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Application of Engineering Economic Analysis Model in the Evaluation of the Development of Paper Industry

Changsheng Xu[1], Lei Xu[2]

[1]*"Shengshi Fengyuan" Develop Science and Technology (Shenzhen) Ltd, Shenzhen, Guangdong, 518000, People's Republic of China*
[2]*"Shang Jingqing" Environmental Technology Co, Zhuhai, Guangdong, 519000, People's Republic of China*

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Abstract: As a traditional industry in China, the paper industry has a great influence on the global paper supply. The evaluation of the development of the paper industry will help to provide guidance for the future development of the industry. In this paper, the development of paper industry is evaluated and analyzed by engineering economic analysis model, including parametric method and non-parametric method. Through the statistical analysis of the input and output of the paper industry in different years by DEA model, it is concluded that the production efficiency of China's paper industry has significantly improved under the positive impact of the improvement of labor quality, scientific and technological progress, improvement of management level and expansion of production scale. Through the calculation and analysis of Cobb-Douglas production function, it is concluded that capital input and scientific and technological progress make a great contribution to the output of the paper industry, but the proportion of scientific and technological progress still needs to be improved. These studies provide good ideas for the future development of the paper industry.

1. Introduction

The paper industry is a traditional industry in China. In recent years, the paper industry has maintained high growth. China has developed into the world's largest papermaker. Generally, the annual report of the paper industry carries out statistical analysis on the production and consumption of paper and paperboard, the completion of economic indicators of paper and paperboard production enterprises, and the import and export of various types of paper and paperboard [1-4]. However, there are few reports on the application of engineering economic analysis models such as input-output economic models to evaluate the development of the paper industry [5, 6].

In this paper, the development of paper industry is evaluated and analyzed by engineering economic analysis model, including parametric method and non-parametric method. Through the engineering economic analysis model, find out the industrial upgrading plan that is more suitable for the development of China's paper industry, in order to provide a new method reference for the development analysis of the paper industry.

2. Model Analysis of Paper Industry

2.1. Production Technical Efficiency Analysis (Non-parametric Method)

2.1.1. Model Analysis

By using the method of Data Envelopment Analysis (DEA), the data automatically generates the efficiency boundary [7-9]. This method is applicable to the structural model of multi-input and multi-output. It does not need to establish a functional equation to determine the corresponding parameters, but uses the structural characteristics of the input-output data set itself to form an efficiency boundary containing all data points. This boundary is composed of linear combination of data points with relatively optimal efficiency (efficiency value is equal to 1), and other points can be calculated by linear comparison with this boundary to obtain corresponding efficiency ratio (ER).

The basic data in Table 1 were derived from the production volume and other data in the annual report of China Paper Association, combined with the price index. We Selected the data structure of "one output, three inputs", namely output (Q), labor input (L), material input (M) and capital input (K).

Table 1: Input-output table of paper industry in different years.

Particular year	Input			Output (100 million yuan)
	Labor input (Person)	Material input (100 million yuan)	Capital input (100 million yuan)	
1998	1203512	1332.87	2218.24	988.66
1999	1192400	1395.02	2455.31	1186.39
2000	1222560	1489.48	2490.58	1050.39
2001	1275125	1734.48	2944.88	1200.25
2002	1338297	1954.93	3307.27	1400.04
2003	1400127	2227.49	3723.16	1700.55
2004	1382574	2599.98	4441.59	3150.78
2005	1351725	2995.99	5196.48	4650.22
2006	1376489	3383.15	5924.33	5150.41
2007	1378208	3678.34	6408.84	7800.94
2008	1406975	4139.30	6982.96	8160.29
2009	1410144	4522.19	7804.08	8555.00
2010	1487502	5286.75	9155.75	10817.52
2011	1430082	6154.14	10560.58	12530.13
2012	1436234	6705.30	11636.08	12575.00

Substitute the above data into the DEA model, and calculate the production efficiency ratio, relaxation value, etc. The results are shown in Table 2.

