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A Study of Efficiency Measurement of Collaborative Innovation of IUR in China's High-tech Industry

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Abstract. *An evaluation index system for the efficiency of collaborative innovation of IUR in high-tech industry is constructed , and the efficiency of innovation of China's high-tech industry is measured using the relational DEA model with shared input. The high-tech industry includes five categories and fifteen segment industries. According to the measurement, the overall analysis and two-stage (R&D and technology transfer) analysis are carried out respectively. Furthermore, based on the efficiency of R&D and technology transfer in each industry, the high-tech industry is divided into four categories, and the suggestions to improve the innovation efficiency are given.*

Keywords: *high-tech industry; efficiency of the collaborative Innovation of IUR; the relational DEA model with shared inputs*

1. Introduction

As a strategic emerging industry of technology intensive, high-tech industry has become a new growth point to enhance the core competitiveness of China's economy. Technological innovation is the key to its development, and collaborative innovation of Industry, University and Research Institute (IUR) is the first choice to develop high-tech industry through technological innovation. The collaborative innovation of IUR is a kind of innovation mode, which is based on the cooperation, resource sharing and risk sharing of enterprises, universities, research institutions and other innovation subjects to achieve the purpose of technological innovation. In recent years, high-tech industrial parks have been set up to develop high-tech industries in most cities of China. The main task of these industrial parks is to carry out

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collaborative innovation of IUR, strengthen the flow of knowledge among major innovation subjects, and improve innovation efficiency. According to « China Statistics Yearbook of China's High Technology Industry », the high-tech industry has developed rapidly, but the efficiency of collaborative innovation of IUR needs to be improved.

The collaborative innovation of IUR began from the innovation theory put forward by Schumpeter. After that, many scholars followed, and the connotation of innovation research continued to improve. In 1980s, with the rise of a large number of emerging industries, most scholars's studying focused on strengthening the integration of IUR, and improving the efficiency of innovation in high-tech industries. At present, the research on innovation efficiency of high-tech industry mainly includes Stochastic Frontier Approach (SFA) and Data Envelopment Analysis (DEA). Because DEA model has obvious advantages in measuring the efficient indicators of inputs and outputs, scholars focused more on the application of DEA method. In 1978, scholars Charnes, Cooper and Rhodes proposed this DEA method for nonparametric evaluation of relative efficiency[1], experienced a single-layer structure model of "black box" DEA. Network DEA was first proposed by Fare and Grosskopf(2000) [2], and Kao (2008) proposed a two-stage network DEA model, including two stages in series and two stages in parallel[3]. In the same year, Yu and Lin initially introduced the situation of shared inputs into the network DEA evaluation model and established a multi activities network DEA model[4]. After that, scholars widely applied the two-stage DEA model with shared inputs to the empirical research of high-tech industry innovation efficiency with two-stage characteristics, and the samples covered the industries and regional levels. Chen Kaihua et.(2011) proposed the efficient measurement and decomposition of the relational two-stage network DEA model with shared inputs for production system[6], which laid a foundation for the application of this method in efficiency. Ye Rui et.(2012) through the empirical analysis of high-tech industry data of 29 provinces in China from 1999 to 2010, obtained that the relational DEA model with shared inputs is more suitable for efficiency measurement and can get the information of intermediate process than other methods[7]. Ma Jianfeng et. (2014) used the the relational network DEA model with shared inputs to measure and decompose the technological innovation efficiency of large and medium industrial enterprises classified by registration type in China[8]. Fan Decheng et.(2019)

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measured the overall efficiency and two-stage efficiency of high-tech industry technological innovation from 2013 to 2015 of 30 provinces in China by using the relational network DEA model with shared inputs [9].

From a large number of literature, we can see the relational two-stage DEA model with shared inputs is suitable for analyzing the efficiency of high-tech industry. Many papers used this method to study the innovation efficiency, and few papers based on the perspective of collaborative innovation of IUR to measure the innovation efficiency; many papers analyzed the samples of different provinces, and few papers focused on the subdivision of industries. In this paper, we use the improved two-stage DEA model to measure and analyze the efficiency of collaborative innovation of IUR in China's five categories and fifteen segment industries from 2013 to 2016.

