t}Y_i),$$

$$\ln\left(\frac{S(t)}{S_0}\right) = \sum_{i=0}^{n-1} ln(1 + \mu\delta t + \ \sigma\sqrt{\delta t}Y_i).$$

For $\delta t \to 0$ and remember $\ln(1+x)\ = x - \frac{x^2}{2}$. Note that

$$x^2 = (\mu\delta t + \ \sigma\sqrt{\delta t}Y_i)^2$$
$$= \mu^2\delta t^2 + \sigma^2\delta t {Y_i}^2 + 2\mu(\delta t)^{3/2}\sigma.$$

Only the terms containing $\sigma^2\delta t {Y_i}^2$ are used in the calculation, so that the following are obtained:

$$ln\left(\frac{S(t)}{S_0}\right) \approx \sum_{i=0}^{n-1} \mu\delta t + \ \sigma\sqrt{\delta t}Y_i - \frac{1}{2}\sigma^2\delta t {Y_i}^2$$

. by ignoring the tribes δt^k for $k > 1$. Next,

$$E\left[\mu\delta t + \ \sigma\sqrt{\delta t}Y_i - \frac{1}{2}\sigma^2\delta t {Y_i}^2\right] = (\mu - \frac{1}{2}\sigma^2)\delta t,$$

$$\text{Var}\left[\ \mu\delta t + \ \sigma\sqrt{\delta t}Y_i - \frac{1}{2}\sigma^2\delta t {Y_i}^2\right] = \sigma^2 t + 0(\delta t).$$

The central limit theorem brings us to the derivation that

$$ln\frac{S(t)}{S_0} \sim N(\left(\mu - \frac{1}{2}\sigma^2\right) t,\ \sigma^2 t).$$

Thus we obtain the formulation for the asset price at t is

$$S(t) = S(0)\, e^{(\mu - \frac{1}{2}\sigma^2)t + \sigma\sqrt{t}Z_i},\ Z_i \sim N(0,1). \quad (1)$$

The results in Equation (1) will be used to model the movement of oil prices in this study.

2.2. Binomial Real Options Model

The real options model that will be used in this study is Benninga's version of the binomial model [21]. In this study, the method is expanded by including expansion options and options in the option period before expiration. The Binomial Real Options method that will be used in this study follows the following steps.

1. Calculating the Present Value of the Project
   To calculate project present value is used the formula
   $$PV = \sum_{t=1}^{T} \frac{E(C_t)}{(1+r)^t}, \quad (2)$$
   where $E(C_t)$ is the expectation of net cash flow, r risk free rate, I_0 is initial investment value, and T is maturity time.
2. Building a binomial tree of project value movement (forward steps)
   The formula used at this stage satisfies Equation (3):
   $$CF_{ij} = CF_0 U^i D^{j-i}\ i = 0, 1,\ \ldots, j, \quad (3)$$
   with $U = e^{\mu+\sigma}$ and $D = e^{\mu-\sigma}$, where μ mean, σ the volatility of the project's market value, the U factor of increase, and the D factor of decrease.

Table 1. Cash flows of petroleum projects

Year (t)	0	1	2	3	4	5	6	7	8	9	10
Oil reserves (million barrels)	0	90.00	75.00	62.25	51.41	42.20	34.37	27.71	22.06	17.25	13.16
Oil production Amount (million barrels)	0	15.00	12.75	10.84	9.21	7.83	6.66	5.66	4.81	4.09	3.47
Oil prices $S_p(t)$ (dollars/barrel)	53.96	46.67	83.77	89.43	81.40	40.25	104.19	31.17	52.13	146.92	146.72
Revenue (million dollars)		700.09	1068.05	969.22	749.89	315.16	693.44	176.31	250.70	600.53	509.74
Production cost (dollars/barrel)	19.71	20.10	20.51	20.92	21.33	21.76	22.20	22.64	23.09	23.56	24.03
Total production Cost+ fixed cost (million dollars)		311.56	271.46	236.68	206.53	180.39	157.73	138.08	121.05	106.28	93.47
Operating revenue (million dollars)		388.53	796.60	732.54	543.35	134.77	535.71	38.23	129.65	494.25	416.27
Share proportion 25%		97.13	199.15	183.13	135.84	33.69	133.93	9.56	32.41	123.56	104.07
Cash Flows $E(C_t)$ (million dollars)		**291.40**	**597.45**	**549.40**	**407.51**	**101.07**	**401.78**	**28.67**	**97.24**	**370.69**	**312.20**

3. Determine the probability of going up and down using Equation (4):

$$q_u = \frac{R-D}{R(U-D)}, \quad q_d = \frac{U-R}{R(U-D)}, \quad R = 1+r, \tag{4}$$

where $q_u R + q_d R = 1$.

