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The Technological Input-output Efficiency of High-technology Enterprises in China Based on the DEA method

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Abstract. High-technology enterprises play the leader role in the regional economic progress, but nowadays technological resources have many problems such as division, separation and dispersing. It's an urgent problem to be solved that how to evaluate input-output productivity of technological resources towards industries and regions scientifically and efficiently. Firstly the article analyzes the input-output efficiency status of technological resources at home and abroad. Then high-technology enterprises in 29 provinces, as the subject of evaluation, are analyzed for their operation efficiency by DEA. The article states the suggestions like balanced development among regions and reasonable structure of input and output by comparing the differences among regions. And the article estimates the technological resources configuration efficiency of 5 leader industries and explains the developmental characteristics and direction among industries. And on these bases the article conducts hypothesis testing for inner elements which might have an influence on the operational efficiency by Tobit model. Finally, the paper proposes many suggestions to the benefits of promoting the productivity of high-technology enterprise according to the comprehensive analysis.

1 Introduction

In modern society, the science and technology plays an increasing role, and its "primary productive forces" status has attracted the attention of all countries. At the same time, the leading role of science and technology to the business, region and even country has been deeply understood by policy makers and resource managers. The effect of leading role is amplified to several times or even hundreds of times through market economy, so increasing investment in science and technology resources has gradually become the main policy of many countries. Meanwhile, science and technology resources has risen to a strategic level [1-3].

Although in recent years there is great progress on science and technology output achievements in China, the scientific and technological achievement of Chinese high-tech enterprises still has much room for improvement compared with the United States and other developed countries. For example, there is imitation and learning stages in the field of aerospace, aircraft technology and Internet applications. The existence of this phenomenon can not only be attributed to the status of national economy development and current nation policy. But the enterprises should also reflect on themselves.

To improve science and technology output with the recent limited resources, it is necessary to analyze input-output efficiency of science and technology, which can help to find the key factors affecting the efficiency. Only in that way, the targeted rationalization proposals can be obtained. Considering that technology investment itself is on a macro level, and there have been many scholars analyzed the macro technology input-output before [4-5]. In highly developed market economy, enterprises have become the main body of carrying technology. High-tech enterprises often have the core intellectual property, along with research and experimental team, and are able to grasp the direction of economic and technology development, which makes them take the lead in the enterprises.

In order to conducting systematic research and analysis, this paper elects the appropriate data from "China Statistical Yearbook on High Technology Industry" and "China Statistical Yearbook of Science and Technology". With selecting a number of important affecting factors of input and output, the same period high-tech companies' operating efficiency in Chinese different regions and different sectors are calculated and analyzed by DEA method, and the high-tech industry input-output efficiency level of various regions are compared and analyzed. Through using the DEA method, the efficiency values can be analyzed by selecting a number of possible factors affecting technology efficiency. To obtain a more objective and comprehensive analysis of the factors impacting the science and technology input-output efficiency, Tobit regression model method has been used to analyze the efficiency values. From the view of government and high-tech enterprises, the paper puts forward some reasonable opinions and suggestions with the results of research and comparison of the different results.

2 Research status of input-output efficiency of science and technology resources

Previous scholars have conducted a series of studies of science and technology resources allocation efficiency with qualitative research and achieved fruitful results. OECD believed that it is necessary to integrate the various input factors and regard them as an organic whole to improve the regional input-output efficiency [6]. Maria applied participating evaluation method to the regional input-output efficiency evaluation, and put the results of evaluation into practice [7]. Through researching and analyzing, Song Yu found that the inefficient and ineffective phenomenon exited in the technology market, which would result in incomplete market environment. Instead of like Adam Smith's theory in which the social resources allocation are adjusted by the market, enterprises and government forces should develop rationalized policies to promote rational distribution and allocation of resources [8]. Ye Rufei and others used the method of institutional economics. They thought information asymmetry which caused the low efficiency of science and they provided the method of improving the efficiency at the same time [9-11]. Wei Shuyan analyzed the experience of foreign countries, and provided that resources sharing strategy should be raised to the strategic perspective in our country and be formulated with corresponding regulations and policies so that the resources sharing could work smoothly [12]. Some scholars also provided suggestion for science and technology resources sharing policy. Through establishing the methods of analysis model and field research, they proposed that in order to improve the overall science and technology resources sharing, it was necessary to increase the sharing of resources flow in a region and improve the usefulness of the market [13-16]. Ge Huili studied varieties of regions and industries, and pointed out the role of government in science and technology resource input-output efficiency. She thought that situation of China was in a weakened economy and market environment and there are many problems in current scientific research system, resources must be controlled by the government. It was possible to improve the control of resources by supervision and evaluation and then improve the efficiency of science and technology input and output [17].

