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Study on the "Four-in-one" Innovative Performance Evaluation System of the Government, Industry, University and Research in Beijing-Tianjin-Hebei Region*

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Abstract*—From the angle of innovation subject, this paper constructs the innovation performance evaluation index system of the government, enterprises, universities and scientific research institutions of Beijing-Tianjin-Hebei Region, and then adopts the TOPSIS theory method. This paper constructs a "Four-in-one" innovation performance evaluation model for the government, industry, university and research in Beijing-Tianjin-Hebei Region, and measures the "Four-in-one" innovation performance of politics, production, education and research of Beijing-Tianjin-Hebei Region. As far as government factors are concerned, the results show that the innovation environment in Hebei is not good, mainly because of the adverse development of the financial environment. The material resources of Tianjin, the technological environment and the financial environment of Beijing all have this severe problem, but they are not as serious as that in Hebei. In terms of enterprise factors, the R & D consciousness of Tianjin and Hebei enterprises is poor, the financial investment is insufficient, the transformation strength of Beijing enterprises' innovation achievement needs to be strengthened and the innovation ability and innovation strength of the three enterprises are out of step. In terms of university factors, Hebei colleges and universities lack of R & D investment, R & D strength still needs to be strengthened, Tianjin colleges and universities have low level of achievements and benefits, and the level of R & D of universities in Beijing has a phenomenon of decline. As far as scientific research institutions are concerned, Hebei and Tianjin have low financial investment level, while the achievements in Beijing and Hebei are not that efficient.

Keywords*—Beijing-Tianjin-Hebei; government; industry; university and research; innovation; performance; evaluation

I. INTRODUCTION

The report of the 18th National Congress of the Communist Party of China puts forward the strategy of innovation-driven development, adheres to the road of independent innovation with Chinese characteristics, strengthens the ability of independent innovation, and constructs a perfect regional innovation system. The regional innovation system is a network system which is composed of participating scientific and technological innovation enterprises, universities, scientific research institutions, various kinds of intermediary organizations and government organizations in order to create, spread and apply knowledge. At present, China has formed three economic circles: the Yangtze River Delta, the Pearl River Delta, the Beijing-Tianjin-Hebei Economic Circle, and the development of the Beijing-Tianjin-Hebei Economic Circle lags behind the Yangtze River Delta and the Pearl River Delta. In February 2014, President Xi Jinping proposed, in a survey in Beijing, that "to promote the coordinated development of Beijing-Tianjin-Hebei Region, we should focus on optimizing and upgrading the industrial structure and realizing innovation-driven development, and strive to achieve complementary advantages and positive interaction, win-win development". At present, Beijing-Tianjin-Hebei Region have not formed a more perfect regional innovation performance evaluation system. Therefore, from the perspective of government, industry, university and research "four in one" in Beijing-Tianjin-Hebei Region, a more perfect evaluation system of innovation performance is constructed, and the trend of innovation performance index of government, industry, university and research "four in one" in Beijing-Tianjin-Hebei Region is evaluated. Thus, it provides favorable support for perfecting the government, industry, university and research "Four-in-one" innovation policy and promoting the government, industry, university and research "Four-in-one" innovation performance of Beijing-Tianjin-Hebei Region.

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II. Research Status

A. The Concept of Regional Innovation

Regional innovation is a regional development organization system composed of production enterprises, research institutions and colleges and universities, which are closely related to each other geographically [1], not just the interaction between the subjects [2], at the same time, the interaction between the main body and the innovation elements is emphasized [3], which belongs to the dynamic cooperation process of innovation subject [4]. The core of regional innovation is the interaction of knowledge production among the four governments, enterprises, universities and scientific research institutes in a given region [5] [6], It is a network of high-tech enterprises, universities and research institutions, as well as government organizations, which interact to create, store and transfer knowledge, skills and new products [7]. At the same time, regional innovation must operate in certain systems and policies. Therefore, in essence, regional innovation is made up of enterprises, universities, research institutions, intermediaries and governments that are interconnected and cooperate with each other in a specific region, the spatial organization structure formed by promoting innovation and promoting regional economic and social development in certain operating environment such as system and policy [8].

Innovation is manifested in the production, diffusion and application of knowledge, from the view of innovation performance, regional innovation can be regarded as composed of knowledge innovation subsystem, technology innovation subsystem, knowledge dissemination subsystem and knowledge application subsystem. From the perspective of innovation structure, regional innovation can be regarded as composed of the subsystem of innovation subject, innovation foundation, innovation resource and innovation environment. From the dynamic process of innovation, regional innovation can be seen as composed of the research and development subsystem, innovation guidance subsystem, innovation operation and regulation subsystem, innovation support and service subsystem. From the point of view of innovation object, regional innovation can be regarded as composed of technological innovation system, system innovation system, organizational innovation system and management innovation system.[9] From the perspective of system theory, regional innovation can be regarded as composed of an organizational innovation system, a system of institutional innovation, a system of policy innovation, a system of process innovation and a system of innovation of basic conditions.[10]

B. Regional Innovation Performance Evaluation Index

In the existing research, when the scholars design the regional innovation performance evaluation index, the innovation main body mainly involves the enterprise, the university, the research institution, some scholars will indirect main body-Innovative intermediaries (governments, financial institutions, etc.) are also included in the scope of the inspection. The factors involved in the innovation process include human, financial and material resources. Among them, most scholars use human and financial resources as the main input indicators. For example, Hu Kai (2012) [11] in the innovation performance investment analysis, takes the local government finance science and technology appropriation to the local finance expenditure proportion, as the innovation performance input index. But a few scholars also regard the material input as the main input index, such as Gao Taishan et al (2014) [12] from the innovation main body, the innovation environment, the innovation support three dimensions to examine the innovation input index, and the innovation infrastructure elements into the index system, this index has been ignored by a large number of scholars.

Because of the complexity of innovation process and the diversity of innovation results, as well as the non-availability of data, the regional innovation output index is more complex than the input index. Most scholars mainly design from two aspects. Namely innovation main body and output form. The output forms of regional innovation mainly include scientific and technological achievements and economic achievements. For example, Kuang Aimin (2010) [13] holds that the innovation output index should include the amount of patent application authorization, the amount of contract transaction in the technology market, the number of scientific and technological papers included in the three foreign systems, and the added value of enterprises above the scale of high-tech industry. High-tech products export sales income, export of high-tech products to earn foreign exchange, export of high-tech products to generate foreign exchange. On this basis, some scholars included social benefits, such as Yang Huafeng and others in the study (2007) to add the per capita GDP, per capita resident income and other social benefit indicators. In addition, some scholars have added the ecological output dimension in the light of the ecological environmental problems which are the focus of China's economic development, such as Sun Bin et al. (2011) [14] added the ecological benefit index on the basis of previous studies.