4. Building binomial trees of market value of project rights The market value of project rights at maturity time follows Equation (5):

$$V_{i,T} = \max\{CF_{i,T} - I_0, 0\}. \tag{5}$$

The market value of project rights is modeled with a binomial tree that follows two conditions. The calculation of the market value of project when there are no additional options satisfies Equation (6):

$$V_{i,j} = q_u.V_{i+1,j+1} + q_d.V_{i,j+1}, \tag{6}$$

where $V_{i,j}$ market value of project at t_j time and there has been an increase in cash flow as many as i times.

In this study, three forms of real options models will be simulated to evaluate the value of oil projects. As for nodes when there are additional options, the project market value is calculated according to the scheme of divestment options, expansion options and the combined options of them.

Suppose in the 6th year the company have the option to release its share ownership because it sees poor market conditions so that the company does not want to risk losses. This option is called a divestment option. In addition, the company also is given the option to expand its share ownership which initially only has 75% of the shares, then it buys 25% of the shares from the shareholders by paying a specified investment fee. As a result, the company will experience an additional proportion of shares by 1/3 of the shares. This scheme is called an expansion option.

In this study, three forms of real options models will be simulated to evaluate the value of oil projects. The first model is real options with divestment options that will be evaluated using Equation (7):

$$V_{i,j} = \max\{(q_u.V_{i+1,j+1} + q_d.V_{i,j+1}); D\}, \tag{7}$$

where $D = 1500\$$ is the amount of divestment paid.

The second model is real options with expansion options calculated using Equation (8):

$$V_{i,j} = \max\{(q_u.V_{i+1,j+1} + q_d.V_{i,j+1}); \text{Expand}\} \tag{8}$$

with Expand $= -I_E + p \times (q_u.V_{i+1,j+1} + q_d.V_{i,j+1})$, $I_E = 300\$$ million is cost of investment, and $p = 1/3$ is the proportion of shares.

The third model is real options with a combination of expansion and divestment options which are evaluated using equations Equation (9):

$$V_{i,j} = \max\{(q_u.V_{i+1,j+1} + q_d.V_{i,j+1}); \text{Expand}; D\}. \tag{9}$$

3. Results and Discussion

This study has used Beninnga's version of the real options binomial method and the Geometric Brownian Motion (GBM) model. Both models have been simulated as a method of valuing the market value of petroleum project rights with case studies of petroleum projects in Indonesia. The data used in this study is cash flow data on one of the petroleum companies in Indonesia combined with several assumptions for unknown parameters.

An oil company XYZ has oil reserves of 90 million barrels with an initial production level of 15 million barrels per year which has decreased by 15% per year. The project will be operated for a period of 10 years. The price of oil per barrel is initially assumed to be $S_p(0) = 53.96\$$ which moves according to the Geometric Brownian Motion (GBM) model with volatility $\sigma_p = 29\%$, the expectation of oil price is $\mu_p = 6\%$, so that the price of oil moves for each time t according to Equation (1).

$$S_p(t) = S_p(0)\, e^{(\mu_p - \frac{1}{2}{\sigma_p}^2)t + \sigma_p\sqrt{t}Z_i}, \quad Z_i \sim N(0,1),$$
$$S_p(t) = (53.96\$)\, e^{(0.06 - \frac{1}{2}0.29^2)t + 0.29\sqrt{t}Z_i}, \quad Z_i \sim N(0,1).$$

where $t = 0, 1, 2, \ldots, 10$. The initial production costs were \$19.71 per barrel and increased by 2% per year, while fixed costs were \$10 million per year. The risk-free interest rate is r=6% and the risk-adjusted discount rate is assumed to be $\mu = 10\%$ and

Table 2. Project value movement (in million dollars)

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2077	3658	6442	11347	19984	35195	61986	109171	192273	338633	596403
	1440	2537	4468	7869	13859	24408	42988	75710	133342	234843
		999	1759	3098	5457	9611	16927	29812	52505	92473
			693	1220	2149	3785	6665	11739	20675	36413
				480	846	1490	2625	4622	8141	14338
					333	1114	1033	1820	3206	5646
						231	773	717	1262	2223
							160	536	497	875
								111	372	345
									77	258
										53