2. Model description and variable selection

2.1 Model description

VRS model is used to measure the efficiency of collaborative innovation of IUR of high-tech industry. The value of efficiency and innovation efficiency are the efficiency of input factors in production activities. Stage efficiency is the value of R&D and technology transfer efficiency. The calculated the values of efficiency are all between 0 and 1. When the value of efficiency is 1, DMU is effective; when the value of efficiency is less than 1, DMU is invalid. The technical invalid value represented as (1-efficiency value). The higher value of efficiency, the lower invalid value, and the more resource waste.

Five industries and fifteen segment industries of high-tech industry can be described as $DMU_j\ (j=1,2\ldots\ldots n)$, each DMU has *m* kinds of innovation inputs, *q* kinds of intermediate outputs, *g* kinds of second stage proprietary inputs and *s* kinds of final innovation outputs. They can be respectively expressed as $X_i(i=1,2,\cdots\cdots,m)$, $Zp(p=1,2\cdots\cdots,q)$, $Z_h(h=1,2,\cdots\cdots,g)$, $Yr(r=1,2,\cdots\cdots,s)$. Initial innovation input (X_i) of each DMU_j is consumed in two sub processes. Suppose the allocation proportion in the R&D stage

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and the technology transfer stage is respectively $\alpha_i X_i$ and $(1-\alpha_i)\ X_i$. The weight of $\alpha_i X_i$ and $(1-\alpha_i)\ X_i$ are can be expressed as $v^1{}_i$ and $v^2{}_i$ *(i = 1, 2, ……, m)* respectively. We use $w^1{}_p$ to represent the weight of the intermediate output (*Zp*) in the first stages. We use $w^2{}_p$ to represent the weight of exclusive investment (Z_h *(h=1, 2, ……, g)*) in the second stages. Finally, the weight of the final innovation output (*Yr*) can be described as u_r*(r = 1, 2, ……, s).*

Then the input and output of R&D stage are respectively:

$$\sum_{i=1}^{m} v^1{}_i \alpha_i X_{ij}, \quad \sum_{p=1}^{q} \omega^1{}_p Z_{pj}$$

The input and output of technology transfer stage are respectively

$$\sum_{i=1}^{m} v^2{}_i (1-\alpha_i) X_{ij} + \sum_{p=1}^{q} w^1{}_p Z_{pj} + \sum_{h=1}^{g} \omega^2{}_p Z_{hj}, \quad \sum_{r=1}^{s} u_r Y_{rj}$$

The total input and output are:

$$\sum_{i=1}^{m} v^2{}_i (1-\alpha_i) X_{ij} + \sum_{h=1}^{g} \omega^2{}_p Z_{hj} + \sum_{i=1}^{m} v^1{}_i \alpha_i X_{ij}, \quad \sum_{r=1}^{s} u_r Y_{rj}$$

The value of efficiency of the first stage (R&D stage) is the ratio of output to input of the first stage ($E^1{}_k$), the value of efficiency of the second stage (technology transfer stage) is the ratio of output to input of the second stage ($E^2{}_k$):

$$E^1{}_k = \left(\max \sum_{p=1}^{q} \omega^1{}_p Z_{pk} - \mu^1{}_k\right) \Big/ \sum_{i=1}^{m} v^1{}_i \alpha_i X_{ik}$$

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$$s.t.\begin{cases} \dfrac{\sum_{p=1}^{q} w^1{}_p Z_{pj} - \mu^1{}_k}{\sum_{i=1}^{m} v^1{}_i \alpha_i X_{ij}} \leqslant 1 \\ j=1,2,\ldots\ldots,n,\ \ 1 \geqslant \alpha_i > 0, v^1{}_i, w^1{}_p \geqslant 0, i=1,2,\ldots\ldots,m \end{cases} \quad (1)$$

