Research Article

Evaluation of Manufacturing Competitiveness of Hubei Province Based on Stochastic Frontier Analysis

Weidong Gai [iD],[1] **Lei Zhou** [iD],[1] **and Chun Chen** [iD][2,3]

[1]*Accounting College, Wuhan College, Wuhan 430022, China*
[2]*School of Literature, Law and Economics, Wuhan University of Science and Technology, Wuhan 430081, China*
[3]*Hubei Small and Medium Enterprises Research Center, Wuhan 430081, China*

Correspondence should be addressed to Chun Chen; chenchun@wust.edu.cn

The manufacturing level directly manifests the comprehensive strength of a country or region. Production efficiency provides an important metric of the competitiveness of the manufacturing industry. Based on the data of China's industrial enterprises of 1999–2011, this paper estimates the production efficiency of manufacturing in Central China's Hubei Province through stochastic frontier analysis (SFA) and thus characterizes the differences between prefectures of Hubei in manufacturing competitiveness. The results show that, on the prefecture level, Xianning and Wuhan saw a decline in manufacturing competitiveness, while Xiangfan and Xiaogan witnessed an increase in manufacturing competitiveness. To enhance local manufacturing competitiveness and make Hubei the forerunner and cornerstone of Central China, different prefectures should adopt different industrial promotion policies, pay attention to cultivating the technological innovation capabilities of enterprises, and strengthen the integration of production, education, and research.

1. Introduction

The manufacturing level directly manifests the comprehensive strength of a country or region. The competitiveness of the manufacturing industry directly bears on the function and depth of the country or region in the international division of labor. Since the subprime mortgage crisis, reshaping the manufacturing industry has become a global campaign to find new economic growth points. This campaign is launched against a new round of technological and industrial revolutions. To enhance the industrial competitiveness of Germany, Hannover Messe 2013 officially launched the concept of Industry 4.0 based on network entity systems and the Internet of Things (IoT). On February 19, 2016, the United States (US) Congress received the first strategic plan for the National Network for Manufacturing Innovation (NNMI), which is jointly submitted by the Secretary of Commerce, the Executive Office of the President, the National Science and Technology Council, and the Advanced Manufacturing National Program Office. This

plan sets out an important goal: enhancing the competitiveness of American manufacturing in an all-round way.

In the meantime, China has entered a new stage of economic development. In the traditional manufacturing industry, the supply and demand are seriously imbalanced. It is urgent to reduce production capacity, inventory, and leverage through structural adjustments and lower costs and solve defects by transforming the production mode. In Government Work Report 2019, the Chinese government pledged to promote the high-quality development of manufacturing, accelerate the construction of a manufacturing power, facilitate the docking of standards with international best practices, improve the quality of products and services, and attract more domestic and foreign users to Chinese products and services. It is telltale that major economies regard enhancing manufacturing competitiveness as the core development strategy. Hubei is a large province in Central China. The manufacturing competitiveness of Hubei represents the manufacturing level in this region of the country and makes up an important part of

Made in China 2025. Therefore, it is of great significance to correctly estimate and evaluate the manufacturing competitiveness of Hubei. The relevant results help to improve the manufacturing competitiveness of the province and even across Central China, promote high-end brands that are made in China across the globe, and contribute to the sustainable development of trade and economy in the country.

Chinese and foreign researchers have explored industrial competitiveness extensively and reached fruitful results. Some of the most representative studies are as follows:

(1) Industrial competitiveness: Porter, a renowned American economist, proposed the famous diamond model and believed that the industrial competitiveness of a region is affected by factor endowments, related industries, corporate strategies, external opportunities, market demand, and government policies, to name but a few [1].

Since the turn of the century, many new theories have emerged on industrial competitiveness. Through analytic hierarchy process (AHP), Sirikrai and Tang [2] analyzed industrial competitiveness from two aspects: strategy and operation management. Fetscherin et al. [3] held that the higher the degree of industrial specialization, the greater the share of the industry in global exports. Meleo [4] examined the impact of international events on regional industrial competitiveness from the perspective of external opportunities. Kleynhans [5] suggested that technology spillover has a significant positive impact on the competitiveness of enterprises and industries. Based on relevant data in Japan, Purwadi [6] found that human resource has gradually developed into an important influencer of industrial competitiveness. Liu [7] constructed an evaluation index system for the industrial competitiveness of Changsha-Zhuzhou-Xiangtan region and evaluated the industrial competitiveness by principal component analysis (PCA).