Table 3. Market value of project rights with divestment option

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2216	3535	6125	11011	19847	35365	62559	110188	193588	339600	595203
	1704	2469	4071	7292	13356	24035	42760	75568	133030	233643
		1438	1831	2720	4721	8866	16209	29096	51690	91273
			1345	1512	1896	2943	5754	10797	19661	35213
				1361	1429	1500	1718	3592	7049	13138
					1429	1500	353	883	2083	4446
						1500	35	107	331	1023
							0	0	0	0
								0	0	0
									0	0
										0

the project volatility is $\sigma = 46.60\%$. Apart from that, it is known that the initial investment value issued was I_0= \$1200 million. By following these parameters movement rules, the cash flows value of the project is obtained which is presented in Table 1.

Each project has its own characteristics. The application of the Geometric Brownian Motions (GBM) model to real options as a valuation of the value of petroleum projects is a fundamental matter. In the valuation of petroleum projects, GBM is used to model oil prices that move stochastically. Based on the simulation results presented in Table 1, the prices of oil, which was initially \$53.96 per barrel, moved fluctuating based on GBM. This confirms the results of Postali's research [20] which states that GBM is a suitable model to represent oil price movements.

After obtaining cash flows expectations in Table 1, the next is to determine the valuation of petroleum project using Binomial Real Options method by following the steps that have been described in the method chapter.

3.1. Calculating the Present Value (PV) of the project

Present value of the project is obtained using Equation (2) based on the cash flows value in Table 1.

$$PV = \sum_{t=1}^{T} \frac{E(C_t)}{(1+r)^t}$$

$PV = \frac{291.40}{(1{,}06)^1} + \frac{597.45}{(1{,}06)^2} + \frac{549.40}{(1{,}06)^3} + \cdots + \frac{312.20}{(1{,}06)^{10}} = 2077$ (on million dollars)

Then, this value is used to build a binomial tree, where $CF_0 = 2077\$$ million. Thus, the market value of project rights with the DCF method is obtained as $NPV = 2077\$ - 1200\$ = 877\$$ million.

3.2. Building a binomial tree of project value movement (forward steps)

Before building a binomial tree, it will first be determined that the factors of increase U and D, where

$$U = e^{\mu+\sigma} = e^{0.1+0.466} = 1.76$$

and

$$D = e^{\mu-\sigma} = e^{0.1-0.466} = 0.69.$$

The binomial tree of the project movement is constructed based on Equation (3) with $CF_0 = 2077\$$ as presented in Table 2.

3.3. Determine the probability of going up and down

The probability of going up and down is determined using Equation (4), where $R = r + 1 = 1.06$,

$$q_u = \frac{1.06 - 0.69}{1.06(1.76 - 0.69)} = 0{,}3238, \quad \text{and}$$

$$q_d = \frac{1.76 - 1.06}{1.06(1.76 - 0.69)} = 0.6286.$$

3.4. Building binomial trees of market value of project rights (bacward steps)

At the time of maturity the market value of the project rights meets Equation (5) with the initial investment cost of $I_0 = 1200\$$ million.

$$V_{i,10} = \max\{CF_{i,10} - 1200,\ 0\}$$

.

Table 4. Market value of project rights with expansion option

0	1	2	3	4	5	6	7	8	9	10
2607	5131	9782	17984	31722	53289	**83112**	110188	193588	339600	595203
	1505	3123	6297	12269	23013	**41962**	42760	75568	133030	233643
		785	1725	3698	7662	**14994**	16209	29096	51690	91273
			361	839	1935	**4466**	5754	10797	19661	35213
				142	338	778	1718	3592	7049	13138
					51	136	353	883	2083	4446
						11	35	107	331	1023
							0	0	0	0
								0	0	0
									0	0
										0

Table 5. Market value of project rights with divestment & expansion options

0	1	2	3	4	5	6	7	8	9	10
2631	4409	7888	14422	26191	46868	83112	110188	193588	339600	595203
	1914	2950	5120	9451	17522	31747	42760	75568	133030	233643
		1526	2056	3276	6009	11521	16209	29096	51690	91273
			1368	1583	2116	3624	5754	10797	19661	35213
				1361	1429	1500	1718	3592	7049	13138
					1429	1500	353	883	2083	4446
						1500	35	107	331	1023
							0	0	0	0
								0	0	0
									0	0
										0

The market value binomial tree of project rights is constructed with backward steps using Equation (6) if the nodes are in a time period that does not contain options, i.e. other than the time period $t = 6$. Meanwhile, at the time period $t = 6$, the project value is built according to the type of options available. Based on the Method chapter, there are three option models that will be simulated in this study, namely real options with divestment options, real options with expansion options, and real options with a combination of them.