$$E^2{}_k = \left(\max \sum_{r=1}^{s} u_r Y_{rk} - \mu^2{}_k\right) / \left(\sum_{i=1}^{m} v^2{}_i (1-\alpha_i) X_{ik} + \sum_{p=1}^{q} w^1{}_p Z_{pj} + \sum_{h=1}^{g} w^2{}_p Z_{hk} \right)$$

$$s.t.\begin{cases} \dfrac{\sum_{r=1}^{s} u_r Y_{rj} - \mu^2{}_k}{\sum_{i=1}^{m} v^2{}_i (1-\alpha_i) X_{ij} + \sum_{p=1}^{q} w^1{}_p Z_{pj} + \sum_{h=1}^{g} w^2{}_p Z_{hj}} \leqslant 1 \\ j=1,2,\ldots\ldots,n, 1 \geqslant \alpha_i > 0, v^2{}_i, w^1{}_p, w^2{}_p, u_r \geqslant 0, i=1,2,\ldots\ldots,m \end{cases}$$

(2)

Innovation efficiency is the ratio of total output to total input（E_k）:

$$E_k = \max \frac{\sum_{r=1}^{s} u_r Y_{rk} - \mu^1{}_k - \mu^2{}_k}{\sum_{i=1}^{m} v^1{}_i \alpha_i X_{ik} + \sum_{i=1}^{m} v^2{}_i (1-\alpha_i) X_{ik} + \sum_{h=1}^{g} w^2{}_p Z_{hk}}$$

We assume that：

$$t = \frac{1}{\sum_{i=1}^{m} v^1{}_i \alpha_i X_{ik} + \sum_{i=1}^{m} v^2{}_i (1-\alpha_i) X_{ik} + \sum_{h=1}^{g} w^2{}_p Z_{hk}}$$

$$V^1{}_i = tv^1{}_i, V^2{}_i = tv^2{}_i, W^1{}_p = tw^1 p, W^2{}_p = tw^2{}_p, U_r = tu_r, \mu^A{}_k = t\mu^1{}_k, \mu^B{}_k = t\mu^2{}_k$$

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Through the Charnes-Cooper transformation, a linear programming model for measuring innovation efficiency can be obtained.

$$E_k = \max \sum_{r=1}^{s} U_r Y_{rk} - \mu^A{}_k - \mu^B{}_k$$

$$s.t.\begin{cases} \sum_{i=1}^{m} V^1{}_i \alpha_i X_{ik} + \sum_{i=1}^{m} V^2{}_i (1-\alpha_i) X_{ik} + \sum_{h=1}^{g} W^2{}_p Z_{hk} = 1 \\ \sum_{i=1}^{m} V^1{}_i \alpha_i X_{ij} - \left(\sum_{p=1}^{q} W^1{}_p Z_{pj} - \mu^A{}_k \right) \geqslant 0 \\ \sum_{i=1}^{m} V^2{}_i (1-\alpha_i) X_{ij} + \sum_{p=1}^{q} W^1{}_p Z_{pj} + \sum_{h=1}^{g} W^2{}_p Z_{hj} - \left(\sum_{r=1}^{s} U_r Y_{rj} - \mu^B{}_k \right) \geqslant 0 \\ 1 \geqslant \alpha_i > 0, V^1{}_i, V^2{}_i, W^1{}_p, W^2{}_p, U_r \geqslant \varepsilon, i = 1, 2, \ldots\ldots, m, j = 1, 2, \ldots\ldots, n \end{cases}$$

(3)

