

An Empirical Analysis of Production Efficiency of the Non-ferrous Metal Industry

Weida He, Rong Hao*, Pei Deng and Haitao Wang

Dongling School of Economics and Management, University of Science and Technology Beijing,
No.30, Xueyuan Road, Haidian District, Beijing, 100083, P.R. China

Received 22 January 2014; revised 24 April 2014; accepted 21 May 2014

This study presents the empirical analysis of production efficiency of non-ferrous metal industry both from static and dynamic aspects by using DEA models and the Malmquist index based on 29 provinces' panel data from 2006 to 2010 in China. The static analysis results show that the production efficiency of non-ferrous metal industry is generally low and greatly influenced by local economic development and that the inefficiency of the whole non-ferrous metal industry is mainly caused by the inefficiency of pure technical efficiency. The regional development of the non-ferrous metal industry is unbalanced. Based on the dynamic analysis of MI, the gap in production efficiency of the non-ferrous metal industry among provinces has gradually widened. Productivity takes on a rising trend in general impacted mainly by the force of advancing technology as the mean of MI is greater than one. The fluctuation of technological progress is negatively correlated to that of technical efficiency, and this interactive fluctuation creates a rising trend of productivity. Also presents some discussions for instructing the healthy and circular economic development of the non-ferrous metal industry.

Keywords: Non-ferrous Metal Industry; Production Efficiency; Energy Saving

Introduction

The non-ferrous metal industry, a subsector of the metallurgical sector, plays an important economic role as the iron and steel industry. In the first 10 months of 2013, the profit of the non-ferrous metal industry in China was 143.8 billion Yuan, a decline of 3.6% from the same period of last year. The non-ferrous metal minerals mining industry decreased by 11.7% and the non-ferrous metal smelting, dressing and processing industry increased by 1.4% over the same period. The output of 10 major non-ferrous metals was 36.91 million tons, an increase of 10.5% over last year¹. China's non-ferrous metal industry is not only one of the most important and basic raw material industries and mainstay industries of the national economy, making a significant contribution to the national economy and social development, but it is also the main driving force in the production and consumption growth of the global non-ferrous metal industry. Although China's non-ferrous metal industry has recently had rapid development, many problems still exist. These problems include low yield rates, low profitability, rising raw material prices, high energy consumption, serious pollution, resources waste², excess production of low-quality non-ferrous mineral

products and heavy importing of high-quality non-ferrous mineral products³. Therefore, it is necessary to research the production efficiency of the non-ferrous metal industry in China. DEA is a linear programming technology and a common non-parametric frontier efficiency analysis method. Since the CCR model was advanced for the first time by Charnes, Cooper and Rhodes in 1978⁴ and the BCC model by Ban in 1984⁵, DEA has developed rapidly and been applied to the analysis of industry production efficiency, technological progress, resources allocation and so on. Zhao Zifang and Shi Jinchuan analyzed the manufacturing industry of 30 provinces from 1999 to 2000, and results show the technical efficiency loss is mainly caused by resources market distortion⁶. Liu Yongchun and Yuan Mao studied industrial efficiency with the DEA method and samples of 31 provinces and carried out classification comparison and hierarchy of industrial comprehensive efficiency by clustering analysis⁷. Guo Yajun performed empirical research on industrial production efficiency in China in 2009 using a three-stage DEA model and proved that three-stage DEA was better than traditional DEA and environment variables had a significant effect on industrial production efficiency⁸.

Jiao Guohua performed empirical research on relative efficiency and scale efficiency of Chinese iron & steel enterprises using DEA and related data of

