Empirical Research about the Regional Innovation Capability Based on China's Patent Application Activities

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***Abstract*--Selects the invention patent applications as measures of China's innovation capability, utilize the characteristic index of patent influence factors. Based on type B grey correlation between two of which to calculate and determine the Lag and index weight of influence of different characteristics of the indicators on China's innovation capability. On this basis, calculate the regional innovation capability of 30 Provinces, municipalities and autonomous regions in 2011 and divided these regions into four echelons.**

I. INTRODUCTION

Science and technology innovation has become the dominant force to promote the development of society with the development of science and technology. As an important part of national innovation system, regional innovation system is an important foundation of national economy and the development of science and technology. There are significant differences of regional innovation capability because of the unbalanced economic development and differences of resource endowment and knowledge technology base. Therefore the research of determining the regional innovation capability has important implications of promoting the innovation in science and technology preferably.

As the core of science and technology assets and the most economic value in the process of innovation, the holding quantity of patent can reflect both the initial innovation capability of country or regions and the market application potential results [5], which can reveal the ability of technology innovation from the essence. Combine with the availability and reliability, a lot of scholars takes them as the evaluation index on measuring the technological innovative ability [2-4],[17], or use different evaluation index and method to research on regional technology innovation ability according to the patent information [12],[16].As the main influence factors of patent applications, the economic development level, science and technology spending and stuff input, technology trading and introduction, high technology products international trade and International Direct Investment Impact on innovation ability in our country in essence, and then manifest as Increase or decrease of patent applications. This paper is different from previous research via choosing the invention patent applications as the metrics on China's innovation ability and based on which to use the B-type grey correlation analysis to confirm the hysteresis and leverage on China's innovation ability of all the factors. Then carry out the inter-comparison of regional innovation capabilities in 2011 to find the disparity and provide decision basis for formulating the regional innovation strategy.

II. RESEARCH METHODS AND DATA SOURCES

A. Grey Correlation Analysis

There is a lag between the Grey Correlation Analysis technology inputs and outputs. Given this lag, in this paper, we put the number of invention patent applications as a characteristic of the innovation ability behavior sequence, and each characteristic index as a behavior sequence. The lagging patent applications (the lag period is denoted by N) respectively corresponds to the characteristic index. Then, we build a Grey Correlation Model of innovation capacity index based on the amount of patent applications to determine how the different characteristics index influence the innovation ability of China. The Grey Correlation Analysis is a factor analysis and a quantitative comparison for the trend changes of a system's development. It is a way to analysis the degree of influence between the factors of a system. Besides, it can measure the contributions of factors to the system main behavior. The basic idea of Grey Correlation Analysis is based on the similarity of the curve sequences to determine their degree of correlation. The more similar the curve, the greater the degree of correlation between the corresponding sequence. There are some typical correlation models, such as Tangs' Correlation, Generalized Absolute Correlation, Type T Correlation, Gray Slope-Correlation, Type B Correlation and Improved Correlation. In this paper, we choose the Type B Correlation, which is a comprehensive description of the correlation degree between the things' development processes and based on their similarity. The steps of the Type B Correlation analysis as follows:

(1) Determine the characteristic behavior sequence of a system X_0, Determine the behavior sequence of the related factors X_i

$$X_0 = (x_0(1), x_0(2), \cdots, x_0(n))$$
$$X_i = (x_i(1), x_i(2), \cdots, x_i(n))$$

(2) Calculating the Zero Starting point

$$X_0^0 = (x_0^0(1), x_0^0(2), \cdots, x_0^0(n))$$
$$X_i^0 = (x_i^0(1), x_i^0(2), \cdots, x_i^0(n))$$

Of which

$$X_i^0(\mathrm{k}) = \frac{x_i(k) - \min\limits_i x_i(k)}{\max\limits_i x_i(k) - \min\limits_i x_i(k)}$$

(i=0.1,$\cdots$,m;k=1,2,$\cdots$,n)