We assume that $\pi^1{}_i = V^1{}_i \alpha_i, \pi^2{}_i = V^2{}_i \alpha_i$,

$$E_k = \max \sum_{r=1}^{s} U_r Y_{rk} - \mu^A{}_k - \mu^B{}_k$$

$$s.t.\begin{cases} \sum_{i=1}^{m} \pi^1{}_i X_{ik} + \sum_{i=1}^{m} V^2{}_i X_{ik} - \sum_{i=1}^{m} \pi^2{}_i X_{ik} + \sum_{h=1}^{g} W^2{}_p Z_{hk} = 1 \\ \sum_{i=1}^{m} \pi^1{}_i X_{ij} - \left(\sum_{p=1}^{q} W^1{}_p Z_{pj} - \mu^A{}_k \right) \geqslant 0 \\ \sum_{i=1}^{m} V^2{}_i X_{ij} - \sum_{i=1}^{m} \pi^2{}_i X_{ij} + \sum_{p=1}^{q} W^1{}_p Z_{pj} + \sum_{h=1}^{g} W^2{}_p Z_{hj} - \left(\sum_{r=1}^{s} U_r Y_{rj} - \mu^B{}_k \right) \geqslant 0 \\ V^2{}_i \geqslant \pi^2{}_i > \varepsilon, \pi^1{}_i, W^1{}_p, W^2{}_p, U_r \geqslant \varepsilon, i = 1, 2, \ldots\ldots, m,\ \ j = 1, 2, \ldots\ldots, n \end{cases}$$

(4)

The innovation efficiency can be calculated by formula (3-4). For the determination of the allocation proportion of initial investment in two stages, some scholars adopt the following methods: firstly, according to the actual situation of the research object, a value range of distribution proportion is given ; secondly, on the premise of given initial value of α_i, traverse the allocation proportion in a certain step, record the allocation proportion with the optimal efficiency ; thirdly, using the way of step-by-step iteration, the iteration is finished until the last few rounds of the

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allocation proportion gap is the smallest, the final value is obtained. However, this method has some limitations: the range of allocation proportion depends on the subjective ideas of researchers. Therefore, this paper uses the method of brief solution: when $\pi^1{}_i = V^1{}_i\alpha_i, \pi^2{}_i = V^2{}_i\alpha_i$, we can use MATLAB programming to solve, obtain the value of π_i and V_i, and finally get the value of α_i. According to the formulas (5) and (6), we can calculate the stage efficiency values of R&D stage and technology transfer stage respectively.

$$E^1{}_k = \left(\max\sum_{p=1}^{q} W^1{}_p Z_{pk} - \mu^A{}_k\right) / \sum_{i=1}^{m} V^1{}_i \alpha_i X_{ik} \tag{5}$$

$$E^2{}_k = \left(\max\sum_{r=1}^{s} U_r Y_{rk} - \mu^B{}_k\right) / \left(\sum_{i=1}^{m} V^2{}_i (1-\alpha_i) X_{ik} + \sum_{p=1}^{q} W^1{}_p Z_{pj} + \sum_{h=1}^{g} W^2{}_p Z_{hk}\right) \tag{6}$$

2.2 Variable selection

After reading a number of papers, on the basis of previous studies on the efficiency evaluation of collaborative innovation of IUR and the efficiency of high-tech industry innovation, considering the availability and accessibility of data, an evaluation index system of the collaborative innovation efficiency of IUR of China's high-tech industry is constructed as shown in the Table 1.

Table 1 Evaluation index system of collaborative innovation efficiency of IUR in high-tech industry

Variables	First level index	Index number	Second level index	Implication	Measure
Input	Cooperation	X_1	Number of	The ability and level	

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indicators	ability of IUR		R&D staff of enterprise	of enterprises, R&D institutions and universities to participate in the cooperation of IUR	
		X_2	R& D expenditure of enterprise		
		X_3	Number of R&D staff in research institutions		
		X_4	Expenditure of research institutions		
		X_5	Number of R&D staff in universities		
		X_6	expenditure of universities		
	Ability to connection of IUR	X_7	Interaction between enterprises and universities (Project Cooperation)	Innovation in project cooperation between enterprises and Universities	The logarithm product of the number of R&D staff of enterprise and the number of projects of university lagging behind two periods
		X_8	Interaction between enterprises and research institutions (Project Cooperation)	Innovation in project cooperation between enterprises and research institutions	The logarithm product of the number of R&D staff of enterprise and the number of projects of research institutions behind two periods