*Author for correspondence
E-mail: haorongnfc@hotmail.com

57 key large and medium sized iron and steel joint enterprises⁹. Qi Ershi used DEA to measure the Malmquist Index for production efficiency in the iron & steel industry in order to evaluate the dynamic efficiency of the iron & steel industry in China¹⁰. Zheng Mingguai and Xie Yingliang used industrial aggregated input-output data to estimate the efficiency of China's non-ferrous metal industry¹¹. Zheng Chunmei and Chai Jing applied the BCC model to analyze the non-ferrous metal industry in 29 provinces in 2008 and found that the DEA efficiency score of non-ferrous industries reached 100% in only five provinces, which is likely caused by low scale efficiency and technical efficiency across regions¹². Wei Ping and Tang Huiquan calculated the technical efficiency of non-ferrous metal minerals mining firms and non-ferrous metal smelting, pressing and processing firms based on financial data from non-ferrous metals listed companies using the DEA method and found that most firms in both sectors are in the state of pure technical and scale inefficient; meanwhile, the technical and scale efficiency of these firms tended to be very low after 2009¹³. Lin Boqiang estimated the electricity intensity of the China's non-ferrous metal industry by applying the cointegration method, and results show that there is a long-run equilibrium between electricity intensity and factors such as R&D intensity, industrial electricity price, enterprise scale and labor productivity¹⁴. Li Jian discussed the relationship between input and output in the copper industry to reveal mechanisms of resources constraints by analyzing time series data¹⁵. Yu Zhitan researched the international competitiveness of non-ferrous metal industry in China based on supply chain alliance theory¹⁶. Sun Lin discussed non-ferrous metal industry integration from the perspective of the integration of industrial organization, vertical integration on industry chains and integration of industrial space¹⁷. Some articles are about energy saving and environmental protection in the non-ferrous metal industry. For example, Juan C. González Palencia et al. developed a linear programming optimization to study the potential of energy efficiency improvement and fuel substitution for CO₂ emissions reduction in the non-ferrous metal industry on a national level¹⁸. Wang Yanjia et al. provided an overview of the non-ferrous metal industry in China from a CO₂ emissions reduction perspective and focused on an analysis of energy efficiency in the production of aluminum, copper and nickel¹⁹.

This study presents the production efficiency of the non-ferrous metal industry for 29 provinces by using the DEA method combining static and dynamic angles to reveal the situation and tendency of production efficiency of the non-ferrous metal industry. First, we prepare the input-output data and construct the DEA model. Second, we decompose the Malmquist Index into technology efficiency and technology progress under the situation of constant returns to scale and decompose technology efficiency into pure technology efficiency and scale efficiency under the situation of variable returns to scale. Third, we analyze the static and dynamic results, respectively.

Experimental Section

Methodology - DEA Model

The CCR and BCC models are used to assess production efficiency of the non-ferrous metal industry. Suppose that a production system has n DMU _{j} ($j=1,2,3,\dots,n$). Each DMU has m inputs $x_j=(x_{1j}, x_{2j}, \dots, x_{mj})$ and s outputs $y_j=(y_{1j}, y_{2j}, \dots, y_{sj})$. Assume that return to scale is constant; DMU efficiency can be obtained from the constructed model, s is the slack variable. If $\theta^*=1$ and $s^*=s^{+*}=0$, then the current evaluated DMU is DEA efficiency. In the CCR model, if a DMU is efficiency, both technology and scale are effective. To discuss pure technical efficiency and scale efficiency, Banker, Charnes and Cooper introduced the convexity assumption and developed the BCC model. The BCC model has a constraint on the weights of DMUs.

$$\sum_{j=1}^n \lambda_j = 1 \quad \dots (1)$$

Suppose scale is changeable. The scale efficiency (SE) of DMU can be measured by the quotient of CCR assessment result ($CRSTE$) and BCC result ($VRSTE$)

$$SE = \frac{CRSTE}{VRSTE} \quad \dots (2)$$

MI was first put forward by Malmquist and developed to maturity by Caves, Fare and Grosskopf, which was applied to assess productivity change. Under the situation of constant returns to scale, Malmquist productivity change can be decomposed into technical efficiency change (TEC) and technological progress change (TC)²⁰. Under the situation of variable returns to scale, TEC can be

further decomposed into pure technology efficiency change (*PTEC*) and scale efficiency change (*SEC*). *MI* shows degree of productivity change from the stage *t* to *t*+1. If *MI* is greater than one, it means an increase in productivity:

$$MI = TEC \cdot TC = PTEC \cdot SEC \cdot TC \quad \dots (3)$$

Experimental Design and Data Analysis

This study selects the gross output value and the amount of profit tax as output indicators and selects the amount of electricity consumption, coal consumption, management cost, net value of fixed assets and the number of employees as input indicators. As non-ferrous metal industry is a high energy consumption industry, it needs to take energy into consideration except from considering other factors. Thus, we select the net value of fixed assets and employees to represent capital and labor investment, respectively, and use electricity consumption and coal consumption to represent energy inputs. Management cost can be used to show management input. This study uses panel data of 29 provinces and related indicators in China’s non-ferrous metal industry from 2006 to 2010. Data comes from the statistical data collection of the non-ferrous metal industry from 2006 to 2010 and yearbooks of each province. The amount of electricity consumption, coal consumption and net value of fixed assets in 2010 are estimated because these data are missing. The estimation method is as follows: Assume the energy utilization rate is increasing year by year for every province and adjusts according to specific conditions. First, calculate the ratio that the electricity and coal consumption account for output value from 2006 to 2009. Second, estimate according to the following situation. If the proportion of a certain indicator of previous years is almost the same in a certain area, the average ratio can be used in 2010. If a certain proportion of an index is on a

downward trend in previous years in a certain area, then calculate the proportion of the index accounting for output value by linear fitting to obtain energy consumption.

The net value of fixed assets in 2010 can be estimated using following method:

$$K_t = K_{t-1}(1 - \alpha) + INV_t \quad \dots (4)$$

Where *K_t* is the net value of fixed assets in the stage of *t*; *α* presents the depreciation rate of that year; *INV_t* is fixed asset investment. First, calculate the annual depreciation rate among regions from 2007 to 2009. Second, use the average depreciation rate to calculate net value of fixed assets among regions in 2010.

Results and Discussion

Average production efficiency for the non-ferrous metal industry can be obtained accordingly (Table 1). It can classify different provinces according to overall technical efficiency, pure technical efficiency and scale efficiency. Average efficiency assessment and specific classification are shown respectively (Table 2). The method used to develop the local economy has a significant effect on efficiency in the non-ferrous metal industry. There is a tendency for the efficiency value to be high in provinces in the east and low in the west. The middle-east developed provinces account for more than 50% in DEA effective provinces from 2006 to 2010. The comprehensive technical efficiency of Beijing is only 0.517, Shanghai 0.642 and Shandong lower. The efficiency value is very low in middle-west less developed provinces. However, Jiangxi province and Xinjiang province are exceptions. Jiangxi province is DEA efficient from 2006 to 2010. Xinjiang province is DEA efficient from 2006 to 2009 and closely DEA efficient in 2010. The pure technology inefficiency

Table 1—Production efficiency of non-ferrous metal industry

Year	Efficiency parameters						DMU number		
	CRSTE		VRSTE		SE		SE	Decreased returns to scale (DRS)	Increased return to scale (IRS)
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation			
2006	0.677	31.8%	0.793	26.1%	0.854	18.9%	7	13	9
2007	0.757	27%	0.875	21%	0.865	17%	7	13	9
2008	0.721	35.2%	0.805	29.4%	0.896	16.1%	9	13	7
2009	0.548	58.5%	0.719	41.8%	0.726	33.2%	5	17	7
2010	0.574	49.4%	0.722	37.3%	0.795	25.9%	6	10	13
Mean	0.655	40.4%	0.783	31.1%	0.827	22.2%	\	\	\

Table 2—Classification of DMUs

Year	Large size SE>0.8, DRS	Optimal size VRSTE =SE=1	Easily improve 0.8<SE<1, VRSTE>0.8	Technical inefficiency 0.8<SE<1, VRSTE<0.8	Small size SE<0.8, IRS
2006	7	7	1	13	2
2007	7	7	8	5	3
2008	7	9	4	8	2
2009	6	5	5	7	1
2010	2	6	2	6	7

