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PROCEEDINGS

The 4th International Conference on Sustainable Innovation (ICoSI) 2020

Cutting Edge Innovations for Sustainable Development Goals

Universitas Muhammadiyah Yogyakarta (Indonesia)
October 13 - 14 2020

https://icosi.umy.ac.id/

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Preface by the Chairperson of the 4th ICoSI 2020

Dr. Yeni Rosilawati, S.IP. S.E., MM.

Assalamu'alaikum Wr. Wb.

All praise is due to Allah, the Almighty, on whom we depend for sustenance and guidance. Prayers and peace be upon our Prophet, Muhammad SAW, his family and all of his companions.

On behalf of the organizing committee, it is my pleasure and privilege to welcome the honourable guests, distinguished keynote & invited speakers, and all the participants.

With the main theme of "Cutting-Edge Innovations on Sustainable Development Goals (SDGs)", the 4th International Conference on Sustainable Innovation (ICoSI) 2020 serves as a forum to facilitate scholars, policy makers, practitioners, and other interested parties at all levels from Indonesia and abroad to present their novel ideas, promote cutting-edge research, and to expand collaboration network. The conference has about 1373 participants participating from more than 8 countries 4 continents all over the world, making this conference a truly international conference in spirit.

This multidisciplinary conference was first held in 2012 and has undertaken various changes and adopted to the current technological trends of our education system. From having this conference with just 175 participants back in 2012 we have come a long way in making the conference a huge success with more than 1373 participants participating in this two-day conference.

Formerly, this conference consisted of only 9 (nine) focal conferences. This year, there are 14 focal conferences from various disciplines, namely: 1) The 2nd International Conference on Pharmaceutical Updates (ICPU), 2) The 6th International Conference on Management Sciences

(ICoMS), 3) The 9th International Conference on Law and Society (ICLAS), 4) The 4th International Conference Medical and Health Sciences (ICMHS), 5) The 6th International Conference for Accounting and Finance (ICAF), 6) The 2nd International Language and Education Conference (ILEC), 7) The 2nd International Conference on Nursing (ICONURS), 8) The International Conference on Information Technology, Advanced Mechanical and Electrical Engineering (ICITAMEE), 9) The 2nd International Conference of Agribusiness and Rural Development (IConARD), 10) The 10th International Conference on Public Organization (ICONPO), 11) The 2nd International Symposium on Social Humanities Education and Religious Sciences (ISHERSS), 12) The 5th Dental Research and Exhibition Meeting (DREAM), 13) The International Conference on Hospital Administration (ICHA), and 14) The 3rd International Conference on Sustainable Agriculture (ICoSA).

Accordingly, We are proud to announce that this year, the 4th ICoSI 2020 breaks the Museum Rekor-Dunia Indonesia (MURI) record as the Virtual Multidisciplinary Conference with the Largest Number of Area of Fields in Indonesia

In addition, this year, this conference holds special value since this is the first conference in the history of our university where the entire conference is taking place remotely on a digital platform through the use of advance technologies due to the Covid-19 Pandemic.

I would take this opportunity to express my highest respect to the Rector of Universitas Muhammadiyah Yogyakarta, Dr. Gunawan Budiyanto who gave approval and ensured the maximal support from all the faculty members of Universitas Muhammadiyah Yogyakarta (UMY) that made this event a big success. In addition, my appreciation goes to all the support teams who have provided their valuable support and advice from planning, designing and executing the program.

Let me conclude my speech by encouraging the delegates to participate with an increasing number in all the activities and discussions through the digital platforms for the next two days. I wish everyone a successful, safe, and fruitful conference.

Thank you!

Wassalamu’alaikum Wr. Wb.

Yogyakarta, Indonesia, 14 October 2020

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Welcoming Remarks by the Rector of Universitas Muhammadiyah Yogyakarta

Assoc. Prof. Dr. Gunawan Budiyanto

Innovation is the beginning of the development of technology, and technology is a development machine that is expected to provide benefits to humans and provide the smallest possible impact on environmental quality. In the concept of sustainable development, development must improve the quality of human life without causing ecological damage and maintain the carrying capacity of natural resources.

