An Empirical Study on Industrial Innovation Ecosystem Niche Fitness
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Abstract. At present, China's economy is in the key period of deepening the structural reform of the supply side and accelerating the process of new and old kinetic energy conversion. The development of the new industry and the transformation and upgrading of the traditional industries should be in accordance with the economic laws. Based on the theory of Niche Fitness, the study on current situation and trend of the industrial innovation ecosystem, which can optimize the allocation of demand, supply and environment in the industrial innovation ecosystem, strengthen the competition and cooperation relationship among the innovators in the industrial innovation ecosystem, and improve the horizontal competitiveness and longitudinal influence of the innovative ecosystem. Taking Shandong Province as an example, the niche fitness of the industrial innovation ecosystem of 6 high-tech manufacturing industries is calculated. On this basis, the suggestions are provided for the optimization and upgrading of the industrial innovation ecosystem and the development and expansion of the “ten strong” industrial clusters in the process of the transformation of new and old kinetic energy.

Literature Review

The internal subsystems of industrial innovation ecosystem need certain rules or institutional arrangements to form an orderly structure, so that qualitative change can produce synergistic effects. This process is the process of gradual formation and overall promotion of industrial innovation ecosystem[1]. Niche refers to the position of species in the community and ecosystem and their function in the ecological community, which reflects the relationship between biological species and the environment. Niche theory is an effective theory to study the competition, cooperation and evolution of biological communities in the ecosystem. It is one of the most important theories in modern ecology. It has been widely used in the fields of innovation and development, regional coordination, enterprise competition and so on. According to the niche theory, the innovation subject in the similar niche within the industry must cooperate with the external environment, standardize the development in the industrial community according to the upstream and downstream requirements, jointly divide limited resources, exchange material, energy and information with each other [2], and carry out competition and cooperation.

In recent years, in order to study the evolution of competition and cooperation among innovation subjects in innovation ecosystem, some scholars began to introduce niche fitness model for evaluation and improvement of innovation ecosystem, mainly focusing on regional or annual comparison of innovation ecosystem. Qin Lili constructed a comprehensive niche fitness model, and evaluated the sustainability of regional innovation ecosystem[3]. Liu Hongjiu quantitatively analyzed the relationship between fitness of regional innovation ecosystem and economic development[4]. Chen Linxing applied niche theory to the evaluation of regional technology innovation environment Fifteen sub-provincial cities in China were empirically analyzed, and the comparability and reliability of the evaluation results were achieved[5].

Niche fitness of industrial innovation ecosystem refers to the degree of closeness between the optimal resource niche required by the innovation subject and the real resource niche provided by the environment when the innovation subject is carrying out innovation activities inside and outside the industry. Its mathematical and physical evaluation can accurately reflect the interaction between the
innovation ecological factors and the resources and environment. It can accurately reflect the niche fitness indicators such as resource possession, survivability and development ability of the innovative subjects within the industry, help to formulate appropriate industrial evolution strategies, and seek the evolutionary path with the least resistance for the transformation and upgrading of traditional industries and the accelerated development of emerging industries. On the basis of existing research, this paper constructs an evaluation model of niche fitness of industrial innovation ecosystem, analyzes niche fitness of industrial innovation ecosystem from three aspects of demand, supply and environmental factors, and provides theoretical basis for promoting the development of leading industrial clusters from the perspective of innovation competitiveness, and then puts forward industry optimizing and perfecting countermeasures of innovative ecosystem, providing suggestions for industrial innovation and development in the process of new and old kinetic energy conversion. The model can also provide a basis for comparative study on niche fitness of industrial innovation ecosystems at regional or national levels.

Model Building

According to the current literature on industrial innovation ecosystem and considering the reality of data acquisition, this paper chooses three kinds of factor indicators to represent the comprehensive niche of industrial innovation ecosystem, including supply niche, demand niche and environmental niche. Supply niche elements refer to the supply capacity of technological innovation within an industry, which covers the amount of input from capital, personnel and market-oriented new product development, and belongs to the driving force in the industrial innovation ecosystem. Demand niche elements refer to the external demand for innovative products of the industry, representing the market demand for new products of the industry, which is the driving force in the industrial innovation ecosystem. Environmental niche elements refer to the environmental factors that affect the industrial innovation ecosystem, such as the government's investment in R&D, which represents the government's support to the industry, R&D expenditure on domestic research institutions and universities respectively represents the domestic research institutions full demand for industrial technology innovation and basic innovation, R&D expenditure represents the degree of open competition of industries, and also represents the intensity of demand for technology innovation, especially basic innovation.

Suppose there are m industries in a certain region, and each industry has n influencing factors of niche fitness of industrial innovation ecosystem, then \( S_{ij} (i = 1,2,3,..., m, j=1,2,3,..., n) \) denotes the i industry, the actual observed value on the j ecological factor, and the observed value of different industries constitutes n-dimensional ecological vector \( S_j=(S_{i1}, S_{i2}, S_{i3},..., S_{in}) \). Different combinations of ecological factors become the supply, demand and environmental factors of industrial innovation ecosystem, which together describe the niche fitness of industrial innovation ecosystem.

Normalization of Indicators

Because the index units of ecological factors are different, the influence of dimension should be eliminated. The data should be normalized by the formula \( S_{ij}'=(S_{ij}-S_{jmin})/(S_{jmax}-S_{jmin}) \). Among them, \( S_{ij} \) represents the variable, \( S_{jmin} \) represents the minimum value of the j ecological factor sequence, and \( S_{jmax} \) represents the maximum value of the j ecological factor sequence.