(3) Calculating $d_{ij}^{(0)}$, $d_{ij}^{(1)}$, $d_{ij}^{(2)}$

$$d_{ij}^{(0)} = \sum_{k=1}^{n} \left| x_i^0(k) - x_0^0(k) \right|$$

$$d_{ij}^{(1)} = \sum_{k=1}^{n-1} \left| x_i^0(k+1) - x_0^0(k+1) - x_i^0(k) + x_0^0(k) \right|$$

$$d_{ij}^{(2)} = \sum_{k=1}^{n-2} \left| \begin{array}{l} \left[x_i^0(k+1) - x_0^0(k+1) \right] \\ -2\left[x_i^0(k) - x_0^0(k) \right] \\ +\left[x_i^0(k-1) - x_0^0(k11) \right] \end{array} \right|$$

(4) Calculating grey correlation degree

$$H = \frac{1}{1 + \frac{1}{n} d_{ij}^{(0)} + \frac{1}{n-1} d_{ij}^{(1)} + \frac{1}{n-2} d_{ij}^{(2)}}$$

B. Index selection and data sources

There are the strong linear correlation between patent application and grant, but patent grant is highly influenced of artificial factors such as government patent office. The increase of uncertainty factors caused easily abnormal changes, the information contained in patent applications covered the patent grant largely, meanwhile has strong timeliness. Hence in this paper, the invention patent applications were selected to measure China's innovation ability.

Domestic scholars carry out a lot of research work and find out that the factors that influence on patent applications is complicated, which can reduce to S&T spending, S&T staff input, technology trading and introducing, international trade of high-tech products and FDI. Among which the S&T spending is the important safeguards of China's S&T innovation activities. Most of the current study is about the raising and spending S&T funding among government, enterprises and universities [7],[11],[14]. The carrying out of technological innovation activities mainly rely on the raise of human quality and innovative thinking ability. The increase of R&D stuffs in region is avail the produce of new ideas, therefore emerging more corresponding scientific and technological achievements output and reveals as the patent application activities [9],[4]. The domestic technology trading has built the technology, knowledge and talent flow mechanism and accelerated diffusion and utilize of innovation outputs. Technology trading emphasized on forming an organic learning network which can both promoting S&T research activities in this region and improve the patent filings, and can attracted the outside research activities to inside. International trades of high-tech products has significant meaning of introducing foreign advanced equipment, technology and talents and realize the invitation activities such as digestion, absorption and innovation. Therefore, the international trades of high-tech products have some impact on the raise of raising of patent applications [13],[10].On the other side, the scholars repeated mentioned the potential roles of FDI of technical progress in developing countries [6].FDI has a positive impact to China's technology via the technology spillover effect, which can pull the technical output and increase patent application [15],[18]. It is obvious that the essence of all the factors effect on the patent application is operate on innovation activity. Hence, this paper takes the influence factors of patent applications as the measurement of innovation activities. This paper use the data of China's invention patent applications from 1991to 2001 and determine innovation ability evaluation index system of China as shown in table 1.

TAB.1 THE EVALUATION INDEX OF CHINA'S INNOVATION ABILITY

Influence Factor	Characteristic Index
S&T spending	Total of nationwide R&D output（100 million）
S&T stuff input	Total of nationwide R&D full-time equivalent(10 thousand per year)
Technology trading and introducing	Total of nationwide of technology development contract（10 thousand Yuan）
	Total of nationwide technical transformation contract（10 thousand Yuan）
	Total of nationwide technical consultation contract（10 thousand Yuan）
	Total of technical services contract（10 thousands Yuan）
	Technology import contracts from abroad（10 thousand dollars）
International trade of high-tech products	Imports of high-tech products(100 million dollars)
	Output of high-tech products(100 million dollars)
FDI	FDI(100 million dollars)

The data of FDI is rooted in the China's statistics bureau's official website and other indexes are from "Science and technology of China statistical yearbook" in year 1992-2011.

III. DATA ANALYSIS

A. A profile of domestic patent applications

As shown in figure 1, with the rapid development of our economy and an increasing number of factors such as R&D input, China's patent application numbers increased form 14372 in 1985 to 1633407 in 2011, which increased by nearly 114 times. Among which, the domestic patent applications increased from 9411 to 128675. We can see from the figure that the growth rate of domestic patent applications is higher than foreign patent applications. But in the past 26 years, the percentage of domestic invent patent applications is lower than the domestic patent applications.

