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The Role of Success Rate, Discovery, Appraisal Spending, and Transitioning Region on Exploration Drilling of Oil and Gas in Indonesia in 2004–2015

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Abstract

Petroleum exploration decision remains a subject of petroleum and economic studies for decades. Most of the studies discuss the investment decision by focusing on either a technical or economic perspective. In reality, economic, geological, and environmental factors are expected to determine the way investors make a decision. This study aims to increase the understanding of best practices in decision-making by scrutinizing integrative perspectives applying panel data of 32 basins in Indonesia in 2004–2015. This study provides several contributions to optimize decisions on wells drilled. First, this study derives an empirical model examining several plausible factors of economy, geology, and environment. Second, the findings demonstrate how to empirically examine which factors significantly determine wells drilled by companies. The last contribution is to empirically support a technical transformation from Western to Eastern exploration due to the natural depletion of oil fields.

Keywords: Basin; exploration; geological and economic variables; wells drilled

JEL classifications: L71; Q35

1. Introduction

The petroleum industry has been an engine of growth for the economic and societal development of Indonesia for decades. Meeting the market demand and managing the geological and environmental challenges constitute the key subjects for the government of Indonesia, oil companies, and related stakeholders. The depletion and maturity of natural oil accelerate technological and policy transformation. Facing these geological challenges, exploration has transformed from oil to gas exploration and enhanced offshore to deep-water development. The government has also transformed policy from production sharing contract (PSC) to gross split (GS).

These transformations have several technical and economic implications that determine the exploration decision. Firstly, gas, offshore, and deep-water drilling require different technology, thus these transformations are expected to substantially increase exploration costs. On the other hand, oil exploration companies tend to be exposed to higher risk from a new GS regime. They have to selectively invest in development and production fields by considering plausible factors and consequences. In this vein, data and decision processes constitute the most important element of investment decisions. The better they collect and analyze data and information, the higher their chance to increase the success rate.

Even though stakeholders are highly concerned about geological data in Indonesia, most of the datasets and information collected by the government and companies are aggregate data. This lack

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of exploration data leads to a lack of empirical evidence and findings. The disaggregate datasets are generally difficult to collect and evaluate empirically (Greiner, Semmler & Mette 1989). This situation may cause a lack of exploration activities and other investments in the oil and gas sector, resulting in the decline of oil reserves and production in Indonesia (Azizurrofi & Mashari 2018).

Generally, the exploration phase consists of investment decisions to undertake scouting, exploratory, and development drilling (Favero & Pesaran 1991; Rao 2000). In Indonesia, the exploration phase includes 6 (six) years with an extension of 4 (four) years upon the request of the Contractor following the fulfillment of the minimum requirements (Azizurrofi & Mashari 2018). They used to perform exploration activities such as Geological & Geophysical (G&G), Seismic & Survey, Exploratory drilling, and other supporting activities. In the event that the contractor finds no commercial discovery during the period, they will be terminated by the Government institution through The Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas) (Azizurrofi & Mashari 2018).

Most fields drilled in the Western region (e.g., Central Sumatera, South Sumatera, and North West Java) have specific characteristics compared to the Eastern region according to geological features and availability of drilling support and infrastructure. Historically, many basins located in Sumatera have been developed for decades. Despite new development in several areas, most of them are classified into saturated oil fields. Generally, data and information are relatively more available in developed than emerging fields. It can be argued that the more datasets available, the higher the success rate of wells drilled. Hypothetically, the success rate may be higher than in other parts of Indonesia, but the discovery size is smaller because of the natural decline in the matured fields.

On the other hand, emerging fields and basins located in Eastern Indonesia (e.g., Tomori, South Makassar, Papua, Salawati) have a lack of geological data and available supporting infrastructure.

Despite a chance of higher discovery size of oil and gas in these locations, the exploration costs are relatively higher. The situation becomes more central when decision-makers have incomplete data, imperfect information, and incomplete understanding (Finch, Macmillan & Simpson 2002). These limitations lead to several implications for exploration decisions. In this vein, it can be contended that the higher the limitation on exploration data e.g. geological features, the higher the bias that may exist on exploration decisions. Secondly, the inability to integrate technical, geographical, and geological values into the exploration model has presented a significant barrier to a more explicit investment decision modeling approach (Hasle, Kjellén & Haugerud 2009; Suslick & Furtado 2001).

This study provides an econometric model that can be applied to optimize investment decisions in the field of oil exploration. The scientific basis empirically tests geological and economic variables using disaggregate data to determine wells drilled in geological basins in Indonesia. Consequently, exploration companies can make investment decisions and plans in oil and gas exploration. The model can be utilized to identify the significance and magnitude of the explanatory variables. In practice, the findings can diminish the subjective blindness and confirmation bias in investment decisions and produce a reasonable and orderly exploration and development of petroleum reserves (Yuhua & Dongkun 2009).

