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# Evaluation of regional innovation ability based on green and low-carbon perspective

H. Wang*, L. An, X. Zhang

*School of Economics & Management, Northwest University, 710127, Shaanxi xi'an. China*

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The aim of this paper is to evaluate the green innovation ability in China. The paper attempted to construct an index system from the three aspects of green innovation and used FAHP to evaluate the innovation ability. The evaluation result of the innovation input and output ability is "general", but the result of innovation environment is "poor ". Thus, countries and regions should pay more attention to the environment and energy factors in innovation in future.

**Key words:** Green innovation, Innovation ability, Evaluation, Innovation input, Innovation output, Innovation environment

## INTRODUCTION

Global climate change is becoming increasingly serious, coupled with the global financial crisis. Since 2008, the world began to seek for green and low-carbon economic development mode, to actively change the traditional mode of economic growth, and make a transition from extensive to intensive and green. In 1999, the World Watch Institute pointed out that both industrialized countries and developing countries must take a long-term development strategy to take an ecological road and promote eco-technological innovation. In recent years, China experienced sustained and rapid economic growth partly at the expense of resource and environment. Air pollution in the Beijing Tianjin Hebei region, the Pearl River Delta and Yangtze River Delta have aroused great concern. The phenomenon of atmospheric haze is prominent and the main pollutant emissions exceed the environment capacity. Environmental problems have become some of the most important threats to human health, public safety and social stability. Economic growth means environment damage. Facing the double pressure of resource waste and environment pollution, Chinese government made a "12$^{th}$ Five-Year plan" putting forward the development concept of energy conservation, emissions reduction, green, low-carbon, promoted resource-saving and environment friendly way of production and consumption and encouraged innovation development strategy and green technology to change the ecological environment and promote China economy towards a healthy and sustainable development road.

Recently, scientific and technologic innovation and environmental crisis consciousness of Chinese government constantly increased resources investment in science and technology innovation. We hope to keep growing the scientific and technologic innovation output, at the same time focussing the attention to environmental protection in order to promote energy conservation and emissions reduction. Some ways such as electric cars, shared cycling, single and double restrictions, etc., have been implemented. Green innovation activity has certain achievements, but there is disparity in comparison with the developed countries's green innovation ability. Trying to find the main factors which influence the innovation ability and measuring region innovation ability have become the major concern in China. According to the main factors that affect the innovation ability, recent research hopes to find a path to promote China's innovation ability, improve the ecological environment, and promote the development of a green innovation process. The evaluation of China region innovation ability and the factors which influence it is practical as a guideline.

## REVIEW

The combination of environment and innovation has become a new hot research spot. So green innovation, also known as ecological environment innovation and sustainable innovation has gradually aroused the attention of scholars. Kemp *et al.* defined green innovation as a new technology or new products to avoid or reduce the damage to the environment [1]. Based on the concept of green innovation, Brunnermeier *et al.* found through analysis of factors influencing environment innovation with econometric models that increasing pollution expenditures affected green innovation [2]. An empirical study of the SEM model used by Chiou *et al.* pointed out that green innovation has a significant effect on environment performance and competitive advantage [3]. Because China is on an upswing of economic and social development based on the traditional innovation theory, introducing green ecological concepts, promoting technology innovation activities can lead to a low-carbon economy, green ecological road, and then enhance China's innovation ability, and reduce environment load.

Research on the evaluation of the innovation

To whom all correspondence should be sent:
E-mail: 165253617@qq.com

 

ability from green low-carbon perspective is still scarce, the majority concentrated on construction of an evaluation index system of innovation ability. Tang and Jiang summarized the research results of the innovation ability evaluation of the final results from three aspects such as evaluation principles, evaluation index system and evaluation index system method [4]. Wei and Han defined the concept and structure of innovation ability, put forward the relevant elements of innovation ability, analyzed the role and impact of different elements of innovation, and pointed out that combining all kinds of elements can achieve sustainable technology innovation [5].

Many attempts have been made to design an evaluation method of innovation ability. Xu *et al.* used a mathematical model of fuzzy comprehensive evaluation to discuss the general program evaluation of innovation ability. The method was scientific, standardized and quantified [6]. Cao and Wang discussed the innovation ability from seven aspects, designed a corresponding index system to correspond to each ability, and gave an explanation to each sub-index connotation [7]. Dong and Fu believed that we must analyze the connotation of innovation ability, follow the design principle of innovation ability evaluation index system, and construct a corresponding evaluation index system. On this basis, Delphy method and multilevel fuzzy comprehensive evaluation method were used to establish a specific evaluation model, so as to provide an operable management analysis tool for the research of innovation ability[8]. Han and Pang searched for a method through all input, output and process features to directly measure the innovation ability. They designed a set of precise evaluation index systems using a fuzzy mathematic method. At last, that research got good results by empirical calculation [9].

