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Evaluation of input output efficiency of oil field considering undesirable output —A case study of sandstone reservoir in Xinjiang oilfield

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Abstract. Based on the input and output data of sandstone reservoir in Xinjiang oilfield, the SBM-Undesirable model is used to study the technical efficiency of each block. Results show that: the model of SBM-undesirable to evaluate its efficiency and to avoid defects caused by traditional DEA model radial angle, improve the accuracy of the efficiency evaluation. by analyzing the projection of the oil blocks, we find that each block is in the negative external effects of input redundancy and output deficiency benefit and undesirable output, and there are greater differences in the production efficiency of each block; the way to improve the input-output efficiency of oilfield is to optimize the allocation of resources, reduce the undesirable output and increase the expected output.

1. Introduction

With the deepening of oilfield development, the contradiction between cost control and economic benefit is critical. Companies that do not consider the optimize the allocation between input and output of measures but instead reduce the total cost index, or increase the output by increasing cost often find that all these condition drives oilfield exploitation situation get worse. At the same time, considerable water is consumed during oil exploitation, due to both maintain the reservoir pressure and process needs. And large amount of waste water with high concentrations of toxic substances pollute the surface water, groundwater and the surrounding environment. It requires the managers in oilfield should not only realize a simulation and stable production from the angle of input-output efficiency of economic benefit, but also take the sewage treatment and environmental protection into account, all these measures have an important meaning to the sustainable development of the oilfield.

As the petroleum enterprise is a complicated system with multiple input and output, the nonparametric Date Envelopment Analysis (DEA) can make an objective and reasonable evaluation of this system. Ye Jingen, Zhang Zaixu uses the data envelopment analysis method to evaluate the investment benefits of Shengli oilfield during 1986 to1998, and puts forward some measures to solve the problems of oilfield exploitation [1]. Bao Hanrui [2] analyzed oilfield enterprise production efficiency and Malmquist index by using Bootstrap technique, adjusted the outcome of conventional DEA, and studied the general rule of entire life-cycle productive efficiency management. An Guixin, Peng Xiujuan [3] established an indicators system to evaluate the develop efficiency of oil enterprise based on the analysis of the factors that affect the petroleum development, and conducted empirical study of the develop efficiency of oil enterprise with the help of DEA model. Liu Huahua, Zhang Jing [4] take natural gas operation cost as the research object, the forecast on its natural gas operation cost of oilfield enterprise is conducted, the prediction method is the grey theory, and optimized the prediction structure by using DEA. Li Kaizhou, Yang Huixian [5] evaluated the DEA efficiency of each block in oilfield by using data envelopment analysis, and judge whether the input-output achieved optimal effect. Song Jiekun, Song Qing [6] evaluate the allocation effectiveness of input-output in oilfield development units from technology or scale by using CCR model, BCC model, projection model and the super-efficiency model, and provide some suggestions for non-DEA efficiency of oilfield development units to realize the optimal allocation. Zhang Shuying, Li Deshan [7] analyzed the input-output efficiency of improved well by using the generalized DEA model and traditional DEA model, and found that the result of the generalized DEA model is inconsistent with the results of the traditional DEA model when the sample unit be selected is not the decision making unit.

In summary, these literatures give a more overall research on economic efficiency, production efficiency, resource allocation efficiency of oilfield enterprise, but they are not taken undesirable output into account. If we ignore undesirable output factors when we evaluate the efficiency of decision-making units, and require the desirable output the more the better is not reasonable, so, this require that we should establish a DEA model with undesirable outputs. To this end, in this paper, we take undesirable outputs into account, and conduct an empirical study of each block's input-output efficiency of Xinjiang oilfield sandstone reservoir by using SBM-Undesirable model, and provide scientific and reasonable advice for the oilfield enterprises decision-making level.

2. Undesirable outputs Non-radial SBM model

The SBM-DEA model constructed by Tone work the slack variables into the objective function, which not only solve the problem of the relaxation of input-output variables, but also avoid the deviation caused by the difference of radial and angle selection. In the case of non-decreasing desirable output, we adjust input and undesirable output in different proportion according to practical needs and establish the non-radial SBM model considering undesirable outputs.

