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The optimal model of oilfield development investment based on Data Envelopment Analysis

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ABSTRACT

The investment problem of oilfield development is to trade off the investment exploration investment and development investment. With low return on investment got by using the existing method to solve this problem, we construct an optimal model to improve it based on Data Envelopment Analysis (DEA) method and the relations about investment and proven reserves, investment and output as well as production cost. Data Envelopment Analysis (DEA) method is used to present a method to determine the optimal scale of productivity construction investment in unit production. The relation between total cumulated proven reserves and cumulative exploration investment is denoted as an exponential model. The relation among productions and remaining recoverable reserves as well as production cost may be described as an exponential operational cost function. Based on above two relation models and investment effectiveness coefficients of every block, we establish an optimal model whose objective function is net present value (NPV) profit maximum, whose constrain conditions include investment, reserve/production ratio, production and some equality constraints under the mode of sustainable development. It can be solved by genetic algorithms. The result of case study shows that this optimal investment of oilfield development has multi-stage investment structure under given conditions; the model can provide scientific basic theory for oil companies to make a long-term strategic program and investment plan in oil exploration and development, may decrease the subjective blindness in the investment and bring about a reasonable and orderly exploration and development of oil resources.

1. Introduction

Thorough investment analysis is crucial to the decision makers in the oilfield development due to the large costs associated with production fields, processing facilities, compressor stations, pipelines and other infrastructures. Many scholars have studied the optimal problem of oilfield development and investment. For example, Kjetil Trovik Midthun [1] presented an optimization model for analysis of system development for natural gas fields, processing and transport infrastructure. Zhang Daoyong [2] proposed two relation models which are Gompertz model and Exponential model about the drill footage and proved reserves. Chermak J M and Patrick R H [3] generalized the existing economic theory about exhaustible resource production and made a type test for extended theory of Halvorsen and Smith [4] using successfully a sample of natural gas resources. Livernois J [5] made empirical evidence analysis about cost functions for conventional oil extraction and obtained three meaningful conclusions. Under technical and geological uncertainties, Almeida L F et al. [6] studied the optimization system of valve control in intelligent wells based on decision support system, constructed optimal models maximizing the net present value (NPV), presented an evolutionary algorithm to solve them, and formed proactive well control strategies as well as optimal operation schemes for oilfield.

Although people have obtained some experience for investing optimally to develop oilfield, its return on investment

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is often very low, especially that of Chinese oil companies is much lower. Its reason is not only the changes of oilfield exploitation environment but also some unreasonable investment to reduce the oilfield development benefit. In this paper, we shall use Data Envelopment Analysis (DEA) method to study the problem of return on investment by considering synthetically production and reserves as well as investment. And we shall establish investment yield structure relation model and a multiple objective optimal model about maximum profit and return on investment as well as above investment-yield-structural relationship to improve return on investment of oilfield development.

2. The investment problem of oilfield development and Data Envelopment Analysis

2.1. The investment problem of oilfield development

Exploration and development of oil are the two parts depending on each other of the oil industry, because oil exploration may provide backup reserves for oil development, oil development is to make the oil be exploited from the underground. Thus the investment problem of oilfield development is to trade off the investment between oil exploration and oil development. Because the investment amount of oil exploration and oil development is limited for an oilfield enterprise, if the investment in exploration of oil is too much, then the investment in oil development is surely too less, and funds will be backlogged in the form of reserves. In the same way, if the investment in development of oil is too much, then the investment in oil exploration is surely too less, and oilfield may be exploited overmuch. Whether excessive development for oilfield or the lack of investment in oil exploration may all decrease the explored oil reserves, which will make oilfield enterprise can not conducive to the long-term stable development of oilfield. Therefore, we have to make sure a reasonable scale of investment for oil and gas exploration and development to coordinate the proportion of investment in exploration and development of oil and gas. Only in this way, can we give full play to the overall function of the system and achieve the best economic effect. Then the oilfield enterprises can realize a sustainable and continuous development.