C. Regional Innovation Performance Evaluation Model

At present, regional innovative performance evaluation methods are divided into two main categories, namely, subjective qualitative evaluation and objective quantitative evaluation, with objective quantitative evaluation as the main method and subjective qualitative evaluation as supplementary. Among them, objective quantitative evaluation method is divided into parametric method and non-parametric method. The nonparametric method was proposed by Farrel (1957), mainly by constructing the production frontier and calculating the production efficiency. Then, on the basis of Farrell, scholars put forward the method of data envelopment analysis (DEA). But the disadvantage of using data envelopment analysis method is that it can not explain and analyze the difference of regional innovation performance evaluation quantitatively. In order to overcome this shortcoming effectively, Nasierowski, Arcelus (2003) [15] proposed a new research method-two-stage I/M/O model of DEA method. In addition, some scholars such as Pan Xiaolin (2009), et al. [16] use principal component analysis and analytic hierarchy process to evaluate regional innovation performance.

Because each research method has its theoretical characteristics, for example, the advantage of parametric method is that it uses production function to describe the innovation process, thus it can control the estimation of innovation efficiency, but its limitation is also related to this. Although the nonparametric method can not guarantee the accuracy of the calculation results because of the assumption that there is no random error, it can contain abundant input and output indexes, and it is more convenient to construct the innovative efficiency of production frontier accounting. Therefore, in the research process, the single research method often can not meet the various requirements of the scholars; scholars tend to adopt a new research method combined with various research methods. For example, Fu Liping et al. (2011) [17] adopted principal component analysis and knowledge production function theory to establish the extended model of knowledge production function.

D. Present Situation of Innovation Performance Evaluation in Beijing-Tianjin-Hebei Region

At present, in view of the research on the performance evaluation of innovation in Beijing-Tianjin-Hebei region, due to the different perspectives of scholars, some scholars mainly focus on the micro level, that is, the enterprise innovation performance in the Beijing-Tianjin-Hebei Region; some scholars focus on macro-level, that is, the overall innovation performance of Beijing-Tianjin-Hebei Region. For example, Guo Jing et al. (2013) [18] take 193 high-tech enterprises in Beijing-Tianjin-Hebei Region as samples, and discuss the influence of market and policy strategic orientation equilibrium on the performance of technological innovation. Guo Bin (2016) [19] through combing the existing literature on the evaluation of regional innovation performance, based on the theory of science and technology resources coupling driven innovation, from the aspects of enterprises, parks and regions, etc., construct the logical framework of Beijing-Tianjin-Hebei cooperative innovation of science and technology with value chain, knowledge chain and industry chain, through factor analysis, combined with analytic hierarchy process and complex network analysis, the weights of evaluation criteria for the performance of scientific and technological collaborative innovation in Beijing-Tianjin-Hebei region are obtained, and the rationality of the evaluation system is verified. In addition, the influence factors of regional innovation performance are further studied and discussed, in order to provide policy suggestions for improving regional innovation ability and innovation effect. For example, Zhao Zengqun et al. (2012) [20] find that Hebei provincial government funds and enterprise funds have long-term stable relationship with patent and new product sales revenue respectively; Tianjin municipal government funds and enterprise funds have a long-term and stable relationship to the sales income of new products; The relationship between variables in Beijing is not significant. Zhang Gui [21] (2016) take four regions of Yangtze River Delta, Beijing-Tianjin-Hebei, five central provinces and seven western provinces as research objects. The study shows that there are positive spillover effects among innovation efficiency in different stages of innovation value chain, and the stronger the regional innovation vitality, the more obvious the value chain spillover effect; Knowledge, product innovation efficiency has significant spatial spillover effect, and the influence degree is increasing from west to east. Bi Juan (2016) [22] analyzes the relationship between innovation drivers (innovation demand and innovation ability), support factors, link factors and safeguard factors (external factors) and innovation performance. The research shows that drivers directly affect innovation performance; other factors indirectly influence innovation performance through influencing drivers.

III. INNOVATION PERFORMANCE EVALUATION INDEX

Based on the present situation of government, industry, university and research "Four-in-one" innovation in Beijing-Tianjin-Hebei Region, regional innovation is divided into government innovation subsystem, enterprise innovation subsystem, university innovation subsystem and scientific research institution innovation subsystem. According to this theoretical framework, each innovation subsystem is further divided into two subsystems: innovation input and innovation output (environment). Then combined with the innovation status of the main innovation agents, further divided into a number of three-level subsystems, Finally, according to the principles of scientific and realistic, systematic integrity, maneuverability, static and dynamic combination, the paper designs the government, industry, university and research "Four-in-one" innovative performance evaluation index system in Beijing-Tianjin-Hebei Region.

A. Government Innovation Subsystem

Economics defines the function of government and market as "visible hand" and "invisible hand" respectively. In the regional innovation network, the government as a "visible hand", plays its macro-control function. Through a series of investment and financial support, such as manpower, financial and material resources, the government has created a good market, industry and technological environment for different innovators, thus creating more patent applications and greater contract volume in the technical market. The government innovation subsystem innovation performance evaluation index is shown in “Table I”.

TABLE I. EVALUATION INDEX OF INNOVATION PERFORMANCE OF GOVERNMENT INNOVATION SUBSYSTEM

Innovation investment	***Financial resources***	Local fiscal expenditure on science and technology (100 million Yuan) Share of government science and technology input in GDP (%)
	material resource	Average number of Internet users per 10,000 (per 10,000) Average number of calls per 100 population (part / 100
	Financial support	Funds for the implementation of National industrialization projects (10,000 Yuan) National Innovation Fund receives funding (10,000 Yuan)
Innovative output	***Technology environment***	Inflow of technical contracts (100 million Yuan) Contract amount for foreign technology introduction (US $10,000)
	Technology environment	Contract value of Technology Market (100 million)
Innovative output	***Conscious environment***	Number of patent applications for 10,000 employed persons (item / 10,000) Ten thousand people absorb the amount of technical achievements (10,000 Yuan / 10,000 people)

B. Enterprise Innovation Subsystem

Enterprise is the main participant of regional innovation, as well as the main beneficiary and competitor of innovation achievement. It not only undertakes the basic research work of innovation, but also undertakes the main work of transformation of innovation achievement. Innovation input is considered mainly from the angle of innovation elements, that is, human resource, financial resource, material resource, the direct and indirect benefits of innovation are considered from the form of output and income of innovation. The enterprise innovation subsystem innovation performance evaluation index is shown in "Table II".