With many advanced analysis methods, scholars around the world also have studied the quantitative research of science and technology resources allocation efficiency for a long time. From the aspect of optimization methods, Li and other groups constructed optimization model through studying the open system of analysis and establishing a function indicators with the numbers of researchers and funds of science and technology in different regions [18]. Li Jianhua and others considered that in the optimization method, only when human and financial resources were in effective restraint state, it could achieve the most matching optimization status [14,15]. With the regression analysis methods, Li Shizhu and others did the quantitative analysis to the various elements and summarized the factors affecting the results of science and technology resources allocation efficiency [19]. In terms of principal component analysis, Li Dongmei showed that the constituent elements of science and technology resources would have an impact on technology efficiency by using the principal component analysis to different regions of China, but the effect of other factors were reflected on the human and financial elements. Thus, it was possible to analyze the main elements of human and financial resources, and grasp the overall aspects [20,21]. As well as the data envelopment analysis (following referred to "DEA") method, there were many articles based on the domestic research for the DEA method itself. Because of that, it was able to have a deep understanding of this method and have more reasonable application by using this method [22]. Wu Hecheng measured the different regions' input-output efficiency by DEA method [16]. Science and technology capabilities of different regions were evaluated and analyzed by Sun Baofeng and others by using DEA method[23]. The science and technology efficiency of China in all regions in recent years were analyzed and evaluated by He Defang and others, and they proposed that it was supposed to increase the size of the efficiency [24]. In regional analysis, Niu Shuhai analyzed the connection with technology resource development regional differences and economic growth by region analysis, which did the basic work for reducing regional disparities [25]. Kerssens van Drogelen's(1999) R&D performance measurement system was mainly: contingency factors influencing R&D performance, measurement methods and techniques, metrics, time frequency, matching method and selection principles [26]. From an empirical point of view, Jooh Lee &Eunsup Shim studied the high-tech industry innovation and efficiency in the United States and Japan, and researched the relationship among investment in technology, market share and corporate long-term performance [27]. Romijn [28] and Neel-ankavil [29] studied the high-tech industry innovation efficiency using multiple regression method and Granger causality method.

Overall, existing researches mainly have following disadvantages: firstly, foreign scholars' research of science and technology input-output efficiency aimed at developed countries, while those empirical results of the study did not necessarily meet the circumstance in China; secondly, the study of the existing literatures on the science and technology input-output efficiency mainly focused on the regional and industry, which basically belong to the meso or macro level, but few scholars studied science and technology input-output efficiency from the microscopic perspective. Thus, they ignored the innovation subjects--enterprises' output efficiency of science and technology investment; thirdly, a part of studies of enterprises science and technology input-output efficiency mainly focused on the aspects such as influencing factors and evaluation system construction etc., but few scholars used quantitative methods to evaluate the input and output efficiency for the business from the empirical point of view. Most researches of enterprises technology input-output efficiency were superficial and did not analyze the basic factors which fundamentally affected science and technology input-output efficiency.

Therefore, by studying the high-tech enterprises in China with DEA method, this paper comprehensively evaluates and analyzes input-output efficiency. This paper broadens the ideas of science and technology input-output efficiency of domestic research and enriches the existing research, which has strong innovation value and theoretical significance. At the same time, the study identifies the deep reasons why high-tech enterprises technology input-output efficiency in China is low, which is an exploratory analysis and has strong practical significance.

3 Evaluation model of input-output efficiency of science and technology investment in Chinese enterprises

3.1 Selecting evaluation index

According to the general principles of system design and the relative effectiveness based on DEA, in order to make sure that input and output indicators are real effective, there are some principles that should be followed when selecting indexes: scientific principle, feasible principle, independent principle, simplified principle, comparable principle and goal-oriented principle. The design for input and output indicators should have the same input-output status of enterprises technology investment and be consistent with the scientific meaning of the respective areas. In addition, when the indexes include the whole information, the indicators should be relatively simplified. The comparable indicator is an important prerequisite to compare and evaluate multiple decision units. According to Index selecting principles and characteristics of DEA, human and financial resources input-output status can be integrated as the appropriate indicators. While there are many factors impacting the enterprises technology input and output, the actual operation should not consider too many factors to avoid lots of DMU's value becoming 1. Dividing the indexes which can replace or complement others into the same type makes sure that there is no correlation between indexes.

Based on feasibility and ease of the operation principle, there are two main selection of science and technology input indicators, including science and technology human and financial resources elements. First, science and technology human resources is the element with the strongest initiative and variability; Second, science and technology financial resources element is the basis and premise for scientific and technological activities. Related indicators reflecting the R&D activities are added to the technology of human and financial resources in the article, which also reflects principles of representation and principles of diversity in index system design.