This paper is scientifically organized as follows. First and foremost, the background and objectives are described. Section 2 discusses an overview of earlier literature. The method containing data collection as well as theoretical and empirical approach is offered in Section 3, followed by findings and discussion in Section 4. Last but not least, several concluding remarks are offered in Section 5.

2. Literature Review

The integration of economic, environmental, and geological variables in an empirical setting dates back to 50 years ago. Most of the studies of exploration refer to a state-of-the-art developed by Fisher's works (Greiner, Semmler & Mette 1989; Mohn & Misund 2009; Mohn & Osmundsen 2008; Patria & Adrison 2015). The model estimates exploration equations by applying the success and discovery rate for different American oil fields over the period 1946-1955. Explanatory variables cover economic factors (e.g., oil prices, drilling costs) and geological proxies (e.g., seismic, discovery rate). The most common model is based on aggregate data for regions, continents, groups of countries, and countries (Mohn & Misund 2009; Mohn & Osmundsen 2008; Patria & Adrison 2015).

Over the past 15 years, the exploration model using disaggregate data has been developed by several scholars, e.g. Kolb, Pindyck, and Hubbert (Mohn & Misund 2009; Mohn & Osmundsen 2008). Kolb (1979) examines Fisher's works for oil-prone districts whose settings are slightly more disaggregated. Pindyck (1974) originates the interest rate in his drilling model. The role of economic variables is more considered in that year. Hubbert (1962) addresses the depletion effect on his model, stimulating insightful findings and implications for economic and policy instruments (Mohn & Misund 2009; Mohn & Osmundsen 2008).

The research trends reveal that empirical models become more complex, demanding disaggregate and intertemporal data across periods. Most of the empirical works in this field are dominated by US and European Countries. Therefore, there is a lack of practicability and generalization of earlier findings in other countries. Over the last 20 years, geological and economic perspectives have been applied to comprehensively study exploration economics (Mohn & Misund 2009; Mohn & Osmundsen 2008). Even though the disaggregate studies lead to better insights, most common studies are still developed by employing aggregate data for groups of coun-

tries, countries, or regions (Greiner, Semmler & Mette 1989; Patria & Adrison 2015).

In Indonesia, one of the empirical analyses using geological basins is conducted by Patria & Adrison (2015) using datasets comprising geological and economic variables. The results discuss determinant factors affecting oil exploration in Indonesia in 2004-2013 that open a way to uncover the role of geological and economic features (Patria & Adrison 2015). Even though earlier studies already tested the model empirically, several economic and institutional variables are overlooked, e.g. appraisal spending and national vs. international oil operatorship. It can be argued that appraisal spending becomes a significant part of the early stages of exploration. Moreover, institutional features such as management policy and operatorship may play an important role both in exploration and production.

3. Method

3.1. Data Collection

The datasets comprised of time series for all variables over the period 2004–2015, split between the two regions in the geological basins of Indonesia. The datasets were retrieved from the database of SKK Migas. This government institution used to collect and evaluate the data and information for monitoring and optimizing upstream oil and gas activities in Indonesia.

According to the stylized facts in Fig 1, the exploration in the East prone is dominated by emerging fields that vary in many wells drilled by exploration companies. On the other hand, the wells drilled in West prone are relatively fewer. This descriptive analysis confirms a transition from West to East Exploration that has different geological features. Petroleum exploration in the geological portions of Indonesia is quite different observed from the standpoint of a petroleum industry (Satyana 2018). The exploration and production have been intensified on the western basins of Indonesia that has less potential of undiscovered fields most probably containing

small to medium size of petroleum. On the contrary, the eastern basins are a relatively high-risk frontier generally under-explored and under-exploited with half of the basins undrilled (Satyana 2018).

Figure 2 describes several variables used in this study such as wells drilled, discovery size of the success rate of oil and gas, and appraisal spending. The distribution of data indicates a difference in drilling activities in these separated geological basins. In line with the earlier discussion, the exploration activities in the East region are relatively higher, as are the success rate and volume discovered by exploration companies. This stylized fact confirms the transition from oil to gas exploration.

Petroleum experts have identified some proven and other potential both in western and eastern basins of Indonesia. They are classified into (i) Paleogene synrift and pre-tertiary basins (Sumatera, Java, Natuna, and Barito); (ii) Neogene delta and deep waters (East Kalimantan and Makassar Straits); (iii) Paleogene synrift and postrift (Offshore West Sulawesi, Bone, and Gorontalo), (iv) Gondwanan Mesozoic sections (Sumatera, Java, and Makassar Straits); (v) Paleogene-Neogene sub- and intra-volcanic (Java and West Sulawesi); (iv) Mesozoic Australian sediments (Gorontalo, Buton, Banggai, Sula, Outer Banda Arc, Lengguru, and Central Ranges of Papua); (vii) Paleozoic sections (Arafura Sea and South Papua), and (viii) Neogene Pacific province of North Papua (Satyana 2018). In a seminal paper, Satyana (2018) identifies and summarizes the worthiest play types of geological basins for future exploration. Several of these play types are geologically proven by oil and/or gas discovery. The rest are conceptual and still rely on seismic data and development.