It can be seen from Table 2 and Figure 1 that the production efficiency value in 2007 and 2011 is 1, that is, the production efficiency is relatively optimal. But the ER value in 2001 was the lowest. The level of production efficiency reflects the amount of various inputs under the condition of unit output. It can be seen that to complete the same output of 100 million yuan, 1062 labor, 144.5 million yuan of materials and 245.4 million yuan of fixed assets need to be invested in 2001. But in 2011, only 114 labor, 49.1 million yuan of materials and 84.3 million yuan of fixed assets were needed, which were lower than those in 2001. The production efficiency in 2011 was much higher than that in 2001.

Table 2: Input and output DEA model calculation table of paper industry in different years.

Particular year	Efficiency ratio (ER)	Relaxation value			Output
		Labor input	Material input	Capital input	
1998	0.36616	266009.4	21.86558	0	-
1999	0.40101	268558.8	0	9.921227	-
2000	0.34648	238022.3	20.79488	0	-
2001	0.33484	214911.5	14.82415	0	-
2002	0.34778	218083.6	19.72931	0	-
2003	0.37524	224945.3	33.99318	0	-
2004	0.58279	249095.6	29.57014	0	-
2005	0.73518	172204.3	9.911345	0	-
2006	0.71784	78160.47	0	21.39512	-
2007	1	0	0	0	-
2008	0.96420	0	116.6512	0	-
2009	0.91051	0	12.22942	0	-
2010	0.99077	0	0	35.4171	-
2011	1	0	0	0	-
2012	0.99928	0	524.3092	1029.331	-

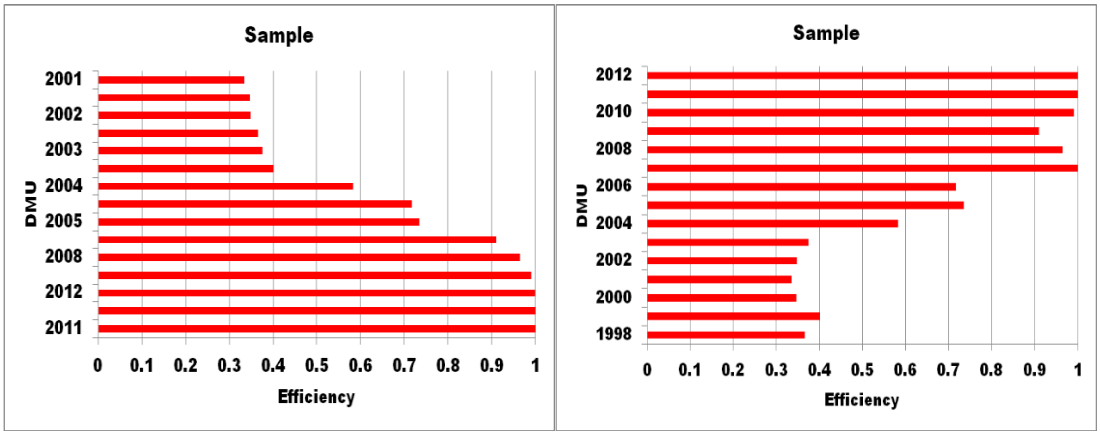

Figure 1: Variation curve of production efficiency ratio with time.

Looking at the data of 15 years, the K/Q in 2012 was the lowest, the L/Q in 2011 was the lowest, and the M/Q in 2007 was the lowest. However, the combination of inputs consumed per unit of output in 2007 and 2011 was better, so they all achieved the best relative production efficiency (ER=1). In addition, from the perspective of time series, L/Q and K/Q showed an obvious downward trend year by year, while M/Q also showed a downward trend, but the range was not large, and even became an upward trend in recent years. On the one hand, it showed that in the production of China's paper industry, the labor cost increases rapidly, and the material cost increases, but there were price fluctuations. On the other hand, it showed that the efficiency of fixed assets (including new machinery, equipment and technology) was improving. For example, the production of advanced production lines and new paper machines had greatly improved production efficiency, especially in terms of labor efficiency.