International Conference on Sustainable Innovation (ICoSI) is an international conference which is an annual conference held by the University of Muhammadiyah Yogyakarta (UMY), Indonesia. In 2020 this raises the issue of "Cutting-Edge Innovations on Sustainable Development Goals." Therefore, on behalf of all UMY academics, I would like to congratulate you on joining the conference, hoping that during the Covid-19 Pandemic, we can still provide suggestions and frameworks for achieving sustainable development goals.

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About The 4th International Conference on Sustainable Innovation (ICoSI) 2020

Cutting Edge Innovations for Sustainable Development Goals

The 2030 Agenda for Sustainable Development is enacted by the United Nations as a shared blueprint for peace and prosperity for people and the planet, now and into the future. It consists of strategies to improve health and education, reduce inequality, and spur economic growth while also conserving natures by 2030.

This year, however, at the first one-third of its timeline, the SDG Reports shows that the outbreak of COVID-19 did hinder the achievement, or at least decelerate the progress of achieving the 17 goals. In fact, according to the report, "some number of people suffering from food insecurity was on the rise and dramatic levels of inequality persisted in all regions. Change was still not happening at the speed or scale required", accordingly.

Therefore, in this event of pandemic, the quantity and quality of research, innovation, and more importantly multi-disciplinary collaboration are indispensable. Furthermore, there needs to be clear ends of those works. That is how those research are applicable and benefits directly to the society. That is how those research is incorporated as the drivers of policy making, and used practically in the society. Hence, the stakeholders especially the triple helix of higher education institution, government, and industry must be re-comprehended and supported to reach the common goal of the SGD.

International Conference on Sustainable Innovation (ICoSI) has been essentially attempting to strengthen this regard since its first establishment. One of the goals of ICoSI is to provide primarily a platform where scholars, practitioners, and government could grasp the development and trends of research. Hopefully, meeting these actors altogether would result in stronger collaboration, sophisticated and advantageous research, and brighter ideas for further research. Based on these reasoning, this year, the 4th ICoSI 2020 UMY is themed 'Cutting-edge Innovations for Sustainable Development Goals".

Improving from last year conference which brought nine focal conference, this year ICoSI 2020 UMY brings 14 disciplines, from social sciences, natural sciences, and humanities. ICoSI 2020 received as much as 1005 papers. The paper works submitted in ICoSI 2020 UMY will be published in Atlantis Proceedings, IOP Proceedings, National/International Journals, and ICoSI ISBN-indexed Proceedings.

Nevertheless, ICoSI believes that publication is only the beginning of research dissemination. The publications will enhance the chance of the research known by wider audience, and then used, applied, and incorporated at either system, institutional, or personal level of human lives.

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Valuation of a Declining Oilfield under Stochastic Oil Prices and Non-Constant Interest Rates

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ABSTRACT

In this research, we develop a model to estimate the value of a declining oilfield under stochastic oil prices and non-constant interest rates. Using the Schwartz-Smith model, oil prices are decomposed into two stochastic elements, the long-term dynamics which follow the arithmetic Brownian motion, and the short-term variation which follows the Ornstein-Uhlenbeck process that reverts to zero. The term structure of interest rates is represented using cubic spline interpolation. Considering the option to abandon before lease expiration, the contingent claim valuation method is employed to determine the oilfield value. Monte Carlo simulation is used to obtain the solution to the multistage valuation problem. Using the fixed sample size procedure, the simulation came up with the probability distribution of oilfield value, with a mean of US$13,341,969 and a 95% conditional value-at-risk of US$9,393,704. The mean of the remaining economic life of the field is 10.4 years.

Keywords: *Schwartz-Smith, cubic-spline, option to abandon, contingent claim valuation, Monte Carlo simulation.*

1. INTRODUCTION

When the lease of a producing oilfield is about to expire, the lessee should decide whether they will apply for renewal or not. Before doing so, the lessee needs information about the oilfield value and the corresponding remaining economic life. In general, oilfield valuation is a complex task due to the lengthy investment period (up to 25 years) and the existence of many sources of uncertainty. These uncertainties may be of market-related like oil prices, interest rates, and exchange rates, technical related like reservoir conditions, or even social and geopolitics.

Valuation of producing oilfields, especially those that have been producing for quite a long period, is much less complex than the unexplored ones. A soon-to-expire oilfield typically has been producing for at least 10-15 years that uncertainty regarding the reservoir condition has been revealed. The subsurface condition of such oil field, represented by a set of reservoir parameters, is known with relatively less variability. This makes production rates can be estimated accurately. The remaining uncertainties are those related to the market and other external factors.

