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Estimation of Collaborative Innovation of Manufacturing and Logistics Industry in Hubei

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Abstract

In the era of big data, the industry is in urgent need for transformation and upgrading, collaborative innovation between the manufacturing and logistics industry is significant for enhancing the overall competitiveness and development of the regional economy. Based on complex system theory and synergetic theory, this paper first estimates the collaborative innovation degree of manufacturing and logistics industry by using the collaborative degree model of complex composite system, then measures the collaborative innovation efficiency of the whole collaborative innovation system by the method of data envelopment analysis. The results show that the collaborative innovation level is low and no effective mutual-benefiting mechanism of the two industries has been established in Hubei province.

Keywords: manufacturing industry, logistics industry, collaborative innovation.

1.INTRODUCTION

In the era of big data, the industry is in urgent need for transformation and upgrading. With the applications of big data and the Internet of things technology, manufacturing and logistics industry has developed to a high degree of integration (Daniels and Bryson, 2002; Francois and Woerz, 2008).And applying big data technology to promote collaborative innovation in manufacturing and logistics industry is essential for industrial restructuring and upgrading.

As for the manufacturing industry, big data can not only help reduce the logistics costs of manufacturing industry, but also improve the target of production and marketing, reduce market risk. The improvement of the logistic industry means the speedup of logistics services, quality improvement, price decline, etc., which can promote the service-oriented transformation of the manufacturing (Moyart, 2005).As for the logistics industry, through data analysis, logistics enterprises can improve the efficiency of transportation and distribution, reduce logistics costs, and meet customer service requirements more effectively. The quick development of the manufacturing industry means increased logistic demand and the improved logistics facilities, which can help the logistic market grow and improve the operational efficiency.

The development of collaborative innovation can produce more social benefits in promoting economy, employment, and increasing income. Collaborative innovation between the manufacturing and logistic industries does not only promote to a great degree the development of the two industries themselves, but also enhances the overall competitiveness of the regional economy, and is significant for the transformation and upgrading of the whole regional economy (Macpherson, 2008).Therefore, study on collaborative innovation of regional manufacturing and logistics industry has practical significance (Larson and Gammelgaard, 2001; Ellinger, 2000).

More and more scholarshave recognized the importance of collaborative innovation of the two industries,and put forward the related mechanism, evolution path and collaborative development strategy.The main research methods include Grey RelationAnalysis (WangandChen, 2010),Panel Data Model (Guet al., 2006; Cheng et al., 2016),Industrial Cluster Theory (Li and Zhang, 2006) and other related methods. However,there is a lack ofin-depth empirical research by qualitative methods to estimate the degree and efficiency of collaborative innovation betweenmanufacturing and logistics industry.

In big data era China’s industry is in urgent need for transformation and upgrading,Hubei Province is a province of traditional manufacturing in China and located in the central region of China. Hubei Province is an abundant in water resources and important channel China waterway freight, where a lot of logistic industries gather. At the same time, it has a large population, and there are many large manufacturing industry clusters, making it an important manufacturing base in China. And like the other parts of China, its current manufacturing has some common problems. Because of rising costs, low product added-value, and shrinking market, Hubei's manufacturing industry is also facing difficulties in the transformation and upgrading. Based on the empirical studyconducted in Hubei Province of China, the research results are representative, which has a good reference value for the analysis of collaborative innovation in China's manufacturing industry and logistic industry.

Collaborative innovation of regional manufacturing and logistics industry refers to the two industries not only compete with each other, but also benefit each other, through the complex nonlinear effects to achieve synergistic effect (Corning, 2010; Cebon, 2006; Serrano and Fischer, 2007).This paper considers the collaborative innovation system of regional manufacturing and logistics industry is a complex system, and also a composite system composed of the manufacturing subsystem and logistics subsystem. The collaborative degree model can be used to measure the consistency of complex composite systems, and the method of data envelopment analysiscan be used to calculate the efficiency of complex systems with multiple inputs and multiple outputs. So this paper does a system empirical study by applying these two measuring methods.