causes inefficiency in non-ferrous metal industry. On average, pure technical efficiency is 0.783, less than the scale efficiency, 0.827, and the standard deviation coefficient of pure technical efficiency is greater than that of scale efficiency. The low level of pure technical efficiency and unsteady coefficient affect the high level of the non-ferrous metal industry's production efficiency. The scale technical efficiency is higher than pure technical efficiency in DEA invalid provinces, and the low level of pure technical efficiency lowers the overall efficiency of the non-ferrous metal industry in these areas. The typical provinces include Shanxi, Hubei, Chongqing, Sichuan and Yunnan. The scale technical efficiency for these provinces is 0.973, 0.907, 0.972, 0.945 and 0.99, respectively, but pure technical efficiency is 0.222, 0.471, 0.432, 0.508 and 0.4, respectively. The low pure technical efficiency means resources waste. On the contrary, the pure technical efficiency for Beijing, Nanjing, Heilongjiang, Shanghai and Shandong is 1, 1, 0.865, 0.929 and 1 in 2010. Their scale technical efficiency is 0.517, 0.57, 0.245, 0.691 and 0.581, respectively, which means these areas have failed to achieve scale economy.

The efficiency value in many provinces has been decreasing, especially after 2008. The number of provinces of assessment value below 0.5 is five, three and seven from 2006 to 2008, accounting for 20.7%, 10.3% and 24.1% of the total, respectively. The number of provinces of assessment value below 0.5 from 2009 to 2010, accounting for 55.2% and 48.3% of the total. On average, there is a larger decline over the last two years compared with the first three years. There is an important turning point in 2008. It is inferred that the global financial crisis in 2008 had a negative impact on non-ferrous metal industry, as both pure technical efficiency and scale efficiency decreased. The scale and technology inefficiency of non-ferrous metal industry have

Table 3—Malmquist index and decomposition

Stage	Year	MI	TEC	TC	PTEC	SEC
1	2006/2007	1.03	1.13	0.92	1.11	1.01
2	2007/2008	0.98	0.92	1.07	0.90	1.03
3	2008/2009	1.19	0.66	1.80	0.83	0.80
4	2009/2010	0.89	1.14	0.78	1.05	1.08
	Mean	1.02	0.94	1.08	0.97	0.97

Note: TEC (technical efficiency change), TC (technology change), PTEC (pure technical efficiency change), SEC (scale efficiency change).

improved to a certain extent, but the scale of some provinces have failed to catch up with the pace of economic development. The number of large size provinces decreased from seven in 2006 to two in 2010. Meanwhile, the number of small size provinces increased from two in 2006 to seven in 2010, including Jilin, Heilongjiang, Shanghai, Guizhou and Ningxia province. The scale efficiency of Beijing and Shanghai fell sharply, which reflects resource waste. The reasons for declines in other areas include funds shortage and unreasonable structure in industry. The average of *MI* and changes of constituent parts of non-ferrous metal industry is shown (Table 3). As assessing *MI* is based on the previous year, and we lack data for 2005, we start from 2007. *MI* of stages 1 and 3 are greater than one, and *MI* of stages 2 and 4 are less than one, which indicates a volatile situation in production efficiency of non-ferrous metal industry. Productivity takes on a rising trend in general from 2006 to 2010 because the mean of *MI* is greater than one. The result also shows that the fluctuation of technological progress is negatively correlated to that of technical efficiency.

Conclusion

Based on the provincial panel data from 2006 to 2010 in China, we carried out an empirical study on production efficiency of the non-ferrous metal industry in 29 provinces with DEA models and the Malmquist index to analyze the data from both static and dynamic aspects. The static analysis results show that the production efficiency of the non-ferrous metal industry is at a low level and is greatly influenced by local economic development. The whole non-ferrous industry's inefficiency is mainly caused by pure technical inefficiency. The regional development of the non-ferrous metal industry is unbalanced, and it is too weak to withstand a sudden economic crisis. Based on the dynamic analysis of *MI*, the gap of production efficiency among provinces has gradually

widened from 2006 to 2010 and some provinces show very low production efficiency. Productivity increased in general from 2006 to 2010, impacted mainly by the force of advancing technology because the mean of MI was greater than one. The fluctuation of technological progress was negatively correlated to that of technical efficiency, and this interactive fluctuation creates a rising trend of productivity for the whole non-ferrous metal industry.