Compared to other asset valuation methods, i.e. relative valuation and intrinsic valuation or discounted cash flow (DCF), contingent claim or real options valuation (ROV) is considered the best method for valuing assets under uncertainty [1]. In ROV, the uncertainty of cash flows as well as the investor's flexibility to cope with such uncertainty are considered. When all uncertainty and flexibility have been accommodated, unsystematic risks can be considered eliminated and the resulted cash flows can be discounted using the risk-free rates [1]. The use of risk-free rates eliminates the problem of determining risk-adjusted rates as in the DCF valuation method.

Among other market-related factors, oil prices are one that has the biggest impact on oilfield value and yet most difficult to predict. In previous research on oilfield valuation, oil prices were represented using various models, i.e. probabilistic with known probability distribution as in [2]; simple stochastic processes as geometric Brownian motion (GBM) as in [3], [4], [5], [6], and [7]; and more realistic mean-reverting processes as in [8] and [9]. GBM was quite popular in the early research on oilfield valuation due to its mathematical convenience which—in many cases—results in closed-form analytical solutions. A mean-reverting process is a more representative model for oil prices. According to [10], instead of going up or going down indefinitely, commodity prices, after going up or down to a certain level, will revert to its long-term equilibrium. Hence, a mean-reverting stochastic process is a more appropriate representation of oil prices than GBM.

In this research, we develop a model for determining the value of a declining oilfield by assuming that the oil prices follow a mean-reverting process. Instead of using the one-factor mean-reverting or one with jumps as in the previous research, the two-factor mean-reverting process [11] is adopted in this research. This stochastic process asserts that oil price dynamics have two components, i.e. the long-term equilibrium that follows an arithmetic Brownian motion, and the short-term dynamics that follows a mean-reverting process that reverts to zero. Furthermore, since the investment period is quite long (20 years), assuming constant interest rates does not make sense. Hence, a term-structure of interest rates is accommodated using the cubic spline interpolation [12].

The investor's flexibility considered in our valuation model is the option to abandon the oilfield when it is no longer profitable. The solution to the contingent claim valuation problem is obtained using the Monte Carlo simulation [13]. The risk of the investment is represented using the conditional value-at-risk [14].

2. METHOD

This section describes the elements of the valuation model that consist of the Schwartz-Smith oil prices model, the term-structure model of interest rates, and the simulation-based contingent claim valuation model.

2.1. The Schwartz-Smith Oil Price Model

In the two-factor mean-reverting process, also known as the Schwartz-Smith model, the log of the oil spot price is represented as the sum of two elements, the long-term equilibrium level and the short-term deviation [11]. If S_t is the oil spot price at time t, then we have

$$\ln(S_t) = \chi_t + \xi_t \qquad (1)$$

In Equation (1), χ_t is the short-term deviation at time t that follows the Ornstein-Uhlenbeck stochastic process which is a one-factor mean-reverting process. Mathematically, this process can be expressed as the following time-dependent differential equation

$$d\chi_t = -\kappa\chi_t\, dt + \sigma_\chi\, dz_\chi \qquad (2)$$

Parameter κ is the mean reversion coefficient that represents the rate at which the short-term deviation diminishes, σ_χ is the volatility of χ_t, while z_χ is a standard Wiener process. The standard Wiener process is defined as $dz_\chi = \epsilon\sqrt{dt}$, where ϵ is a normally distributed random variable with a mean of zero and a standard deviation of one.

The long-term equilibrium level at time t, ξ_t, is defined mathematically as

$$d\xi_t = \mu_\xi\, dt + \sigma_\xi\, dz_\xi \qquad (3)$$

where μ_ξ is the drift rate, σ_ξ is the volatility of ξ_t, and z_ξ is the corresponding standard Wiener process for ξ_t. Both stochastic components in Equation (1), z_χ and z_ξ, are correlated such that $dz_\chi\, dz_\xi = \rho_{\chi\xi}\sigma_\chi\sigma_\xi$, where $\rho_{\chi\xi}$ represents the association between dz_χ and dz_ξ.

According to [11], the parameters of the Schwartz-Smith model can be estimated by transforming it into the corresponding risk-neutral form, convert it into a state-space representation, and then iteratively employ the combination of maximum likelihood and the Kalman filter [15]. This estimation process requires the oil spot and futures price data. The method and Matlab code from [16] were used to estimate the parameters of the oil price model in this research.