Indonesian Petroleum Association (2014) reports that most of the exploration in East prone is dominated by primary oil and gas fields. Several basins such as Tarakan, Banggai, Seram, Sulawesi, and Bintuni fall into this category except for Barito and Kutai. On the contrary, most of the oil exploration in West prone is secondary oil and gas fields. Several basins such as South Sumatera, Sunda, North

West Java, and East Java are classified into this category. In addition to the tertiary oil and gas fields, Central Sumatera as the biggest oil producer is classified into tertiary oil fields. The Rokan Block, operated by Chevron Indonesia, has been the largest oil producer applying a tertiary oil field development, namely Enhancement Oil Recovery (EOR).

The findings cover spending per well by exploration companies in a certain basin. The East exploration is apparently more distributed in number. They also spend higher in line with the discovery size of oil and gas found in a certain basin. This indication constitutes the important key issue of why the economic factor does matter.

This figure also reveals other important findings. The transformation of gas exploration can be simply depicted through a comparison chart of ultimate recovery factors of gas fields. Several basins have higher recovery factors, such as Barito, South Makassar, Bone, Banggai, and Bintuni. Even though certain exploration has higher recovery factors such as North Central Java and South Sumatera, most of the exploration in West prone has a lower rate. This indication constitutes the important key issue of why the geological factor does matter. Overall, the findings confirm the importance of the economic and geological factors.

3.2. Theoretical Framework

Oil exploration aims to discover new petroleum reserves through an all-inclusive process comprising Geology and Geophysics (G&G) activities in potential areas. This study presents a theoretical model and research framework relied on theoretical economics derived from a previous model of geological and economic variables in the case of petroleum exploration. A research model was developed by employing profit maximization as a key assumption for the expected return on investment and its considerable risk. The model adopted the earlier model (e.g., Mohn & Osmundsen 2008; Patria & Adrison 2015).

The model employed several wells drilled by explo-

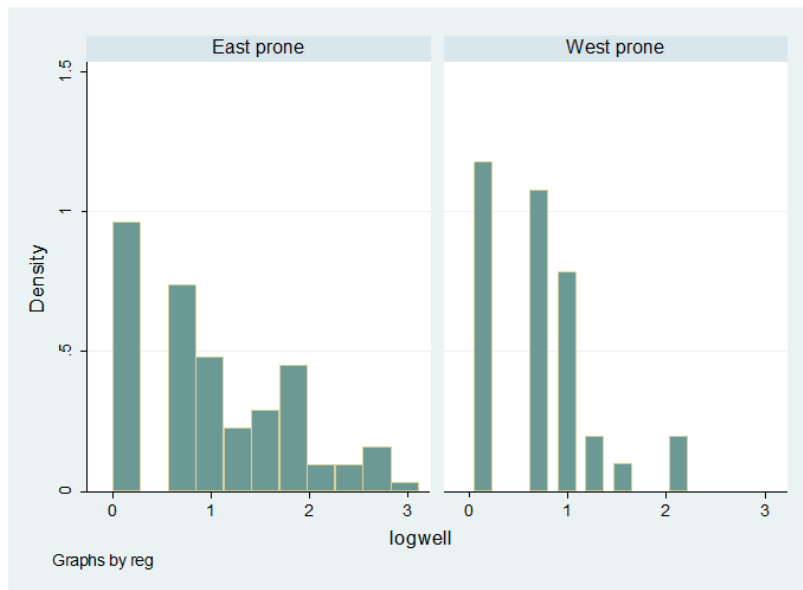


Figure 1. Wells Drilled in East and West Prone (in logarithmic form)