High-tech enterprises are knowledge production-oriented enterprises, and the patent as a direct manifestation of knowledge is to be included in the output indicators; New product is also coagulation of technology and knowledge, which can be used as indicators to measure the output of science and technology resources; Finally, to evaluate disposition of technology resources from the view of overall development of high-tech business, it is necessary to have a total index so the added value of enterprises can display the effect of technology resources investment properly.

Referring index selected principles, Chinese basic national conditions and the availability and timeliness of the data, the index system is initially identified as follows:

Science and technology input indicators are: R&D Equivalent to full-time equivalent staff(X1), New Product Development Expenditure(X2), R&D personnel amount(X3) and R&D expenditure(X4).

Science and technology output indicators are: Sales of new products(Y1) and the amount of valid invention patents(Y2).

Each indicator can be briefly represented in the following table:

Table 1. Science and technology input-output indexes.

input indicators	output indicators
R&D Equivalent to full-time equivalent staff	Sales of new products
New Product Development Expenditure	valid invention patents
R&D personnel amount	
R&D expenditure	

Each indicator is explained as below:

R&D equivalent to full-time equivalent staff is the summary of R&D full-time staff and part-time staff work according to the actual working hours.

New product development expenditure is the funding of new product research.

R&D personnel amount refers to the total number of R&D institutions in enterprises.

R&D expenditure means the cost of internal R&D activities of enterprises in reporting period.

Sales of new products is new products' sales revenue in the prime operating business income and in other operating income.

The amount of valid invention patents refers to the number of patents which one enterprise has in an investigation period.

3.2 Selecting sata

The data of R&D in equivalent full-time equivalent personnel, new product development expenditure, R&D personnel amount, R&D expenditure, sales of new products and the effective number of patent in this study are from the "China Statistical Yearbook on High Technology Industry 2013", "international Statistical Yearbook 2013" and the "China Science and Technology statistical Yearbook 2005-2013".

High-tech enterprises input and output data in 29 provinces of mainland China from 2000 to 2012 are selected as a sample in this paper. Based on the general requirements of using DEA model to measure efficiency, there are 29 samples selected, which are more than twice as the number of input and output data which meet the model requirements. At the same time the industry's DMUs are also evaluated to obtain comprehensive efficiency evaluation.

3.3 Research methods

Efficiency evaluation method used in this paper is DEA method. The basic idea of DEA method is to define different kinds of objects as one decision-making unit(referred to as the "DMU"). For each DMU, selecting the same input and output indicators and creating the appropriate models can help to calculate and analyze these input and output indicators. Calculating the relative indicators for each DMU and adjusting parameters can make sure the maximum efficiency is 1, which means that efficiency value is fully effective while other DMUs not being 1 means that they are not completely effective. This method analyzes the causes and gaps and provide decision-making information for researchers [22,30]. This method can achieve accurate calculation of the multiple decision units of a plurality of input and output indexes, and the result is compared with efficiency values, which is more objective and accurate without the interference of external human factors.

4 Example for science and technology input-output efficiency evaluation

4.1 Case study

According to the raw data of the medium-sized high-tech enterprises investment production in 29 provinces from 2000 to 2012, it is possible to obtain the technology efficiency of the provinces and the industry as well as pure technology efficiency and scale efficiency by using software DEAP 2.1 and BCC model. 2012 concrete results are shown in Table 2.

From Table 2 and Table 3, there are only 4 regions having the whole science and technology input-output efficiency in 2012 high-tech enterprises. That is to say, only 13.8% region's input and output efficiency are both scale effective and technology effective. And 86.2% of the area which needs to improve science and technology inputs and outputs are non-relatively effective. What's more, the enterprises in China have been increasing science and technology investment in general. They just don't make full use of those investment to get the maximum output.

Table 2. High-tech enterprises input-output efficiency in 2012.

DMU	TE	PTE	SE	RTS
Beijing	1.000	1.000	1.000	-
Tianjin	1.000	1.000	1.000	-
Hebei	0.629	0.653	0.962	drs
Shanxi	0.523	0.649	0.805	drs
Inner Mongolia	0.645	0.985	0.655	irs
Liaoning	0.427	0.442	0.966	drs
Jilin	0.772	0.815	0.948	drs
Heilongjiang	0.412	0.713	0.578	drs
Shanghai	0.514	0.560	0.918	drs
Jiangsu	0.647	1.000	0.647	drs
zhejiang	0.610	0.610	1.000	-
Anhui	0.514	0.536	0.960	drs

