Review and evaluation of the research status of science and technology innovation index

Yan Chang, Yongpeng Shi

Yan Chang, female, State Grid Energy Research Institute Co., Ltd., research direction for scientific and technological innovation and R&D, and corporate management.

Abstract: At present, technological innovation has become the most important competitiveness of a country. Starting from the scientific and technological innovation index, this paper firstly reviews the research status and evaluation criteria of science and technology innovation index at multiple levels such as the national, regional, and enterprise levels. Then the practice of the current science and technology innovation index is systematically combed and studied. Finally, on the basis of literature review and status quo, this paper reviews the current research on sci-tech innovation index, and points out that selecting appropriate index system according to different stages of economic development and different levels of sci-tech development is the foundation of constructing sci-tech innovation index.

1. Research Status of Literature on Science and Technology Innovation Index

1.1 Research Status of Science and Technology Innovation Index

From the national or regional level, scholars have conducted in-depth research on the classification of national science and technology innovation index dimension. Luis Suarez-villa (1990) considered NIS as the embodiment of innovation ability at the national level. Education and intellectual property system of a country were of great significance to the improvement of innovation ability of a country, and the level of patent was taken as an indicator to measure the development of NIS.

Niosi (1993) measured a country's innovation level from two dimensions of trade and patent data. Liu & White (2001) conducted an in-depth study on the comparison of NIS performance before and after China's reform and opening up. They selected five dimensions to construct the NIS index system: research and development, education, production, communication and final use. Based on these five dimensions, the structure-operation model was proposed, and it was concluded that structural changes had a greater impact on the change of national innovation performance. Based on the research method of OECD (1999), Chang & Shih (2004) comprehensively analyzed and compared the innovation system and operational performance of mainland China and Taiwan from six dimensions, including the formulation of technology policy, R&D implementation, R&D investment, talent development, technology transfer and entrepreneurship.

Porter & Stern put forward the measurement indexes of national innovation capacity from five dimensions, including talent equivalent, innovation policy index, innovation environment index, innovation connection index and innovation orientation index. Furman, Porter & Stern (2002) proposed the FP&S model based on the theory of national competitive advantage and from the perspective of influencing factors at the two levels of infrastructure and innovation environment. The indicators of FP&S model focused on the measurement of upstream indicators, such as accumulation of technical experience and trade openness. Hu & Mathews (2005) believed that innovation potential, sustainability...
and institutional change were of great significance to the improvement of national innovation capacity, and proposed M&J model, whose indicators focused on the measurement of downstream indicators, such as GDP, talent density, scientific and technological journals, utilization of foreign capital and market share. Porter (2002) used the research method of NIC (National innovation capacity) to rank the innovation capacity of different countries from large to small. Nasiowksi et al. (2003) studied and developed a data package analysis model, and built a fairly complete measurement system by refining and quantizing NIS indicators. Balzat (2006) proposed an NIS performance model based on the research of 18 international NIS scholars. Through six dimensions: innovation incentive, innovation ability, knowledge base, financial environment, organizational framework and internationalization degree, a total of 58 evaluation index system was composed. John et al. (2001) divided national innovation policy support into seven dimensions by comparing the innovation capacity of Eurasian countries: public research policy, research and development innovation policy, innovation support policy, innovation structure governance policy, new enterprise encouragement policy, knowledge and technology transfer policy and innovation framework construction.