(2) Manufacturing competitiveness: the foreign studies on manufacturing competitiveness can be traced back to the 1960s. Many researchers have studied the factors affecting manufacturing competitiveness. Moreno [8] established a regression model to identify the determinants of Spanish manufacturing competitiveness. Wong and He [9] stated that technological innovation plays an important role in manufacturing development and the enhancement of manufacturing competitiveness. Purwadi [6] discovered that human resource is developing into a major impactor of manufacturing competitiveness in Japan. Hannigan et al. [10] learned that the competitiveness of different types of manufacturing enterprises varies with development strategies. Singh et al. [11] highlighted the importance of government support, new technologies, and investment to manufacturing competitiveness. Dong and You [12]

analyzed the status quo of China's aerospace manufacturing from the angles of competitive strength, competitive potential, and competitive environment and established an evaluation system.

(3) Evaluation of industrial competitiveness: some researchers measured international competitiveness of industries from the macro perspective, mainly using trade specialization coefficient (TSC), export market share (EMS), and revealed comparative advantage (RCA) [13–15]. Hannan et al. [16] measured industrial competitiveness with the RCA and concluded that the competitiveness of the auto industry is positively correlated with economic performance, human capital development, urbanization, and tariff level and negatively correlated with loan rate and carbon emissions. Carraresi and Banterle [17] adopted the EMS and RCA to measure competitive performance. Jin et al. [18] evaluated the international competitiveness of China's manufacturing industry in terms of market share and product profitability.

Some researchers measured industrial competitiveness from the meso perspective. Since the 1980s, the World Economic Forum (WEF) and the International Institute for Management Development (IMD) in Lausanne, Switzerland, have been researching this topic and have formed a relatively complete competitiveness evaluation system. To evaluate industrial competitiveness, many Chinese scholars have probed into the evaluation index systems, formation mechanism, and empirical analysis of industrial competitiveness. For example, Wei and Wu [19] constructed an evaluation index system for competitiveness, which covers the following dimensions: industrial technological innovation ability, rational resource allocation ability, industrial growth potential, and market influence.

Some researchers measured enterprise competitiveness from the micro perspective. On the microlevel, the enterprise competitiveness is mainly measured and compared in terms of production efficiency, market share, and enterprise scale. The relevant evaluation index systems primarily focus on production efficiency, enterprise scale, and market growth/scale.

Firstly, production efficiency of enterprises is mainly measured by the nonparametric methods of data envelopment analysis (DEA) and stochastic frontier analysis (SFA) and the semiparametric method of Olley–Pakes (OP) production function. These methods decompose production efficiency into an efficient part and an inefficient part, before comparing the level or magnitude of enterprise efficiencies. Papahristodoulou [20] used the DEA to analyze the cost performance of 121 different models produced by auto enterprises in different countries in 1996 and compared the market competitiveness of auto enterprises from different countries. With the aid of DEA, Oh et al. [21] evaluated the

cost performance of cars produced by Korean auto enterprises and compared the market competitiveness between auto enterprises in Korea.

Secondly, enterprise size is mainly measured by the number of employees, gross output, and per-capita output of each enterprise. With these metrics, the scale and growth rate of each enterprise are determined and used to judge the competitiveness at the enterprise level. Considering the positive correlation between technological innovation and enterprise output, Melitz and Trefler [22] believed that a large enterprise tends to have a strong ability to engage in technological innovation and a strong export capacity.

Thirdly, market growth/scale is mainly measured by market concentration and locational Gini coefficient and used to characterize enterprise competitiveness. Li and Tang [23] held that market concentration has a significant positive effect on the competitiveness of large enterprises and evaluated the competitiveness of large enterprises from five aspects: scale, benefit, operating efficiency, debt repayment, and growth.

In summary, industrial competitiveness has been deeply explored in the academia, yielding a wealth of literature. The existing studies mainly deal with the influencing factors and evaluation of industrial competitiveness. However, there are several defects with these studies: there is not yet a consensus on how to define and estimate competitiveness, how to select the evaluation indices, and how to measure competitiveness. As a result, the existing methods have limited explanatory power on industrial competitiveness. Besides, there are not many reports on the competitiveness of enterprises in Central China, not to mention the manufacturing competitiveness of Hubei on enterprise level. Based on the data of China's industrial enterprises of 1999–2011, this paper estimates the production efficiency of manufacturing in Central China's Hubei Province through SFA, compared the difference between the 17 preferences of the province in manufacturing competitiveness, and fully discussed the interactions and fluctuations between the factors affecting the manufacturing competitiveness. On this basis, several countermeasures were proposed to enhance the manufacturing competitiveness of Hubei. The research results provide a solid basis for Hubei Province to transform its manufacturing industry, enhance manufacturing competitiveness, and realize high-quality development.