Fujian	0.634	0.843	0.752	drs
Jiangxi	0.540	0.543	0.994	irs
Shandong	0.470	0.723	0.650	drs
Henan	0.396	0.401	0.988	drs
Hubei	0.511	0.591	0.864	drs
Hunan	0.773	1.000	0.773	drs
Guangdong	1.000	1.000	1.000	-
Guangxi	0.615	0.622	0.988	irs
Hainan	0.320	0.332	0.964	drs
Chongqing	0.685	0.696	0.984	drs
Sichuan	0.475	0.483	0.983	drs
Guizhou	0.682	1.000	0.682	drs
Yunnan	0.876	0.900	0.973	irs
shanxi	0.384	0.611	0.629	drs
Gansu	0.349	0.355	0.982	irs
Ningxia	0.365	0.459	0.795	irs
Xinjiang	1.000	1.000	1.000	-

Table 3. 2012 high technology businesses input-output efficiency in various areas.

DMU	TE		PTE		SE	
	amount	proportion	amount	proportion	amount	proportion
effective	4	13.8%	7	24.1%	5	17.2%
Non-effective	25	86.2%	22	75.9%	24	82.8%
	CRS	5	IRS	6	DRS	18

From the statistic results, the level of efficiency value has not been necessarily connected with the location in Chinese eastern, central or western area. For example, cities in eastern China such as Beijing, Tianjin and others have fully effective input-output efficiency, while in the other cities in the east such as Anhui and Shandong, the technology efficiency are 0.514 and 0.470. Central and western regions in China also have the similar phenomenon. Not as the same as common understanding, when technology investment income and high-tech enterprises income are overall lower than other areas, its technology efficiency would be relatively higher, such as high-tech enterprises in Xinjiang in 2012. The science and technology input-output efficiency value is 1 in Xinjiang's enterprises, which is perfectly valid. Also in the west area like Yunnan in 2012, the high-tech enterprise technology input and output of TE, PTE and SE are 0.876, 0.900 and 0.973, which are relatively at a high level. Science and technology input-output efficiency is a comprehensive evaluation index, which refers not only the amount of the science and technology output, but also considers the ratio of input and output. So there are many factors which can influence the indicator like science and technology input, R&D staff full-time equivalents in an area and new product R&D expenditures, and it is also related to the local scientific research departments, business administration, even the tax administration's comprehensive management level. Only when the investment of technology, scale of local enterprises, employees and relative policies can be matched legitimately, the science and technology input and output efficiency in the area can reach to a higher level.

From the view of returns to scale, few areas are at constant returns to scale. From Table 4, the number of regions around 2010, which were at constant returns to scale, are relatively more than other years. The reason why DEA is so invalid is that uncoordinated inputs and outputs are at the current scale situation, which means that the input is inadequate or excessive at the same output level. Therefore, 24 regions should adjust their input or output to improve the efficiency of inputs and outputs in 2005.

Table 4. 2000--2011 region input-output efficiency statistics of high-tech enterprises.

Year	DMU	TE		PTE		SE		Scale changes		
		amount	proportion	amount	proportion	amount	proportion			
2011	Effective	6	20.7%	8	27.6%	5	17.2%	CRS	IRS	DRS
	Non-effective	23	79.3%	21	72.4%	24	82.8%	6	4	19
2010	Effective	7	24.1%	11	37.9%	7	24.1%	CRS	IRS	DRS
	Non-effective	22	75.9%	18	62.1%	22	75.9%	7	6	16
2009	Effective	6	20.7%	11	37.9%	7	24.1%	CRS	IRS	DRS
	Non-effective	23	79.3%	18	62.1%	22	75.9%	7	6	16
2008	Effective	3	10.3%	8	27.6%	3	10.3%	CRS	IRS	DRS
	Non-effective	26	89.7%	21	72.4%	26	89.7%	4	11	15
2005	Effective	3	10.3%	8	27.6%	3	10.3%	CRS	IRS	DRS
	Non-effective	26	89.7%	21	72.4%	26	89.7%	3	1	24
2000	Effective	4	13.8%	12	41.4%	4	13.8%	CRS	IRS	DRS
	Non-effective	25	86.2%	17	58.6%	25	86.2%	4	4	21

Table 5. High-tech and medium-sized enterprise in high-tech industry technology input-output evaluation index.

Input index	Output index
R&D Equivalent to full-time equivalent staff	New product sale revenues
R&D internal expenses	

Table 6. High-tech and medium-sized enterprises in high-tech industries input-output efficiency in 2012.