Based on previous research, the evaluation of innovation ability on green and low-carbon perspective, needs to develop a set of index systems including input/output of general innovative activities, energy and environment. The evaluation index system can measure the innovation ability based on the green and low-carbon perspective in line with the actual needs of economic and social development.

## EVALUATION METHOD

### *Evaluation index*

From the green and low-carbon point of view, the innovation ability index system should include innovation input, innovation output and innovation environment considering energy and environment conditions[10,11]. According to the observability and comparability of the evaluation index system [12], this paper will cover green innovation input, green innovation output and green innovation environment to construct a regional innovation ability evaluation index system for a certain period of time.

Innovation input is the basic prerequisite for enterprises to carry out technological innovation activities, including resource input and personnel input innovation. R&D personnel and innovation team as the key carrier of tacit knowledge transfer, is an important force to carry out technology innovation [13]. The continuous introduction and cultivation of innovative talents requires adequate financial support. Advanced instruments and equipment provide a guarantee for continuous development of technological innovation activities, and can effectively promote the output of innovative achievements.

Innovation output includes new invention, new technology and new product produced by an area, which can effectively promote social progress, improve work efficiency, or make people's life more convenient [14]. Some potential scientific and technological achievements are also included. Of course, the emergence of technical service undertaking for scientific, technological research is the prerequisite for new products, new technologies and new inventions.

Innovation environment provides an effective guarantee for the cultivation and promotion of regional innovation capability [15]. At the same time, innovation also has a profound impact on the environment and resources. Green innovation advocates the creation of new products, new technologies which do not destroy the natural resources and environment. Specific indicators are embodied in the following.

### *Fuzzy AHP comprehensive evaluation*

X indicates the first level index, and $X_i$ is used as evaluation index i. The evaluation indices are set X={X1, X2, X3}. Innovation input is X1, innovation output X2, innovation environment $X_3$. $X_{ij}$={$X_{i1}$, $X_{i2}$, . . . $X_{ik}$}, i=1, 2, 3, j=1, 2, . . . K. The second-level indicators belong to first-level index.

Use V to denote the hierarchy collection, V={$V_1$, $V_2$, . . . $V_P$}, each level corresponds to a fuzzy subset. If p is too large, it is difficult to describe the attribution of the class. If p is too small, the evaluation is rough and it is difficult to guarantee the quality of evaluation. This article uses 5 levels of evaluation, that is, p=5, the corresponding rating for {very good, good, general, poor, very poor}.

Generally speaking, each index in an evaluation index system is not equally important, and their effects on the evaluation results are different. Therefore, before synthesizing, the weights of each index should be determined, and the weight is the variable of a certain index in the total evaluation index system, which represents the contribution degree of the index to the overall evaluation system. Here, the weight is the weight vector, expressed by $\omega$.

A fuzzy judgment matrix is established to determine the relative importance of the elements. According to the fuzzy judgment scale, the fuzzy judgment matrix is judged by the expert as shown in Table 1.

**Table 1** Fuzzy judgment matrix

| X | $X_1$ | $X_2$ | $X_3$ |
|---|---|---|---|
| $X_1$ | 0.5 | 0.4 | 0.7 |
| $X_2$ | 0.6 | 0.5 | 0.6 |
| $X_3$ | 0.3 | 0.4 | 0.5 |

The fuzzy judgment matrix then is transformed into fuzzy consistent matrix. The fuzzy consistent matrices of $X_1$, $X_2$ and $X_3$ are obtained. Then continue to calculate the relative weight as shown in Tables 2 and 3.

**Table 2.** Weight of first-level indicators

| First-level indicators | Weight |
|---|---|
| Innovation input ($X_1$) | 0.32 |
| Innovation output ($X_2$) | 0.31 |
| Innovation environment($X_3$) | 0.37 |

According to the calculation method described in the preceding section, the membership degree of qualitative and quantitative indexes is calculated respectively.