- $$\min\rho = \frac{1-\frac{1}{m}\sum_{i=1}^{m} s_i^{b-} / b_{ik}}{1+\frac{1}{q_1+q_2}\left(\sum_{r=1}^{q_1} s_r^{+} / y_{ik}+\sum_{t=1}^{q_2} s_r^{b-} / b_{rk}\right)} \quad (1)$$

- $$\text{s.t.}\begin{cases} \boldsymbol{X\lambda + s^{-} = x_k} \\ \boldsymbol{Y\lambda - s^{+} = y_k} \\ \boldsymbol{B\lambda + s^{b-} = b_k} \\ \boldsymbol{\lambda \geq 0, s^{-} \geq 0, s^{+} \geq 0} \end{cases} \quad \mathbf{(2)}$$

In the formula, the objective function ρ is strictly decreasing, $0 \leq \rho \leq 1$, if the efficiency value of the SBM model is$\rho = 1$, DMU is strong efficiency, and there is no weak efficient problem of radial DEA. s^{-}, s^{+} , s^{b-} represents slack variable for input, desirable outputs and undesirable outputs, respectively; x_k , y_k , b_k represents decision-making units for the value of input, desired value and undesired value; λ is weight vector; the projection value (target value) of $\mathrm{DMU}_k$is evaluated the value of for:

- $$\hat{x}_k = x_k - s^{-}, \hat{y}_k = y_k + s^{+}, \hat{b}_k = b_k - s^{b-} \quad (3)$$

If the not-expected output is to be fixed in the above model, and the objective function does not contain non-expected outputs. That is to say, the degree of discretion of the undesirable outputs is 0 %, and the weight of undesirable output is set to 0, then the target value is fixed to the original value, and the target value is not included in the objective function. The above model can be transformed into as the follow:

- $$\min\rho = \frac{1-\frac{1}{m}\sum_{i=1}^{m} s_i^{-} / x_{ik}}{1+\frac{1}{q_1}\left(\sum_{r=1}^{q_1} s_r^{+} / y_{ik}\right)} \quad (4)$$

$$\text{s.t.}\begin{cases} \boldsymbol{X\lambda} + \boldsymbol{s}^- = \boldsymbol{x_k} \\ \boldsymbol{Y\lambda} - \boldsymbol{s}^+ = \boldsymbol{y_k} \\ \boldsymbol{B\lambda} = \boldsymbol{b_k} \\ \boldsymbol{\lambda} \geq \boldsymbol{0}, \boldsymbol{s}^- \geq \boldsymbol{0}, \boldsymbol{s}^+ \geq \boldsymbol{0} \end{cases} \quad (5)$$

Owing to the model is a nonlinear programming model, it can be transformed into a linear scale model according to the Charnes-Cooper transformation method.

3. Data sources and explanation

3.1. Partition block

This thesis regards sandstone reservoir of Xinjiang oilfield as the object of research. According to the needs of research, we divide the sandstone reservoirs in Xinjiang oilfield, and there are some representative blocks: Ji 7, Di 20, Chepaizi, Xiquan 1, Shinan 21, Mo 116, Mo 116, Mobei 11, Erchangsanqu (see Table 1).

Table 1. Division of sandstone reservoir in Xinjiang Oilfield

sandstone reservoir	Middle porosity	Ji 7	Di 20	Chepaizi
	Low permeability	Xiquan1	Shinan 21	Mo 116
	Very low permeability	Mobei 11	Erchangsanqu	

3.2. Selection of decision-making units

Selecting the decision-making unit (DMU) is to determine the reference set. Because the data envelopment analysis is the relative validity analysis of the same type of DMU, the basic requirement of DMU is the same type of DMU. According to the actual situation of sandstone reservoir in Xinjiang oilfield, this paper selects the representative blocks, and each block is regard as a DMU, all of this constitutes a panel data.

3.3. Input and output index system

This paper takes the staff costs, maintenance and repair costs, material costs, fuel costs, workover cost of well, well logging and testing costs, power costs, other expenses, depreciation (depletion) as the input indicators, and takes the oil production as the desirable output indicators. In the process of oil production, the main pollution sources and pollutants is oily sewage which is output with oil at the same time, so we take sewage quantity as the undesirable output indicators (see Table 2).

Table 2. Evaluation index system of input and output of sandstone reservoir in Xinjiang Oilfield

input indicators	staff costs, maintenance and repair costs, material costs, fuel costs, workover cost of well, well logging and testing costs, power costs, other expenses, depreciation (depletion)
desirable output indicators	oil production
undesirable output indicators	sewage quantity[a]

4. A case study of sandstone reservoir in Xinjiang Oilfield

In this paper, the SBM-undesirable model is used to evaluate the efficiency of eight sandstone blocks in Xinjiang oilfield, and divide the result into technical efficiency and scale effect (see Table 3).