The remainder of this paper is organized as follows: Section 2 establishes the model, explains the data sources, and selects the variables; Section 3 estimates the production efficiency of manufacturing enterprises in Hubei; Section 4 sums up the findings and provides the countermeasures.

2. Model Construction, Data Sources, and Variable Selection

2.1. Model Construction. This paper selects the production efficiency of enterprises to measure the manufacturing competitiveness of Hubei Province. The measurement of production efficiency was pioneered by Farrel [24]. Currently, the popular ways to measure production efficiency include nonparametric estimation methods like DEA and parameter estimation methods like SFA. The nonparametric estimation methods are generally unstable in output and in need of high-quality data. By contrast, the SFA can both calculate the production efficiency of an enterprise with a suitable production function and reflect the impact of background variables (i.e., various environmental factors) on the explained variable (i.e., the production efficiency of the enterprise). Therefore, the SFA was selected to estimate and measure the manufacturing competitiveness of Hubei.

The SFA model was proposed as early as 1977 by foreign scholars like Aigner and Meeusen. The basic idea of SFA is as follows.

Let $f(z_i, \beta)$ be the production function of enterprises and $q_i = f(z_i, \beta)$ be the optimal production function of the i-th enterprise without random interference and efficiency loss. However, inefficiency is commonplace among enterprises. Normally, the actual output of an enterprise is smaller than its optimal output. Thus, the actual output of the i-th enterprise can be defined as

$$q_i = f(z_i, \beta)\xi_i, \tag{1}$$

where ξ_i is the production efficiency of the i-th enterprise. The ξ_i value inevitably falls within (0, 1]. If $\xi_i = 1$, the enterprise utilizes the optimal technology of the production function $f(z_i, \beta)$; in this case, the enterprise can achieve the optimal output and boast the highest competitiveness. If $\xi_i < 1$, the enterprise cannot fully utilize the inputs z_i under the given conditions. Since $q_i > 0$ (the output is strictly positive), there must exists $\xi_i > 0$ (technical efficiency must be positive). Assuming that the enterprise output could be affected by random shocks, the output of an enterprise under random shocks can be expressed as

$$q_i = f(z_i, \beta)\xi_i \exp(v_i). \tag{2}$$

Taking the natural logarithm of both sides:

$$\ln(q_i) = \ln\{f(z_i, \beta)\} + \ln(\xi_i) + v_i. \tag{3}$$

Suppose there are k kinds of inputs with linear logarithmic form, and $u_i = -\ln(\xi_i)$. Then, the output function under random shocks can be rewritten in logarithmic form as

$$\ln(q_i) = \beta_0 + \sum_{j=1}^{k} \beta_j \ln(z_{ji}) + v_i - u_i, \tag{4}$$

where u_i is a subtracted term in the output logarithmic function. This term must be greater than or equal to zero, such that the enterprise efficiency meets the condition $0 < \xi_i \le 1$. In this case, function (4) is a stochastic frontier production function.

On this basis, Kumbhakar and Lovell derived a dual production cost function in 2000:

$$\ln(c_i) = \beta_0 + \beta_q \ln(q_i) + \sum_{j=1}^{k} \beta_j \ln(p_{ji}) + v_i + u_i, \tag{5}$$

where c_i is cost; q_i is output; p_{ji} is price of elements. The other variables are the same as above. If an enterprise is

inefficient, the output will decline or the production cost will increase.

2.2. Data Sources and Variable Selection.

2.2. Data Sources and Variable Selection. To measure the manufacturing competitiveness of Hubei from the enterprise level, the data on manufacturing enterprises of Hubei were extracted from China Industrial Enterprise Database (1999–2011) through the following steps.

Firstly, rename all the variables named "Hubei Province" among the "province/autonomous region" variables, as well as the place names within the province, to "Hubei Province." For example, the variables named "Hubei," "Huangshi," and "Wuhan" were uniformly coded as "Hubei Province," after checking the "Administrative Region Code." In this way, all enterprises in Hubei were clearly identified as belonging to that province.

Secondly, extract the enterprises from "Hubei Province" after the renaming process. A total of 226 variables and 112,034 observations were extracted.

Thirdly, screen and sort out the variables. The main purpose is to delete the duplicate values and convert and sort out the attributes, numbers, and characters in the variables.