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		X_9	Interaction between enterprises and universities (Staff Exchange)	Innovation in communication between enterprises and university staff	The logarithm product of the number of R&D staff of enterprise and the number of R&D staff of university behind two periods
		X_{10}	Interaction between enterprises and research institutions (Staff Exchange)	Innovation in communication between enterprises and R&D institutions staff	The logarithm product of the number of R&D staff of enterprise and the number of R&D staff of research institutions behind two periods
Intermediate variable		Z_1	Number of patent	The important embodiment of the active degree of technological innovation activities	Number of patent
		Z_2	Number of new product development projects	Direct results of collaborative innovation of IUR	Number of new product development projects
		Z_3	Number of R & D projects in universities	The level of innovation knowledge output of universities	
		Z_4	Number of R&D projects in research institutions	The level of innovation knowledge output of R &D institutions	
Exclusive investment		Z_5	Expenditure of new product		

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			development		
Final output	Economic performance	Y	New product sales revenue	The most fundamental driving force for high-tech enterprises to participate in collaborative innovation of IUR	New product sales revenue

3 Empirical analysis

3.1 Data sources

In this paper, the original data, which about the collaborative innovation efficiency evaluation index of high-tech industry, are collected from «China Statistical Yearbook on Science and Technology » and « China Statistics Yearbook of China's High Technology Industry ». This paper measures the collaborative innovation efficiency of the selected data from 2013 to 2016 for four consecutive periods.

There is usually a lag in the collaborative innovation activities of IUR, that is, there is a delay in the time of input and output. It is assumed that the overall lag period of collaborative innovation activities in high-tech industry is 2 years, and the R&D and transformation stage is 1 year. Therefore, the data of input index is from 2011 to 2014, 2012 to 2015 is the data of intermediate output, and the data of final output is from 2013 to 2016. It is divided into four sections, the first section (2011-2013), the second section (2012-2014), the third section (2013-2015) and the fourth section (2014-2016).

3.2 Overall analysis

According to the innovation efficiency value calculated by the data during 2014-2016 (during the fourth evaluation period), the results are shown in Table 2. As a whole, the innovation efficiency of China's high-tech industry is relatively high, with an average of 0.81. Among the five industries of high-tech industry, industris

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with the highest value of efficiency are Electronic Computer and Office Equipment Manufacturing Industry (ECOEI) and Electronic and Communication Equipment Manufacturing Industry (ECEI), followed by Aerospace Manufacturing Industry (AAMI), Pharmaceutical Manufacturing Industry (MPPI), and the industry with the lowest value of efficiency is Medical Equipment and Instrument Manufacturing Industry (MTIMI). Compared with the average value of collaborative innovation efficiency of high-tech industry, the innovation efficiency of Electronic Computer and Office Equipment Manufacturing Industry (ECOEI), and Electronic and Communication Equipment Manufacturing Industry(ECEI), is higher than the average level of high-tech industry, while that of Aerospace Manufacturing Industry (AAMI), Pharmaceutical Manufacturing Industry (MPPI),and Medical Equipment and Instrument Manufacturing Industry (MTIMI) is slightly lower than that of high-tech industry level.

For fifteen segment industries of high-tech industry, there are four segment industries below the average value of innovation efficiency, accounting for 33% of the total number of sub industries. Among them, the eight segment industries with the highest efficiency value are Chemical Manufacturing, Chinese Patent Medicine Manufacturing,Spacecraft Manufacturing, Communication Equipment Manufacturing, etc. The value of innovation efficiency is 1, which DEA is effective; the Instrument Manufacturing Industry with the lowest efficiency value is 0.71.

Table 2 Efficiency values of collaborative innovation in the fourth evaluation period

DMU	E
MPPI	0.69
Chemical Manufacturing	1
Chinese Patent Medicine Manufacturing	1
Biological and Biochemical Products Manufacturing	0.93
AAMI	0.70
Aircraft Manufacturing and Repair	0.74
Spacecraft Manufacturing	1
ECEI	1

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Communication Equipment Manufacturing	1
Radar and Supporting Equipment Manufacturing	1
Electronic Device Manufacturing	0.75
Electronic Component Manufacturing	0.75
Home Audio-visual Equipment Manufacturing	0.89
ECOEI	1
Electronic Computer Complete Manufacturing	1
External Equipment of Electronic Computer Manufacturing	1
Office Equipment Manufacturing	1
MTIMI	0.67
Medical Equipment and Devices Manufacturing	0.97
Instrument Manufacturing	0.70
Average	0.81
Min	0.70
Max	1

