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Evaluation to China Construction Sustainable Development

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Abstract: The article utilizes Data Envelopment Analysis (DEA), based on panel data of China construction industry from 1997 to 2010, evaluates China construction sustainable development in general. It leads to the fact that China construction industry went through the tendency from down to up. It went to positive development trend since 2004. However, overall development level is comparatively low. Having adjusted the factors, it is presented that increased capacity mainly rely on optimized employment structure, investment, improved efficiency of mechanical equipment as well as active market enlargement.

Key words: Construction industry, DEA modal, sustainable development evaluation

INTRODUCTION

Over 30 years since reform and opening up, with the lead of fast domestic economic development, Chinese construction industry improves at high speed. The output of construction industry changed from less than 580 billion in 1995 to 6200 billion in 2008. Meanwhile, it provided working opportunity for over 330 billion population which effectively drove real estate industry as well as other related infrastructure industry. Construction industry has become one leading supporting industry and basic industry. It triggers domestic economic development, fastens urbanization and solves employment. Currently, along with the rising concept of sustainable development of society, the concept has been taken to all walks of life and construction industry should follow the concept as one supporting industry to domestic economy. Accordingly, it is important to evaluate the sustainable development capacity of construction industry which is via the assistance of evaluation materials to understand construction industry development situation and via evaluation outcome to provide reference to development policy.

There are quite some methodologies to evaluate the sustainable development capacity and researchers have made quite in-depth study (Zhang, 2010). In summary of researchers contributions, the evaluation methodologies all encountered issues, including too strong subjective sense at the time of fixing weighting index, difficulty at fixing relevance of index. Above methodologies are evaluation only which makes no adjustment according to evaluation outcome. Accordingly while the article utilizes DEA to China construction sustainable development capacity, it is not necessary to fix weighting of index which is due to the reason of avoiding objective factors. That is to say, it is more objective and effective to get the evaluation results and makes more sense to make adjustment according to the results.

DEA BASIC CONCEPT AND MODEL

DEA basic concept: DEA is index method of evaluate more than one decisive unit efficiency and its effectiveness. It was raised by Charnes *et al.* (1997). Its basic concept is based on comparative efficiency. Each evaluated unit is a DMU. And all DMU are put into the evaluation. With the observed samples as well as via the mathematical method, each DMU is assessed for its comparative efficiency index to make comprehensive evaluation for input and output data. Meanwhile, each DMU could be told as effective DEA or not. It could be told by projection methods why each DMU is an effective DEA and direction and extent ion of adjustments. Because it is not necessary to predict index, it is advantageous in terms of avoiding subjective factors and simplified operation and minimized errors (Sheng *et al.*, 1996).

DEA model: The article utilizes C^2 model for analysis. This model is as below:

$$\begin{cases} \text{Min}\left[\theta-\varepsilon\left(\sum_{r=1}^{t}s_r^{+}+\sum_{i=1}^{m}s_i^{-}\right)\right] \\ \text{s.t.}\sum_{j=1}^{n}\lambda_j x_{ij}+s_i^{-}-\theta x_{ij0}=0 \\ \sum_{j=1}^{n}\lambda_j y_{ij}-s_r^{+}=y_{ij0} \\ \lambda_j\geq 0, j=1,2,\cdots,n \\ s_i^{-}\geq 0 \\ s_r^{+}\geq 0 \end{cases} \quad (1)$$

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In Eq. 1, λ_j is the combined ratio which reconstructs j decision making unit of an effective DMU combination relative to DMU_i; n is number of DMU; m is number of input indicators; t is number of output indicators; x_{ij} is the input amount of j decision making unit to i type; y_{rj} is the output amount of j decision making unit to r type; s_r^+ and s_i^- are slack variable, mean input redundancy and output deficiency; ε is an non-Archimedean infinitesimal, generally $\varepsilon = 10^{-6}$; θ is the valid values of DMU, that is relative efficiency of input relative to output. λ_j, s_r^+, s_i^- and θ are the parameters to be estimated (Sun and Yan, 2008).