TABLE II. INNOVATION PERFORMANCE EVALUATION INDEX OF ENTERPRISE INNOVATION SUBSYSTEM

Innovation investment	***Human resources***	Full-time equivalent of R & D personnel in Industrial Enterprises above scale (Human year) Proportion of R & D employees in Industrial Enterprises above scale (%)
	Financial resources	Internal expenditure of R & D funds of industrial enterprises above scale (100 million Yuan) Expenditure on the introduction of technology funds to industrial enterprises above scale (100 million Yuan) Industrial enterprises absorb expenditure above scale (100 million Yuan) Expenditure on purchasing domestic technology funds by industrial enterprises above scale (100 million Yuan) Expenditure on technological Transformation of Industrial Enterprises above scale (100 million Yuan) Expenditure on New Product Development of Industrial Enterprises above scale (100 million Yuan)
	Material resource	Number of high-tech enterprises (number) Number of R & D institutions in industrial enterprises above scale (number) Original price of R & D instruments and equipment for industrial enterprises above scale (100 million Yuan)
Innovative output	***Technical achievements***	Number of effective invention patents for industrial enterprises above scale (part) Number of R & D projects in industrial enterprises above scale (item) Number of new product development projects for industrial enterprises above scale (item)
	Indirect benefit	Sales revenue of new products of industrial enterprises above scale (100 million Yuan) Proportion of output value of High-tech Industry to GDP (%)

C. University Innovation Subsystem

In the regional innovation network, colleges and universities are the main carriers of knowledge creation and talent training, as well as the ability of technology research and development. For the innovation investment subsystem of colleges and universities, it can be divided into three aspects: manpower, financial and material resources. According to the characteristics of innovation output, it is divided into four subsystems: paper achievement, patent achievement, talent achievement and indirect benefit. The university innovation subsystem innovation performance evaluation index is shown in "Table III".

TABLE III. EVALUATION INDEX OF INNOVATION PERFORMANCE OF INNOVATION SUBSYSTEM IN COLLEGES AND UNIVERSITIES

Innovation investment	***Human resources***	R & D personnel full-time equivalent(person year)
		Number of scientists and engineers (person years)
		Number of college degree or above(per 10,000)
		The proportion of the employed population with tertiary education and above in the working population of the province (%)
	Financial resources	Internal expenses for R & D funds (100 million Yuan)
	Material resource	Number of R & D institutions in Colleges and Universities(Number)
		Project number of R & D (item)
Innovative output	***Paper achieveme nt***	Collection of Science and Technology papers in China by main Retrieval tools abroad(article)
		Publication of scientific and technological papers (article)
		Publication of scientific and technological works (species)
	Patent achieveme nts	Number of patents for effective inventions in Colleges and Universities (item)
		Number of winners of three national scientific and technological achievements (items)
		Scientific and technological Progress Awards of various departments under the State Council (item)
		Number of International Project acceptance in Colleges and Universities (item)
	Indirect benefit	Number of R & D Achievement Application and Science and Technology Services in Colleges and Universities (item)
		Patent ownership transferand licensing income(10,000 Yuan)
		Amount of Technology transfer contract in Colleges and Universities (10,000 Yuan)

D. Scientific Research Institution Innovation Subsystem

As a technological research base in regional innovation, scientific research institutions play an important role in applied research. The division of innovation input system of scientific research institutions is similar to that of enterprises and colleges and universities, and only the selection of evaluation indexes is different. The innovation output subsystem of scientific research institutions mainly includes the achievements of papers, patent achievements and indirect benefits. Indirect benefit is mainly the transfer income of patent ownership.

TABLE IV. EVALUATION INDEX OF INNOVATION PERFORMANCE IN INNOVATION SUBSYSTEM OF SCIENTIFIC RESEARCH INSTITUTIONS

Innovation investment	***Human resources***	R& D personnelfull-time equivalent (person year)
	Financial resources	Internal expenditure of R&D Funds(100 million Yuan)
	Material resource	Expenditure on scientific instruments and equipment (10,000 Yuan)
		Project number of R & D (item)
Innovative output	***Paper achievem ent***	Collection of Science and Technology papers in China by main Retrieval tools abroad(article)
		Publication of scientific and technological papers (article)
		Publication of scientific and technological works (species)
	Patent achievem ents	Number of valid invention patents (item)
	Indirect benefit	Income from transfer and licensing of patent title (1,0000 Yuan)

IV. INNOVATIVE PERFORMANCE EVALUATION METHOD

A. Evaluation Index Weight Determination

The entropy weight method is used to empower the innovation performance evaluation index of "four in one" of government, industry, university and research. Entropy weight method is a method to determine the weight of each index according to the impact of the relative change degree of evaluation index on innovation performance, that is, the greater the relative change degree, the greater the influence on the difference between different regions at different time, thus giving a greater weight. The specific steps are as follows:

Firstly, the dimensionless treatment of the index value of the "Four-in-one" innovation performance evaluation of government, industry, university and research, see formula (1).

$$\begin{cases} x_{ij} = \dfrac{y_{ij} - \min y_{ij}}{\max y_{ij} - \min y_{ij}}, j \in J \\ x_{ij} = \dfrac{\max y_{ij} - y_{ij}}{\max y_{ij} - \min y_{ij}}, j \in J' \end{cases} \quad (1)$$

Secondly, calculate the entropy value of each index e_j and coefficient of difference g_j , as shown in formula (2).

$$\begin{cases} e_j = -\dfrac{1}{\ln n}\sum_{i=1}^{n}\left(\dfrac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \ln \dfrac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}\right), i = 1,2,\cdots,n; j = 1,2,\cdots,m \\ g_j = 1 - e_j, i = 1,2,\cdots,n; j = 1,2,\cdots,m \end{cases} \quad (2)$$

The smaller the e_j is, the bigger the g_j is, the greater the difference of the j index in different time and region, the greater the effect of the j index on the comparison of innovation performance, the more important the index is, the greater the weight should be assigned.

Finally calculate the weight ω_j of the j index, as follows:

$$\omega_j = \frac{g_j}{\sum_{j=1}^{m} g_j}, j = 1, 2, \cdots, m \tag{3}$$

B. Valuation Model Construction

The ideal solution (TOPSIS) is used to evaluate the innovation performance of "four in one" in government, industry, university and research. The basic idea of the ideal solution is to determine the optimal index data combination and the worst index data combination for the normalized raw data matrix. Then the distance between the region and the combination of the best index data and the worst index data is calculated, and the degree of proximity between the region and the best scheme is obtained. It is used as the basis for evaluating the innovation performance of government, industry, university and research "four in one" in different regions at different times. The specific steps are as follows:

Step 1, the decision problem is defined and the decision matrix is used to describe the problem.