In terms of domestic scholars, Wang haiyan (2001) selected 46 indicators from two perspectives of resource status and allocation capacity, as well as three levels of capital input, talent training and knowledge creation, and built a national innovation capacity indicator system. Zhang hongxing and Cheng xi (2005) constructed 64 specific indicators from four dimensions of innovation operation, innovation resources, innovation value and innovation motivation to measure national innovation capacity. Qiu junping and Niu peiyuan (2007) measured national innovation capacity from three dimensions of innovation environment, innovation resources and innovation performance. Liu fengchao and Sun yutao (2008) studied the mechanism of national innovation capability, and expounded the dynamic process of NIS construction from the perspectives of environmental capability, input capability and output capability. Ji baolong, Zhao Yanyun (2008) published by the China innovation index research report, from eight dimensions, the index of China contains 39 innovation ability evaluation index system, the eight dimensions of innovation resources, public relations ability, the radiation effect of talent, technology, innovation, value realization, the innovation coherence and social network aided innovation ability. This evaluation system was applied to the level of region, country, industry and enterprise, but the index system it built was less targeted. National innovation capability evaluation report published by development research center of China association for science and technology (2009) constructed a national innovation capability measurement index system including 21 indicators from three perspectives of innovation input, innovation output and innovation potential. Guan jiancheng (2011) evaluated the innovation performance of 21 countries with DEA method from the perspective of quantitative analysis and from the three dimensions of innovation input, innovation transformation and comprehensive process.

From the perspective of enterprises, at present, most scholars at home and abroad evaluate enterprises' scientific and technological innovation activities from the mode of input-activity-output. Li ting (2019) constructed indicators from the aspects of science and technology funds, science and technology activity personnel and innovation performance. Chen menglai (2018) combined innovation input and activities into the innovation process, and divided the scientific and technological innovation evaluation of enterprises into innovation process evaluation and innovation performance evaluation. Some other scholars, in their research on enterprise scientific and technological innovation, did not build the index system completely in accordance with the input-activity-output model, but still made appropriate increases and decreases on this basis, and the core idea of index system construction did not change substantially. For example, Hu bin et al. (2005) proposed that enterprise innovation vitality includes innovation assets, human resources, innovation organization and management, innovation performance and innovation environment. Ma chin (2018) took the three parts of sci-tech innovation resources, sci-tech innovation system and sci-tech innovation achievements as the first-level indexes when evaluating enterprise sci-tech innovation index. Liao kaiji and Yi cong yuan (2010) constructed an evaluation system from five perspectives of innovation management ability, innovation research
and development ability, innovation production ability, innovation marketing ability and social benefit through TRIZ theory research.

In addition, some scholars reduced or modified the indexes in the input-activity-output model according to the actual situation, so as to establish a more objective and realistic index system. For example, Xu guangwei and Chen shuyi (2015) proposed ways to improve enterprises' scientific and technological innovation ability based on complementary assets, innovation environment and information exchange based on the analysis of the current situation of input and output of Chinese enterprises' scientific and technological innovation. Zhou huilai and Li li (2007) designed the index system as two major parts: science and technology input capacity and science and technology output capacity, and omitted the consideration of science and technology activity capacity. Chang youling and Chang youxin (2010) replaced the output index in the input-activity-output model with the environmental protection index, and added the evaluation index of scientific and technological awareness ability. Finally, the evaluation index was divided into four categories: scientific and technological input ability, scientific and technological activity ability, scientific and technological environmental factors, and scientific and technological awareness level.

Some scholars believed that the input-activity-output model is not omnipotent. Kong Xiangdou (2018) put forward three levels of design target, criterion and indicator layers when evaluating Shanghai's scientific and technological innovation ability, and selected innovative input ability, innovation implementation ability, innovative marketing ability, innovation management ability and environment supporting indicators and other indicators to build an evaluation index system for enterprise innovation capabilities.

Some scholars also proposed suggestions for enterprises to construct scientific and technological innovation evaluation system from different perspectives. David W. brechall and George Tovstiga (2006) put forward five dimensions to evaluate the ability of scientific and technological innovation according to the main purpose of enterprises at present: future focus, market influence, capability and image, process, sustainability and overall effectiveness. V Dewangan and M Gose (2014) proposed that enterprises need a process-based evaluation program of scientific and technological innovation capability. They believed that the difference between development and discovery should be emphasized in the evaluation program and this should be taken as the guiding principle of evaluation index of scientific and technological innovation capability. Chen jin (2017) et al. reorganized the connotation of enterprise technological innovation capability by systematically reviewing relevant literature, and proposed a brand new enterprise technological innovation capability evaluation system composed of problem-driven, thinking about the future, diversified knowledge and other dimensions from the perspective of knowledge management to value creation.