The first model is real options with expansion options. In the time period $t = 6$, the model is constructed based on Equation (7) as presented in Table 3. Based on Table 3, the market value of project rights with the backward steps method is 2216$ million. This implies that if in the 6th period the company is given option to release part of its share ownership with divestment yield of 1500$, then the estimated market value of the project rights obtained is 2216$ million. The value has increased compared to the results of the calculation with the previous DCF method.

The second model is the real options model with expansion options. The market value of the project rights in the 6th period is determined based on Equation (8). The binomial tree is presented in Table 4. The results in Table 4 show that the market value of the project rights using real options and expansion options is $2607 million. This implies that if company manager is given the option to expand his share ownership by 25% from the previous one by paying an investment fee of $300 million, then the estimated value of the project rights to be obtained is $2607 million. This value has increased compared to the DCF method and the real options method with divestment options.

The third model is real options model with a combination of divestment options and expansion options. The binomial tree for this model in the 6th period will be determined based on Equation (9). The results of the calculation are presented in Table 5. Based on Table 5, the market value of project rights using real options and combined divestment and expansion options is 2631$ million. This implies that if in the 6th period the company manager is given the option to divest his share ownership with a yield of $1500 and is given the option to expand his share ownership by 25% from the previous one with an investment cost of $300, then the estimated market value of the project rights is $2631 million. These results have improved compared to the results of the DCF method and the previous two real options models.

The comparison of the market value of the petroleum company's project rights with the DCF method and the three real options models can be seen in Figure 1.

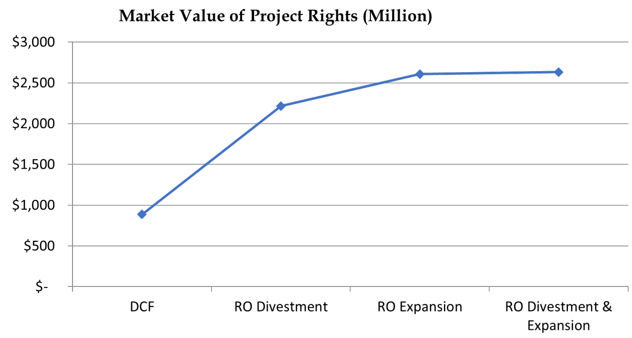

Figure 1. Project Value Results with DCF and three models

The results in Figure 1 show that there is a significant increase between the project valuation value with the DCF method and the project calculation method with real options. These results are supported by previous research, such as those conducted by Tolga [11] and Kim [23], who applied real optoins to call center and renewable energy projects, respectively. The results of both showed that the real options method was more precise than DCF. On the other hand, when comparing the results of model one and two, which contain only one option, with the real options, model 3, which contains combined options, then the larger result is model 3, which has more options. This is in line with the theory said by Myers [7], that the strength factor of real options is how much flexibility the opportunity is considered.

4. Conclusion

Based on the results and discussion in the previous section, we can conclude that calculating the value of oil projects using the real options method is more precise than the results of calculating using the DCF method. On the other hand, real options is a more flexible method because it can take into account possibilities that will occur while the project is running. Apart from that, it can also be concluded that the more possible options a company can choose when a project is carried out, the greater the company's opportunity to increase profits or reduce losses. On the other hand, we can also conclude that the incorporation of the Geometric Brownian Motion (GBM) model on real options for petroleum projects is relevant and can improve the accuracy of the valuation model constructed.

This research makes a theoretical contribution to the development of research in the field of real options by building a new valuation model that is more precise. In addition, this research contributes practically to investment managers by developing a new model that can be used as a basis for assessing investment in petroleum projects in Indonesia.

Author Contributions. **Paiz Jalaluddin:** Conceptualization, methodology, formal analysis, resources, data curation, writing–original draft preparation, writing–review and editing. **Ani Nuraini:** Conceptualization, validation, writing–review and editing, supervision. **Alrafiful Rahman:** Conceptualization, validation, writing–review and editing, supervision. All authors have read and agreed to the published version of the manuscript.

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