Fourthly, sort out the locations of the enterprises by four standards in turn: the "Area Codes" of Hubei, "Prefectural Codes" of Hubei, "County Codes" of Hubei, and "Enterprise Name." In this way, all enterprises in Hubei were allocated to the 17 prefectures. Table 1 lists the serial numbers of the 17 prefectures, i.e., the area codes of these prefectures.

Fifthly, allocate the enterprises in Hubei to the 17 prefectures according to the above classification. After removing the enterprises that cannot be allocated to any prefecture, the distribution of the enterprises is shown in Table 2.

According to the theory on enterprise competitiveness (i.e., the stochastic frontier production function), the main variables were extracted as follows:

(1) Enterprise output: there are many ways to measure enterprise output. By tradition, this paper measures output with gross industrial output (g1911) in its logarithmic form (lg1911).

(2) Enterprise inputs: the fixed infrastructure, labor, and labor training cost were measured by the mean balance of net fixed assets (g2123), number of employees (g2515), and human capital (g2416), respectively; these metrics were also expressed in logarithmic forms (lg2123, lg2515, and lg2416).

Table 3 shows the descriptive statistics on the above variables.

3. Estimation of Production Efficiency

3.1. Estimation Method. According to the proposed function and variable definitions, the SFA model for production efficiency estimation can be established as

$$\ln\left(\lg 1911_{it}\right) = \beta_0 + \beta_1 \lg 2123_{it} + \beta_2 \lg 2515_{it} + \beta_3 \lg 2511_{it} + \beta_4 \lg 2416_{it} - u_{it} + v_{it}.$$

$$(6)$$

It was assumed that u_i obeys half-normal distribution, and v_i obeys normal distribution.

Table 4 lists the analysis results on the main variables, including the coefficients about how the output (lg1911) is correlated with number of employees (lg2515), mean balance of net fixed assets (lg2123), and human capital (lg2416). The results show that the correlations are credible, nullifying the null hypothesis (the correlation coefficients equal zero) at the significance level of 1%.

The production efficiency of manufacturing enterprises in Hubei was estimated in four steps: first, select and analyze the relevant variables of the production function; second, estimate and test the parameters of the SFA model based on the data of industrial enterprises in Hubei 1999–2011; third, estimate the production efficiency of each enterprise in the 17 prefectures and calculate the annual mean production efficiency in each prefecture; fourth, compare the manufacturing competitiveness between the 17 prefectures, with the annual mean production efficiency as the metric and draw the basic conclusions.

3.2. Parameter Estimation. The parameters of the SFA model were estimated based on the enterprise data collected from China Industrial Enterprise Database (1999–2011). The estimated results are recorded in Tables 5 and 6.

The following can be learned from the analysis results in Table 5.

First, the mean balance of net fixed assets had positive effect on the gross industrial output of industrial enterprises. The correlation coefficient was significantly different from zero in both equations. Hence, fixed assets like infrastructure promote the output of industrial enterprises. Besides, the correlation coefficient remained significant on the 1% level, suggesting that the mean balance of net fixed assets objectively influences the added value of industrial enterprises.

Second, labor had an immense impact on the gross industrial output of industrial enterprises. The coefficient of number of employees was significant, whether in ordinary regression analysis, cross-section SFA, or panel data SFA. Thus, labor determines the added value of industrial enterprises in the long run.

Third, human capital also had a huge impact on the gross industrial output of industrial enterprises. The cross-section and panel data SFAs show that human capital had a significant coefficient. This means the enterprise expenditure on labor training determines the gross industrial output of enterprises.

Fourth, lnsig2u _cons and mu _cons were the p values reflecting that u_i differs from the null hypothesis. The random interference term (u_i) in the SFA model was significantly different from zero. As a result, the random interference term clearly exits and objectively affects enterprise output.

TABLE 1: Serial numbers of prefectures.

Prefecture	Wuhan	Xiangfan	Ezhou	Xiaogan	Yichang	Enshi	Shiyan	Suizhou	Huanggang	Huangshi	Xianning	Jingzhou	Jingmen	Xiantao	Qianjiang	Tianmen
Serial number	027	0710	0711	0712	0717	0718	0719	0722	0713	0714	0715	0716	0724	0725	0726	0728

Note. Xiantao, Qianjiang, Tianmen, and Shennongjia are directly administers by the provincial government. According to geographical location, the 0728 area code shared by Xiantao, Qianjiang, and Tianmen was broken down into 0725 for Xiantao, 0726 for Qianjiang, and 0728 for Tianmen.

TABLE 2: Distribution of industrial enterprises in the 17 prefectures of Hubei.