DMU	TE	PTE	SE	RTS
Pharmaceutical	0.81	0.827	0.979	drs
Aerospace vehicles and equipment	0.313	0.353	0.887	irs
Electronics and communications equipment	1.000	1.000	1.000	-
Computer and office equipment	1.000	1.000	1.000	-
Medical equipment and instruments	0.728	1.000	0.728	irs

Science and technology input-output efficiency trend during these seven years shows that technology input and output efficiency in Beijing always stayed in 1 during this period. It indicates that the input-output efficiency in recent years has been effective. As for Tianjin, technology efficiency has been always fully effective except in 2008. The region which Technology efficiency was less than or equal to 0.6 has been further analyzed, and the amount was 16, 21, 22, 14, 14, 18 and 14. In the period, there has been a large proportion of all the regions which technology efficiency value was less than or equal to 0.6, which indicates that the relative efficiency was low in mang areas. Therefore, these areas where efficient value is relatively low can improve the efficiency of input and output in the region through organizational learning, studying from Beijing and Tianjin, adjusting the allocation of resources, developing suitable policies and encouraging personnel training.

From the above data processing and analysis, the conclusions can be drawn as follows: (1) the output efficiency in technology investment of the high-tech enterprises in China is low; (2) From the perspective of returns to scale, a large part of the region are in increasing or decreasing phase to the return of scale, and they can achieve efficient scale through increasing investment and efficiency and adjusting the direction and amount of output; (3)Chinese medium-sized high-tech enterprises science and technology input and output efficiency values are distributed in the lower range, and the efficiency has not been improved significantly in the seven-year study period.

In order to have more understanding of input and output efficiency in Chinese medium-sized high-tech enterprises, the paper has further analyzed and researched different industries.

Select the following five industries as analysis units: 1.Pharmaceutical Manufacturing; 2. Aerospace vehicles and equipment manufacturing; 3.Electronics and communications equipment manufacturing; 4.Computer and office equipment manufacturing; 5.Medical equipment and instruments. To make the efficiency analysis more intuitive and more representative, R&D Equivalent to full-time equivalent staff(X1) and R&D internal expenses(X2) are selected as input indicators, while new product sales(Y) is selected as output indicator.

Calculating the medium-sized high-tech enterprises input-output data in five high-tech industries in 2012 according to the selected samples by using DEAP2.1 software, CCR and BCC models, it is easy to get technology efficiency in various industries(TE), pure technology efficiency(PTE) and scale efficiency(SE). 2012 concrete results are shown in Table 6.

From Table 6, enterprises technology input and output are overall effective in five high-tech industries elected in 2012, namely the two of indexes (TE, PTE and SE) were both 1, accounted 40% for selected DMUs. Three industries' pure technology efficiency were 1, accounted for 60%. Although the amount of elected DMUs was few, from the results of the analysis, overall science and technology input and output indicators of the high-tech industry were relatively balanced, and they were all at a high level. There was only one industry which the overall efficiency was less than 0.6, accounted for 20% of all the DMUs. According to its own characteristics of the DEA method, it can be considered that science and technology efficiency of the high-tech industry is more average in China.

In these five industries, only the efficiency values of aviation, the spacecraft and the equipment manufacturing industry are low, and the overall efficiency value has been only 0.313. From further analysis, the electronics and communications equipment manufacturing, the medical manufacturing, the computer and office equipment manufacturing, the medical equipment and the instruments which have the high values of efficiency are in a high degree of market. Close connection with the market will lead management system and the system to be market-oriented. The role of market in resource allocation is very obvious, especially with efficiency value calculated by the sales of new product being higher. The aerospace industry is mostly state-owned enterprises. With rigid institutions, not being sensitive for market and even the existence of political tasks, there are some reasons that make low efficiency in the industry. Through the field research, many phenomena and factors are consistent with analysis. For example, by investigating some certain aerospace institutes, we find that large equipment's utilization is low, which is because they don't have access to use the equipment. But because of the funding management system, these enterprises have to buy some large equipment. In response to this phenomenon, high-tech enterprises of the aerospace industry are proposed to meet the market integration as soon as possible and make full use of the advantages to break the traditional system limitation, and then they finally form a Chinese characteristics route of high efficiency. Government also should introduce policies from the macro management level to promote traditional state-owned enterprises breaking the rigid system and to meet the market integration as soon as possible. At the same time, it is important to use advanced technology to improve the industry technology input-output efficiency.

In addition, the aviation and spacecraft and equipment manufacturing and pharmaceutical manufacturing also expose input and resources wasted phenomena by analysis of DEA method. On the one hand, those industries should reduce unnecessary investment; on the other hand, what is more important is to adjust the industrial scale, optimize the industrial results and improve resource control system. Only in this way, they can increase the technology input-output efficiency, expand the status and role of the industry in the entire field, and finally achieve promoting the development of the social economy with high technology.