DEA model's economic implication: If θ is equal to 1 and $s_r^+ = s_r^- = 0$, then DMU is DEA efficient. The formative efficient frontier is invariant scale income. And DMU is scale and technically efficient. If θ is equal to 1 but $s_r^+ \neq 0$ or $s_r^- \neq 0$, then DMU is DEA weak efficient. If $\theta<1$, then DMU is DEA inefficient. That is technically inefficient or scale inefficient.

For the inefficient DMU, if $\sum \lambda_j = 1$, then DMU is technically efficient, otherwise it is technically inefficient. When $K = 1/\theta \sum \lambda_j = 1$, if k = 1, then DMU is scale efficient; if k<1, returns to scale is increasing; otherwise it is decreasing.

When DMU is inefficient, we can improve it by relatively projection on the effective plane. If θx_0-S_i^-, $y_0^*+s_r^+$, then (x_0^*, y_0^*) is projection of (x_0, y_0) on the effective plane, then primary n DMU is efficient.

In considering the time factor t of DEA dynamic evaluation, when i>0, if $\theta(t-i)<\theta(t)$, then the system is positive development and efficiency improvements as time progressed; if $\theta(t-i) = \theta(t)$, then the system is neutral development; if $\theta(t-i) = \theta(t)$, then the system is inferior development (Zheng, 2001).

ACTUAL CASE ANSLYSIS

Data Resource and model index choice: Based on DEA model, it is taken in this article of China construction industry's 1997-2010 as decisive time range, historical panel data as resources for analysis basis for output index. Main data are from China Statistical Yearbook dating from 1999 to 2010.

From output angel, construction industry's sustainable development system covers input son system and output son system. Each key factor in the son system is chosen as index for input and output. Since main manufacturing in construction industry includes human resources, capital investment and actual materials, it is chosen in the article that Chinese construction industry employment population, construction industry fixed assets and self-owned mechanical year end total power as input index which represent capital labor input, capital investment and mechanical equipment. Output index is represented by construction industry total value and value added. The industry total value, compared to business income, total benefit and other output index, better represents industry general manufacture efficiency. And industry added value could effectively represents the industry's value added ability and space.

From the view of input and output, construction industry's sustainable development system covers input subsystem and output subsystem. Each key factor in the subsystem is chosen as index for input and output. Since main manufacturing in construction industry includes human resources, capital investment and actual materials, it is chosen in the article that Chinese construction industry employment population, construction industry fixed assets and self-owned mechanical year end total power as input index which represent capital labor input, capital investment and mechanical equipment. Output index is represented by construction industry total value and value added. The industry total value, compared to business income, total benefit and other output index, better represents industry general manufacture efficiency. And industry added value could effectively represents the industry's value added ability and space.

Accordingly, in DEA model, it is assured in the article that the input index are: employment population, industry fixed assets and self-owned equipment year end total power; And output index are industry total value and value added. See the input and output datum in Table 1.

Model calculation and solution: The article utilizes software Maxdea 5.0 to take Table 1 input and output data into C^2R model for solution. The resolution is represented in Table 2.

Model results analysis: According to DEA model, China construction sustainable development capacity results are shown in Table 3. According to results of Table 3, only 2010's sustainable development capacity analysis results are shown as effective DEA which means input and output results reach their best status and efficiency of the scale and the technology works. The rest analysis results dating from 1997 to 2009 are ineffective and efficiency fluctuation is relatively large which represents the trend of first down then up V curve. Among all data, before 2004, the industry developed at a relatively low speed and general development trend is going down and 2004 development level reached the lowest which refers to comparative efficiency at 0.532. That is to say, with the same returns to scale, 46.8% investment is wasted. After