Prefecture	Number	Percentage	Downward cumulative percentage
Wuhan	19,275	19.88	19.88
Huangshi	4,500	4.64	24.52
Shiyan	4,665	4.81	29.33
Yichang	7,070	7.29	36.62
Xiangfan	7,363	7.59	44.21
Ezhou	3,227	3.33	47.54
Jingmen	5,902	6.09	53.63
Xiaogan	7,813	8.06	61.68
Jingzhou	7,909	8.16	69.84
Huanggang	8,989	9.27	79.11
Xianning	5,177	5.34	84.45
Enshi	2,358	2.43	86.88
Suizhou	4,807	4.96	91.83
Shenglongjia	143	0.15	91.98
Xiantao	3,120	3.22	95.20
Qianjiang	2,328	2.40	97.60
In total	96,973	100	100

Data source: China Industrial Enterprise Database (1999–2011).

TABLE 3: Descriptive statistics on the variables of industrial enterprises in Hubei.

Variable	Observation	Mean	Standard deviation	Minimum	Maximum
Output (lg1911)	89636	9.753957	1.444135	0	13.65094
Number of employees (lg2515)	96960	4.542324	1.256794	1.098612	7.889834
Fixed assets (lg2123)	96956	9.55079	1.528341	5.192957	14.09054
Human capital (lg2416)	78315	9.455429	1.565896	0	17.92006

Data source: China Industrial Enterprise Database (1999–2011). Notes: there were huge differences between the observations of the above variables, a sign of many missing values. Subsequently, the observations with lots of missing values were removed before analysis.

TABLE 4: Correlation analysis on relevant variables of manufacturing enterprises in Hubei.

	lg1911	lg2515	lg2123	lg2416
Output (lg1911)	1.0000			
Number of employees (lg2515)	0.6078	1.0000		
Fixed assets (lg2123)	0.6836	0.6325	1.0000	
Human capital (lg2416)	0.8241	0.4663	0.6220	1.0000

TABLE 5: Estimations of SFA parameters for the 17 prefectures.

	(1) Cross-section stochastic frontier lg1911	(2) Panel data stochastic frontier lg1911
lg2515	0.0901*** (30.95)	0.157*** (43.21)
lg2123	0.172*** (74.84)	0.189*** (64.66)
lg2416	0.653*** (333.14)	0.532*** (231.60)
_cons	1.060*** (22.74)	7.105 (0.37)
lnsig2v _cons	−1.098*** (−208.25)	
lnsig2u _cons	−14.60 (−0.10)	
lnsigma2_cons		−0.987*** (−119.37)
ilgtgamma _cons		0.332*** (19.57)
mu _cons		5.549 (0.29)
N	71979	71979
Annual dummy (control) variable	Yes	Yes
Industrial dummy (control) variable	Yes	Yes

t statistics in parentheses: $^{*}p < .1$, $^{**}p < 0.05$, and $^{***}P < 0.01$.

TABLE 6: Estimated production efficiencies of industrial enterprises in the 17 prefectures of Hubei (annual mean).