(1) From the perspective of comprehensive technical efficiency, the average efficiency of these eight blocks in different years is invalid. Among the eight blocks, the average efficiency of Shinan 21 for the period 2006-2013 is the highest, and the value is 0.9308; the average technical efficiency of Chepaizi and Mobei 11 is 0.8661 and 0.8923; the average efficiency of Mo 116 and Sanqu is 0.7968 and 0.7245; the average technical efficiency of Ji 7, Xiquan 1and Di 20 is low, only 0.2273, 0.2474 and 0.3510. (2) From the perspective of pure technical efficiency, the pure technical efficiency of Shinan 21 is valid, and the pure technical efficiency of Ji 7, Di 20 and Xiquan 1 is very low. The pure

technical efficiency of other four blocks is invalid, but they all above 0.75. (3) From the perspective of returns to scale, the average scale effect of the eight blocks is up to more than 0.9.

As for the comprehensive technical efficiency of each decision-making unit, the overall technical efficiency of Ji 7 in the year of 2010-2013, Di 20 in the year of 2012-2013 and Xiquan 1 in the year of 2009-2013 is markedly low. The reason can be clearly seen from table 3 that the scale effect value of these decision-making unit are higher than the pure technical efficiency value, that is to say, the main reason for the low comprehensive technical efficiency is the low pure technical efficiency. The technical efficiency reflects the distance between the inspected unit and the production frontier. Because the cost of the three blocks is large, and the output is low, eventually there is a gap between the technology utilization level of the three blocks and Shinan 21.

In addition, as the table 3 shows, the comprehensive technical efficiency and the pure technical efficiency of Ji 7, Xiquan 1, and Mo 116 decreased with time. Oil managers should pay more attention to this situation, should strengthen the rational allocation of resources, enhance the technological superiority, save cost, improve stimulation efficiency, and narrow the gap between the existing technology and the production frontier. Table 4 is the cost slack variables for each decision-making unit, that is, cost of redundancy.

Table 3(a). Efficiency value of each block in sandstone reservoir[e]

block	T	DMU	comprehensive technical efficiency[ad]	pure technical efficiency[b]	Scale effect[c]
Ji 7	2010	1	0.281	0.288	0.974
	2011	2	0.24	0.241	0.993
	2012	3	0.212	0.212	0.997
	2013	4	0.176	0.176	0.999
	mean		0.2273	0.2293	0.9908
Di 20	2012	5	0.312	0.313	0.995
	2013	6	0.39	0.391	0.997
	mean		0.351	0.352	0.996
Chepaizi	2006	7	0.729	0.736	0.99
	2007	8	1	1	1
	2008	9	0.526	0.528	0.996
	2009	10	1	1	1
	2010	11	1	1	1
	2011	12	1	1	1
	2012	13	1	1	1
	2013	14	0.674	0.674	1
	mean		0.8661	0.8673	0.9983
Xiquan 1	2009	15	0.314	0.332	0.945
	2010	16	0.265	0.267	0.994
			Table 3(b)		
	2011	17	0.257	0.258	0.996
	2012	18	0.206	0.207	0.994
	2013	19	0.195	0.196	0.995
	mean		0.2474	0.252	0.9848
	2006	20	1	1	1
	2007	21	0.787	1	0.787

Shinan 21	2008	22	0.659	1	0.659
	2009	23	1	1	1
	2010	24	1	1	1
	2011	25	1	1	1
	2012	26	1	1	1
	2013	27	1	1	1
	mean		0.9308	1	0.9308
Mo 116	2010	28	1	1	1
	2011	29	1	1	1
	2012	30	0.773	1	0.773
	2013	31	0.414	0.416	0.997
	mean		0.7968	0.854	0.9425
Mobei 11	2006	32	1	1	1
	2007	33	0.914	1	0.914
	2008	34	0.717	0.724	0.99
	2009	35	0.857	0.875	0.979
	2010	36	0.886	0.893	0.993
	2011	37	1	1	1
	2012	38	1	1	1
	2013	39	0.764	0.767	0.996
	mean		0.8923	0.9074	0.984
Sanqu	2006	40	1	1	1
	2007	41	1	1	1
	2008	42	1	1	1
	2009	43	1	1	1
	2010	44	0.483	0.483	1
	2011	45	0.387	0.387	1
	2012	46	0.375	0.375	1
	2013	47	0.551	1	0.551
	mean		0.7245	0.7806	0.9439

a. Comprehensive technical efficiency =pure technical efficiency * scale effect.
b. Pure technical efficiency is the production efficiency influence by enterprise management and technical.
c. The scale effect is the production efficiency influenced by enterprise scale and it is the gap between the real scale and optimal production scale.
d. Comprehensive technical efficiency is used to measure and evaluate the ability of decision-making units' resource allocation, the rate of resources utilization and others.
e. Errors may occur due to retention of decimal points.