The rest of the paper is organized as follows: First, the paper evaluates the collaborative innovation degree by using the collaborative degree model of complex composite system in China's Hubei Province in Section 2, then measures the collaborativeinnovation efficiency of manufacturing and logistic industry by using the method of data envelopment analysis in Section 3, Section 4 discusses the possible reasons for the results, and Section 5is the conclusions.

2.EVALUATION OF COLLABORATIVE INNOVATION DEGREE

2.1 Collaborative degree model of complex composite system

The paper considers that the manufacturing and logistics industries in the same region are interrelated and influenced by each other, and the collaborative innovation development system of manufacturing and logistic industry is a complex composite system. Based on the complex system theory and synergetic theory, the paper holds that only when the various subsystems within the system are to promote mutually, innovate and develop cooperatively, can the operation and development of the whole collaborative innovation system be in a most efficient and optimal state.

Based on the method of collaborative degree evaluation of composite system (Meng and Han, 2000), this paper evaluates the collaborative innovation of manufacturing and logistic industry in Hubei Province. This evaluation method can measure the innovation degree of the composite system, which consists of the 2 subsystems. By calculating the value of collaborative innovation, we can accurately measure the internal state of the composite system. And we could estimate whether the two subsystems are in an efficient state of benign interaction and coordinated development.

The collaborative degree model of complex composite system model is described as follows (Meng and Han, 2000):

$S=\{S_1,S_2,S_3, ...,S_k\}$, $S$is defined as thecomposite system, S_j is the jth subsystem that consists thecomposite system S,$j=1,2,3,......,k$. As a subsystem, S_j is also made up of several subsystems or basic elements, which is represented as $S_j=\{S_{j1},S_{j2},...,S_{jk}\}$, which contains many order parameters$e_{ji}=(e_{j1}, e_{j2}, ..., e_{jn})$. These order parameters are used to describe the development and operation of the subsystem. If these order parameters show a positive development trend, the value of the order parameters are proportional to the collaborativedegree of the composite system, vice versa.

The ordering degree of an order parameter component in a complex composite system can be calculated according to the following formula (1):

$$u_j(e_{ji}) = \begin{cases} \dfrac{e_{ji} - \beta_{ji}}{\alpha_{ji} - \beta_{ji}}, i \in (1, l_1) \\ \dfrac{\alpha_{ji} - e_{ji}}{\alpha_{ji} - \beta_{ji}}, i \in (l_1 + 1, n) \end{cases} \quad (1)$$

And it is easy to infer that $u_j(e_{ji}) \in (0,1)$, so the formula of ordering degree is as follows:

$$\begin{aligned} u_j(e_j) &= \sqrt[n]{\prod_{i=1}^{n} \lambda_j u_j(e_{ji})}, \lambda_j \geq 0, \sum_{i=1}^{n} \lambda_j = 1 \\ u_j(e_j) &= \sqrt[n]{\prod_{i=1}^{n} u_j(e_{ji})} \end{aligned} \quad (2)$$

Then, the collaborative innovation degree of the complex composite system can be calculated according to the following formula (3):

$$c = \theta^k \sqrt{\left| \prod_{j=1}^{k} \left[u_j^1(e_j) - u_j^0(e_j) \right] \right|} \quad (3)$$

In which,

$$\theta = \frac{\min_j \left[u_j^1(e_j) - u_j^0(e_j) \neq 0 \right]}{\left| \min_j \left[u_j^1(e_j) - u_j^0(e_j) \neq 0 \right] \right|}, \ j = 1,2,3,\ldots\ldots, k$$

The classification standards of collaborative innovation degree are different. According to previous studies, this paper classifies the evaluation of collaborative innovation degree into the following criteria as shown in Table 1.

Table 1 Evaluation level of collaborative innovation degree

Collaborative innovation degree	0-0.4	0.4-0.6	0.6-0.8	0.8-1
Level of Collaborative innovation	Low level	Generallevel	Good level	High level

2.2 Index evaluation system of collaborative innovation

According to the principle of science and rationality, and to ensure the integrity and availability of data, thisresearch selected the following index to measure the collaborative innovation degree of manufacturing and logistics subsystem, and established index evaluation system of collaborative innovation as shown in Table 2.