2.2. The Term-Structure Model of Interest Rates

The risk-free interest rates available in the market are usually in the form of zero rates. The n-year zero-coupon interest rate (or zero rates) is the rate of interest earned n years from now on an investment made today [13]. In normal condition, greater n usually corresponds to greater interest rate, since people are less certain about cash flow earned in a longer period in the future. The data of zero rates in the market are usually available only in several maturities, e.g. 1, 3, 5, 10, 20, and 30 years. To estimate the zero rates for maturities between those periods, we need to do an interpolation. In this research we use the cubic spline to interpolate those interest rate values [12].

Suppose we have k pairs of data, each consist of maturity and the corresponding zero rate, denoted as $(t_0, r_{t_0}), (t_1, r_{t_1}), \ldots, (t_{k-1}, r_{t_{k-1}})$. Cubic spline interpolation aims to obtain a piecewise cubic polynomial function of time, $f(t)$ consisting of $k-1$ segments, where the jth segment, denoted as $f_j(t_j)$ or simply f_j , is defined over $[t_j, t_{j+1}]$ interval. Constraints regarding the continuity of the first derivative $f'(t)$, and the second derivative $f''(t)$ are imposed to ensure continuity. Based on [12], the jth polynomial segment, f_j, will take the following form

$$f_j = a_j + b_j(t - t_j) + c_j(t - t_j)^2 + d_j \qquad (4)$$

where $a_j = t_j$, $b_j = d'_j$, and

$$c_j = \frac{1}{t_{j+1} - t_j}\left(3\frac{f_{j+1} - f_j}{t_{j+1} - t_j} - 2f'_j - f'_{j+1}\right) \qquad (5)$$

$$d_j = \frac{1}{(t_{j+1}-t_j)^2}\left(-2\frac{f_{j+1}-f_j}{t_{j+1}-t_j} + f_j' + f_{j+1}'\right) \quad (6)$$

where Equation (5) and Equation (6) are defined in the same domain of $j = 0, \ldots, n-2$. The procedure for estimating the parameters in Equation (4), (5), and (6) can be found in [12].

The solution to the contingent claim valuation problem can be obtained by discretizing the time continuum and do the backward induction from the terminal period to time 0. At each point of time, a choice between executing and not executing the option is made and one with greater payoff is chosen. Not executing the option at time t would give a reward equal to the expected reward at time $t+1$ discounted to time t. This calculation requires information about the interest rate between time t and $t+1$ based on the interest rate data available at time 0; this is called the forward rate [13]. Suppose r_{t_1} and r_{t_2} are the zero rates for maturities t_1 and t_2, respectively, where $t_2 > t_1$. The forward interest rate between t_1 and t_2, denoted by $r_{f_{t12}}$, can be calculated as follows

$$r_{f_{t12}} = \frac{r_{t_2} \cdot t_2 - r_{t_1} \cdot t_1}{t_2 - t_1} \quad (7)$$

2.3. Contingent Claim Valuation using Monte Carlo Simulation

The contingent claim valuation problem in this research will be solved using the Monte Carlo simulation with the following algorithm:

1. Set the values of all parameters, i.e. oil prices model parameter, production volume estimates, and fiscal regime parameters.
2. Calculate zero rates of all maturities and the corresponding forward rates between two consecutive maturities
3. Generate oil prices sample path
4. Calculate net cash flow for each period
5. Do backward induction as follow:
    - i. Starting from the terminal period, calculate the termination payoff. Go back one period.
    - ii. Calculate the payoff at this period as the maximum between payoff if the oilfield is abandoned at this period and the payoff from the next period, discounted to this period using the forward rate. Repeat the same procedure until time 0.
    - iii. Record the result
        - The oilfield value is the value at time 0
        - The corresponding abandonment time is the earliest period at which the abandonment payoff is greater than the discounted value of the expected future payoff.
6. Repeat step 3-5 as many as the sample size needed

The required sample size is calculated using the fixed-sample-size procedure [17]. In this procedure, initial replications of size n are made, and the corresponding sample mean, $\bar{X}(n)$, and sample variance, $S(n)$, are calculated. The number of replications required to achieve $(1-\alpha)$ confidence level with a relative error of γ, denoted as n_r^*, is calculated as follows

$$n_r^* = \min\left\{ i \geq n : \frac{t_{i=1,1-\alpha/2}\sqrt{S^2(n)/i}}{|\bar{X}(n)|} \leq y' \right\} \quad (8)$$

where $y' = \gamma/(1+\gamma)$.