Table 1: China construction industry input/output from 1997 to 2010

	Input			Output	
	Employment population x_1 10,000 people	Fixed asset x_2 Billion Yuan	Self-owned equipment year end power x_3 10,000 Kilowatt Year	Total output y_1 billion yuan	Value added y_2 billion yuan
1997	1497.90	1850.76	7056.50	5795.73	1668.64
1998	2121.90	2685.89	9804.80	8282.25	2405.62
1999	2101.50	3083.81	8668.50	9126.48	2540.54
2000	2029.99	3380.89	8656.52	10061.99	2783.79
2001	2020.10	3752.66	9077.77	11152.86	3022.26
2002	1994.30	4204.71	9228.11	12497.60	3341.09
2003	2110.70	4951.31	10251.72	15361.56	4023.57
2004	2245.20	6183.80	11022.52	18527.18	3822.42
2005	2414.30	6548.74	11712.38	23083.87	4654.71
2006	2500.28	7148.85	14584.05	29021.45	5615.75
2007	2699.90	7621.45	13765.56	34552.10	6899.71
2008	2878.20	8395.68	14156.29	41557.16	8116.39
2009	3133.70	9175.82	15579.39	51043.71	9944.35
2010	3314.95	10258.00	18195.37	62036.81	11911.65

Data from China Statistical Yearbook 1997-2010

Table 2: China Construction Industry 1997-2010 C^2 model resolution

Year	θ	$\sum\lambda_j$	S_1^-	S_2^-	S_3^-	S_4^-	S_5^-
1997	0.776	0.140	698.620	0.000	2929.998	2894.678	0
1998	0.771	0.202	967.150	0.000	3887.901	4246.407	0
1999	0.709	0.213	783.923	0.000	2269.228	4104.851	0
2000	0.709	0.234	664.714	0.000	1885.864	4436.206	0
2001	0.694	0.254	560.000	0.000	1679.384	4587.307	0
2002	0.684	0.280	434.880	0.000	1211.137	4903.058	0
2003	0.700	0.338	357.329	0.000	1028.178	5593.508	0
2004	0.532	0.321	131.403	0.000	28.670	1380.283	0
2005	0.612	0.391	182.404	0.000	59.005	1158.224	0
2006	0.676	0.471	128.584	0.000	1287.775	225.816	0
2007	0.780	0.579	184.763	0.000	192.436	1382.130	0
2008	0.876	0.681	261.929	363.272	0.000	713.635	0
2009	0.975	0.835	287.979	382.824	0.000	747.244	0
2010	1.000	1.000	0.000	0.000	0.000	0.000	0

Table 3: China construction industry development capability trend

Year	θ	$\sum\lambda_j$	K	Scale effectiveness	Technology effectiveness	Development path
1997	0.776	0.140	0.180	Progressively increase	Ineffectiveness	—
1998	0.771	0.202	0.262	Progressively increase	Ineffectiveness	Worse than track
1999	0.709	0.213	0.300	Progressively increase	Ineffectiveness	Worse than track
2000	0.709	0.234	0.330	Progressively increase	Ineffectiveness	Little worse than track
2001	0.694	0.254	0.366	Progressively increase	Ineffectiveness	Worse than track
2002	0.684	0.280	0.409	Progressively increase	Ineffectiveness	Worse than track
2003	0.700	0.338	0.483	Progressively increase	Ineffectiveness	On the track
2004	0.532	0.321	0.603	Progressively increase	Ineffectiveness	Worse than track
2005	0.612	0.391	0.639	Progressively increase	Ineffectiveness	On the track
2006	0.676	0.471	0.697	Progressively increase	Ineffectiveness	On the track
2007	0.78	0.579	0.742	Progressively increase	Ineffectiveness	On the track
2008	0.876	0.681	0.777	Progressively increase	Ineffectiveness	On the track
2009	0.975	0.835	0.856	Progressively increase	Ineffectiveness	On the track
2010	1.000	1.000	1.000	Progressively increase	Effective	On the track
Mean	0.750	0.424	0.546	—	—	—

2003, general development capacity developed at a rising speed. It reaches proper efficiency in 2010. During the 14 years, effective DEA years make up 7% and non-effective years make 93%, in which there are 5 years with less than 0.7 comprehensive efficiency index, 6 years between 0.7 and 0.8 and 3 years with more than 0.8. Average data is 0.75 from 1997 to 2009. This shows China construction industry development is at a relative low level.