| Prefecture	1999	2000	2001	2002	2003	2005	2006	2007	2010	2011
Wuhan	0.00864946	0.00888881	0.00990813	0.01016356	0.0115944	0.01269094	0.0129358	0.01264344	0.01241972	0.01235955
Huangshi	0.00912404	0.00906635	0.00928386	0.0092479	0.00927902	0.00965555	0.0094157	0.00949741	0.00930071	0.00923054
Shiyan	0.00751613	0.00757303	0.00796029	0.00802157	0.00844919	0.00818838	0.0081401	0.00801579	0.00783633	0.00777346
Yichang	0.00929037	0.00955172	0.00935373	0.00917235	0.00905062	0.00896731	0.0088519	0.00859723	0.00842023	0.00834386
Xiangfan	0.00948962	0.00998555	0.00947397	0.01173034	0.01093264	0.0089419	0.00867732	0.00875403	0.00857594	0.00850064
Ezhou	0.01000637	0.01011546	0.01021252	0.01057368	0.0110661	0.01032068	0.0099913	0.00955672	0.00935569	0.00928364
Jingmen	0.00805834	0.00815295	0.00912962	0.00943033	0.00858202	0.00849949	0.0084705	0.00830046	0.00811671	0.00805716
Xiaogan	0.00973147	0.0098395	0.00978824	0.00957678	0.00918027	0.00881024	0.00864634	0.00832201	0.00812854	0.00807617
Jingzhou	0.00927887	0.00940402	0.00927839	0.00919883	0.00881849	0.00823173	0.00806799	0.00795142	0.00777513	0.0077147
Huanggang	0.0102116	0.01024694	0.00980688	0.00989584	0.00982209	0.00847602	0.00872432	0.00844615	0.00826024	0.00819901
Xianning	0.00870017	0.00973885	0.00943499	0.00949509	0.00927374	0.00875819	0.00861993	0.00838231	0.00822935	0.00816259
Enshi	0.00671094	0.00682235	0.00696588	0.00718961	0.0075859	0.00791164	0.00770298	0.00769715	0.00752765	0.00746994
Suizhou	0.01064086	0.01050217	0.01051528	0.01080381	0.01040744	0.00977538	0.0097586	0.00946632	0.00926008	0.00919313
Shenlongjia	0.00554867	0.00520701	0.00586326	0.00558253	0.00574757	0.00732859	0.00669766	0.00694146	0.00678114	0.00672837
Xiantao	0.00991318	0.01021604	0.01032507	0.01004784	0.00982655	0.00928097	0.00925784	0.00887959	0.00868365	0.0086191
Qianjiang	0.00956769	0.00957655	0.00941302	0.00898894	0.00893513	0.0095304	0.00938846	0.01009957	0.00989641	0.00982944
Tianmen	0.01062473	0.0105404	0.0104514	0.01055547	0.01026098	0.00991886	0.00970058	0.00924737	0.00906298	0.00897785
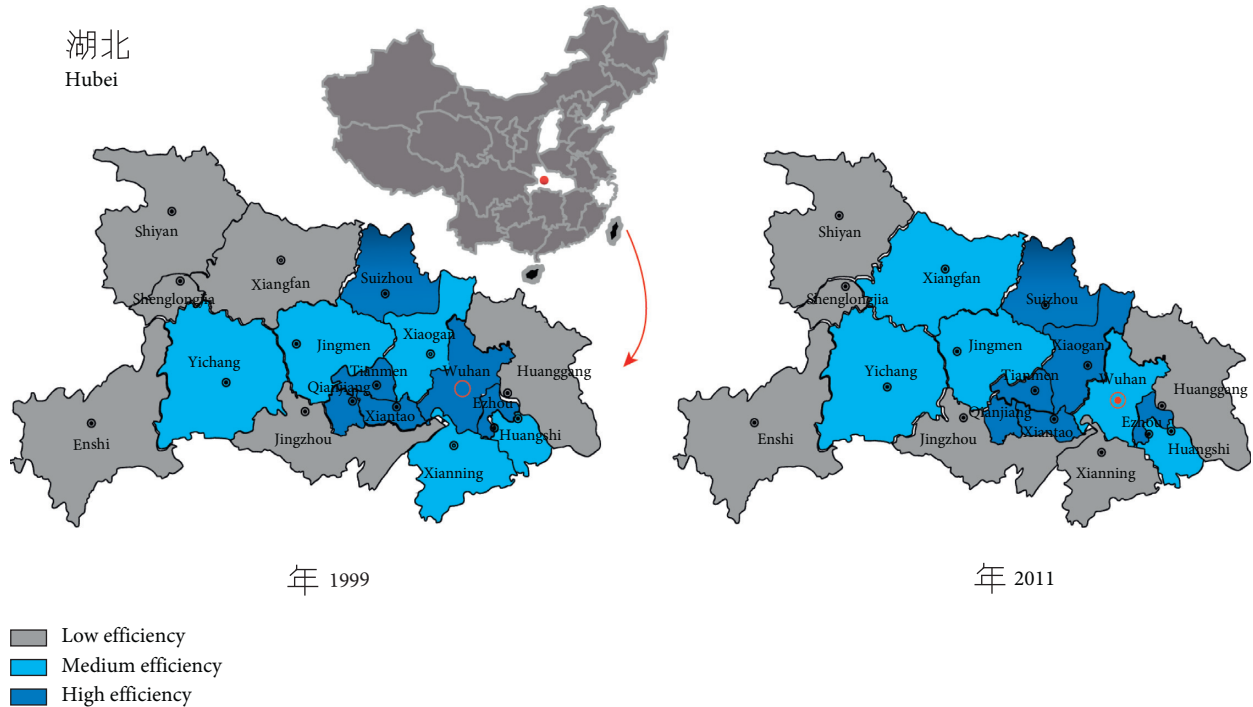
FIGURE 1: Grouping of the 17 prefectures by production efficiency of manufacturing companies.

To sum up, the estimation results of the SFA model parameters of manufacturing enterprises in Hubei are robust, and the selected model is suitable for this research.