4.2 Analysis outside influence of input-output

After calculating the regional high-tech enterprises technology input and output efficiency in 2000, 2005, 2008-2012 by DEA method, and using Tobit regression model, we identify outside efficiency affecting factors except the efficiency of input items and output items to provide more scientific and rational policy recommendations which can improve the science and technology input and output efficiency.

In order to understand the efficiency affected factors and degree of these factors, there are two-stage method derived from DEA. This method firstly analyzes the efficiency values of DMU by DEA, and then the method uses regression analysis with taking the efficiency values as the dependent variable and selecting possible factors as independent variables.

Standard Tobit model is as follows:

$$y^* = \beta x_i + \varepsilon$$
$$y_i = y^*(if\ \ y^* > 0)$$
$$y_i = 0(if\ \ y^* \le 0)$$

Here ε~N(0, σ2); β is the regression parameter vector; x_i is explanatory variable vector; y^* is the potential for variable vector; y_i is the observed dependent variable. When $y^* > 0$, observed dependent variable y is equal to y^*, but when $y^* < 0$, y is equal to 0.

Tobit model can analyze more deep-seated reasons related to the efficiency values. This article selects regions business prime operating revenues(a hundred million yuan, F1), high-tech enterprise taxes(a hundred million yuan, F2), delivery value of export(a hundred million yuan, F3), technical reform costs(a hundred million yuan, F4) and new fixed assets(ten thousand yuan, F5) as the environmental variables of science and technology input-output efficiency, and the paper makes the assumption that eastern region technology input-output efficiency is higher than in the west.

The Tobit model is built as follows:

$TE_i = \beta 1F_{1i} + \beta 2F_{2i} + \beta 3F_{3i} + \beta 4F_{4i} + \beta 5F_{5i} + \beta 6 Region + \varepsilon$ The dependent variable TE is a enterprises technology input-output efficiency value calculated by DEA; *Region* means the location that every region belongs to (eastern=1, western=0); ε is the error term in regression model; $\beta 1$-$\beta 6$ are the regression coefficients of independent variables; i means region(i=1,2,…,29).

This article selects the indexes of factors impacting the high-tech enterprises technology investment value output efficiency of 2012 as sample data in regression analysis, which descriptive statistics are shown in Table 7 by using Eviews 6.0.

Table 7. Tobit results of Influencing Factors of high- tech enterprises science and technology input-output efficiency in 2012.

	Coefficient	Std. Error	z-Statistic	Prob.
enterprise prime operating revenue (F1)	8.05E-05	4.89E-05	1.647877	0.0994
enterprise taxes (F2)	-0.000613	0.000576	-1.063875	0.2874
delivery value of export (F3)	-7.25E-05	5.96E-05	-1.21606	0.224
Technical reform cost(F4)	-8.70E-07	3.30E-07	-2.633749	0.0084
new fixed assets (F5)	-6.42E-05	0.000191	-0.336845	0.7362
C	0.565513	0.025377	22.28407	0

The regression results show that: enterprise prime operating revenue and high-tech enterprises technology input-output efficiency has the significantly positive correlation; technology reform costs and high-tech enterprises technology input-output efficiency has the significantly negative correlation; corporate taxes, delivery value of export and high-tech enterprises science and technology input-output efficiency have shown no presence of significantly negative correlation, while new fixed assets has no significant correlation with high-tech enterprises science and technology input-output efficiency.

The significantly positive correlation between high-tech enterprises science and technology input-output efficiency and enterprise prime operating revenue indicates that the high-tech enterprises science and technology input-output efficiency, the whole region economies of scale and the economic trend have a relatively close relationship. When the overall economic situation is good, input-output efficiency value is relatively high, whereas when the overall economic situation is weak, the input-output efficiency value is lower than when economic situation being good. It can be also analyzed if the local government policies on economic management is reasonable and effective from the view of enterprise prime operating revenue. These policies affect the input-output efficiency of high-tech enterprises in the same way. The amount of technology market trade contracts and regional GDP show a positive correlation with high-tech enterprises science and technology input-output efficiency.

The technical reform costs and high-tech enterprise science and technology input-output efficiency have a negative correlation. In the tradition, it is common that the reform is bound to the increase of output value. But the analysis has indicated that the cost of investment in technical reform is redundancy. In a nationwide analysis, the reason for such a result is that the region high-tech enterprises fund is wasted and idled. However, from the analysis above, it has shown that high-tech enterprises in technical reform fund still have room for improvement, where the conversion of investment in research funding and technical reform fund have existed inefficiency. Because of the phenomenon, the use of research fund must be strictly controlled by local governments to make sure that the fund is fully used and used in the right way.

Meanwhile, high-tech enterprises should also control the inside use of the research fund. Only in that way, it is able to ensure the input-output efficiency and maintain the competitiveness of enterprises.

