Production Efficiency Analysis of an Electric Power Design Consulting Firm

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***Abstract*—The non-parametric DEA method and the parameter Cobb-Douglas method were used to calculate and analyze the production efficiency of an electric power design consulting company from 2004 to 2015. The results show that the production efficiency of the electric power design consulting firm does not increase with capital investment and technological progress, but there is a significant downward trend in production efficiency.**

***Index Terms*—electric power design consulting; production efficiency; data envelopment analysis; Cobb-Douglas production function**

I. DESCRIPTION OF CURRENT STATUS

Since 2000, with the rapid development of the national economy, the demand for electricity has increased sharply. The state has further liberalized the examination and approval of large-scale construction projects such as power plants[1-4]. Major energy investment enterprises quickly seized the coal-fired power and nuclear power generation market. The power industry ushered in a decade of gold development. The upstream and downstream of the power industry prospered, and the enterprises involved in the industrial chain expanded rapidly[5,6]. However, with the expansion of the market and enterprises, whether the production efficiency of the power industry is truly consistent with the development trend of the industry? In this paper, for the 12 years after 2004 (2004-2015), the input and output data of a electric power design consulting enterprise in Guangdong were analyzed by parametric and nonparametric methods.

II. DEA NONPARAMETRIC ANALYSIS

A. Research methods and models

DEA is a nonparametric econometric method that directly uses the structural characteristics of the input-output data set to form an efficiency boundary containing all data points[7]. The boundary is formed by a linear combination of data points with relatively high efficiency, and the remaining points can be calculated by linear comparison with this boundary to obtain their respective relative efficiency values E_R. Obviously, $0 \le E_R \le 1$. Without loss of generality, assuming that there are m inputs and k outputs, there are n sets of data. Inputs and outputs can be represented as matrices $X_{n\times m}$ and $Y_{n\times k}$, respectively. It is also assumed that the matrices $X=[x_{i1} \quad x_{i2} \quad K \quad x_{im}]$ and $Y=[y_{i1} \quad y_{i2} \quad K \quad y_{ik}]$ are the input matrix and the output matrix for the efficiency data point to be calculated, respectively. The above questions can be expressed as a standard linear programming form:

$$\theta^* = \min \theta$$
$$\text{s.t.} \begin{cases} \lambda Y \ge Y \\ \theta X - \lambda X \ge 0 \\ \lambda \ge 0 \end{cases} \tag{1}$$

Where, $\lambda = [\lambda_1 \quad \lambda_2 \quad K \quad \lambda_{in}]$ is an n-dimensional variable row matrix, and the univariate minimum value θ^* is the required efficiency value E_R. According to the basic data in Table 1, m=2, k=1, and n=12.

B. Data description

All the basic data here (2004-2015) are from the official database of China Electric Power Planning & Engineering Association. According to their characteristics, the data structure of "single output, three inputs" is selected and defined as follows:

The total output value of the consultation completed by the firm is defined as output (Q); the total number of people employed to complete the output value is defined as labor input (L); capital investment (K) is the total value of fixed assets involved in the completion of gross output. Since the basic data has spanned more than a decade, in order to ensure the comparability of the data for each year, considering the impact of inflation, the inputs and outputs measured in monetary terms are discounted[8,9]. The year 2004 is selected as the base year, and the output value Q is discounted according to the ratio of the product to the initial year charge, and K is discounted according to the inflation rate. Since the labor input L is based on the number of people, it is not discounted. The final basic data obtained are shown in Table 1.

TABLE 1. BASIC DATA ON INPUT AND OUTPUT OF AN ELECTRIC POWER DESIGN CONSULTING FIRM IN GUANGDONG PROVINCE (2004-2015)

S/N	Year	Number of people under evaluation (person)	Total output value (104 yuan)	Total assets (104 yuan)
1	2004	702	67774	69076

2	2005	741	80030	130133
3	2006	1144	99231	137085
4	2007	1032	107700	110706
5	2008	1460	117484	121701
6	2009	1578	147277	152074
7	2010	1543	171375	184982
8	2011	1642	141559	225764
9	2012	1807	193783	275800
10	2013	1663	223861	378429
11	2014	1642	177881	335943
12	2015	1834	214490	435235

C. Analysis of computing result

Substituting the basic data into the mathematical model (1), the production efficiency values of each year can be calculated, and the calculation results are shown in Table 2.