Assuming that there are m time regions and each scheme has n index attributes, then we can use the decision matrix to mathematically describe the multi-objective evaluation problem as:

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ y_{i1} & \cdots & y_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \tag{4}$$

Step 2, the decision matrix is normalized, and the index weight is determined according to entropy weight method.

$\omega = (\omega_1, \omega_2, \cdots \omega_n)^T$.

$$\begin{cases} z_{ij} = \begin{cases} (y_{ij} - y_{j\min}) / (y_{j\max} - y_{j\min}) & y_{j\max} \neq y_{j\min} \\ 1 & y_{j\max} = y_{j\min} \end{cases} & y_{ij} \text{ is a benefit index} \\ z_{ij} = \begin{cases} (y_{j\max} - y_{ij}) / (y_{j\max} - y_{j\min}) & y_{j\max} \neq y_{j\min} \\ 1 & y_{j\max} = y_{j\min} \end{cases} & y_{ij} \text{ is a cost index} ; \end{cases} \tag{5}$$

Thus constitute the decision matrix after normalized empowerment $Z = (\omega_{ij} \times z_{ij})_{m \times n}$.

Step3, deterministic ideal solution Z_J^* and Negative ideal solution

Z_J^-, that is

$$\begin{cases} Z_j^* = \left\{ \left(\max_i Z_{ij} \mid j \in J \right), \left(\min_i Z_{ij} \mid j \in J' \right) \right\} \\ Z_j' = \left\{ \left(\min_i Z_{ij} \mid j \in J \right), \left(\max_i Z_{ij} \mid j \in J' \right) \right\} \end{cases} \tag{6}$$

in the formula

J — A set of subscripts of an efficient object；

J' — A set of subscripts for cost-based targets.

$J \cup J' = \{1, 2, \cdots, n\}$，$J \cap J' = \Phi$

Step 4, using the weighted Euclidean norm, measure the Euclidean distance from the actual solution to the ideal solution.

$$\begin{cases} S_i^* = \sqrt{\sum_{j=1}^{n} (Z_{ij} - Z_j^*)^2}, i = 1, \cdots, m \\ S_i' = \sqrt{\sum_{j=1}^{n} (Z_{ij} - Z_j')^2}, i = 1, \cdots, m \end{cases} \tag{7}$$

Step 5, the relative closeness of the ideal solution for each practical solution is calculated, the superior and inferior order in which schemes are arranged from small to large.

$$C_i^* = S_i' / (S_i^* + S_i'),\quad i = 1, \cdots, m \tag{8}$$

If a region is closer to the ideal solution point at a given time, the farther the negative ideal point is, the larger C_i^* is, In this period, the regional government, industry, university and research "four in one" innovation performance is higher.

V. EMPIRICAL STUDY

Taking the macro data of Beijing-Tianjin-Hebei Region as samples, the paper evaluates the innovation performance of "four in one" in Beijing-Tianjin-Hebei region. The data are mainly from “China Statistical Yearbook”, “China Science and Technology Statistics Yearbook”, “Beijing Statistical Yearbook”, “Tianjin Statistical Yearbook”, “Hebei

Statistical Yearbook" and "China Torch Statistical Yearbook". In addition, some of the data are from "the Compendium of Science and Technology Statistics in Colleges and Universities", "the compilation of Science and Technology Statistics", "the Report of the National Innovation Fund" and "the Report on the Regional Innovation ability of China".

A. *Evaluation of Input-output Status of Innovation*

1) Innovation input evaluation

a) R & D funds input: R & D funding is the basis of R & D activities and the core index to measure the scale, innovation ability and level of regional R & D.

Judging from the input scale of R & D funds, during the 12th Five-Year Plan period, the three places in Beijing-Tianjin-Hebei Region showed an overall growth trend, and the growth rate and GDP growth rate remained balanced. During the "12th Five-Year'' Plan, the expenditure on R & D in Beijing-Tianjin-Hebei Region is shown in "Fig. 1".

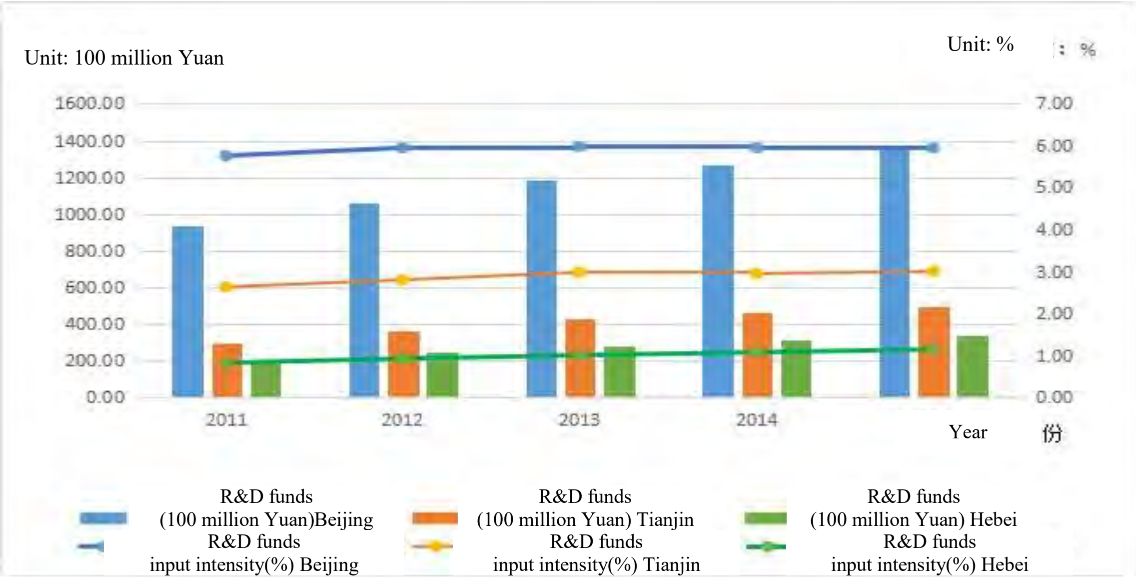

Fig. 1. Expenditure of R & D funds in Beijing-Tianjin-Hebei during the 12th Five-Year Plan period.