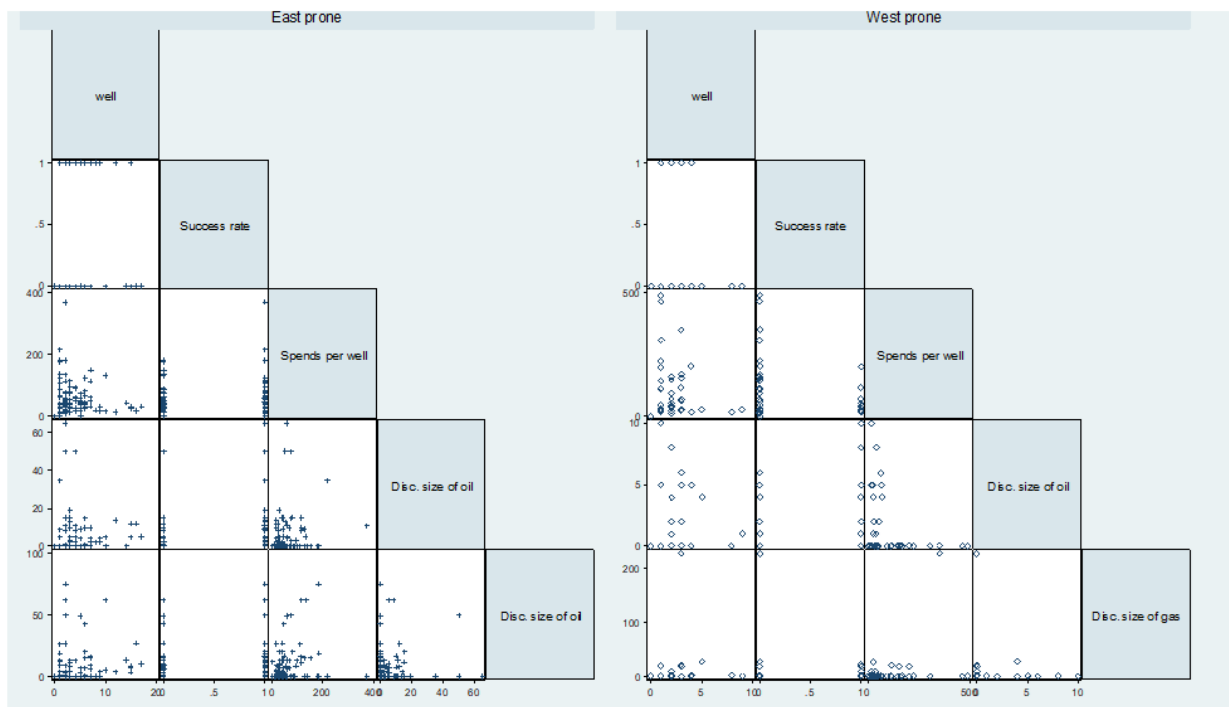


Figure 2. Wells Drilled in East and West Prone

ration companies as a single dependent variable. Meanwhile, the explanatory variables cover two major geological and economic factors. The first factors contain the success rate and discovery size of both

oil and gas in exploration activities. These factors also embrace other geological proxies by applying the region and location of the geological basins where the companies drill the wells. The higher the