Table 4(a). Slack variable of operating cost in each block of sandstone reservoir[a] (unit: 10000 yuan)

block	DMU	staff	maintenance and repair costs	Material	fuel	workover cost of well	Well logging and testing	power	other	depreciation (depletion)

Ji 7	1	-158.31	-13.58	-21.01	-3.42	-90.42	-15.64	-59.5	-68.25	-112.36
	2	-901.16	-75.87	-104.3	-16.16	-394.28	-63.97	-297.71	-420.51	-482.34
	3	-2451.64	-166.35	-607.82	-37.76	-831.85	-174.62	-654.79	-631.32	-1528.39
	4	-5396.6	-778.37	-800.11	-80.83	-2719.47	-466.09	-1432.37	-1436.94	-7154.13
Di 20	5	-1154.38	-116.94	-427.9	-44.38	-136.44	-25.72	-869.16	-410.05	-2903
	6	-1146.53	-78.27	-328.02	-39.21	-173.68	-25.72	-798.79	-383.76	-2195.39
Chepaizi	7	-200.64	-68.19	-131.98	0	-183.66	-23.03	-245.75	-221.42	-1748.29
	8	0	0	0	0	0	0	0	0	0
	9	-1439.76	-951.65	-1746.8	0	-571.77	-117.69	-445.61	-173.64	-3363.36
	10	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0
	12	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0
	14	-3396.51	-961.84	-590.5	0	-251.27	-301.93	-830.64	-246.34	0
Xiquan 1	15	-54.3	-4.06	-3.4	-8.76	-28.69	-8.98	-26.05	-16.62	-38.51
	16	-846.08	-77.09	-100.68	-16.19	-474.27	-85.58	-320.39	-377.67	-535.26
	17	-1362.56	-113.26	-139.71	-27.13	-595.68	-92.32	-450.85	-704.25	-653.34
	18	-1625.55	-115.05	-382.61	-27.36	-552.11	-115.57	-439.18	-447.42	-941.85
	19	-981.62	-143.38	-133.69	-13.81	-495.14	-84.35	-260.18	-281.28	-746.52
	20	0	0	0	0	0	0	0	0	0
	21	-	-78.64	-	-	-289.91	-	-	-	-1989.17

		351.47		928.91	11.31		212.19	414.65	2617.24	
Shinan 21	22	-923.18	-129.54	-1729.37	-43.99	-709.87	-407.74	-855.76	-5956.01	-2719.35
	23	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0
Mo 116	28	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0	0	0
	30	-411.01	-0.22	-67.15	-2.85	-92.97	-71.87	-226.46	0	-1636.77
	31	-1070.31	-594.73	-562.03	-26.92	-887.62	-106	-557.1	0	-3429.48
Mobei 11	32	0	0	0	0	0	0	0	0	0
	33	-0.02	-0.63	-0.46	-0.02	-1	-0.07	-0.59	0	-11.06
	34	-3.69	-3.69	-9.9	-0.22	-6.13	-2.59	-5.66	0	-82.87
	35	-2.9	-1.39	0	-0.09	-1.27	0	-3.26	-1.54	-44.02
	36	-2.17	-1.57	-0.65	-0.07	-2.55	-0.53	-1.78	0	-18.37
	Table 4(b)									
	37	0	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	0	0	0
	39	-9.78	-4.46	-6.99	-0.27	-7.32	-0.28	-3.19	0	0
Sanqu	40	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0
	43	0	0	0	0	0	0	0	0	0
	44	-1849.42	-121.66	-493.94	-3.98	-243.92	-124.06	-832.85	-660.9	-1384.68
	45	-2322.91	-193.1	-712	-6.6	-463.35	-155.68	-935.76	-831.46	-1957.83
	46	-3038.88	-264.03	-529.18	-10.17	-1156.94	-226.89	-1020.58	-530.92	-2640.45
	47	-3215.	-61.18	0	-12.2	-1053.4	-259.6	-1065.	-216.5	-1966.12

99		1	6	1	81

a. calculated by MAXDEA6.4 software.

5. The suggestions to improving the efficiency of input and output in oilfield

5.1. Optimize the resource allocation and improve the innovation management of cost elements

With the deepening of market economy, oilfield managers should aim to economic benefit maximization, should improve the innovation management of cost, should perfect the fine management of cost, and build evaluation system of accounting. Oilfield enterprises should optimize the investment projects and strengthen fund investment management of exploratory development, to ensure the high return on investment; they should actively implement cost management and expand to cover every aspect of production, and enhance the three-class responsible working mode of production crew, group and individual; they should push forward the budget management, and try to achieve a comprehensive, integrative budget management, ultimately, they can achieve the rational allocation of element resources, and realize the integration between the oil production stabilization and the oil production costs control.