7. Calculate the estimated oilfield value using the average of oilfield values from all replications, and the corresponding risk using the 95% conditional value-at-risk (CVaR) of oilfield value from all replications.

With the distribution of the oilfield value on hand, the 95% CVaR can be calculated as the average oilfield value of the lowest 5% data.

To increase the estimation efficiency, we employed the antithetic variate [17] to reduce the variance. Under this scheme, each simulation sample is calculated as the average of a pair or simulation runs; one is run using the set of random number U and the other one using the complementary set of random number $1-U$. The variance reduction is induced by the negative correlation between the results obtained from those runs.

3. RESULT AND DISCUSSION

3.1. Estimation of The Oil Price Model Parameters

The parameters of the oil price model are estimated using Brent crude oil price data from the period of 22 December 2002 – 21 April 2019. The data consists of spot price and future price with a maturity of 1, 6, 12, 24, and 36 months. The resulting parameters are presented in Table 1 with a log-likelihood value of 11,089.8337.

Table 1. Parameter values of the oil price model

Parameters	Estimates	Standard Error
k	0.6187	0.0041
s_c	0.2291	0.0028
l_c	-0.2307	0.0144
m_x	-0.1111	0.0376
s_x	0.1971	0.0039
r_{xc}	0.2403	0.0013

Since the investment horizon of our valuation model is 1 January 2020 – 31 December 2042, the oil price model with parameters as in Table 1 is then validated using oil spot price daily data from the period of 22 April 2019 – 31 December 2019. The result is depicted in Figure 1. The dashed line in Figure 1 represents the 95% confidence band implied by the parameters in Table 1. It can be observed that almost all data falls within the band, except data number 2, 3, and 4. Since the fraction of data that falls outside the band is only $4/180 = 2.22\%$, it can be concluded that the oil price model is valid.

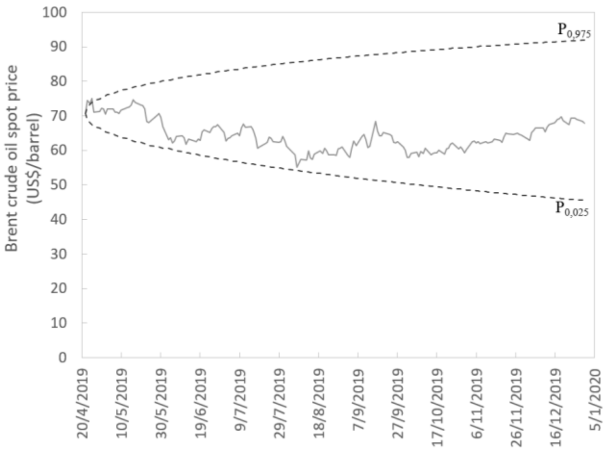

Figure 1. Validation of the oil price model

After this research was concluded, we found that during the pandemic oil prices fell below the 95% confidence band in Figure 1. In this situation, the oil price model needs to be re-parameterized using recent data and then re-validated, accordingly.

3.2. Term Structure Model of the Interest Rates

Due to the investment horizon that we analyze, we need to estimate the interest rates for the period of 1 January 2020 – 31 December 2042. We use data of the Indonesia Government Bond Yield Rates as of 31/12/19, as presented in Table 2.

Table 2. *The government bond yield rates as of 31/12/2019*

Maturities, in Year	Annual Yield
1	5.05%
3	6.24%
5	6.42%
10	7.10%
20	7.68%
30	7.66%

The term structure in Table 2 represents a typical situation where investors are less certain about a longer period in the future. The exception is for the maturity of 20 and 30 years where investors are slightly less certain about the shorter period. If this happens for shorter maturities (e.g. 3-5 years) and the difference is significant, it is an indication of a crisis. This is not the case in our case study.

The term structure model is then estimated using cubic spline interpolation and the resulting cubic functions are presented in Table 3 and graphically depicted in Figure 2. Using the functions in Table 3, we can estimate the interest rates for all maturities and calculate the corresponding forward rates that we need for our valuation model.