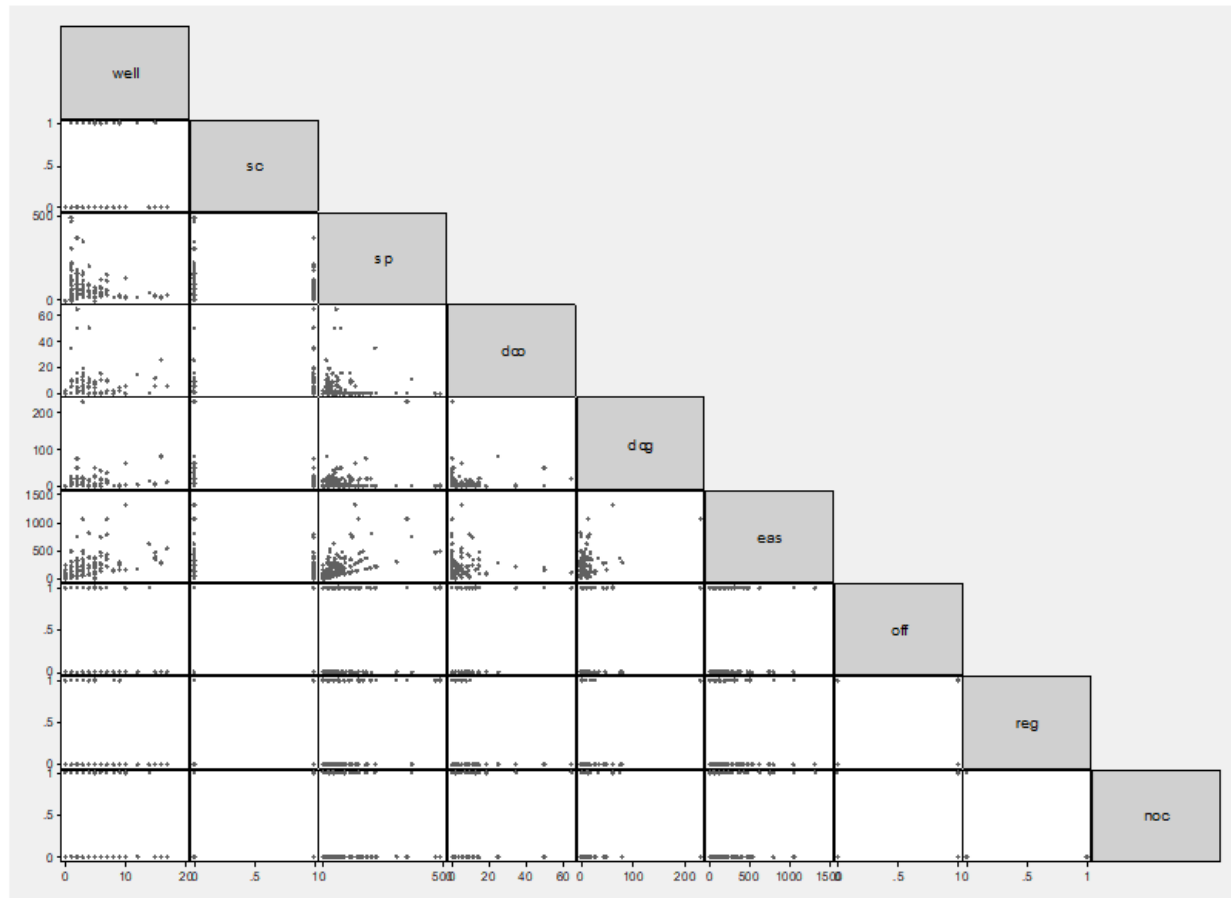


Figure 3. Descriptive Analysis of Overall Datasets

success rate and discovery size in exploration activities in an earlier year, the higher the chance of the companies to drill a well. This study attempts to include a variable of exploration cost by applying the amount of cost spent by exploration companies. This study, therefore, regresses the number of exploration wells drilled on the explanatory variables.

First, this model implemented a production function $Y = f(Z, W) = W^\alpha Z^\beta$, wherein W is demarcated as several exploration wells drilled by companies against Z as the geological and economic variables with an assumption of decreasing return to scale $\alpha + \beta < 1$. Even though the theoretical model presents a terminology of Cobb-Dougllass, α and β indirectly represent a conception of the degree of sustainability. α means an exploration intensity determined by how many wells drilled by

exploration companies, while β represents a geological intensity estimated by purely exogenous factors in given geological basins. The return of exploration is defined as a multiplication between expected oil price and reserves derived from the discovery size of oil and gas $p(t) \cdot f(Z, W)$, while s is a success rate.

The cost of exploration is then modeled by the expenditure function $C = \phi_w W + \phi_z Z$ wherein ϕ_w is defined as the specific cost of exploration wells. The choice of exploration wells drilled depends upon the success rate at a previous time, considering the success rate of $p(t)$ is $p(t)e^{(s-r)t}$.

The purpose is then to maximize the corresponding

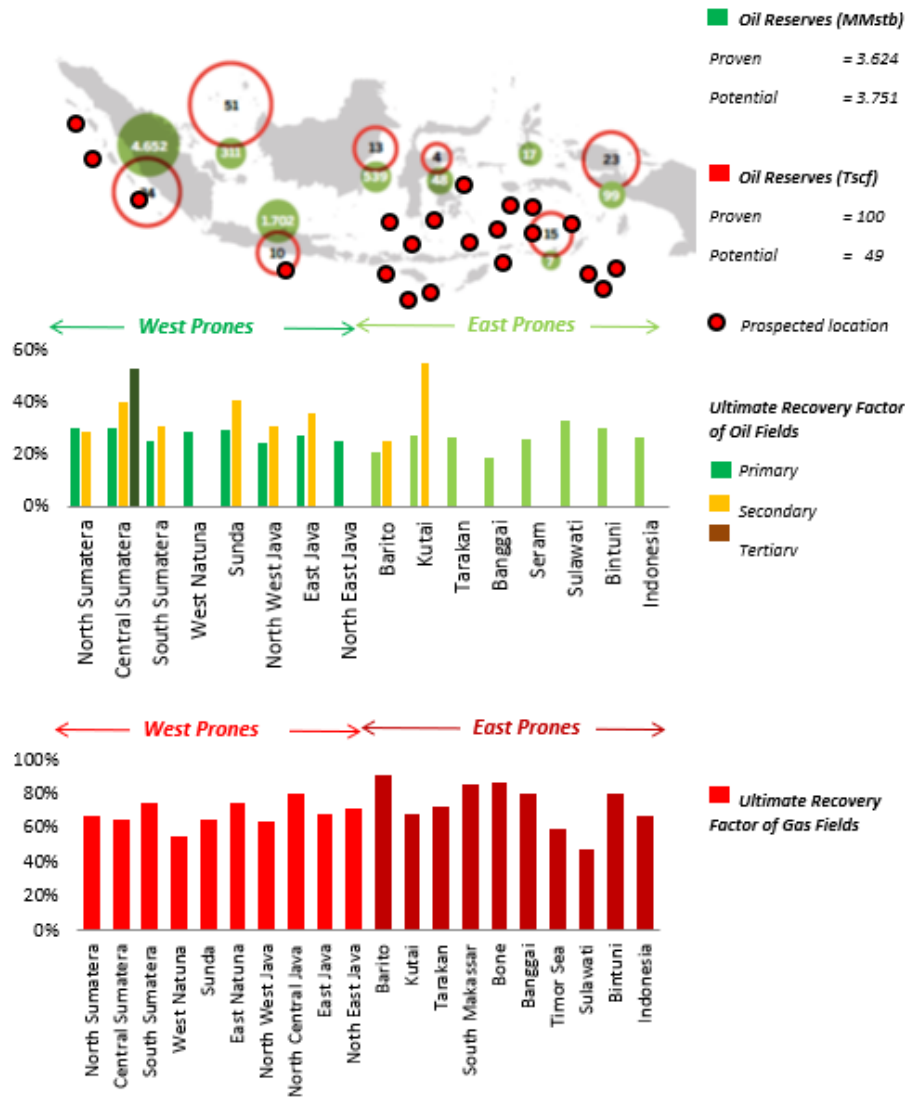


Figure 4. Exploration Profile in Geological Basins in Indonesia

profit function:

$$\pi = \sum_{i=1}^n [pf(Z_i, W_i)e^{(s-r)t} - \vartheta_w W_i e^{-rt} - \vartheta_w Z_i e^{-rt}] \quad (1)$$