This phenomenon can further explain via the difference of structure of patent application. As it is shown in figure 2, though the percent of domestic patent applications appears a sustained growth trend and reached the maximum value 27.63 percent, but the value is lower than the 38.64 percent of utility model and 33.73 percent of appearance design. In contrast, the foreign patent applications are mainly constitute of patent for invention, which is over 80 percentages over the years. It can be also found that there is a boundary of China's percent of patent for invention, and through a development process that first decreased then rise in 1999. The boundary of China's percent of design patent and patent for utility models is 2007 and 1988. The peak value of percent of utility models is 77.64 in 1988 and decreased year by year.

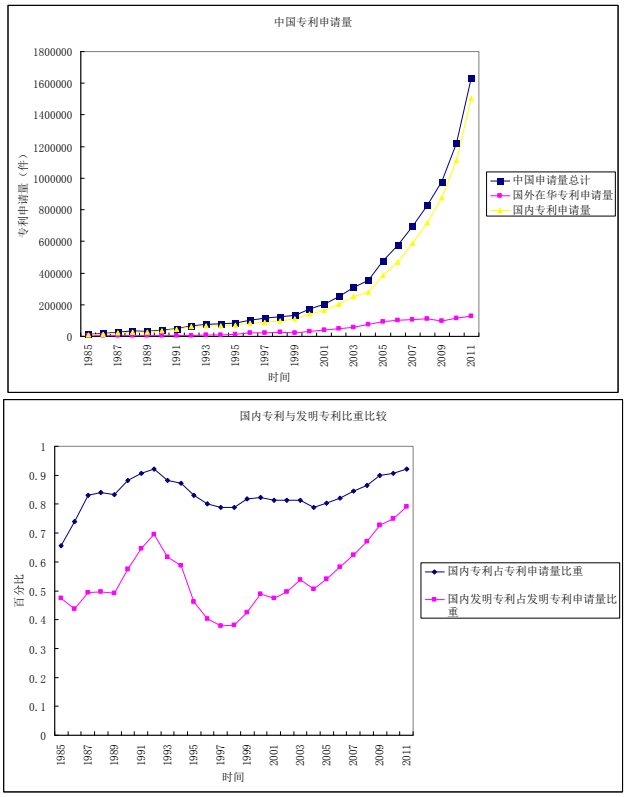

Fig.1 China's patent applications and proportion comparison of domestic patents and invention patents

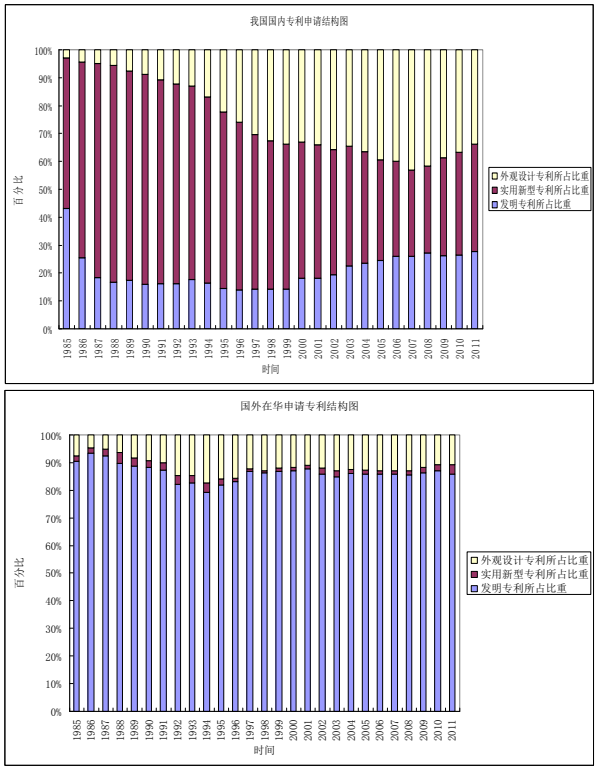

Fig.2 The composition of China's patent applications and foreign patent applications in China

Summarizes the process of China's patent application, it is observed that:

(1) The design patent increased day by day with the development of foreign trade in our country; (2) The enterprise has not yet becoming the innovation main body before the law" The central committee of the communist party of China about the reform of state-owned enterprises and the development of several major issues" in 1999.The former enterprise system is unable to fully arouse the enthusiasm of scientific research stuffs because of lacking of effective assessment and incentive mechanism. (3) Patent for utility models plays important roles in the patent application activities because of the low creative requirement and simple approval process. But with the development of economy and innovation consciousness of S&T stuffs, the percentage of patent for utility models is decrease year by year.