The analysis has shown that there are certain problems during the development of non-ferrous metal industry; this study also presents some recommendations for non-ferrous metal industry committee to take some necessary regulation and release some positive policies for instructing the healthy and circular economic development of the non-ferrous metal industry: (1) Make full use of resources, develop the circular economy and enhance the overall industry productivity; (2) Release preferential policies at the underdeveloped provinces to ease the unbalanced regional development situation; (3) Reasonably adjust the product structure and improve the quality in the industry value chain to strengthen international competitiveness; (4) Improve the technical level and use the impact of scale effect to the production efficiency to ensure faster and better development of the whole non-ferrous metal industry; (5) Conduct industrial restructuring and upgrading and better coordinate various industries to avoid an unnecessary waste of resources; and (6) Learn from the valuable experiences of developed areas and develop the regional non-ferrous metal industry with its own characteristics.

References

- 1 Non-ferrous metal industry association in China, The condition of non-ferrous metal industry in China in November 2013, <http://www.chinania.org.cn/>, **EB/OL**, 2013-12-30.
- 2 General Office of the State Council, The Non-ferrous metals industry revitalization plan, <http://www.gov.cn/>, **EB/OL**, 2009-05-11.
- 3 Analysis of non-ferrous metal industry operation in 2012 and outlook 2013, *J Reso Sci*, **2** (2013) 11-13.
- 4 Charnes A, Cooper W W & Rhodes E, Measuring the efficiency of decision making units, *Eur J Operat Res*, **2** (1978) 429-444.
- 5 Banker R D, Charnes A & Cooper W W, Some models for estimating technical and scale inefficiencies in data envelopment analysis, *Manage Sci*, **30** (1984) 1078-1092.
- 6 Zao Zifang & Shi Jinchuan, Empirical analysis of industrial efficiency loss in Chinese distortion factor market based on DEA, *Chinese Ind Economy*, **10** (2006) 40-48.
- 7 Liu Yongchun & Yuan Mao, Research of China's industrial efficiency based on DEA method, *Producti Res*, **18** (2007) 103-105.
- 8 Guo Yajun, Research on industrial production efficiency based on three stage DEA method, *Sci Res Manage*, **11** (2012) 16-23.
- 9 Jiao Guohua, Jiang Feitao & Chen Ke, The relative efficiency and scale efficiency of China's iron and steel enterprises, *Chinese Ind Economy*, **10** (2007) 37-44.
- 10 Qi Ershi, Analysis of Malmquist Index of China's iron and steel industry production efficiency, *J Tianjin University (Social Science Edition)*, **6** (2009) 486-489.
- 11 Zheng Minggui & Xie Yingliang, Overall economic benefit assessment on China's non-ferrous metal industry based on DEA model, *J China Mining*, **2** (2010) 33-36.
- 12 Zheng Chunmei & Chai Jing, Efficiency evaluation of the non-ferrous metals industry in some provinces - Based on data envelopment analysis, The 8th China Non-ferrous Metals Association, Conference Proceedings. Beijing, **C** (2010) 643-648.
- 13 Wei Ping & Tang Huiquan, Measuring technical efficiency of Chinese non-ferrous metals enterprises on a background of industry consolidation, *Trans. Non-ferrous Met. Soc. China*, **23** (2013) 2797-2806.
- 14 Lin Boqiang & Zhang Guoliang, Estimates of electricity saving potential in Chinese non-ferrous metals industry, *Energy Policy*, **60** (2013) 558-568.
- 15 Li Jian, Study on the resources constraint on non-ferrous metal industry of China—taking copper industry as an example, Bei Jing: China University of Geosciences, **D**, 2005.
- 16 Yu Zhitan, Research on promoting the international competitiveness of non-ferrous metal industry base on supply chain alliance, Hu Nan: Central South University, **D**, 2005.
- 17 Sun Lin, A study on China's non-ferrous metal industry integration, Hu Bei: Wu Han University of Technology, **D**, 2012.
- 18 Juan C, González Palencia, Takaaki Furubayashi & Toshihiko Nakata, Analysis of CO2 emissions reduction potential in secondary production and semi-fabrication of non-ferrous metals, *Energy Policy*, **52** (2013) 328-341.
- 19 Wang Yanjia & William Chandler, The Chinese non-ferrous metals industry—energy use and CO2 emissions, *Energy Policy*, **38** (2010) 6475-6484.
- 20 FARE R & LOVELL C, Measuring the technical efficiency of production, *J Economic Theory*, **19** (1978) 150-16.