Table 3. The cubic functions of the term structure model

Maturities, t	Cubic-Spline Function of the Interest Rates, $f(t)$
[1,3)	$f(t) = 4.35 \times 10^{-2} + 6{,}28 \times 10^{-3}t + 1{,}00 \times 10^{-3}t^2 - 3{,}34 \times 10^{-4}t^3$
[3,5)	$f(t) = 2.36 \times 10^{-2} + 2{,}63 \times 10^{-2}t - 5{,}66 \times 10^{-3}t^2 + 4{,}07 \times 10^{-4}t^3$
[5,10)	$f(t) = 7.93 \times 10^{-2} - 7{,}16 \times 10^{-3}t + 1{,}02 \times 10^{-3}t^2 - 3{,}91 \times 10^{-5}t^3$
[10,20)	$f(t) = 3.55 \times 10^{-2} + 5{,}97 \times 10^{-3}t - 2{,}89 \times 10^{-4}t^2 + 4{,}68 \times 10^{-6}t^3$
[20,30]	$f(t) = 7.09 \times 10^{-2} + 6{,}67 \times 10^{-4}t - 2{,}83 \times 10^{-5}t^2 + 2{,}64 \times 10^{-7}t^3$

3.3. Estimating the Oilfield Value

The oilfield that we study has been producing for at least 30 years that the production rates can be predicted quite accurately. Using production data from the last 7 years (the only available data), we fitted the data with an exponential decline model using the least-squares method and came up with the following formula for the annual production rate, $p(t)$

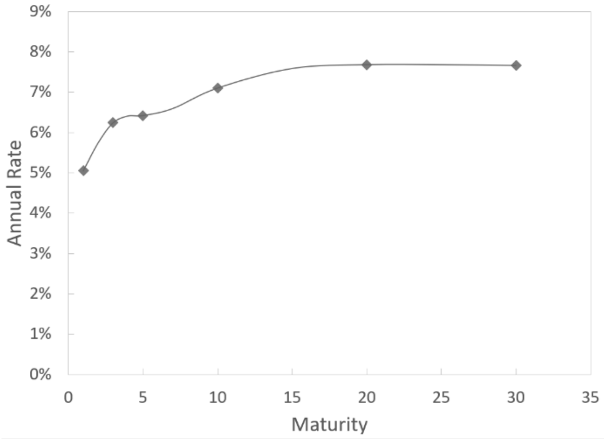

Figure 2. The term structure model of interest rates

$$p_t = 6{,}808{,}662.0241\ e^{-0.0629\,t} \qquad (9)$$

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The corresponding R^2 resulted from Equation (8) is 0.9752 which indicates that the model has a very good fit with the data.

We consider three categories of costs in our valuation model, i.e. fixed costs, variable costs, and abandonment cost. From past data, we found that the ratio of fixed cost to total cost increases as the production volume decreases. Hence, once we have the annual production volume prediction, we can estimate the fixed cost proportion. Using least squares estimation, we came up with the following relationship between that ratio, FCR_t, and the annual production rate, p_t

$$FCR_t = 0.3014\, e^{-4.9887\times10^{-7}\, p_t} \qquad (10)$$

The R^2 of the model in Equation (8) is 0.9432 which shows very good fitness.

The variable cost is assumed to be US$20/barrel, while the abandonment cost is US$2 million and paid at the end of the field's life. We also assume that the volume of oil produced is the same as the volume lifted and all are sold at the same market price. The current policy of the production sharing contract of the oil and gas exploration and production in Indonesia is that investors may choose between two fiscal regimes, i.e. cost recovery and gross split. In this research, we assume a production sharing contract under the cost recovery scheme with government-contractor shares of 85:15, and a 35% corporate tax rate.

We develop a simulation model using the algorithm described in Section II.C. The model was run with initial replications of 20, a relative error of 1%, and a level of significance of 5%. Based on the sample mean and sample variance calculated from those 20 replications, using the fixed-sample-size procedure we came up with the required number of replications of 398,791. For each replication, the oilfield value is calculated as the average of two simulation runs generated with complementary streams of random number. After removing outlier data, we came up with the probability distribution of the oilfield value as depicted in Figure 3.