Although the ER value also fluctuates with time, overall, the production efficiency of China's paper industry had indeed improved significantly, with an average annual growth rate of about 0.08%.

Most of the relaxation values in Table 2 are zero. The non-zero relaxation values are L from 1998 to 2006, M from 1999, 2006, 2007, 2011 and 2012, and K from 1999, 2006, 2010 and 2012. The

corresponding values of these inputs with non-zero relaxation values are smaller. It can be seen that the relaxation value of K is zero in the most years, indicating that the utilization of fixed assets is relatively sufficient. However, the relaxation values of M and L in most years are not zero, which indicates that the waste of materials and labor is serious, which indicates that the production efficiency of the industry is low. Especially in the early years, the paper industry consumed a lot of raw materials to produce paper, and the labor input was large, and the degree of automation was low.

2.1.2. Conclusion

According to the statistical analysis of the input and output of the paper industry in different years by DEA model, the overall production efficiency of China's paper industry has indeed improved significantly. The main reasons are as follows.

(1) Improvement of labor quality. In recent years, enterprises had paid attention to the training of employees. They trained production management personnel, professional technicians and operators. Through education and training, the labor productivity of employees had been improved, and the absorption and promotion of new technologies had also been accelerated. In addition to the rapid expansion of university education resources in the papermaking, professional technical colleges and universities had also increased their efforts to carry out joint training with enterprises. The school trained technicians and operators at all levels for enterprises. Through professional and technical education, the paper industry had been provided with a large number of qualified professional and management talents and skilled workers, thus improving labor productivity.

(2) Progress in science and technology. Papermaking is one of the four great inventions in ancient China. Papermaking industry is a traditional industry in China. The country pays more attention to the improvement of paper-making technology. Since the establishment of the State Key Laboratory of Pulp and Paper Engineering of South China University of Technology in the 1990s, with the increasing support of the national science and technology department for the state key laboratory's science and technology projects, the paper industry had made considerable research achievements, and had constantly emerging new technologies. Especially in recent years, advanced technology, high-end equipment, advanced production lines and new paper machines in the paper industry had been introduced and put into production from developed countries and regions. China's paper industry has developed rapidly, and its paper production capacity has increased by leaps and bounds, even surpassing the United States, becoming the first in the world.

(3) Improvement of management level. In today's society, the progress of science and technology is not only reflected in the professional production technology and automation, but also reflected in the management field. Especially the research and practice of project objective management, interpersonal relationship, organizational form, communication art, incentive mechanism and corporate culture, as well as the application and popularization of computers and the promotion of online monitoring and control system, will promote the improvement of the management level of paper enterprises, and thus improve the overall production efficiency.

(4) The expansion of production scale. Economic theory shows that the expansion of production scale can improve productivity. From 1998 to 2012, the total output value of China's paper industry increased almost linearly and monotonously. The total output value in 2012 was 12.72 times that of 1998. The expansion of production capacity and the stimulation of demand also led to the improvement of production efficiency. With the further tightening of the national environmental protection policy, the paper industry has undergone large-scale enterprise transformation and upgrading, industry mergers and acquisitions, and the elimination of backward production capacity. In the process of multiple rounds of industry resource integration and pattern reshuffle, the industry situation of large-scale production with strong competitiveness has gradually formed, which has greatly promoted the improvement of production efficiency.

2.2. Production Technology Function (Cobb-Douglas Equation)

2.2.1. Model Analysis

Cobb-Douglas production function is a production function model with labor and capital as the main factors of production, which establishes an exponential relationship [10-12]. The basic data in Table 1 are derived from the production volume and other data in the annual report of China Paper Association, combined with the price index. Select the data structure of "one output, two inputs", output (Q), labor input (L), and capital input (K). Cobb-Douglas production function calculation and growth curve drawing are performed for the particular years according to the output value, labor input and capital input.