Table 2 Index evaluation system of collaborative innovation

System	Subsystem	Index	Order parameters	Unit
Complex composite system(S)	Manufacturing subsystem(S1)	employees of manufacturing industry	e11	10 thousand
		Average wage of employees of manufacturing industry	e12	RMB Yuan
		Investment in fixed assets of manufacturing industry	e13	100 million RMB
		Annual gross domestic product of manufacturing industry	e14	100 million RMB
		total amount of import and export trade of manufacturing industry	e15	100 million USD
	Logistics subsystem(S2)	employees of logistics industry	e21	10 thousand
		Average wage of employees of logistics industry	e22	RMB Yuan
		Investment in fixed assets of logistics industry	e23	100 million RMB
		freight volume	e24	10 thousand tons
		freight turnover	e25	100 million tons/km

2.3 Empirical analysis

(1)The statistics are from the HUBEI STATISTICAL YEARBOOK (2008-2015). By applying the statistics, the ordering degree of the subsystems, based on Formula (1), is calculated. The results are shown in Table 3 and Table 4.

Table 3 Ordering degree of manufacturing subsystem

Index	e11	e12	e13	e14	e15
2007	0.0248	0.0026	0.0826	0.1013	0.0135
2008	0.0629	0.0715	0.1031	0.1638	0.0913
2009	0.1336	0.1826	0.1762	0.2533	0.1726
2010	0.2638	0.2238	0.2433	0.3175	0.2362
2011	0.4162	0.3348	0.4217	0.3854	0.2917
2012	0.4407	0.4657	0.4911	0.4539	0.3381
2013	0.6723	0.6014	0.5519	0.6854	0.4417
2014	0.6927	0.7351	0.6258	0.7911	0.5014

Table 4 Ordering degree of logistics subsystem

Index	e21	e22	e23	e24	e25
2007	0.0664	0.0639	0.1637	0.1361	0.0792
2008	0.1642	0.1016	0.2399	0.2363	0.1448
2009	0.2112	0.2441	0.2735	0.2582	0.3106
2010	0.2234	0.3197	0.3043	0.4844	0.3761
2011	0.2703	0.4475	0.4226	0.5112	0.4733
2012	0.5883	0.5358	0.5253	0.6326	0.5014
2013	0.6049	0.7506	0.6379	0.8319	0.6037
2014	0.6973	0.8039	0.7218	0.8872	0.6953

(2) Dimensionless treatment of the statistics in Table 3 and Table 4. Dimensionless method is used here, and the results are shown in Table 5 and Table 6.

Table 5 Dimensionless of ordering degree in the manufacturing subsystem

Index	e11	e12	e13	e14	e15
2007	-1.462215	-1.361939	-1.48293	-1.472194	-1.361534
2008	-1.319158	-1.14293	-1.043518	-1.037459	-1.301635
2009	-1.02315	-1.036183	-0.507424	-0.735182	-1.035143
2010	-0.839473	-1.351839	-0.837113	-0.614378	-0.52839
2011	-1.104529	0.715386	0.984617	0.846109	0.731934
2012	-1.364913	0.881342	0.745146	1.046153	0.923516
2013	0.361983	1.03052	1.045194	1.418645	1.035183
2014	0.836183	1.327934	1.462938	1.745144	1.284361

Table 6 Dimensionless of ordering degree in the logistics subsystem

Index	e21	e22	e23	e24	e25
2007	0.351947	1.371539	0.946154	1.461443	0.93153
2008	0.936154	1.113451	0.361448	1.284952	0.735188
2009	1.37193	0.935143	1.471547	1.015288	0.503614
2010	1.461834	0.734193	0.347154	0.902534	0.13764
2011	0.351845	0.519354	0.579149	0.713327	0.314518
2012	0.835142	0.739154	0.901543	0.504514	0.693512
2013	1.045173	0.90157	1.310972	0.601427	0.775143
2014	1.448452	1.438134	1.447246	0.863413	1.036146

(3)Based on the data in Table 5 and Table 6, the regression analysis of manufacturing subsystem and logistic subsystem is carried out based on SPSS19.0 software, and the correlation coefficient and weight coefficient are calculated. The results are shown in Table 7 and Table 8.