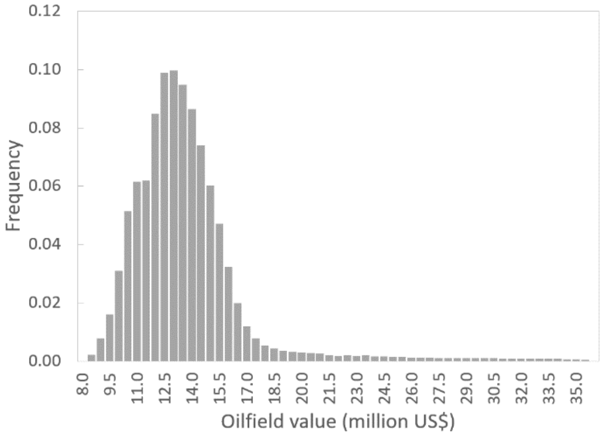

Figure 3. The distribution of the oilfield value

The mean of the oilfield value is US$13,341,969. It can be seen from Figure 3 that the distribution of the oilfield value is positively skewed which means that the oilfield value is more likely to deviate in a positive direction (greater than the mean). This is consistent with the characteristics of a declining oilfield where the economic viability is not an issue. Rather, the investor is more interested in estimating the remaining value and remaining economic life of the field, based on which they will manage the field accordingly. The distribution of the remaining economic life of the oilfield is depicted in Figure 4.

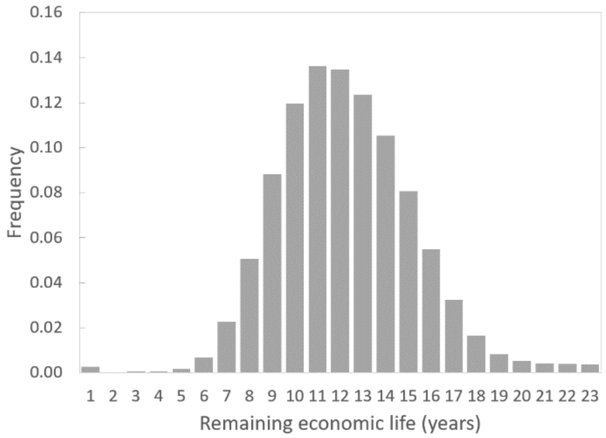

Figure 4. The distribution of the oilfield's remaining economic life

The mean of the oilfield's remaining economic life is 10.4 years. Figure 4 shows that the remaining economic life is quite dispersed, with the corresponding 95% confidence interval between 2.12 to 17.60 years. From an investment viewpoint, this is unfavorable because it will be more difficult for the investor to make a long-term commitment regarding the oilfield. Nevertheless, this is also valuable information that the investor may start to make necessary changes to the existing organization to anticipate this uncertainty.

The risk measures regarding the value and remaining economic life of the field are expressed using the 95% CVaR. Rather than assuming a theoretical probability distribution (e.g. normal), these risk measures are estimated based on their empirical distributions obtained from the simulation model. We came up with 95% CVaR of US$9,393,704 and 2.24 years for the oilfield's value and remaining economic life, respectively. This indicates a good investment in terms of economic value, but quite challenging in terms of the uncertain investment period.

The validity of our model can be inferred from the validity of the model's elements. We have shown that the oil price model has good predictive validity, at least until the beginning of the investment period. It is also shown that the sub-models that we use to estimate the production rates and fixed cost proportion have a very good fit with the past data.

The resulting oilfield value and remaining economic life assume that there is no new oil discovery that will significantly increase the production rates. Until several years ago, exploration and development are still underway, but the additional production rate is not significant. It only makes the current production decreasing less steeply, rather than increasing it to a completely higher level.

4. CONCLUSION

We develop a contingent claim valuation model of a declining oilfield under stochastic two-factor mean-reverting oil prices. The model considers the option to abandon before lease expiration when the abandonment value is greater than the corresponding discounted expected future value. Due to the lengthy investment period, instead of assuming a constant value, the interest rates are assumed to follow a deterministic term structure represented by the cubic spline interpolation. The solution to the corresponding multistage decision problem was obtained using the Monte Carlo simulation. To reduce variances, we use the antithetic variates, while the required number of replication is determined by the fixed-sample-size procedure. We came up with the mean of the oilfield value of US$13,341,969, with a 95% conditional value-at-risk of US$9,393,704. The mean of the remaining economic life of the field is 10.4 years.

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