Equation (1) is the profitability function frequently applied in natural resource modeling. Companies make exploration decisions with special regard to expenditure and other resource constraints (Patria & Adrison 2015; Suslick & Furtado 2001). Moreover, exploration drilling has several existing plausible

risks ranging from geological uncertainty regarding reservoir structure, sedimentation characteristics, and volume of hydrocarbons (Liang et al. 2014; Salazar-Aramayo et al. 2013; Suslick & Furtado 2001). Therefore, the equation of profit maximization for wells drilled can be differentiated by the following equation:

$$\frac{d\pi}{dW} = \sum_{i=1}^n \left[pe^{(s-r)t} \frac{dY}{dW} - \vartheta_w W_i e^{-rt} \right] \quad (2)$$

To maximize the profit, the first-order condition is applied:

$$\sum_{i=1}^n \left[p e^{(s-r)t} \frac{dY}{dW} - \emptyset_w W_i e^{-rt} \right] = 0 \quad (3)$$

Thus, the equation can be simplified into:

$$p e^{(s-r)t} \frac{dY}{dW} = \emptyset_w W_i e^{-rt} \quad (4)$$

Substituting the following equation $\frac{dY}{dW} = \alpha \frac{Y}{W}$ into equation [4], the corresponding function for formulating several wells drilled for new exploration (W) can be expressed as follows:

$$p e^{(s-r)t} \alpha \frac{Y}{W} = \emptyset_w W_i e^{-rt}$$

Rearranging the equation, the final model is

$$W = \frac{p e^{(s-r)t} \alpha Y}{\emptyset_w} \quad (5)$$

Substituting the equation $Y = f(Z, W) = W^\alpha Z^\beta$, the following function summarizes the number of wells drilled for the exploration model:

$$W = \frac{p e^{(s-r)t} \alpha W^\alpha Z^\beta}{\emptyset_w} \quad (6)$$

Simplifying the equation, the corresponding function can be expressed by:

$$W^{1-\alpha} = \frac{p e^{(s-r)t} \alpha Z^\beta}{\emptyset_w} \quad (7)$$

Therefore, the exploration behavior from the field may be written as:

$$W = \left(\frac{p e^{(s-r)t} \alpha Z^\beta}{\emptyset_w} \right)^{\frac{1}{1-\alpha}} \quad (8)$$

The model is then used to estimate the impact of the given geological and economic variables. Supposing the exploration spends a well in \emptyset_w , a pos-

itive relation between wells drilled and geological variables can be analyzed from differentiation as $\frac{dW}{dZ^\beta} > 0$. This model confirms a stylized fact that the higher the success rate as well as the discovery size of oil and gas, the higher the chance of a company to explore a well. On the contrary, the negative relation between wells drilled and exploration cost can be analyzed as $\frac{dW}{d\emptyset_w} < 0$. This model confirms a stylized fact that the higher the cost spent for exploration drilling, the lower the chance of a company to explore a well.

3.3. Empirical Method

This section aims to transform the theoretical model into an empirical model for hypotheses development regarding the exploration of oil and gas wells in Indonesia. Adopting Fisher (1964), the empirical model consisted of an average discovery size of oil and gas as well as success rate. To construct the model, this study covers geological and economic features such as region, location either onshore or offshore drilling, operatorship either by national or international oil company, and appraisal spending.

The multiple regression model was employed to empirically assess the geological and economic predictors that offer a more suitable and compatible way for causal model. The ceteris paribus was widely applied in the multiple regression in order to maintain the remaining conditions constant. Thus, it allows an interpretation of the parameter of each predictor, with the effect of other predictors statistically eliminated. According to equation (8) and aforementioned variables, the equation can be modeled as follows:

$$\begin{aligned} \text{discussed } W_{it} &= \alpha_i + \beta_{1i} S_{C_{i,t-1}} + \beta_{2i} D_{O_{i,t-1}} \\ &+ \beta_{3i} D_{G_{i,t-1}} + \beta_{4i} \ln Sp_{it-1} \\ &+ \beta_{5i} Of_{i,t-1} + \beta_{6i} Reg_i + \beta_{7i} No_i \\ &+ e_{it} \end{aligned} \quad (9)$$

W_{it} stands for the number of wells drilled. The geological variables are explained by the success rate $S_{C_{i,t-1}}$ and discovery size of oil and gas respectively $D_{O_{i,t-1}}$ and $D_{G_{i,t-1}}$ in the previous year. The

economic variable is then expressed by the exploration cost spent by companies in the previous year $SP_{i,t-1}$. The β_{ni} is the coefficient to be estimated, while α_i and e_{it} are the intercept and the error of the econometric model, respectively. Each explanatory variable varies across basins and period. This model applied lag variables on exploration explaining the behavioral model of companies.