1.2 Summary of current status of scientific and technological innovation index
In October 2001, the European Commission launched the "European innovation scoreboard" to quantitatively compare the innovation performance of EU member states, which used the United States and Japan as benchmarks to analyze the strengths and weaknesses of EU countries. In the EU Innovation Index Report (2008), the innovation index consisted of three indicators: innovation-driven, corporate innovation behavior and innovation output. EIS measured the comprehensive performance of innovation input and innovation output from countries in terms of innovation performance. In 2002, Jeffrey L Furman, Porter and Stern jointly published the article "Determinants of National Innovation Capabilities". Based on theories of thought-driven growth, national competitive advantage models, and national innovation systems, this article defined the connotation of national innovation capability and established a general mathematical model of the interrelationship between the elements of national innovation capability. According to the study, the national innovation capability indicator system included a total of 20 secondary indicators. The first-level indicators included innovation output, quality of public innovation infrastructure, innovation environment of specific industrial clusters, quality of innovation linkages, and innovation output. Based on data from 1973-1995, Freeman calculated the innovation capability index for each year of the OECD17 countries. The Robert
Huggins Association of the United Kingdom released the Global Knowledge Competitiveness Index (WKCI), which proposed a theoretical framework and model for assessing regional knowledge competitiveness centered on major cities around the world, and selected major cities (circles) in the world as assessment targets. Then, the knowledge competitiveness indices of these regions are ranked accordingly. In 2005, the WKCI report evaluation index system consisted of five modules: human capital, intellectual capital, financial capital, regional economic output and knowledge sustainability, which was a measure of knowledge innovation capability.

The Index of Silicon Valley is used to evaluate the overall development of Silicon Valley, which is released annually by Silicon Valley specialized agencies. The Silicon Valley Index (2010) included 16 indicators in five aspects: population, economy, society, space and management. The number of patents, gazelle enterprises and venture capital were three important indicators reflecting the innovation ability of Silicon Valley, and others belonged to social and economic development index indicator. The Silicon Valley Index can only be compared vertically with its own annual indices. The silicon valley index can only be compared longitudinally with its own annual index. The evaluation of silicon valley is mainly from the perspective of technological innovation and patents, and the number of venture capital and public companies, as well as the number of individual companies that have reached a certain scale and maintained rapid growth for four consecutive years. The silicon valley index focuses on the evaluation of specific micro data, and advocates the measurement from the perspective of maintaining the continuous competitive advantage of enterprises. As the first index in China to reflect the development of regional high-tech, the “Zhongguancun Index” mainly describes and evaluates the development status, development level and trend of high-tech industries in Beijing, and focus on the judgment of macro data. The “Zhongguancun Index” is conducive to analyzing the main factors affecting the development of Beijing's high-tech industry, monitoring the development and changes in different fields, and facilitating the timely and comprehensive grasp of the development trend of high-tech enterprises in Beijing. The Zhongguancun Index's indicator system “Zhongguancun Index” includes Zhongdiancun Science Park Haidian Park, Fengtai Park, Changping Park, Electronic City Science and Technology Park, Yizhuang Science and Technology Park, Desheng Science and Technology Park (Jianxiang Park has no data). All of the more than 14,000 high-tech enterprises accounted for more than 90% of the city's high-tech enterprises, which had a certain representativeness. It consists of five sub-indexes, namely the economic growth index, the economic benefit index, the technological innovation index, the human capital index and the enterprise development index. Each sub-index is composed of three indicators, totaling 15 indicators.