According to Table 2 data, in 2010 which is with effective DEA, s_r^+ s_r^- = 0 means that general input surplus and output lose are zero in the industry which represents the best ratio from input to output. While in other non-effective DEA year, there are surplus in all areas of input which represent underutilization of resources in the industry. In all the non-effective years, the most surplus occurred in employment resources and self-owned equipment year end total power which are 13 and 10 years,

Table 4: DEA adjustment results of China construction industry development

Year	Potential save by employment population 10,000 people	Potential save from fixed assets Billion Yuan	Potential save power by year end self-owned equipment 10,000 Kilowatt
1997	1033.496	413.771	4507.607
1998	1452.398	614.233	6130.150
1999	1394.491	895.964	4787.756
2000	1255.275	983.563	4404.205
2001	1179.051	1149.969	4461.185
2002	1064.492	1327.451	4124.504
2003	990.921	1486.317	4105.608
2004	1181.431	2892.032	5183.669
2005	1118.888	2540.226	4602.183
2006	937.446	2312.714	6005.839
2007	779.766	1679.601	3226.065
2008	619.411	1406.058	1758.283
2009	366.249	612.007	389.124

respectively. That is to say, China construction employment qualification is low and degree of mechanization is low. The whole industry is still labor intensive. And from output point of view, general values of the industry are shown as insufficient output. And the variable is 0 which indicates a general good picture of China construction industry.

From technology point of view while in 2008 when DEA is effective, $\sum\lambda_j$ equals to 1 and technology efficiency works. While in non effective DEA years when $\sum\lambda_j$ less than 1, technology efficiency is non-effective which interprets that while in the period of 1997 to 2009, package of construction industry input and output does not reach the best status. The package structure needs to be further optimized. However it is pleasing that in non-effective DEA years, index of technology efficiency is rising from 0.140 in 1997 to 0.835 in 2009, then to 1 in 2010.It represents that technology in construction industry is improving. From effectiveness of industry scale point of view, when K is less than 1 from 1997 to 2009, the model is ineffective. Before 2006, the K is less than 0.5, scaled benefit increased at a relatively low speed. The whole effectiveness of the industry is low. Since 2007, scaled benefits increased at high speed and the scale reaches proper size in 2010. Generally speaking, as technology improves and business scale enlarges, the industry scaled benefits will increasingly rise. Even if in non-effective DEA years, the scaled efficiency will also increase.

From industry dynamic development point of view, it could be told from Table 3 that, before 2004, due to the slow development of construction industry, the whole industry did not achieve healthy development. After 2004, as improvement of employment qualification, technology and ever prosperity of construction market, China construction industry is on the right track of healthy development.

If data in Table 3 is adjusted, results will be presented in Table 4 It could be told that, having made adjustment on non-effective DEA units, the industry development track are achieved from huge investment in labor resources and capital investment. Also, it resumes quite a lot of resources which could be told from employment population, fixed assets and year end power from self-owned equipments.

CONCLUSION

Via analysis for China construction industry sustainable development capability from 1997 to 2010, it could be concluded as below.

China construction industry sustainable development ability is low and average effectiveness is 0.75, amongst which effective DEA years make up only 7%; Construction industry represents first down then up V curve. After 2002 the development path shows healthy trend.

During years of construction industry development path, technology makes little account in most years. But effective technology is ever increasing. Industry scale is improper. But the scale is increasing. That is to say, China construction industry is rising although general development is at low level.

According to DEA adjustment results, there are quite some surplus in terms of industry employment population, fixed assets investment and mechanical equipment efficiency which leads to deficit. China construction industry is still labor intensive type of industry type.

Based on analysis results, it is suggested there should be more measures in terms of optimized structure and population of employment human resources, improved human resources technology qualification, reasonable ratio of investment input, rising efficiency of mechanical equipment and reduced non-effective investment of manufacturing factors. Meanwhile, there should be actions to actively enlarge construction market, especially overseas market.

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