Delivery value of export has non-significantly negative correlation with input-output efficiency, which indicates that the number of exported goods transaction does not play a significantly positive role in boosting the overall business conditions of enterprises. High-technology is the core competence of high-tech enterprises. The high-technology has higher requirement on the core intellectual property rights. The analysis results describe that most parts of China should not only just focus on the delivery value of export, but also should build their own technology and industry to boost economic growth.

In addition, enterprises taxes and the location of the high-tech enterprises have a negative correlation with science and technology input-output efficiency, which indicates that Chinese tax policy could seriously affect the high-tech enterprises technology input-output efficiency. The negative relationship also shows that the force of imposing taxes of high technology enterprises has greatly affected the input-output efficiency of enterprises. With the economic development, the state can provide more preferential tax policies for high-tech enterprises. Location of enterprises and the input-output efficiency have the negative correlation, which can be explained as the results of the analysis described above. With the Chinese economic development and the continuous increase of science and technology resources investment, the eastern region has been changed from the status of lack funds to ample funds status. But the idle and waste of funds will take place with the change. In this situation, putting too much fund in the east has no benefit to improve the efficiency. However, the investment of resources in the western region is still short, and there are still some western regions which actually have certain technology development capacity, such as Xinjiang province whose efficiency value is 1.

Overall, government should focus on building a whole region economic policy, strictly controlling the use of research funding in high-tech enterprises, increasing investment to where needed and avoiding waste and idle. Meanwhile, it is necessary to improve the level of corporate governance to make all Chinese high-tech enterprises holding science and technology input-output efficiency in a high level.

5 Summary

5.1 Studying results

In this paper, in order to analyze Chinese high-tech enterprises, we select high-tech enterprises of 29 regions in 2000, 2005, 2008-2012 as samples, using descriptive statistical analysis, DEA method and Tobit regression analysis to analyze and evaluate the current situation of science and technology input-output in China. We research enterprises science and technology input-output efficiency in the targeted area and industry. And we find out the other factors affecting enterprises science and technology input-output efficiency, and make recommendations to rationalize the allocation of resources. The main conclusions are as follows:

(1)High-tech enterprise science and technology input-output efficiency is generally low by region. By using DEA, the evaluation of the high-tech enterprise science and technology input-output efficiency of various provinces shows that the number of provinces which achieves science and technology effective are less than a half of them, and the high-tech enterprises science and technology input-output efficiency are low on the whole. We can’t find the significant relationship among the input-output efficiency, technology investment and province location, and there is also the overall effective province in western regions while some provinces in the east are still having low efficiency. A large part of the regions are in increasing or decreasing returns to scale phase, which need to increase investment or adjust the direction and amount of output to improve efficiency and achieve the efficient scale.

(2)Tobit regression analysis shows that the enterprise main operating revenue and high-tech enterprises science and technology input-output efficiency have a significantly positive correlation. The technology reform costs and the high-tech enterprises science and technology input-output efficiency have significantly negative correlation. Meanwhile, there are the negative correlation among the enterprises taxes, delivery value of export and high-tech enterprises science and technology input-output efficiency.

5.2 Policy recommendations

According to the research and analysis above, there are some policy recommendations to improve the Chinese high-tech enterprises science and technology input-output efficiency.

Allocate science and technology resources rationally and improve the input-output efficiency.

When each region has continuously increased investment in the science and technology resources, they also need to focus on the science and technology resources input-output efficiency. Making full and effective use of science and technology resources and improving the allocation efficiency to achieve higher levels of output are important. Otherwise, serious waste of human and material resources could take place. Throughout all the provinces whose DEA are effective, all of them have shown the importance of science and technology resources input-output rational structure. That is, only when the ratio of science and technology research fund and the amount of research personnel are proper and the structure of them are reasonable. It is possible to achieve maximum output with fixed science and technology resources investment, or put minimum of resources under a given output. The area might takes advantage of a variety of investment resources and achieve high input-output efficiency of science and technology resources. In recent years, although the Chinese high-tech enterprises science and technology input has been growing, the output efficiency still has not been increased as the same proportion. The proportion of input in science and technology has not reached the optimal allocation ratio, and the redundancy and inadequate of individual technology resources makes the formation of a barrel effect, which resulted in a waste of the rest of resources. We need to regard the intensification of resource utilization as the core concept, improve the operation of enterprises resources investment and management capabilities, allocate the research fund rationally, strengthen scientific equipment procurement plan, and strive to improve the quality of research Specialist Staff to avoid input redundancy or shortage.

Develop all regions and strengthen the support to central and western enterprises.