In general, the evaluation of national innovation capabilities is shown in Table 1:

| Serial number | name | Publishing organization | Starting year | Release cycle | Evaluation object | Evaluation dimension |
|---------------|------|------------------------|--------------|--------------|------------------|----------------------|
| 1             | Global innovation index(GIH) | Cornell University, World Intellectual Property Organization, European Business School | 2007 | Two year | More than 100 countries and regions | Institutional environment, human capital, infrastructure, market maturity, business maturity, innovation output |
| 2             | European Innovation Alliance Scoreboard (EIS—IUS) | European Innovation Policy Research Center | 2007 | One year | National innovation investment capacity and enterprise activities examine the input and output of innovation subjects from | Innovation driving factors, corporate activities, innovation output |

Table 1. National Innovation Capability Evaluation Indicator
From the perspective of enterprises, there are four relatively mature evaluation methods for innovation capability at home and abroad. From the following table, it can be clearly seen that the name, issuing institution, starting year, evaluation cycle and evaluation object of the evaluation methods have their own characteristics, wide application and great influence. As shown in table 2:

Table 2. Enterprise innovation ability evaluation index

| Serial number | Name                                      | Publishing organization                                         | Starting year | Release cycle | Evaluation object                 | Evaluation dimension                                                                 |
|---------------|-------------------------------------------|----------------------------------------------------------------|---------------|---------------|-----------------------------------|---------------------------------------------------------------------------------------|
| 1             | European industry R&D investment, R&D scorecard | EU                                                             | 2004          | One year      | Global enterprise                 | R&D investment, net sales income, capital expenditure, operating profit, total number of employees, market value |
| 2             | Global Top 100 Innovative Organizations    | Corey Wein (Thomson Reuters)                                    | 2011          | One year      | Global enterprise                 | Factors such as R&D strength, intellectual property protection and business success, and the selection of the most innovative institutions in the world |
| 3             | China Enterprise Innovation Capability Evaluation Report | Technology, China Academy of Science and                        | 2014          | One year      | Chinese company                  | Innovative input capability, collaborative innovation capability, |
2. Summary of the Evaluation of Science and Technology Innovation Index

Although foreign scholars have done a lot of research on the constituent dimension of scientific and technological innovation evaluation, there is no recognized and fixed constituent dimension at present. As Porter&Stern (2002) said, only certain types of innovation could be measured, and it was difficult to achieve a perfect state of innovation measurement. Freeman&Sotete (2009) also believed that it was difficult to determine the measure of innovation indicators. Grupp&Schubert (2010) and Porter&Stern (2002) pointed out the limitations of innovation index measurement and introduced radar map to make up for the defects of innovation index measurement. Therefore, if an enterprise chose the index of scientific and technological innovation, it needed to consider the characteristics of the enterprise, the development of science and technology in the industry and the development environment of the enterprise.

When measuring the science and technology innovation index, it is measured and elaborated from a macro perspective. However, it is difficult to unify the standard for the measurement of the enterprise. Otherwise, there is no authoritative organization to establish an authoritative evaluation report on the enterprise science and technology innovation index. As we are familiar with the brand 100 and Fortune 500, which is the authoritative and widely recognized evaluation system, the establishment of the enterprise science and technology innovation evaluation index system needs to be actively promoted by all parties.

At the same time, how to choose scientific and technological innovation index evaluation method is also a very important step. Although there are many ways to solve the evaluation of enterprise science and technology innovation index at present, such as linear method, nonlinear method and so on, the specific selection needs to start from the characteristics of the index to select the appropriate method. For example, the evaluation method of scientific and technological innovation index adopts the fuzzy comprehensive evaluation method to solve the problems of multiple indexes and attributes including qualitative and quantitative indexes in the evaluation system of enterprise independent innovation capability, and the problems of the uncertainty and fuzziness in the evaluation indexes. Based on the principle of fuzzy relation, some factors with unclear boundary and difficult to be quantified in the evaluation of enterprise independent innovation are quantified, so as to realize the comprehensive evaluation of enterprise independent innovation ability. For example, data envelopment analysis takes the weights of input and output of decision making units as variables, avoiding the determination of weights of each index in the sense of priority. It is highly objective and has a very good effect in solving the evaluation of quantitative indicators.

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