The logarithmic equation of the production function for the 15 years is obtained by regression calculation.

$$\ln Q=0.2383+2.437551*\ln L+0.8577577*\ln K \quad (1)$$

$$Q=3.5576462*L\text{-}1.7758K1.9592 \quad (2)$$

$$\alpha=-1.7758,\ \beta=1.9592 \quad (3)$$

Table 3: Test value of fitting equation.

Inspection items	Inspection value
Multiple R	0.9854
R^2	0.9710
Adjusted R^2	0.9661
Standard error	0.18162

It can be seen from Table 3 that the equation has a good fit and good applicability.

Through the function calculation and figures 2, 3 and 4, it can be seen that the total output value of China's paper industry has shown a significant increase curve in the past 15 years (1998-2012). Compared with 1998, the total output value increased by 12.72 times in 2012. Compared with the previous year, the total output value decreased slightly in 2000, but then recovered rapidly, reaching a larger growth rate of more than 40% in 2005. Taken together, all the years showed a monotonous growth trend, with an average annual growth rate of 22.01%. In terms of input, the labor and capital input in 2012 were 1.19 times and 5.25 times of that in 1998, respectively, with an average annual growth rate of 1.31% and 12.66%. The gap between the growth rate of input and output reflects the improvement of production efficiency. Among the basic data Q, L and K, Q increased significantly, while the growth of K and L decreased in turn.

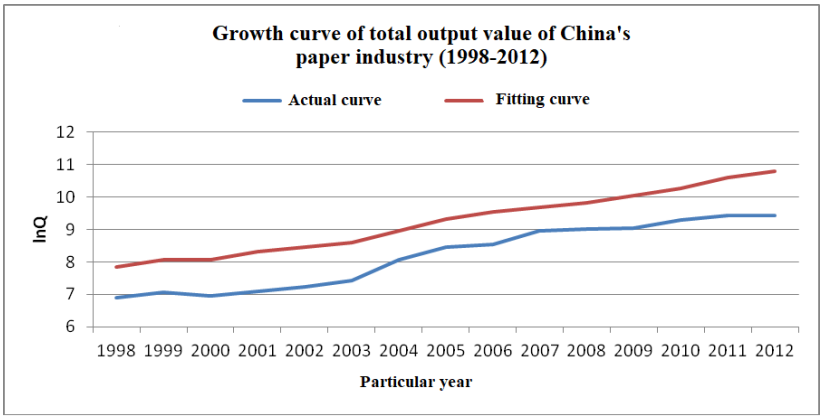

Figure 2: Growth curve of total output value of China's paper industry from 1998 to 2012.

Figure 3: Change curve of the number of employees in China's papen industry from 1998 to 2012.

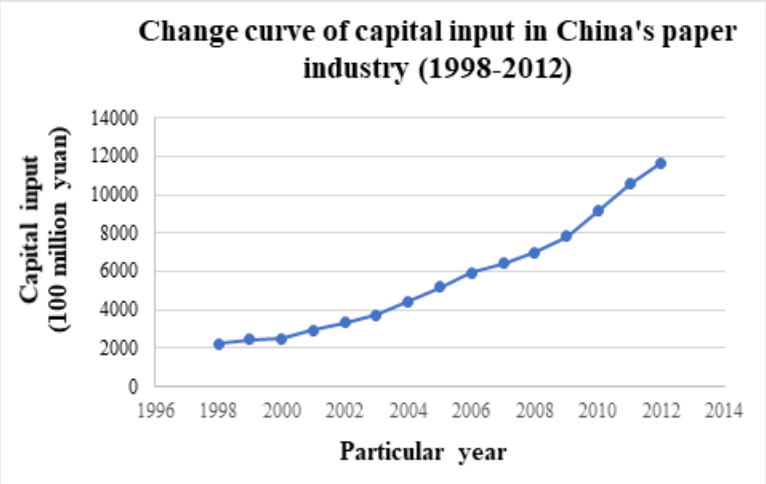

Figure 4: Change curve of capital input in China's paper industry from 1998 to 2012.