Generally speaking, in the progress of China's S&T development, the percent of patent for invention, which can reflect a national science and technology innovation ability, is generally lower. This illustrates that although China's science and technology innovation level gradually increase, but the real innovative products are rarely in S&T innovation activities. Both the number and quality of innovations should synchronous improve to eventually to realize our country with international innovation of science and technology innovation activities.

B. Determine the index weight of grey correlation analysis

There are lag between input and output of science and technology as is shown in a lot of scholar's outputs. Considering of the lag, this paper take invention patent applications as the characteristics of behavior sequence and mark it as Y1.And use each characteristic index as behavior sequence, take the N terms(N=0,1，…,5) delay patent applications to corresponding with the characteristic indexes. Then built the China's innovation complicities based on the patent application and give the no lag and lag for 1 to 5 stages' grey correlation results as shown in Table 2.

The table shows:

1) The grey correlation peak of total of nationwide R&D output and invention patent applications appears at lag 3 phase, which is 0.9444. This shows there is significance hysteresis effect between S&T spending and invention patent applications.
2) The R&D stuff full-time equivalent has 1 year lag phase to invention patent applications and the value is 0.9043.
3) There is no lag phase between total of nationwide of technology development, transformation and services contract and invention patent applications. And the lag phase between total of nationwide technical consultation contract and total of nationwide of technology transformation contract is 5.The maxim value of technology import contracts from abroad appears at 3 lag phase.
4) Two characteristic indexes of international trade of high-tech products and invention patent applications

appear at 2 lag phase, and the value is 0.9320 and 0.9272.

5) The lag phase between FDI and domestic invention patent applications is the same, and the peak value of grey correlation appears at 1 lag phase, which is 0.7232.

Thus, the hysteresis and index weight of each characteristic index is shown in table 3

C. The empirical study of China's regional innovation ability

Standard for the hysteresis and index weight of each characteristic indexes and select the Innovation ability corresponding to the different characteristics of indicators as shown in table 4.

This paper selected the linear weighted model to carry out the comprehensive assessment on regional innovation capability of 30 Provinces, municipalities and autonomous regions, and get the values and ranks as shown in table 5

TAB.2 THE RESULTS OF GREY RELATIONAL ANALYSIS

Characteristic Index	No lag	Lag 1 phase	Lag 2 phase	Lag 3 phase	Lag 4 phase	Lag 5 phase
Total of nationwide R&D output	0.9424	0.9424	0.8302	0.9444	0.9252	0.9186
Total of nationwide R&D full-time equivalent	0.9008	0.9043	0.7911	0.89	0.8326	0.8259
Total of nationwide of technology development contract	0.9343	0.9045	0.8173	0.8952	0.9241	0.8796
Total of nationwide technical transformation contract	0.8246	0.8004	0.7854	0.8283	0.8105	0.8894
Total of nationwide technical consultation contract	0.7556	0.7158	0.7063	0.7703	0.785	0.8598
Total of technical services contract	0.9237	0.9024	0.8094	0.893	0.9	0.8728
Technology import contracts from abroad	0.6102	0.6129	0.5973	0.6304	0.5729	0.5278
Imports of high-tech products	0.8854	0.8567	0.932	0.9291	0.9044	0.8369
Output of high-tech products	0.9006	0.8837	0.9272	0.9071	0.8876	0.8409
FDI	0.7162	0.7232	0.7083	0.7099	0.7015	0.6458

TAB.3 THE LAG AND WEIGHT INFLUENCED BY CHARACTERISTICS INDEXES

Characteristic Index	Lag	Weight	Characteristic Index	Lag	Weight
Total of nationwide R&D output	3	0.1089437	Total of technical services contract	0	0.1065558
Total of nationwide R&D full-time equivalent	1	0.1043178	Technology import contracts from abroad	3	0.0727214
Total of nationwide of technology development contract	0	0.1077786	Imports of high-tech products	2	0.1075132
Total of nationwide technical transformation contract	5	0.102599	Output of high-tech products	2	0.1069595
Total of nationwide technical consultation contract	5	0.0991844	FDI	1	0.0834266