Thorough comparing various science and technology resources input, it has shown that the amount of science and technology input is relatively few in central and western regions. It also indicates a downward trend in recent years, but the results of DEA has indicated that there is no significant difference of the high-tech industry science and technology resources input-output efficiency between the west and the east. Tobit regression analysis has shown that the increasing science and technology investment in the west has benefits for increasing the overall efficiency. But increasing science and technology investment in the eastern region does not have the obvious benefit to the overall efficiency compared with the western region, because of the sufficient resources and exceeding the overall enterprises configuration. In addition, government should increase science and technology input in the western region from the perspective of coordinated regional development, and enhance scientific and technological competitiveness in these areas and drive the overall economic development by high-tech enterprises. At the same time, the development of the overall economic situation will have the react on high-tech enterprises science and technology input-output efficiency as well.

(3)Government can implement balanced development policy and improve the necessary industry and region in high-tech enterprises.

Regional technology market turnover contract amount and area GDP have a positive correlation with high-tech enterprises science and technology input-output efficiency, which indicates that high-tech enterprises science and technology input-output efficiency, the whole economies of scale and the economic situation have a relatively close relationship. Development of high-tech enterprises depends on the overall economic situation of the entire region, so the government must establish a regional economic policy which begins with the guide of government, and it is supported by national policy. Besides, the policy should regard the high-tech enterprises as the vanguard and we must focus on the overall economic development. Only in this way, the development and improvement of high-tech enterprises will be more durable and the Chinese technology industry can achieve long stable development.

What's more, the government should establish benign tax policy, reward science and technology output and make some supporting policies to create the environment where the attitude of scientific research is positive and healthy. Besides, the government should try to maintain the vitality of the national high-tech enterprises and let the enterprises lead the regional economy healthy and stable.

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References

1. J.Z. Zhou, Science and technology resources, 107-113(1999).
2. P. Shi, Research on the relationship between science and technology resource allocation and institutional arrangement, (2001).
3. Q. Liu, Journal of Luoyang Normal University, **19**,2, 41-53(2000).
4. B. Sun, J.H. Li, Social Science Front, **5**, 36-39(2001).
5. P. Shi, Y. Li, China Soft Science, **12**, 55-57(2000).
6. OECD, "National Innovation System", Paris(1997).
7. A. Maria A, Decentralization and Evaluaion, **4**, 276-315(2000).
8. Y. Song, Quantitative and Technical Economics, **10**, 29-31(1999).
9. R.F. Ye, X.R. Chen, X.B. Yu. Research and Development Management, **5**, 113-118(2004).
10. J.J. Mei, S.Z. Li, Journal of Beijing Insititute of Machinery Industry, **2**, 59-64(2002).
11. Z.J. Yang, Science and Technology Management, **2**, 213-216(2007).
12. S.Y. Wei, Innovation and Technological Progress, 95-97(2005).
13. C.Q. Wu, Principle of regional economics, 89-90(2008).
14. J.H. Li, S.J. Zhou, B.F. Sun, Scientific Management Research, **6**, 72-76(200l).
15. Y. Ma, Y.L.Gao, Journal of Northeast Normal University, **3**, 24-28(2002).
16. H.C. Wu, C.Y. Zheng, Scientific Management Research, **10**, 93-96(2003).
17. H.L. Ge, Technology Management Research, **24**, 14-16(2010).
18. X.Q. Li, K.F. Xie, J.Z. Li, Technology Economy, **11**, 48-50(1999).
19. S.Z. Li, D.M. Li, W.X. Tang, Scientific Management Research, **2**, 60-63 (2003).
20. D.M. Li, S.Z. Li, W.X. Tang, Journal of Beijing Insititute of Machinery Industry, **1**, 50-55(2003).
21. S.H. Wei, G.S. Wu, Studies in Science of Science, **4**, 467-473(2005).
22. Q.L. Wei, Science Bulletin, **17**, 1793-1808(2000).
23. B.F. Sun, J.H. Li, Y.S. Yang, Application of Statistics and Management, **2**, 52-58 (2004).
24. D.F. He, Information Journal, **6**, 740-748(2006).
25. S.H. Niu, F.J. Jin, Y. Liu, "The difference of regional science and technology resource allocation", Resources Science, vol.1, pp.61-68(2004).
26. K. Drogelen, J. Bilderbeek, R&D management, **29**, 1, 35-46(1999).
27. J. Lee, E. Shim, The Journal of High Technology Management Research, **6**, 179-191(1995).
28. H. Romijn, A. Mike, Regional Studies, **36**, 1, 81-86(2002).

29. J.P. Neelankavil, V.T. Alaganar, Journal of Business Research, **6**,493-502(2003).
30. V. Korhonen, R. Tainio, J. Wallenius, European Journal of Operational Research, **130**, 121-132(2001).