ECOEI and ECEI are mainly improved innovation, which requires low degree of innovation, and most of them are imitative. Therefore, the R&D cycle is short, the product market update iteration is fast, so the value of innovation efficiency is high. However, MPPI, AAMI and MTIMI technology content are relatively high, which require high degree of product innovation. Most of them are brand-new product innovation. Therefore, the R&D cycle is long, and the market update iteration speed is slow, so the efficiency of collaborative innovation is relatively low.

3.3 Two-stage analysis

The values of efficiency of R&D stage and technology transfer stage are calculated using the DEA model with shared inputs are shown in the table below (see Table 3).

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Table 3 Efficiency value of R&D stage and technology transfer stage in the fourth evaluation period

DMU	R&D Efficiency （E_1）	Technology Transfer Efficiency （E_2）
MPPI	0.71	0.70
Chemical Manufacturing	1	1
Chinese Patent Medicine Manufacturing	1	1
Biological and Biochemical Products Manufacturing	0.87	0.93
AAMI	0.32	0.78
Aircraft Manufacturing and Repair	0.74	0.78
Spacecraft Manufacturing	1	1
ECEI	1	1
Communication Equipment Manufacturing	1	1
Radar and Supporting Equipment Manufacturing	1	1
Electronic Device Manufacturing	0.77	0.77
Electronic Component Manufacturing	0.73	0.76
Home Audio-visual Equipment Manufacturing	0.72	0.90
ECOEI	1	1
Electronic Computer Complete Manufacturing	1	1

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External Equipment of Electronic Computer Manufacturing	1	1
Office Equipment Manufacturing	1	1
MTIMI	0.87	0.67
Medical Equipment and Devices Manufacturing	0.51	0.97
Instrument Manufacturing	0.89	0.69
Average	0.78	0.83
Max	1	1
Min	0.51	0.69
Standard Deviation	0.25	0.14

From table 3, the order of five industries in China's high-tech industry is: ECEI, ECOEI, MTIMI, MPPI, AAMI, sorted by the values of R&D efficiency from big to small. The values of R&D efficiency respectively are: 1, 1, 0.87, 0.71, 0.33.The order sorted by the values of efficiency of technology transfer stage is: ECEI, ECOEI, AAMI, MPPI, MTIMI. The values of efficiency are 1, 1, 0.7, 0.70, 0.67 respectively. From table 3, the order of the innovation efficiency of five industries in high-tech industry is: ECEI, ECOEI, AAMI, MPPI, MTIMI, and the value of efficiency s are 1, 1, 0.70, 0.69 and 0.67 respectively.

From table 3, it can be seen that in the five industries of China's high-tech industry, the efficiency performance of collaborative innovation activities of IUR in different stages is not obvious as a whole, except that the efficiency of R&D in AAMI is significantly lower than that of technology transfer, and the efficiency of R&D in other industries is higher than that of technology transfer.

In terms of fifteen segment industries of high-tech industry, the average efficiency of the R&D stage of collaborative innovation of IUR of high-tech industry in China is 0.78, there are five segment industries that the values are lower than the average efficiency, accounting for 41% of the total number of segment industries. With the same value of innovation efficiency, ECEI and ECOEI are

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relatively effective in R&D stage and the efficiency values are all 1. However, the value of efficiency of MTIMI in the R&D stage is low, only 0.51.

The average value of efficiency of technology transfer stage is 0.83, and there are four segment industries below the average efficiency value, accounting for 33% of the total number of segment industries, indicating that relatively few industries have serious problems in technology transfer stage. The same as the values of innovation efficiency and R&D efficiency, ECOEI and ECEI are also DEA effective in the technology transfer stage, with the value of efficiency of 1. However, the value of efficiency of MTIMI and its segment industries' Instrument Mmanufacturing in the technology transfer stage is less than 0.7. Compared with other industries, R&D activities fail to bring due economic output.