To a certain extent, R & D funds can reflect the development of innovation activities in various places. The concentration of innovation subjects in Beijing-universities, scientific research institutions, and enterprises is twice as high as that in Tianjin and Hebei. The input scale of R & D funds in Beijing reached 136.75 billion Yuan in 2015, 1.6 times that of R & D in Tianjin and Hebei, which is consistent with the distribution of innovative resources in Beijing-Tianjin-Hebei Region. Although the input scale of R & D funds in Beijing is large, it is distributed to every innovation subject and is close to that of Tianjin and Hebei. According to "Fig.1", according to the intensity of R & D funds input, during the 12th Five-Year Plan period, the intensity of R & D investment in the three places of Beijing-Tianjin-Hebei Region maintained a steady growth trend and kept pace with the growth of GDP.

Among them, the R & D input intensity of Beijing is stable at 5.95, but the R & D input intensity of Tianjin and Hebei is obviously lower than that of Beijing, and only keeps a small increase. Hebei R & D input intensity is about 1%, Tianjin is about 3%.

The difference in R & D investment intensity among Beijing-Tianjin-Hebei Region is mainly due to the distribution of innovation resources. The concentration of innovation resources in Beijing leads to a higher degree of innovation driving economic development, and then leads to increasing the investment intensity of R & D funds. Therefore, the gap of innovation input in Beijing-Tianjin-Hebei Region is not the root of innovation gap, and the concentration of innovation resources is the main reason to determine the difference of innovation ability.

From the sources of R & D funds in the three places of Beijing-Tianjin-Hebei Region, Beijing is mainly dependent on government funds, followed by enterprise funds. In 2014, the proportion of government funds reached 55.21%, and the proportion of enterprise funds reached 34.24%. Tianjin and Hebei mainly rely on enterprise funds. The proportion of enterprise funds in Tianjin reached 78.74% and that in Hebei reached 84.22%.Judging from the distribution of R & D funding departments in the three places of Beijing-Tianjin-Hebei Region, Hebei had the highest proportion of R & D funds in 2014, reaching more than 75%, while the proportion of R & D funds of scientific research institutions in Beijing was the largest, reaching 50.51%,the proportion of R & D funds in enterprises accounted for 36.53, and the proportion of R & D funds in the three departments was balanced with the proportion of R & D funds in their respective sources of R & D funds. Therefore, the R & D funds of enterprises are mostly from within enterprises, and R & D funds from scientific research institutions and universities are mostly from government investment. Therefore, the innovation in Beijing mainly depends on the government and belongs to the government-driven innovation. Tianjin, Hebei's innovation mainly depends on the enterprise, belongs to the enterprise-driven innovation. The source and distribution of R & D funding for Beijing-Tianjin-Hebei Region in 2014 are shown in “Fig. 2”.

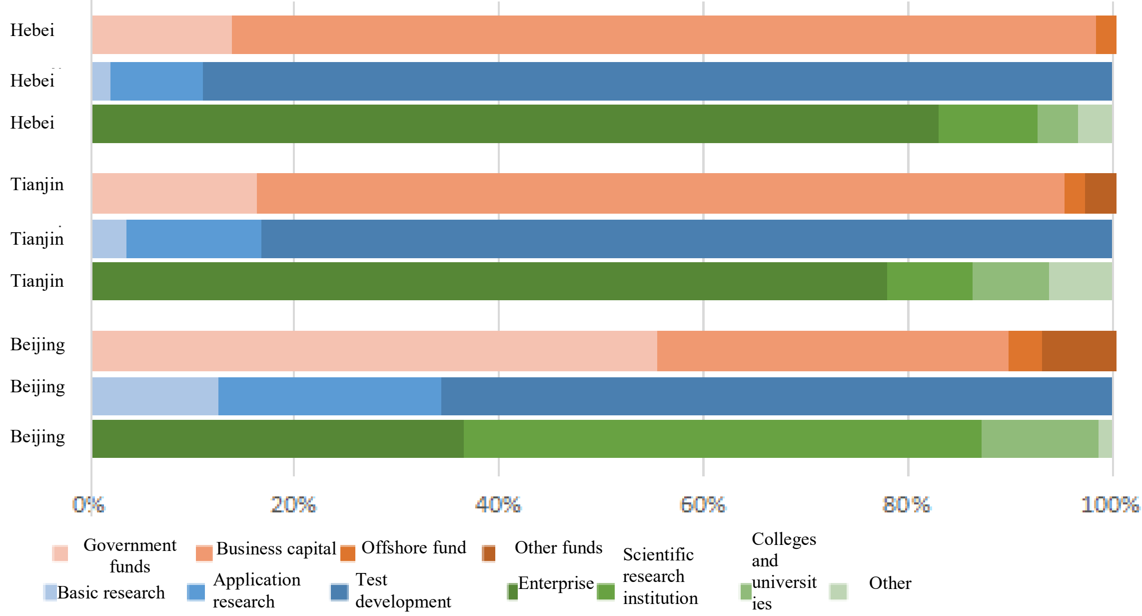

Fig. 2. Sources of funding and distribution of R & D in Beijing-Tianjin-Hebei Region in 2014

As shown in “Fig. 2”, from the distribution of R & D funding activities in Beijing-Tianjin-Hebei three places, the proportion of funds occupied by experimental development in 2014 was over 50%, followed by applied research, and the proportion of basic research was the lowest. The basic research and applied research in Beijing were higher than those in other places, 12.57% of the R & D funds were used for basic research, 21.67% of the R & D funds were used for applied research, 65.67% of the R & D funds were used for experimental development. In Tianjin, only 3.46% of the funds were used for basic research, 13.18% for applied research, and 83.36% for experimental development. Hebei had less than 2% of basic research funds and less than 10% of applied research funds. Therefore, the three places in Beijing-Tianjin-Hebei Region attach the most importance to the research of experimental development and weaken the applied research and basic research. Tianjin and Hebei have invested more in the research of experimental development, and Beijing has paid the most attention to basic research and applied research. This is mainly due to the rapid results of experimental development research and the high demand, basic research requires a high level of knowledge and ability.

b) R & D Personnel Input: R & D personnel are the main participants in regional R & D activities and R & D management. The R & D personnel ratio reflects the distribution of human resources in regional scientific and technological investment and determines the quality of R & D results. In 2011-2014, R & D personnel in Beijing-Tianjin-Hebei Region showed an overall growth trend, but the growth rate was declining. The development of R & D personnel in Beijing-Tianjin-Hebei Region during the 12th five-year Plan period is shown in “Fig. 3”.