Table 7 Regression analysis results ofmanufacturing subsystem

	e11	e12	e13	e14	e15	Weight coefficient
e11	1	0.972	0.891	0.785	0.836	0.166
e12	0.735	1	0.914	0.861	0.893	0.184
e13	0.801	0.906	1	0.932	0.915	0.173
e14	0.813	0.873	0.992	1	0.964	0.269
e15	0.864	0.875	0.875	0.904	1	0.208

Table 8 Regression analysis results of logistics subsystem

	e21	e22	e23	e24	e25	Weight coefficient
e21	1	0.972	0.901	0.782	0.943	0.184
e22	0.942	1	0.945	0.856	0.896	0.163
e23	0.874	0.991	1	0.891	0.867	0.157
e24	0.881	0.864	0.927	1	0.973	0.228
e25	0.806	0.873	0.936	0.944	1	0.268

Table 9 Collaborative innovation degree of system

Year	S1	S2	S
2007	0.201164	0.163419	0.066442
2008	0.263481	0.23491	0.074789
2009	0.316498	0.339465	0.074524
2010	0.392649	0.417653	0.093448
2011	0.472546	0.476549	0.086243
2012	0.607341	0.564973	0.095384
2013	0.715493	0.664392	0.058362
2014	0.826487	0.743649	0.183479

After the correlation coefficient and weight coefficient of the subsystems were obtained by SPSS19.0, based on formula (2),the collaborative innovation degree of the two kinds of subsystems was calculated; based on formula (3), the collaborative innovation degree of the complex composite system is calculated. The calculated data of collaborative innovation degree from 2007 to 2014 is shown in Table 9. Based on Table 9, the collaborative innovation development trend chart of the manufacturing subsystem, logistics subsystem and complex composite system (Hubei Province) is shown in Figure1.

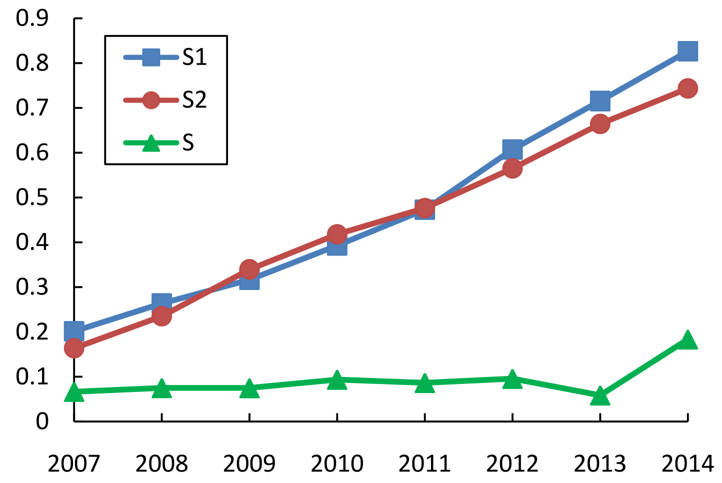

Figure 1. Collaborative innovation development trend

According to the Table 9 and Figure1, it can be seen that between the eight years (2007-2014) both the manufacturing and logistic industry developed very quickly. When the two are independent subsystems, the internal collaboration innovation degree is in quick rise, and the value is very high. As for the complex composite system, which is composed of two subsystems, the collaborative innovation degree is not stable, with the degree always below 0.1. But in 2013 there was a relatively clear upward trend. It can be inferred that for the complex composite system, the high collaboration innovation degree within the subsystems does not mean the good collaborative innovation capacity of the whole composite system. The rise in the internal collaboration degree does not necessarily imply the rise of the composite system. The current regional logistic development and the development of the manufacturing industry in Hubei Province do not match with each other. The collaborative innovation development of complex composite system has not been significantly improved, and the support function of regional logistics has not really been reflected, which is without doubt not conducive to upgrading of the manufacturing industry structure.