3.3. Estimated Production Efficiencies. Next, the authors further analyzed the industrial competitiveness within Hubei. Based on the selected SFA model, the annual mean production efficiencies of industrial enterprises in the 17 prefectures of Hubei 1999–2011 were derived on Stata (Table 6).

As shown in Table 6, the 17 prefectures differed sharply in estimated production efficiency from 1999 to 2011. For comparison, the 17 prefectures were divided into three groups by the production efficiency of manufacturing companies: low efficiency group, medium efficiency group, and high efficiency group. Due to the lack of space, the three groups were compared only in 1999 and 2011.

As shown in Figure 1, Hubei Province had a generally low production efficiency of manufacturing companies. About 2/3 of all prefectures belonged to the medium efficiency group. The production efficiency of manufacturing companies in Hubei had not been significantly improved in the sample period. From 1999 to 2011, the industrial production efficiency in most prefectures did not change significantly, and only 4 prefectures witnessed changes in that efficiency. Specifically, Xianning dropped from medium efficiency group to low efficiency group; Wuhan fell from high efficiency group to medium efficiency group; Xiangfan promoted from low efficiency group to medium efficiency group; Xiaogan climbed up from medium efficiency group to high efficiency group. All the other prefectures remained in the original group.

4. Conclusions

To reveal the impact of production efficiency improvement on manufacturing competitiveness, this paper carries out SFA to estimate the production efficiency of manufacturing in Hubei Province, based on the data of Chinese industrial enterprises from 1999 to 2011. The main conclusions are as follows:

(1) Mean balance of net fixed assets and fixed assets (e.g., infrastructure) both had positive impact on the gross industrial output of manufacturing companies. This means the added value of manufacturing companies in Hubei depends much on the long-term investment and fixed asset investment of enterprises. Therefore, the enterprises should actively increase the share of fixed asset investment and long-term investment in corporate assets and pay particular attention to the cultivation of technological innovation capabilities. Meanwhile, the enterprises should digest, absorb, and reinnovate the introduced technologies and equipment, manufacture highly technical products, and enhance their own competitiveness.

(2) Labor and human capital had relatively great impact on the gross output of manufacturing companies and determined the industrial added value of enterprises in the long term. Therefore, Hubei Province should attach importance to human resources and strengthen the integration of production, education, and research. It is also important to encourage the interaction between enterprises, colleges, and research institutions. The province should give play to

its advantages in science and education and establish a long-term cooperation platform between enterprises, colleges, and research institutions.

(3) From 1999 to 2011, the industrial production efficiency in most prefectures did not change significantly, and only 4 prefectures witnessed changes in that efficiency. Specifically, Xianning dropped from medium efficiency group to low efficiency group; Wuhan fell from high efficiency group to medium efficiency group; Xiangfan promoted from low efficiency group to medium efficiency group; Xiaogan climbed up from medium efficiency group to high efficiency group.

The above changes in production efficiency mainly arise from geographic relations, especially the development of Wuhan Metropolitan Area. For example, Xiaogan has certain advantages in space and transportation and mainly develops light industries like the production and processing of grain, cotton, oil, animal husbandry, and aquatic products. Xianning focuses its energy to build a production and processing base for green agriculture, forestry, and aquatic products, as well as characteristic agricultural and sideline products. Wuhan functions as an advanced manufacturing base and a research and industrialization base of high-tech industries. Nevertheless, the Wuhan Metropolitan Area has not grown fast enough, and the relevant cities lack clear division of labor and cooperation.

To solve the above structural problems, Hubei Province should make full use of its geographical advantage as "a thoroughfare leading to nine provinces" and strive to build a modern industrial system that appeals to foreign investors. With Wuhan playing the leading role in regional coordinated development, the province needs to speed up the formation of a regional economic structure for mutual promotion and development. Under the structure, Wuhan serves as the center, six other large cities serve as the pillar, and the counties serve as the basis. In addition, Hubei must further improve the industrial chain within clusters, promote the integration of regional manufacturing, and thereby enhance its manufacturing competitiveness.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

References

[1] M. E. Porter, *The Competitive Advantage of Nations*, Harvard Business Review, Boston, MA, USA, 1990.

[2] S. B. Sirikrai and J. C. S. Tang, "Industrial competitiveness analysis: using the analytic hierarchy process," *The Journal of High Technology Management Research*, vol. 17, no. 1, pp. 71–83, 2006.

[3] M. Fetscherin, I. Alon, and J. P. Johnson, "Assessing the export competitiveness of Chinese industries," *Asian Business & Management*, vol. 9, no. 3, pp. 401–424, 2010.