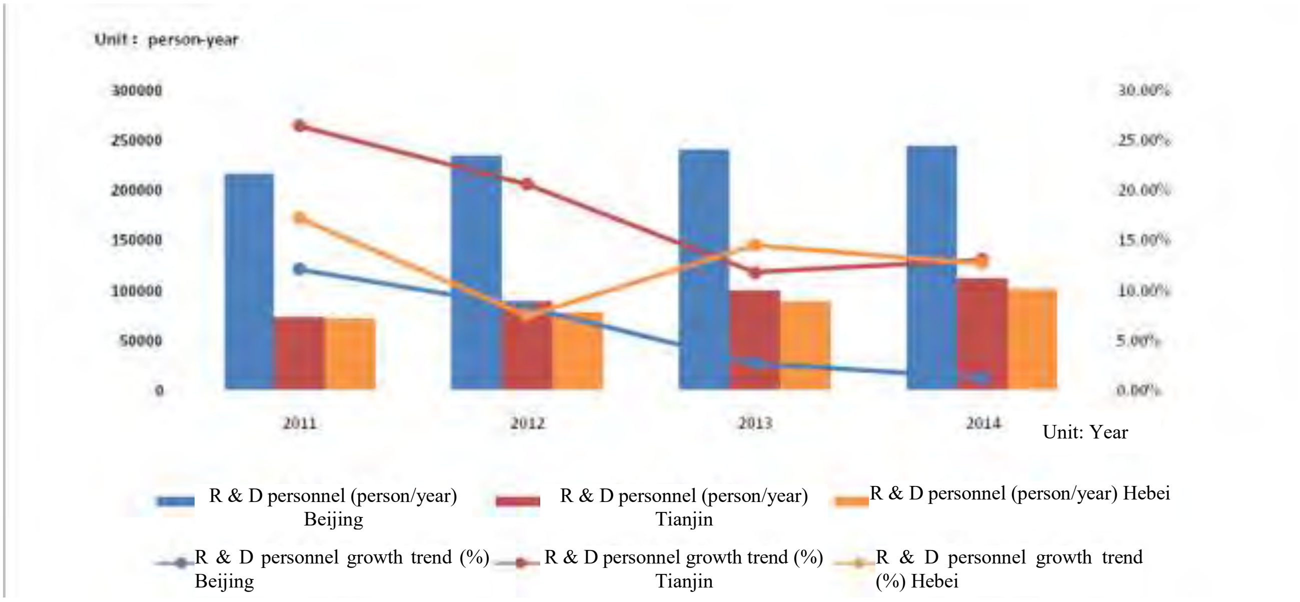

Fig. 3. The development of R & D personnel in Beijing-Tianjin-Hebei during the 12th Five-Year Plan period.

According to "Fig. 3", the growth rate of R & D personnel in Beijing decreased obviously from 12.15% to 1.33%, but the supply of R & D personnel with high growth rate could not provide the corresponding R & D benefit. Tianjin R & D personnel growth rate has been higher than Beijing about 10 percentage points. Tianjin's geographical advantage has prompted Beijing to achieve a strong radiation effect on Tianjin's economic development. Under the policy support of the integration of Beijing-Tianjin-Hebei Region, the transfer of industry and the transfer of talents have been carried out effectively, and the R & D personnel in Tianjin have maintained a rapid growth Hebei R & D personnel growth rate showed a "first decline, then growth" evolution trend, first from 17.21% of high-speed growth to 7.54%, then fluctuations to the same as Tianjin, with a 12.72% growth rate.

Although Hebei is faced with the problems of unbalanced regional economic development and urgent adjustment of industrial structure, the internal problems in Hebei will gradually weaken with the passage of time after the radiation effect of Beijing and Tianjin, and the balance between the two places will be gradually weakened, and Beijing-Tianjin balance.

2) Innovative output

a) Number of patent applications and patent authorizations: Patent is an important index to measure the R & D ability and strength of a region. Whether the number of patent applications or patent authorizations, Beijing-Tianjin-Hebei Region overall maintain the trend of growth, but the growth is slow. The number of patents in Beijing-Tianjin-Hebei Region changed during the 12th Five-Year Plan period, as shown in "Fig. 4".

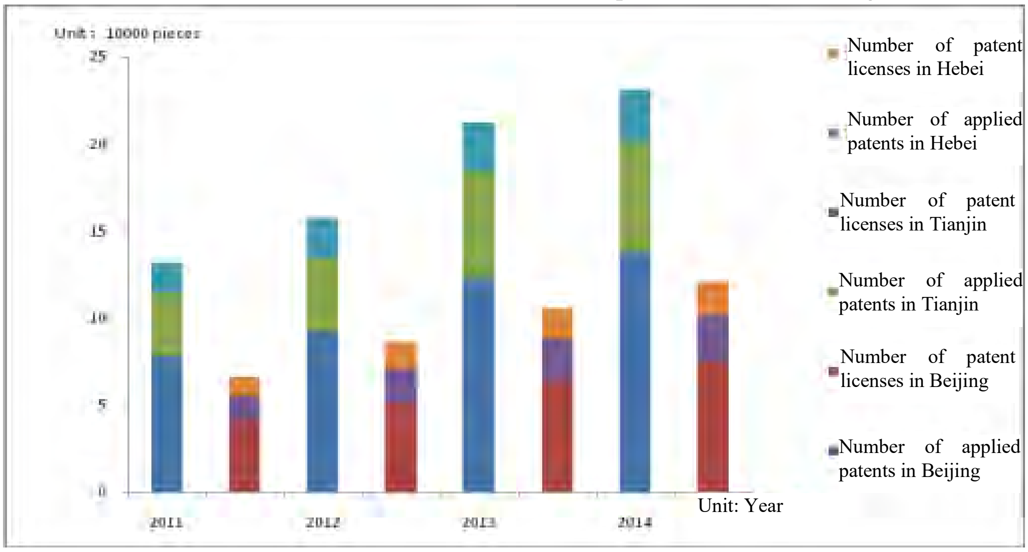

Fig. 4. Changes in the number of patents in Beijing-Tianjin-Hebei during the Twelfth Five-Year Plan.

According to “Fig. 4”, for patent applications, the proportions of Beijing, Tianjin, and Hebei are maintained at 60%, 27% and 13% respectively. In addition, the proportion of patents granted to Beijing, Tianjin, and Hebei is maintained at 60%, 22% and 17%.The proportion of Beijing-Tianjin-Hebei Region patents granted in 2014, as shown in “Fig. 5”.