5.2. Increase input in science and technology and improve limiting economic rate

During medium to late term of oil field, on the one hand, they should increase the fund in the research, improve the science and technology hardware conditions, and strengthen innovative dynamics. They also should take scientific and technological progress as the important measures to decrease the cost and improve limiting economic rate of improved well. On the other hand, they should strengthen technological exchanges and cooperation with domestic and foreign advanced enterprises, bring in advanced production technology and equipment, and learn the advanced production technology and management experience from Shell, BP, Exxon Mobil and other foreign oilfield enterprise. At the same time, they should accelerate the application of petroleum scientific findings, perfect petroleum Science and technology promotion and service system, and conduct with universities' petroleum development institute in order to increase the scientific input efficiency of oilfield enterprise.

5.3. Enhance the enforcement of harnessing environment and limit the negative external effects of oilfield development process

There are mainly four types of wastes arising from the oil exploration and exploitation, there are oilfield produced water, well flushing waste water, drilling wastewater and downhole operation wastewater. Oilfield managers should adopt corresponding measures in technique: First, they should reinforce the dynamic of setting deadlines for eliminating pollution, and make sure all the wastes meet the discharge standards. Second, they should use the advanced production technology of oil extraction wastewater reinjection, and ensure no discharge of wastewater. Third, they should close the high-water-cuts and non-commercial wells. Fourth, to control pollution from the source, enterprises should find out the causes and sources of environmental pollution and carry on comprehensive treatment to minimize the risk of contamination. Finally, they should raise environmental awareness and establish an effective ecology compensation mechanism of oil-gas field development when calculating the environment cost.

5.4. Strengthen the construction of innovative talents

The survival and development of petroleum enterprises depend on the innovation and progress of science and technology, and the innovation and progress of science and technology needs high-level talents. So the oilfield enterprises must train and enroll the innovative talents of science and technology, strengthen the construction of innovative talents, and improve whole diathesis of personal, which is not only ensure the efficient implementation of the measures to increase production, but also provide the human resources guarantee for realizing high and steady yield in oilfield. Petroleum enterprises should continue to innovate the necessary measures of staff's selecting, training and evaluating, and lay more emphasis on both career ethics and skills in vocational education. They should summon a learn spirit of diligently study and endure hardship. They should focus on testing skilled personal in uniting theory with practice, and attention should also be paid to motivate staff' market consciousness, efficiency consciousness and innovation consciousness.

6. Conclusion

We find that each block is in the negative external effects of input redundancy and output deficiency benefit and undesirable output, and there are greater differences in the production efficiency of each block. The way to improve the efficiency of input and output is to optimize the allocation of resources, reduce the undesirable output and increase the expected output.

References

[1] Jingen Ye and Zaixu Zhang 2001 *Evaluation of investment benefit of Shengli oilfield with Date Envelopment Analysis theory* Journal of the University of Petroleum china pp119-121
[2] Hanrui Bao 2009 *Reswaech on efficiency appraisal of oil field using non-parametric approach* (Tianjing: Tianjing University) p10-15
[3] Guixin An,Xiujuan Peng and Zaixu Zhang 2009 *An evaluation of oil development efficiency with DEA* Industrial Technology Economy vol28(1), pp65-68
[4] Huahua Liu,Jing Zhang and Deshan Li 2012 .*Research based on the GM-DEA to natural gas operation cost forecast and input-output optimization.* Science Technology and Industry vol12(4), pp90-93
[5] Kaizhou Li and Huixian Yang 2013 *Evaluation of Economic Benefit of Oilfield Blocks with Data Envelopment Analysis* Energy Technology and Management vol38(2), pp176-178
[6] Jiekun Song and Qin Song 2014 *Production efficiency evaluation of oilfield development units based on DEA* Sino-Global Energy vol19(12), pp51-56
[7] Shuying Zhang,Deshan Li and Wanghong Lu 2015 *Evaluation of measure well efficiency in Laojunmiao M reservoir in later period of oilfield development*. Xinjiang Petroleum Geology vol6(1), pp65-69
[8] Gong Ma 2008 *Analysis of Efficiency of Oil and Gas Operating Cost with DEA* (Tianjing: Tianjing university) p27-30
[9] Tone K 2007 *Dealing with undesirable outputs in DEA: a slacks-based mensure(SBM)* The Operations Research Society of Japan
[10] Gang Cheng 2014 *Data Envelopment Analysis Method and MAXDEA Softwar* (Beijing: Knowledge Publishing House)