3. MEASUREMENT OF COLLABORATIVE INNOVATION EFFICIENCY

Based on the method of data envelopment analysis (DEA)(Charnes et al., 1978), applying the BCC model (Banker et al., 1984), the paper estimates the collaborative innovation efficiency of the complex composite system composed of manufacturing and logistics industry by DEAP2.1 software. Base on the BCC model, in order to facilitate two-way calculation, the paper selects representative indicators such as employees (10 thousand) and investment in fixed assets of (100 million Yuan), to measure the collaborative innovation efficiency of manufacturing and logistics industry. The statistics are from the HUBEI STATISTICAL YEARBOOK (2008-2015).When manufacturing industry data is the inputs, and the logistics industry data is the outputs, the paper does DEA analysis by using DEAP2.1 software, and the results are shown in Table 10.

Table 10 DEA analysis of situation 1

DMU	Crste	Vrste	Scale
2007	0.471	1	0.471 irs
2008	0.444	0.532	0.834 drs
2009	0.962	1	0.962 drs
2010	0.675	0.917	0.736 irs
2011	1	1	1.000-
2012	0.561	0.852	0.659 irs
2013	0.694	1	0.694 irs
2014	1	1	1.000-

Based on the data in Table 10, the trend of collaborative innovation efficiency of the complex composite systemis shown in Figure 2. As shown in table 10 and Figure 2,in situation 1, when manufacturing industry data is the inputs, and the logistics industry data is the outputs, it is easy to see that only in 2011 and 2014,the decision making units (DMU)are DEA efficient, others are non-efficient or weak efficient. In other words, only in 2011 and 2014, the development in the manufacturing industry has brought significant growth in the logistics industry.

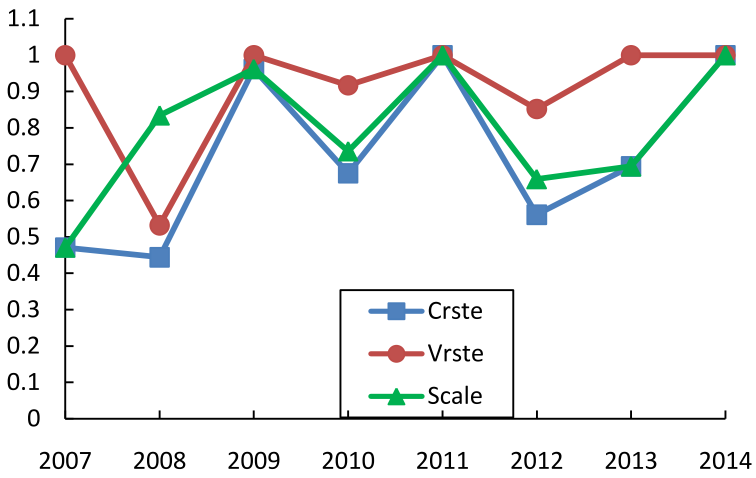

Figure 2. DEA analysis of situation 1

In situation2, When logistics industry data is the inputs, and the manufacturing industry data is the outputs, the paperdoes DEA analysis by using DEAP2.1 software, and the results are shown in Table 11.

Table 11 DEA analysis of situation 2

DMU	Crste	Vrste	Scale
2007	0.520	0.762	0.683 irs
2008	1.000	1.000	1.000 -
2009	0.791	1.000	0.791 irs
2010	0.887	1.000	0.887 irs
2011	0.728	0.803	0.906 irs
2012	0.721	0.847	0.852 drs
2013	0.726	0.901	0.806 drs
2014	1.000	1.000	1.000 -