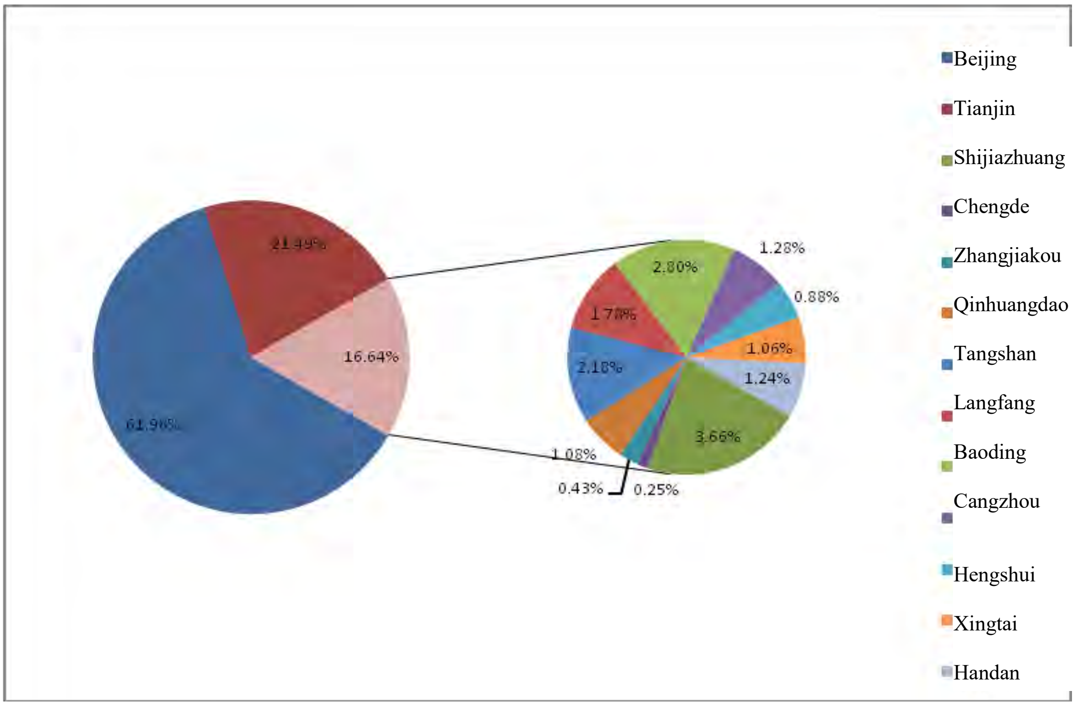

Fig. 5. Proportion of patent licenses in Beijing-Tianjin-Hebei Region in 2014.

According to “Fig. 4” and“Fig. 5”, Beijing has the most abundant R & D achievements, and its quality is equal to that of Beijing-Tianjin-Hebei Region as a whole. The proportion of patent license in Tianjin is relatively lower than that in patent application, and the R & D strength still needs to be improved, while the proportion of patent license in Hebei is higher than that in patent application, which indicates that the R & D quality of Tianjin is higher than the average level of Beijing-Tianjin-Hebei. Beijing-Tianjin-Hebei Region should further improve the quality of patent applications in order to improve patent recognition and realize the transformation of scientific and technological achievements. As can be seen from “Fig. 5”, there is a certain gap in the amount of patent license among the three provinces and cities of Beijing-Tianjin-Hebei Region, and there is also a significant gap in Hebei Province. Among them, Baoding City, Shijiazhuang City, Tangshan City and Langfang City are adjacent to Beijing, based on geographical advantages and government innovation drive, some innovative resources have been acquired earlier,−such as the formed high-tech zones, industrial parks and so on, and their R & D strength is relatively strong. In order to further narrow the innovation gap in Hebei, we must strengthen the role of the government in order to promote industrial transfer and industrial upgrading.

b) Technology market turnove: Technical market turnover reflects the ability of regional technology application and transformation of scientific and technological achievements. During the 12th five-year Plan period, the overall growth rate of Beijing-Tianjin-Hebei Region was 20%, slightly lower22% than that of the whole country. From the analysis of the technological application and the ability to transform scientific and technological achievements, the overall strength of Beijing-Tianjin-Hebei is relatively strong during the 12th Five-Year Plan period, but the internal development of Beijing-Tianjin-Hebei is quite different. Among them, Beijing has the highest degree of technology market opening and the strongest ability of technological transformation. But there was a slowdown (Slow down by 10 percentage points); under the background of collaborative innovation, Tianjin has been developing smoothly, and the industrial innovation has taken on the transformation base of Beijing research achievements effectively, thus showing an extremely high growth trend of 37%. Hebei’s development trend is relatively slow, technical contract turnover shows a downward trend. During the twelfth five-year plan period, the turnover of Beijing-Tianjin-Hebei Region technology contracts, see “Table V”.

TABLE V. THE TRANSACTION AMOUNT OF BEIJING-TIANJIN-HEBEI TECHNOLOGY CONTRACT DURING THE TWELFTH FIVE-YEAR PLAN

Year	Jing-Jin-Ji	Beijing	Tianjin	Hebei
2011	2086	1890.3	169.4	26.3
2012	2728.6	2458.5	232.3	37.8
2013	3159.5	2851.7	276.2	31.6
2014	3555	3137.2	388.6	29.2
2015	3910.5	3452.6	418.4	39.5

a. Data source: "China Statistical Yearbook"

b. Unit: 100 million Yuan

B. Evaluation Results of Innovation Performance Index

From 2010 to 2015, the Beijing-Tianjin-Hebei Region's government, industry, and university and research "Four-in-one" innovation performance index is shown in "Table VI", "Table X".

TABLE VI. INNOVATION PERFORMANCE INDEX OF GOVERNMENT INNOVATION SUBSYSTEM IN BEIJING-TIANJIN-HEBEI REGION (2010-2015)

Year	Beijing	Tianjin	Hebei
2010	0.500	0.208	0.263
2011	0.570	0.206	0.136
2012	0.611	0.324	0.157
2013	0.695	0.313	0.116
2014	0.701	0.366	0.180
2015	0.710	0.409	0.208

As can be seen from "Table VI", the overall innovation performance index of the government innovation subsystem in the Beijing-Tianjin-Hebei region from 2010 to 2015 is as a whole, Beijing is superior to Tianjin, Tianjin is better than Hebei, and the innovation performance index of government innovation subsystem of Beijing-Tianjin-Hebei Region is increasing. Specifically, during the 12th Five-Year Plan period, the Beijing government innovation subsystem innovation performance index reached 1.7-2.8 times of Tianjin, as high as 3.4-6.0 times of Hebei. According to the increase of innovation performance index of government innovation subsystem in Beijing-Tianjin-Hebei region, the increase rate of innovation performance index of Beijing-Tianjin-Hebei Region government innovation subsystem is 42.0996.40% and -21.00% respectively during the 12th Five-Year Plan period.