TABLE 2. PRODUCTION EFFICIENCY VALUE OF AN ELECTRIC POWER DESIGN CONSULTING FIRM IN GUANGDONG PROVINCE (2004~2015)

S/N	Year	Efficiency value	Ranking
1	2004	1	1
2	2005	0.8762563	8
3	2006	0.7811816	11
4	2007	1	1
5	2008	0.9838978	6
6	2009	0.9870615	5
7	2010	1	1
8	2011	0.7502041	12
9	2012	0.9070719	7
10	2013	1	1
11	2014	0.8359518	10
12	2015	0.8688021	9

The above results indicate that:

(1)In 2004, 2007, 2010 and 2013, the productivity value is 1, that is, the production efficiency reaches the relative best level; in 2011, the productivity value is the lowest.

(2)With the advancement of social economy and technology, the efficiency in the near future should be improved in 2014 and 2015, but the results are not satisfactory.

(3)The production efficiency of this electric power design consulting firm has not kept an upward trend with the development of economy and technology, but has declined.

The production efficiency decreasing instead of increasing with technological progress can be qualitatively attributed to the following reasons:

(1)Technological advancement and the adoption of computer aided design methods have not significantly improved the efficiency of production.

(2)The increase in total asset allocation is not significant for the improvement of production efficiency.

(3)Affected by the state-sponsored project general contracting model, after 2010, the firm began to expand the general contracting business on a large scale and increase the project management personnel. However, the revenue of the general contracting project is much lower than that of the design consulting, and the general contracting management efficiency of the design consulting firm is low due to lack of experience.

(4)The design consulting market is highly competitive, and the charging standards are declining year by year. Increasing production value requires more manpower and assets.

III. ANALYSIS BY COBB- DOUGLAS PARAMETRIC METHOD

A. Research methods and models

The Cobb-Douglas production function is a production function model that establishes an exponential relationship with labor and capital as the main production factors. This method was chosen here, and the overall development of the consulting firm from 2004 to 2015 was analyzed and studied in terms of technical efficiency.

The Cobb-Douglas production function is one of the most commonly used production functions, and was proposed by mathematician Cobb and economist Douglas in 1928. Since the production function is very convenient and simple to use, it is widely used in various production fields. The simplest form of this function is as follows:

$$Q = AL^{\alpha}K^{\beta} \quad (2)$$

Q———Output;

K———Use of capital;

L———Use of labor;

A———Average production technology level;

αβ———Respectively the elasticity of Q relative to L and K;

Although this function is in the form of an exponential function, the use of statistical regression is more complicated. The logarithms of both sides of the original equation are taken to make it a linear relationship

(Equation 3). The linear regression can be used to determine the parameters A, α, β. Once the Cobb-Douglas equation is determined, a series of economic indicators can be obtained, which can be used to analyze production efficiency.

$$\ln Q = \ln A + \alpha \ln L + \beta \ln K \quad (3)$$

$\frac{\partial Q}{\partial L}$ =αALα-1 Kβ———The unit income of labor, that is, the marginal output value of L;

$\frac{\partial Q}{\partial L}$ =βALαKβ-1———The unit income of capital, that is, the marginal output value of L;

$\frac{\partial Q}{\partial L} \cdot L$ L=αALαKβ=αQ———Total income of labor (total wages);

$\frac{\partial Q}{\partial K} \cdot K$ =βALαKβ=βQ———Total income of capital;

WL=QL·LQ=α———The labor elasticity of output, that is, the proportion of labor income to total income;

WK=QK·KQ=β———The capital elasticity of output, that is, the proportion of capital income to total income;

Rate of wage= $\frac{\alpha Q}{L}$ ———Gold consumption rate;

Rate of capital= $\frac{\beta Q}{K}$ ———Optimal rate of accumulation;

B. Data description

TABLE 3. BASIC DATA ON FIRM INPUTS AND OUTPUTS (2004-2015)

Year	Input		Output	Input (ln)		Output (ln)
	L (person)	K (104 yuan)	Q (104 yuan)	lnL (104 persons)	lnK (108 yuan)	lnQ (108 yuan)
2004	702	69076	67774	-2.656406968	1.932622	1.913594
2005	741	130133	80030	-2.602339747	2.565969	2.079812
2006	1144	137085	99231	-2.1680542	2.618017	2.294862
2007	1032	110706	107700	-2.271086426	2.404294	2.376761
2008	1460	121701	117484	-1.924148657	2.49898	2.463718
2009	1578	152074	147277	-1.846426871	2.721782	2.68973
2010	1543	184982	171375	-1.86885652	2.917675	2.841272
2011	1642	225764	141559	-1.806670082	3.116907	2.650131
2012	1807	275800	193783	-1.710917081	3.317091	2.964155
2013	1663	378429	223861	-1.793961893	3.633444	3.10844
2014	1642	335943	177881	-1.806670082	3.514357	2.878527
2015	1834	435235	214490	-1.696085719	3.7733	3.065676

Input (L) ———The total number of employees, which is a measure of the amount of labor input relative to the output;

Input (K) ———The total value of fixed assets and current assets, which reflects the amount of capital invested relative to the output.