The exploration model used in this study took geological distribution into account. Each well drilled in geological basins is an integer. Whereas, the discovery size of oil and gas are decimal data. Therefore, these different types of data in the model were then estimated by selecting the Poisson regression model. The regression model analyzed the distribution with the intensity parameter μ determined by the explanatory variables. One of the assumptions that should be sufficient is equidispersion, wherein the variance is equivalent to the mean value, unless this situation may lead to overdispersion that lowers the standard error of each parameter.

To address the overdispersion, this study applied Poisson regression. This type of regression becomes one of the most popular tools for modeling the relationship. In particular, it is recommended to estimate the model comprising discrete data in the dependent variable and a set of explanatory variables with mixed characteristics ranging from the decimal, discrete, and categorical data. Negative binomial regression aims to overcome overdispersion since this method contains a dispersion parameter.

Poisson and negative binomial models are supposed to be applied to address overdispersion. The "rare events" of the nature of wells drilled are controlled in the formula of negative binomial regression. The difference between these two models lies on the assumption of conditional mean and variance of the distribution. Poisson model preassumes equality on conditional mean and variance while negative binomial regression preassumes that the variance is relatively higher than the conditional mean. Concerning the descriptive data, wells drilled have a variance of 7.2648 and a mean of 1.3594.

All variances are relatively higher than the mean except for dummy variables of offshore location and geological region. Therefore, this study applied negative binomial regression to overcome overdispersion.

4. Results and Analysis

This paper empirically examines an economic model of petroleum exploration for oil and natural gas fields. The econometric model comprises fixed and random effects, as represented by Equation (9). Table 3 reports the estimation results to capture the geological and economic factors in the exploration drilling efforts in Indonesia. First, success rate statistically and positively determines the number of wells drilled for all regression models, both fixed and random effects. It can be concluded that the success rate derived from earlier drilling significantly leads to the next drilling effort. The positive result confirms that the higher the success rate, the higher the chance of a company to drill. The similar result supports earlier literature on the exploration model (Boyce & Nøstbakken 2011; Patria & Adrison 2015).

Second, the discovery size of oil statistically and positively determines the number of wells drilled for all regression models, both fixed and random effects. The consistent result demonstrates that the model is relatively stable for all regression models. The positive relationship confirms the hypothesis that larger size of oil discovered in an exploration well means higher chance for a company to drill the well. The similar result supports earlier literature on the exploration model (Mohn & Osmundsen 2008; Patria & Adrison 2015).

The first two results are consistent to uncover the phenomena of exploration in Indonesia where exploration companies review and examine the drilling efforts based on geological facts found in the previous year. The larger the size and the higher the success rate, the higher the chance of a drilling company to drill a well.

Table 1. Descriptive Analysis of Drilling Data in Indonesia during 2004–2015

Variable	Symbol	Mean	Standard deviation	Minimum	Maximum
Wells drilled	W_d	13.5940	2.60	0	17
Success rate	S_c	0.1640	0.37	0	1
Discovery size of oil	D_o	15.1830	6.00	0	65
Discovery size of gas	D_g	32.3690	14.60	0	248
Spending per well	S_p	27.7500	61.00	0	490
Offshore	O_f	0.5000	0.50	0	1
Region	R_g	0.4375	0.49	0	1
National oil company	N_o	0.1875	0.39	0	1

Source: Author

Table 2. Descriptive Analysis of Drilling Data in Indonesia during 2004–2015

Variable	Symbol	Mean	Variance	Skewness	Kurtosis
Wells drilled	W_d	13.594	72.648	30.779	141.972
Success rate	S_c	0.1640	0.1375	18.142	42.915
Discovery size of oil	D_o	15.183	36.05	68.267	591.627
Discovery size of gas	D_g	32.369	213.35	108.318	1.544.425
Spending per well	S_p	27.75	3760	39.278	230.660
Offshore	O_f	0.50	0.2506	0.00	1.00
Region	R_g	0.4375	0.2467	0.2519	10.634
National oil company	N_o	0.1875	0.1527	16.012	35.641