2.2. Data Envelopment Analysis

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (DMUs). When the production process presents a structure of multiple inputs and outputs, it is essentially a linear programming methodology to measure the efficiency of DMUs by as follows model.

Let the number of DMUs as n, in which there are υ input variables $x_{ij},\ i=1,2,...,\upsilon, j=1,2,\cdots,n$ and s output variables $y_{rj}(r=1,2,...,s)$. If the maximum ratio of the linear combination of output variables and the linear combination of input variables in j_0-th DMU is set as the goal, and that the ratio of the linear combination of output variables and input variables for all DMUs is less than or equal to 1 is set as constraint conditions, then we get a DEA model of comprehensive relative efficiency evaluation for j_0-th DMU. By the Charnes Cooper conversion, its specific form is as Equation (1-1) [6].

$$\min\quad \theta-\varepsilon\left(\sum_{i=1}^{\upsilon}s_i^-+\sum_{r=1}^{s}s_r^+\right)$$
$$s.t.\begin{cases}\sum_{j=1}^{n}\lambda_j x_{ij}+s_i^-=\theta x_{ij_0}, & i=1,2,...,\upsilon\\ \sum_{j=1}^{n}\lambda_j y_{rj}-s_r^+=y_{rj_0}, & r=1,2,...,s\\ \lambda_j\geq 0, s_i^-\geq 0, s_r^+\geq 0, j=1,2,...,n\end{cases}\tag{1-1}$$

Assume that we solve model (1-1) and get its optimal solution $\theta^*,\lambda_j^*,s_i^{*+},s_r^{*-},\quad j=1,2,\cdots,n\ ;\ i=1,2,\cdots,\upsilon\ ;\ r=1,2,\cdots,s.$ If $\theta^*=1$, then the j_0-th DMU is weak effective of DEA; if $\theta^*=1,\ s^{*+}=s^{*-}=0$, then the j_0-th DMU is effective of DEA; if $\theta^*<1$, then the j_0-th DMU is not effective of DEA.

3. The method and models about oilfield development investment

3.1. The method to determine the optimal scale of productivity construction investment based on DEA

It will first be solved to determine the investment scale of development engineering construction in unit production in considering oilfield development investment plan, which is always studied by using Empirical analysis method and averaging method. That is to calculate the average investment scale of construction investment for unit productivity in study area according to available data. When use these two methods, the premise is that all the happened investment is reasonable and effective, it does not exclude occasional factor and does not make analysis on the input/output result for previous investment. Therefore, the investment scale for unit productivity obtained by above methods is not always the optimal investment scale. With this weak point, we use the DEA method to determine optimal investment scale of development engineering construction by considering of oilfield practices in this paper.

The optimal scale of productivity construction investment in unit production is determined by using DEA method as follows:

(1) Collect history data of oil development in one year before beginning programming year, and classify the data of different types of developed reservoirs with method of clustering analysis.

In order to determine accurately the optimal scale of productivity construction investment in unit production, we first need to classify the data of different types of developed reservoirs to construct of decision making units (DMUs) of evaluating productive efficiency in one year before beginning programming year.

Let the number of reservoir samples as l, each sample $X_h(h=1,2,\ldots,l)$ represents a category reservoir. In which there are μ input indexes $X_{h\tau},\ h=1,2,...,l;\tau=1,2,\cdots,\mu$ (such as reserves, drilling investment, surface engineering construction investment, recovery factor, etc.). Then sample matrix is written as:

$$X=\begin{bmatrix}X_1\\ \vdots\\ X_h\\ \vdots\\ X_l\end{bmatrix}=\begin{bmatrix}X_{11} & \cdots & X_{1\tau} & \cdots & X_{1\mu}\\ \vdots & & \vdots & & \vdots\\ X_{h1} & \cdots & X_{h\tau} & \cdots & X_{h\mu}\\ \vdots & & \vdots & & \vdots\\ X_{l1} & \cdots & X_{l\tau} & \cdots & X_{l\mu}\end{bmatrix}\tag{2-1}$$

First, calculate the distance matrix D_0 between two samples according to Equation (2-3):