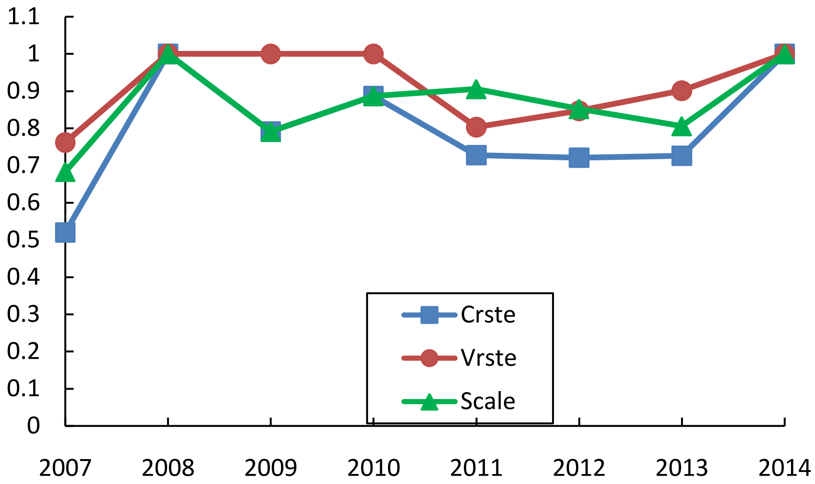

Figure 3. DEA analysis of situation 2

Based on the data in Table 11, the trend of collaborative innovation efficiency of the complex composite system is shown in Figure 3. As shown in table 11 and Figure3, when logistics industry data is the inputs, and the manufacturing industry data is the outputs, it is easy to find thatonly in 2008 and 2014, the DMUareDEAefficient, others are non-efficient or weak efficient. In other words, only in 2008 and 2014, the development in the logistics industry has brought significant growth in the manufacturing industry.

Only when the DMU areDEA efficient in both cases, the complex system of collaborative innovation is DEA efficient.Based on the data both in Table 10 and Table 11,it is easy to find that only in 2014the manufacturing and logistics industryhas been the overall efficient collaborative innovation in Hubei Province.

4.DISCUSSION

The results of collaborative innovation and efficiency between two industries from 2007 to 2014 show that the collaborative innovation level is low and no effective mutual-benefiting mechanism of the two industries has been established in Hubei Province. However, with the popularity of big data technology and networking technology, the level of collaborative innovation in 2014 has been greatly improved, and the development of collaborative innovation has a good rising trend.

There are some possible reasons for the lack of collaboration innovation between manufacturing and logistic industries.

(1) Since 2013 the big data has received great attention and application in China, the manufacturing industry and logistics industry have a low degree of data sharing before 2013. After 2013, with the widespread application of big data, big data has been applied to all aspects of manufacturing and logistics industry, bring high benefit. After 2013, although the total collaborative innovation efficiency has improved, the overall degree of collaborative innovation is still very low. It illustrates that the information and data sharing between manufacturing enterprises and logistics enterprises are not enough, so the synergy between them is also inadequate.

(2) For manufacturing enterprises, most of them in Hubei Province of China belong to the traditional manufacturing industry, which generally tend to build their own logistic system, which will often result in high cost and low efficiency. Their logistics service awareness is to be improved and cost control and risk awareness not strong, which makes the manufacturing logistic development lag behind. Even if the manufacturing enterprises have realized the advantages of logistic outsourcing, they will face the problem of exiting the threshold.

(3) For the logistics enterprises, the problem is the homogenization of logistic services. Until March 2016, there are 325 above A-class logistics enterprises in Hubei Province, including 10 five A-class and 115 four A-class

logistic enterprises. Small scale logistic enterprises not only caused serious disorder competition, but also seriously dispersed the logistic resources.

(4) In the aspect of government policies and institutions, the development of collaborative innovation involves many aspects, such as rational planning the highway, railway and aviation, striving to develop the big data application, Internet things technology and information platform, effectively using tax and subsidy policy. At present the government should work further on how to effectively integrate the various departments and institutions, and provide reasonable planning and guidance.

5.CONCLUSION

Collaborative innovation between the manufacturing and logistics industries pose great significance on enhancing the competitiveness and regional economic development. Based on complex system theory and synergetic theory, this paper first evaluates the collaborative innovation degree of manufacturing and logistics industry by using the collaborative degree model of complex composite system, and then measures the collaborative innovation efficiency of the whole collaborative innovation system by the method of data envelopment analysis. The results show that the collaborative innovation level is low and no effective mutual-benefiting mechanism of the two industries has been established in the empirical study region. However, with the popularity of big data technology and Internet of things technology, the level of collaborative innovation has improved. Since Hubei Province is a province of traditional manufacturing in China, where a lot of manufacturing and logistic industries gather, the empirical research results have a good reference value for the study of collaborative innovation in China’s manufacturing industry and logistic industry.

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