**Table 3.** Weight of second-level indicators

| Second-level indicators | Weight |
|---|---|
| Number of professional and technical personnel per 10000 persons ($X_{11}$) | 0.23 |
| Total number of R&D personnel ($X_{12}$) | 0.19 |
| Technology developers accounted for the proportion of employees ($X_{13}$) | 0.24 |
| Funding for scientific and technological activities ($X_{14}$) | 0.19 |
| Proportion of technological development funds in product sales revenue ($X_{15}$) | 0.16 |
| Patent grant ($X_{21}$) | 0.23 |
| Proportion of added value of scientific research and comprehensive technical services ($X_{22}$) | 0.18 |
| Technology market turnover ($X_{23}$) | 0.19 |
| Proportion of output value of new products in total industrial output value ($X_{24}$) | 0.24 |
| Collected papers ($X_{25}$) | 0.16 |
| Environment pollution index ($X_{31}$) | 0.35 |
| Comprehensive energy consumption output rate ($X_{32}$) | 0.37 |
| Government policy, innovation, support ($X_{33}$) | 0.28 |

*Membership degree of the evaluation index*

Taking the index of "government policy innovation support strength" as an example, the membership degree of qualitative index is calculated. Because of the fuzziness of qualitative indices, 10 experts were invited to participate in the evaluation of the survey. Take the quantitative indicators of "the amount of funding for science and technology activities" as an example. The average amount of funding value is 317, the highest is 446, and the lowest is 106. The difference will be divided into 5 regions: (106, 174) (174, 242) (242, 310) (310, 378) (378, 446). This index's membership degree "very good" is 0, "good" is 0.11, "general" is 0.89, "poor" and "very poor" is 0.Other statistics are shown in Table 4.

**Table 4** Membership degree

| Indic-ators | Grade | | | | |
|---|---|---|---|---|---|
| | Very good | Good | General | Poor | Very poor |
| $X_{11}$ | 0 | 0 | 0.48 | 0.52 | 0 |
| $X_{12}$ | 0 | 0 | 0.16 | 0.84 | 0 |
| $X_{13}$ | 0 | 0.19 | 0.81 | 0 | 0 |
| $X_{14}$ | 0 | 0.11 | 0.89 | 0 | 0 |
| $X_{15}$ | 0 | 0.25 | 0.75 | 0. | 0 |
| $X_{21}$ | 0 | 0.43 | 0.57 | 0 | 0 |
| $X_{22}$ | 0 | 0.32 | 0.68 | 0 | 0 |
| $X_{23}$ | 0 | 0 | 0.67 | 0.33 | 0 |
| $X_{24}$ | 0 | 0.46 | 0.54 | 0 | 0 |
| $X_{25}$ | 0 | 0 | 0.64 | 0.36 | 0 |
| $X_{31}$ | 0 | 0 | 0 | 0.48 | 0.52 |
| $X_{32}$ | 0 | 0 | 0 | 0.57 | 0.43 |
| $X_{33}$ | 0.2 | 0.6 | 0.2 | 0 | 0 |

Thus, the membership matrix of the first-level index can be obtained.

$$\begin{pmatrix} & & 0 & 0 & 0.48 & 0.52 & 0 \\ & & 0 & 0 & 0.16 & 0.84 & 0 \\ PX1 & = & 0 & 0.19 & 0.81 & 0 & 0 \\ & & 0 & 0.11 & 0.89 & 0 & 0 \\ & & 0 & 0.25 & 0.75 & 0 & 0 \end{pmatrix}$$

The other first-level index subordinate degree matrix can also be obtained. As a result, the comprehensive evaluation result vector of innovation input: $Zx_1=\omega_{X1}\times P_{X1}=$ (0, 0.10, 0.62, 0.28, 0); the comprehensive evaluation result vector of innovation output: $Zx_2=\omega_{X2}\times P_{X2}=$ (0, 0.27, 0.61, 0.12, 0); the comprehensive evaluation result vector of innovation environment: $Zx_3=\omega_{X3}\times P_{X3}=$ (0.055, 0.17, 0.055, 0.38, 0.34).

Corresponding to the maximum membership degree of the evaluation results, the grade of the maximum membership degree is the tendency grade of the evaluation result. The maximum membership degree is valid in principle through the validity test.

## RESULTS AND DISCUSSION

This paper used FAHP to evaluate the regional green innovation ability in China. The final result is that innovation input ability and innovation output ability are "general", while innovation environment is "poor". This conclusion is basically consistent with the reality of China's innovation. In the past, the whole society had been pursuing economic growth excessively, while ignoring the environment. In recent years, people have been fully aware that innovation cannot be achieved at the expense of environment and waste of energy. Sustainable economic and social development can be achieved only by making full use of green resources and creating new technologies to conserve energy.

## CONCLUSION

Research on innovation capability, especially green innovation ability, is designed with many different research indicators and research methods. In this paper, the selection of indicators and methods should be further studied to be more scientific and practical. With regard to future research, The authors hope that there will be more research on green innovation, and also hope to make a breakthrough in the construction of a green innovation ability index system and methods.

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