[4] L. Meleo, "On the determinants of industrial competitiveness: the European union emission trading scheme and the Italian paper industry," *Energy Policy*, vol. 74, no. 11, pp. 535–546, 2014.

[5] E. P. J. Kleynhans, "Factors determining industrial competitiveness and the role of spillovers," *Journal of Applied Business Research (JABR)*, vol. 32, no. 2, pp. 527–540, 2016.

[6] D. Purwadi, "The role of Japanese human resource planning practices for increasing industrial competitiveness," *Procedia—Social and Behavioral Sciences*, vol. 65, pp. 253–259, 2012.

[7] L. Liu, "Research on industrial competitiveness evaluation and promotion policy of Changzhutan," *Scientific and Technological Progress and Countermeasures*, vol. 27, no. 1, pp. 65–67, 2010.

[8] L. Moreno, "The determinants of Spanish industrial exports to the European union," *Applied Economics*, vol. 29, no. 6, pp. 723–732, 1997.

[9] P. K. Wong and Z. L. He, "A comparative study of innovation behaviour in Singapore's KIBS and manufacturing firms," *The Service Industries Journal*, vol. 25, no. 1, pp. 23–42, 2005.

[10] T. J. Hannigan, M. Cano-Kollmann, and R. Mudambi, "Thriving innovation amidst manufacturing decline: the detroit auto cluster and the resilience of local knowledge production," *Industrial and Corporate Change*, vol. 24, no. 3, pp. 613–634, 2015.

[11] M. K. Singh, H. Kumar, M. P. Gupta, and J. Madaan, "Analyzing the determinants affecting the industrial competitiveness of electronics manufacturing in India by using TISM and AHP," *Global Journal of Flexible Systems Management*, vol. 19, no. 3, pp. 191–207, 2018.

[12] J. Dong and Y. You, "Empirical Analysis on the international competitiveness of China's aerospace manufacturing industry," *Scientific and Technological Progress and Countermeasures*, no. 2, pp. 55–58, 2012.

[13] A. Banterle and L. Carraresi, "Competitive performance analysis and European union trade: the case of the prepared swine meat sector," *Food Economics—Acta Agriculturae Scandinavica, Section C*, vol. 4, no. 3, pp. 159–172, 2007.

[14] S. Lall, "Competitiveness indices and developing countries: an economic evaluation of the global competitiveness report," *World Development*, vol. 29, no. 9, pp. 1501–1525, 2001.

[15] R. Sarker and S. Ratnasena, "Revealed comparative advantage and half-a-century competitiveness of Canadian agriculture: a case study of wheat, beef, and pork sectors," *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, vol. 62, no. 4, pp. 519–544, 2014.

[16] A. Hannan, F. Haider, N. Ahmad, and T. Ishaq, "Impact of economic, social and environmental variables on competitiveness of automotive industry: evidence from panel data,"

International Journal of Economic Behavior and Organization, vol. 3, no. 1, pp. 10–17, 2015.

[17] L. Carraresi and A. Banterle, "Agri-food competitive performance in EU countries: a fifteen-year retrospective," *International Food & Agribusiness Management Review*, vol. 18, no. 2, pp. 37–62, 2015.

[18] B. Jin, G. Li, and Z. Chen, "Empirical analysis on the international competitiveness of China's manufacturing industry since its accession to the WTO," *China's Industrial Economy*, vol. 23, no. 10, pp. 5–14, 2006.

[19] H. Wei and L. Wu, "Evaluation of industrial competitiveness in China," *China's Industrial Economy*, vol. 19, no. 11, pp. 54–62, 2002.

[20] C. Papahristodoulou, "A DEA model to evaluate car efficiency," *Applied Economics*, vol. 29, no. 11, pp. 1493–1508, 1997.

[21] I. Oh, J. D. Lee, S. Hwang, and A. Heshmati, "Analysis of product efficiency in the Korean automobile market from a consumer's perspective," *Ratio Working Papers*, vol. 38, no. 1, pp. 119–137, 2006.

[22] M. J. Melitz and D. Trefler, "Gains from trade when firms matter," *Journal of Economic Perspectives*, vol. 26, no. 2, pp. 91–118, 2012.

[23] S. Li and X. Tang, "A positive analysis of the market concentration and the competitiveness of large enterprises: based on the empirical evidence of China's equipment manufacturing industry," *Journal of Shandong University (Philosophy and Social Sciences edition)*, vol. 48, no. 6, pp. 34–44, 2013.

[24] M. J. Farrell, "The measurement of productive efficiency," *Journal of the Royal Statistical Society. Series A (General)*, vol. 120, no. 3, pp. 253–281, 1957.