To sum up, it can be seen that in the fifteen segment industries of high-tech industry in China, when DEA is effective as a whole, the DEA of two stages are also effective respectively. In addition, the average values of innovation efficiency in two stages of high-tech industry are 0.78 and 0.83 respectively, which indicates that there are some defects in the R&D stage of high-tech industry in China as a whole, and the low efficiency of R&D in AAMI is the main reason for the low efficiency average value.

4 Conclusion

In order to further explore the performance of collaborative innovation of IUR activities in different stages of high-tech industries, this paper takes the average efficiency of the R&D and technology transfer as the boundary, and divides the high-tech industries into four categories by comparing the R&D efficiency and the technology transfer efficiency of each industry, as shown in Figure 3, Industries, that the value of R&D efficiency is between 0.78 and 1, are high R&D efficiency industries; that the value of R&D efficiency is between 0 and 0.78 ,are low R&D efficiency industries; that the value of technology transfer efficiency is between 0.83 and 1, are high transformation efficiency industries; that the value of technology transfer efficiency is between 0 and 0.83, are low transformation efficiency. The classification of high-tech industries is shown in Table 4.

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Table 4 High-tech industry classification

Categories	Industries
Low R&D efficiency, high transformation efficiency	Home Audio-visual Equipment Manufacturing of ECEI; Medical Equipment and Devices Manufacturing of MTIMI
Low R&D efficiency, low transformation efficiency	Aircraft Manufacturing and Repair of AAMI; Electronic Device Manufacturing, Electronic Component Manufacturing of ECEI
High R&D efficiency, low transformation efficiency	Instrument Manufacturing of MTIMI
High R&D efficiency, high transformation efficiency	Chemical Manufacturing, Chinese Patent Medicine Manufacturing, Biological and Biochemical Products Manufacturing of MPPI Spacecraft Manufacturing of AAMI; Communication Equipment Manufacturing, Radar and Supporting Equipment Manufacturing of ECEI; Electronic Computer Complete Manufacturing, External Equipment of Electronic Computer Manufacturing, Office Equipment Manufacturing of ECOEI

From table 4，it can be seen that most industries of China's high-tech industry with collaborative innovation of IUR activities are focused on high R&D efficiency and high transformation efficiency, but more attention should be focused on other three industries, making full use of collaborative innovation of IUR to improve R&D efficiency and transformation efficiency.

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(1) Low R&D efficiency and high transformation efficiency industries. It includes Home Audio-visual Equipment Manufacturing, Medical Equipment and Devices Manufacturing. This type of industry should improve the efficiency of R&D mainly by improving the strength of R&D, and specifically should increase the introduction, imitation, digestion and innovation of advanced technology, and promote collaborative innovation of IUR.

(2) Low R&D efficiency and low transformation efficiency industries. For example, Aircraft Manufacturing and Repair of AAMI. These industries have invested a lot of resources in the early stage, including three parties' personnel and funds, but they do not pay attention to efficiency. At the same time, in the technology transfer stage, the quality of investment is poor, the market value of research achievements and the collaborative innovation activities of IUR are not paid enough attention to. Therefore, it is urgent to improve the efficiency of the use of innovative resources.

(3) High R&D efficiency and low transformation efficiency industries. For example, Instrument Manufacturing of MTIMI. At present, for MTIMI, developed countries hold high-end technologies, while China mostly adopts the idea and method of technology introduction and innovation digestion. In the R&D stage, the industries are mainly based on practical patents, with few independent innovation of high-end technologies, and thus there are more patent applications and higher value of R&D efficiency. For this type of industry, we should further improve the efficiency of achievement transformation and strengthen the research and development of high-end and core technologies.

(4) High R&D efficiency and high transformation efficiency industries. For example, Electronic Computer Complete Manufacturing, External Equipment of Electronic Computer Manufacturing and so on. These industries are the "traditional" high-tech industries that have been developed earlier in China, and they have good R&D basis and market application prospects. For this type of industry, we should further accelerate the change of innovation strategy and pay attention to quality while improving efficiency.

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