It is clear that in the past 12 years, the electric power consulting firm has developed rapidly, and its number of people and output value have shown a significant growth trend. In 2015, the number of people increased by 2.6 times compared with 2004, the average annual growth rate was 22%, the output value increased by 2.2 times, the average annual growth rate was 17%, the assets increased by 8.5 times, and the average annual growth rate was 71%.

The linear regression calculation is performed using MATLAB software, and the test results of the fitted equations are checked. The calculation results meet the accuracy requirements and can be used for the result analysis. The logarithmic equation of the production function between 2004 and 2015 is calculated by regression:

$$\ln Q = 3.3223 + 0.6057 \ln L + 0.1149 \ln K$$

The Cobb-Douglas production function equation is:

$$Q = 27.7237\, L^{0.6057} K^{0.1149}$$

Where,α= 0.6057, β=0.1149

The calculation results of various economic indicators are shown in Table 4.

C. Calculation results and analysis

According to the basic data in Table 4, the linear regression was performed by Cobb-Douglas equation, and the relevant parameters were calculated to obtain the economic indicator data in Table 5, so as to analyze the labor and capital efficiency of the construction industry from 2004 to 2015. Through the unit income of labor (marginal productivity of labor), that is, the increase in the output value of the unit labor when the capital is constant, it is clear that from 2004 to 2015, the indicator has not increased significantly, and in 2004 and 2005, the unit income of labor was relatively high, and the effect of increasing labor input was not obvious. In terms of the unit income of capital (marginal productivity of capital), the income is slow, and the increase in unit capital contributes less to the increase in the total output value of the consulting firm. The analysis indicates that it is not feasible to increase manpower or capital investment in the current situation of the electric power consulting firm.

TABLE 4 ECONOMIC INDICATOR RESULTS

Year	Unit income of labor	Unit income of capital	Total income of labor	Total income of capital	Labor elasticity	Capital elasticity	Rate of wage	Rate of capital

	$\frac{\partial Q}{\partial L}$ (104 yuan/ person)	$\frac{\partial Q}{\partial K}$ (104 yuan/104 yuan)	$\frac{\partial Q}{\partial L}\cdot L$ (104 yuan)	$\frac{\partial Q}{\partial K}\cdot K$ (104 yuan)	WL	WK	$\frac{\alpha Q}{L}$	$\frac{\beta Q}{K}$
2004	59.7636	0.1152	4.1051	0.7787			63.5674	0.0674
2005	63.04819	0.0669	4.7103	0.8935			49.3513	0.0756
2006	53.53586	0.0820	5.6458	1.0710			59.1150	0.0965
2007	54.69692	0.0893	6.1007	1.1573			45.7304	0.0908
2008	48.54425	0.0963	6.6766	1.2665			49.7430	0.0860
2009	48.26096	0.0834	7.8494	1.4890			57.5517	0.0774
2010	49.98413	0.0672	8.8802	1.6846			44.1420	0.0491
2011	50.20528	0.0559	7.2481	1.3750			52.5813	0.0514
2012	49.61608	0.0485	9.5014	1.8024			63.2486	0.0402
2013	53.3582	0.0339	10.5182	1.9953			47.6898	0.0332
2014	52.98804	0.0369	7.8307	1.4855			47.8549	0.0283
2015	52.34272	0.0310	8.7766	1.6649	0.6057	0.1149	58.4768	0.1127

In the analysis of the elasticity coefficient α of labor output and the elasticity coefficient β of capital output, in economic analysis, α+β>1 is generally considered to be an incremental reward type, indicating that it is advantageous to increase production by expanding production scale according to the existing technology; α+β< 1 is referred to as the declining reward type, indicating that it is disadvantageous to increase production scale to increase output according to the existing technology; α+β= 1 is referred to as the constant reward type, means that production efficiency will not increase with the expansion of production scale. Only by improving the technical level will economic efficiency be improved. According to the analysis data α+β<1, the expansion of the electric power consulting firm according to the existing technology is unfavorable for increasing the profit, which is consistent with the nonparametric analysis.

IV. Conclusions

By analyzing the production data of the firm with the parametric method and non-parametric method, it is concluded that the expansion of the power consulting enterprise according to the existing technology is not conducive to increasing revenue and increasing the number of employees can neither improve production efficiency. After the golden decade of power development, in the current downward trend of the energy industry and the saturation of the power consulting market, enterprises must expand their business sources in various ways to increase production value, and at the same time guide the diversion of personnel positions to improve efficiency, and actively transform the sectors that are strongly supported by the state, such as PPP projects and sponge cities and urban integrated corridors.

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