Table 4: Input-output increment and annual growth rate.

Partic-ular year	ΔQ (100 million yuan)	ΔL(Person)	ΔK(100 million yuan)	ΔQ/Q (%)	ΔL/L (%)	ΔK/K (%)	ΔA/A (%)
1998							
1999	197.73	-11112	237.07	20.00	-0.92	10.69	10.24
2000	-136	30160	35.27	-11.46	2.53	1.44	-15.43
2001	149.86	52565	454.3	14.27	4.30	18.24	-8.27
2002	199.79	63172	362.39	16.65	4.95	12.31	-0.61
2003	300.51	61830	415.89	21.46	4.62	12.58	4.27
2004	1450.23	-17553	718.43	85.28	-1.25	19.30	67.24
2005	1499.44	-30849	754.89	47.59	-2.23	17.00	32.82
2006	500.19	24764	727.85	10.76	1.83	14.01	-5.08
2007	2650.53	1719	484.51	51.46	0.12	8.18	43.16
2008	359.35	28767	574.12	4.61	2.09	8.96	-6.44
2009	394.71	3169	821.12	4.84	0.23	11.76	-7.15
2010	2262.52	77358	1351.67	26.45	5.49	17.32	3.64
2011	1712.61	-57420	1404.83	15.83	-3.86	15.34	4.35
2012	44.87	6152	1075.5	0.36	0.43	10.18	-10.26
Average				22.01	1.31	12.66	

It can be seen from Table 4 that the absolute growth of output Q reached the maximum in 2007 (265.053 billion yuan), the growth of labor input L was the largest in 2010 (77358 people), and the growth of capital input K was the largest in 2011 (140.483 billion yuan). In terms of relative growth rate, output Q reached the maximum in 2004, input L reached the maximum in 2010 and input K reached the maximum in 2004, reaching 85.28%, 5.49% and 19.30% respectively. In the years of negative growth, Q had once, L had four times, and K had none. The relative growth rate of scientific and technological progress items was the most significant in 2004, while the performance in 2000 and 2012 was poor.

In the 22.01% annual growth of output Q, we consider α and β, Analyze by absolute value. Labor input L contributed 1.31% on average, capital input K contributed 12.66%, and scientific and technological progress a contributed 8.04%. In other words, the relative contribution rates of labor L, capital K and technological progress A to output growth are 5.95%, 57.52% and 36.53% respectively. The contributions of L and K come from the increase of employees and capital investment respectively. And the contributions of scientific and technological progress A include the development of education, the popularization of training, the improvement of labor quality, the improvement of capital use efficiency, the improvement of production technology, the improvement of operation technology and the improvement of management level.

2.2.2. Conclusion

Although there is a high growth overall, most of the growth of total output comes from the increase of capital investment. The contribution rate of scientific and technological progress is 36.53%, which also plays an important role. Therefore, it can be said that the large-scale enterprise transformation and upgrading, elimination of backward production capacity and industrial structure adjustment in the paper industry in recent years have gradually formed the industrial status quo of large-scale production with strong competitiveness, which is no longer the extensive development model of resource consumption with high investment, high consumption and high pollution in the past.

3. Conclusions

By using data envelopment analysis and Cobb-Douglas production function analysis to analyze the development of China's paper industry, we can see that the overall production efficiency of China's paper industry has significantly improved. However, it must be pointed out that the proportion of the contribution rate of scientific and technological progress still needs to be improved. It still needs to further adjust the industrial structure, further eliminate backward production capacity, further reduce the discharge of paper pollutants, reduce resource consumption, increase environmental protection treatment input, further improve production efficiency, strengthen management, save resources, reduce consumption, improve quality, and develop new technologies and new products, Improve the intelligence level of personnel, gradually transform to intensive type, and take the road of sustainable development.

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