TABLE VII. INNOVATION PERFORMANCE INDEX OF ENTERPRISE INNOVATION SUBSYSTEM IN BEIJING-TIANJIN-HEBEI REGION (2010-2015)

Beijing	Tianjin	Hebei
0.337	0.363	0.290
0.379	0.428	0.329
0.431	0.484	0.310
0.497	0.519	0.351
0.527	0.547	0.424
0.498	0.567	0.445

As can be seen from "Table VII", from 2010 to 2015, the innovation performance index of enterprise innovation subsystem in Beijing-Tianjin-Hebei region is as a whole, Tianjin is superior to Beijing, Beijing is superior to Hebei, and the innovation performance index of enterprise innovation subsystem in Beijing-Tianjin-Hebei Region is increasing. Specifically, during the 12th Five-Year Plan period, the innovation performance index of Tianjin enterprise innovation subsystem reached 1.0-1.2 times that of Beijing and 1.2-1.6 times of that of Hebei. According to the growth rate of innovation performance index of enterprise innovation subsystem in Beijing-Tianjin-Hebei area, the growth rate of innovation performance index in Beijing-Tianjin-Hebei Region enterprises during the 12th Five-Year Plan period was 47.83%, 56.20%and 53.20%, respectively.

TABLE VIII. INNOVATION PERFORMANCE INDEX OF INNOVATION SUBSYSTEM OF UNIVERSITIES IN BEIJING-TIANJIN-HEBEI REGION (2010 - 2015)

Year	Beijing	Tianjin	Hebei
2010	0.661	0.131	0.042
2011	0.695	0.147	0.052
2012	0.730	0.166	0.051
2013	0.748	0.194	0.053
2014	0.778	0.214	0.064
2015	0.840	0.220	0.080

As can be seen from "Table VIII", from 2010 to 2015, the innovation performance index of university innovation subsystem in Beijing-Tianjin-Hebei region is as a whole, Beijing is superior to Tianjin, Tianjin is better than Hebei, and the innovation performance index of innovation subsystem of Beijing-Tianjin-Hebei Region is increasing. Specifically, during the 12th Five-Year Plan period, the innovation performance index of the innovation subsystem in Beijing's colleges and universities reached 3.6-4.8 times of that in Tianjin and 10.0-14.3 times of that in Hebei Province. From the point of view of the increase of innovation performance index of university innovation subsystem in Beijing-Tianjin-Hebei Region, the increase of innovation performance index of Beijing-Tianjin-Hebei Region colleges and universities is 27.06% 67.98% and 89.13% respectively during the 12th Five-Year Plan period.

TABLE IX. INNOVATION PERFORMANCE INDEX OF INNOVATION SUBSYSTEM OF SCIENTIFIC RESEARCH INSTITUTIONS IN BEIJING-TIANJIN-HEBEI REGION (2010-2015)

Year	Beijing	Tianjin	Hebei
2010	0.657	0.013	0.002
2011	0.638	0.013	0.011
2012	0.683	0.017	0.012
2013	0.760	0.028	0.013
2014	0.793	0.029	0.017
2015	0.825	0.037	0.024

As can be seen from "Table IX", the innovation performance index of innovation subsystem of scientific research institutions in Beijing-Tianjin-Hebei region from 2010 to 2015 is as a whole, Beijing is superior to Tianjin, Tianjin is better than Hebei, and the innovation performance index of innovation subsystem of Beijing-Tianjin-Hebei Region is increasing. Specifically, the innovation performance index of innovation subsystem in Beijing is 22.4-48.3 times higher than that in Tianjin and 34.3-57.9 times higher than that in Hebei. According to the increase of innovation performance index of scientific research institutions in Beijing-Tianjin-Hebei region, the increase of innovation performance index of innovation subsystem in Beijing-Tianjin-Hebei Region during the 12th Five-Year Plan period is 25.64% and 986.6% respectively.

TABLE X. INNOVATION PERFORMANCE INDEX OF GOVERNMENT, INDUSTRY, UNIVERSITY AND RESEARCH "FOUR-IN-ONE" IN BEIJING, TIANJIN, HEBEI AND HEBEI REGION (2010-2015)

Year	Beijing	Tianjin	Hebei
2010	0.539	0.179	0.150
2011	0.571	0.198	0.132
2012	0.614	0.248	0.133
2013	0.675	0.263	0.133
2014	0.700	0.289	0.171
2015	0.718	0.308	0.189

As can be seen from “Table X”, on the whole, from 2010 to 2015, for the government, industry, university and research "four in one" innovation performance index in the Beijing-Tianjin-Hebei region, Beijing is superior to Tianjin, Tianjin is better than Hebei, and the government, industry, university and research "Four-in-one" innovation performance index of Beijing-Tianjin-Hebei Region is increasing. Specifically, Beijing’s government, industry, university and research "Four-in-one" innovation performance index reached 2.3-2.9 times of Tianjin’s, and 3.7-5.1 times of Hebei’s. Judging from the increase of the "Four-in-one" innovation performance index in the Beijing-Tianjin-Hebei region, the growth rate of the government, industry, university and research "Four-in-one" innovation performance index in Beijing-Tianjin-Hebei Region during the 12th Five-Year Plan period was 33.36%, 72.45% and 26.51% respectively.

VI. CONCLUSION

In general, in the process of "Four-in-one" innovation development of government, industry, university and research in Beijing-Tianjin-Hebei Region, the government is too dominant and neglects the subjective initiative of the innovation subject, which leads to the repeated fluctuation of the innovation level of each innovation element. At the same time, the distribution of innovation resources in the three places of Beijing-Tianjin-Hebei Region is not balanced. Due to the limitation of geography and departments, each innovation main body is in its own right, and the innovation elements can not flow effectively, which leads to the inability of each of them to achieve complementary advantages and coordinated development. Therefore, it is necessary to speed up the cooperation and innovation of the government, industry, university and research in Beijing, Tianjin, Hebei and Hebei, and promote the efficiency of cooperation between government, production, education and research in Beijing-Tianjin-Hebei Region, to improve the efficiency of cooperation and innovation the government, industry, university and research in Beijing-Tianjin-Hebei Region.

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