Source: Author

Table 3. Estimation Results of Wells Drilled Mode

Variables	Wells drilled (W_d)					
	Fixed Effect			Random Effect		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Success rate	1.282*** (0.160)	1.054*** (0.168)	1.071*** (0.178)	1.260*** (0.162)	1.030*** (0.170)	1.022*** (0.180)
Spends per well	3.69e-05 (0.00114)	0.000784 (0.00118)	0.000750 (0.00119)	-0.000412 (0.00116)	0.000231 (0.00121)	0.000253 (0.00122)
Discovery of oil	0.233*** (0.0756)	0.196*** (0.0753)	0.192** (0.0764)	0.230*** (0.0756)	0.195*** (0.0735)	0.196*** (0.0741)
Discovery of gas	0.00132 (0.0183)	0.00525 (0.0177)	0.00567 (0.0178)	0.00180 (0.0183)	0.00559 (0.0172)	0.00541 (0.0172)
Appraisal spending	0.00300*** (0.000325)	0.00266*** (0.000337)	0.00271*** (0.000371)	0.00314*** (0.000329)	0.00280*** (0.000341)	0.00278*** (0.000384)
Offshore		-0.133 (0.151)	-0.133 (0.150)		-0.125 (0.150)	-0.125 (0.150)
Region (west)		-0.637*** (0.192)	-0.658*** (0.205)		-0.671*** (0.194)	-0.662*** (0.206)
National company			-0.0575 (0.201)			0.0271 (0.200)
Constant	-1.366* (0.722)	-1.133* (0.682)	-1.116 (0.684)	-1.689*** (0.365)	-1.302*** (0.382)	-1.312*** (0.390)
Observations	382	382	382	382	382	382
Number of t	12	12	12	12	12	12
\ln_r				16.58	17.83	16.96
\ln_s				17.35	18.52	17.66
<i>Log-likelihood</i>	-40.565.326	-39.939.531	-39.935.438	-4.520.357	-44.522.924	-44.521.999

Note: Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In addition to geological characteristics, the third finding supports the drilling transformation from west to east prone in the geological basins of Indonesia. A proxy for the region shows that drilling in the eastern areas has increased for years, consisting of emerging basins with higher discovery sizes of oil and gas. In addition, these emerging basins tend to have a higher success rate than mature basins mostly located in the western areas. The mature basins are expected to have less discovery size of oil and gas since they naturally face a depletion effect. The significance of the geological region of western and eastern Indonesia is in line with earlier studies (Patria & Adrison 2015; Satyana 2018) describing the geological evolution and diversity of sedimentary basins that have been developed and deformed.

This geological regime is the key to understand the petroleum systems of geological basins to unlock their petroleum potential (Satyana 2018). Exploration conditions in the geological portions of Indonesia is quite different observed from the standpoint of a petroleum industry (Satyana 2018). The exploration and production have been intensified on the western basins of Indonesia. The western areas relatively have less potential of undiscovered fields most probably containing small to medium size of petroleum. On the contrary, the eastern basins are relatively high-risk frontier generally under-explored and under-exploited with half of the basins undrilled (Satyana 2018).

Last but not least, an economic variable such as expenditures spent by a company for appraisal leads to several wells drilled for all regression models, both fixed and random effects. Appraisal drilling is a transitional stage between petroleum exploration and field development. This stage is relatively complicated in which geological characteristics play an important role (Dijkers 1985). The higher the uniqueness and complexity, the higher the uncertainty that occurs in this early stage of exploration. This result is also in line with a stylized fact in petroleum exploration in Indonesia. Exploration companies selectively invest in proven ex-

ploration fields presumably having better historical datasets and exploration experience that in turn leads to a higher success rate.

The significant and negative constant confirms a deteriorating activity in petroleum exploration in Indonesia. Statistically, this constant is often defined as the mean of the dependent variable when all explanatory variables are set to zero. The result demonstrates the importance of this study for discovering and testing the significant variables. Subsequently, those variables can be used to increase exploration activities.

5. Conclusion

The purpose of the present paper is to denote and empirically test a model of exploration behavior of companies in the geological basins of Indonesia. The specification of a model offers a way to identify significant variables and optimize them in the case of investment decisions. The findings have important implications for geological and economic policy: the effect of any changes in exogenous variables, such as discovery size of oil, success rate, appraisal spending, and transitioning region, is possible to be fully scrutinized on oil and gas exploration.

Observed from a methodological point of view, these findings highlight the importance of geological and economic factors in the econometric modeling of oil exploration. Subsequently, exploration companies can make investment decisions and plans in oil and gas exploration and development by managing the significant variables ranging from success rate, discovery size of oil, appraisal spending, and region.

In practice, the findings can diminish the subjective blindness and confirmation bias in investment decisions (Patria, Wahyuni & Kusumastuti 2019; Patria 2021) and produce a reasonable and orderly exploration and development of oil and gas reserves (Yuhua & Dongkun 2009). A decreasing trend is observed for exploration in Western basins across the model, suggesting an increased emphasis on

the Eastern basins for investment in exploration activities. The results also confirm that there is relatively similar behavior in exploration activities conducted by national oil companies (NOCs) and international oil companies (IOCs). Therefore, it can be concluded that there is a weak relation between resource nationalism and exploration intensity.

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