TAB.4 THE YEAR DISTRIBUTION OF CHARACTERISTICS INDEXES CORRESPONDING TO THE INNOVATION CAPABILITY

Characteristic Index	Year	Characteristic Index	Year
Total of nationwide R&D output	2008	Total of technical services contract	2011
Total of nationwide R&D full-time equivalent	2010	Technology import contracts from abroad	2008
Total of nationwide of technology development contract	2011	Imports of high-tech products	2009
Total of nationwide technical transformation contract	2006	Output of high-tech products	2009
Total of nationwide technical consultation contract	2006	FDI	2010

TAB.5 THE COMPREHENSIVE EVALUATION VALUE AND RANKING OF REGIONAL INNOVATION CAPABILITY IN 2011

Region	comprehensive evaluation value	Ranking	Region	comprehensive evaluation value	Ranking
Guangdong	0.6297146	1	Chongqing	0.0778722	16
Beijing	0.5980362	2	Hebei	0.0738877	17
Jiangsu	0.5979341	3	Jilin	0.0637545	18
Shanghai	0.5243974	4	Heilongjiang	0.0623594	19
Shandong	0.2905265	5	Jiangxi	0.0551238	20
Zhejiang	0.2691777	6	Shanxi	0.0529707	21
Liaoning	0.2495414	7	Inner Mongolia	0.0491166	22
Tianjin	0.1961586	8	Yunnan	0.0282108	23
Sichuan	0.1239531	9	Guangxi	0.0270355	24
Henan	0.1187359	10	Gansu	0.0242908	25
Hubei	0.118377	11	Xinjiang	0.0237077	26
Fujian	0.1101856	12	Guizhou	0.0165371	27
Shanxi	0.1082198	13	Qinghai	0.0081286	28
Hunan	0.082481	14	Hainan	0.0080828	29
Anhui	0.082028	15	Ningxia	0.0047906	30

IV. CONCLUSIONS

The results of comprehensive assessment show that there is a significant regional difference. The eastern regions appear highest regional innovation capability, followed by central regions, and western appear lowest regional innovation capability. The gap between eastern, central and western regions is very large.

In this paper, the 30 Provinces, municipalities and autonomous regions are divided into four echelons, among which, the Guangdong, Beijing, Jiangsu and Shanghai is the first echelon, which have the absolute advantage on regional innovation capability. The common characteristic of the 4 regions is good economic and technological basis, high level of education, higher entrepreneurship, developed market economy, higher degree of economic development, more FDI and higher production-study-research cooperation level.

The second echelon includes Shandong, Zhejiang, Liaoning and Tianjin. These regions are mostly in the eastern coastal areas, and because of higher degree of opening, they can attract all kinds of foreign investment. Therefore, they have certain advantages on technological innovation, innovation cooperation and transfer capability. Besides, these regions obtained more national investment and policies support, which make these regions have bigger innovation advantages than other regions,

Sichuan, Henan, Hubei, Fujian, Shan'xi, Hunan, Anhui, Chongqing, Hebei, Jilin，Heilongjiang， Jiangxi，Shanxi and Inner Mongolia are the third echelon with an average level of regional innovation capability. Most of these regions are in the middle or northeast area. The geographical location is not as good as the first and second echelon but have a tremendous industrial base. Because of the enhance investment in science and technology and perfection of talent introduction policy, the innovation capability of this echelon will improve in the further future.

Other religions are forth echelon, most of which is in the western area and have an obvious disadvantage of geographical location. Meanwhile they are lagged behind other regions in funding, stuff, foreign capital absorb and innovation cooperation. Therefore, the government should enhance the regional innovation intellectual support and guarantee system construction in the aspects of to enhance investment in science and technology, to strengthen the construction of infrastructure, to increase the degree of regional development, to deepen its scientific and technological cooperation with developed areas, to give policy support on the introduction and training of personnel and establish characteristic industry chain and stimulate creativity to improve regional innovation ability.

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