Niche Fitness Measurement Model

Assuming that the optimal niche of ecological factors is \( S_{aj} \), \( S_{ij}' \) represents the actual niche of the j ecological factor, and \( S_{aj} \) represents the optimal niche of the j ecological factor, \( S_{aj}=\text{MAX}(S_{ij}') \) can be expressed by a formula.

The niche fitness measurement model of industrial innovation ecosystem is constructed.

\[
NF_i = \sum_{j=1}^{n} \phi_j \frac{\min[|S_{ij}'-S_{aj}|]+\epsilon \max[|S_{ij}'-S_{aj}|]}{|S_{ij}'-S_{aj}|+\epsilon \max[|S_{ij}'-S_{aj}|]},
\]
In the above formula, \( NF_i \) represents the niche fitness of the first industrial innovation ecosystem. In the formula, the parameter is represented by \( \varepsilon \), and the weight of the \( j \) ecological factor is expressed by \( \phi_j \), which reflects the importance of the ecological factor in the innovative ecosystem. The value of \( \phi_j \) is determined by entropy weight method.

**Determination of Parameter \( \varepsilon \) of Niche Fitness Measurement Model**

The size of \( \varepsilon \) is generally determined by \( NF_i = 0.5 \). The following calculation procedure is used to obtain: 
\[
T_{ij} = |S_{ij}' - S_{aj}| \quad (i=1,2,3,..., m, \ j=1,2,3,..., n).
\]
\[
T_{\text{max}} = \max\{T_{ij}\}, \ T_{\text{min}} = \min\{T_{ij}\}.
\]
When \( T_{ij} = \overline{T_{ij}}, \ NF_i = 0.5, \overline{T_{ij}} = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} T_{ij} \),

The result is:
\[
\varepsilon = \frac{T_{\text{ij}} - 2T_{\text{min}}}{T_{\text{max}}}. \tag{2}
\]

**Determination of Parameter \( \phi_j \) of Niche Fitness Measurement Model**

After standardized data processing, the weight of each evaluation index \( \phi_j \) is determined by entropy weight method.

\[
\phi_j = \frac{(1 - E_j)}{\sum_{j=1}^{n} (1 - E_j)} \tag{3}
\]

In the formula, \( E_j = - \frac{1}{\ln m} \sum_{i=1}^{m} p_{ij}\ln p_{ij}, \ j = 1,2,3,\cdots n, \ p_{ij} = \frac{S_{ij}'}{\sum_{i=1}^{m} S_{ij}'} \).

**Calculation of Evolutionary Momentum**

Evolutionary momentum denotes the intensity of the adaptive effect of the real niche of an industrial innovation ecosystem on its optimal niche. The greater the evolutionary momentum, the greater the gap between the actual niche and the optimal niche, and the stronger the role of its adaptation, and vice versa.

\[
EM_i = \sqrt{\frac{\sum_{j=1}^{n} T_{ij}}{n}}, \ i = 1,2,3,\cdots m, j = 1,2,3,\cdots n. \tag{4}
\]

Based on six high-tech manufacturing industries in Shandong Province, this paper selects the ecological factors of supply, demand and environmental niche elements which constitute the industrial innovation ecosystem as the relevant indicators to conduct an empirical study on the industrial innovation ecosystem and optimize the demand in the industrial innovation ecosystem. The allocation of factors such as supply and environment should be strengthened to strengthen the competition and cooperation among the innovation subjects in the industrial innovation ecosystem, and to enhance the horizontal and vertical competitiveness of the industrial innovation ecosystem.

**Index Selection and Model Calculation of High-tech Manufacturing Industry in Shandong**

**Index Selection**

Based on the data of Industrial Enterprises above the scale of 2015 in Shandong Statistical Yearbook, this paper compares the industrial innovation ecosystems of six high-tech manufacturing industries in Shandong Province. The selected statistical data are divided into three categories, namely, supply, demand and environmental factors, with 8 items in total. The market value of the representative enterprises is the largest listed company in Shandong Province. It shows that the financing ability and market recognition of the industry in the open market are shown in Table 1.

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Table 1. Evaluation index system of industrial innovation ecosystem.

| First level index       | Second level index                                      |
|-------------------------|--------------------------------------------------------|
| Supply niche elements   | R&D personnel equivalent to full time (person year)    |
|                         | R&D expenditure internal expenditure (10000 yuan)      |
|                         | Expenditure on new product development (10000 yuan)    |
| Demand niche elements   | Number of patent applications (pieces)                  |
|                         | Number of new product development projects (item)      |
| Environmental niche     | Market value of representing enterprises (100 million yuan) |
| elements                | Possession of invention patent (pieces)                |
|                         | Number of enterprises with R&D activity                |

Model Calculation and Results

According to the formula of niche fitness model of industrial innovation ecosystem (1) - (4), the supply, demand, environmental and comprehensive niche fitness and evolutionary momentum of industrial innovation ecosystem in six industries of high-tech manufacturing in Shandong Province were calculated, as shown in Table 2. The results show that the industries with niche fitness above 0.5 are pharmaceutical manufacturing, electronic and communication equipment manufacturing, computer and office equipment manufacturing. Compared with the other three industries, they have stronger innovation competitiveness.

Table 2. Niche fitness data table of Shandong's high-tech manufacturing innovation ecosystem.

| High-tech manufacturing industry | Supply niche fitness | Demand niche fitness | Environmental niche fitness | Comprehensive niche fitness | Evolutionary momentum |
|----------------------------------|----------------------|----------------------|-----------------------------|----------------------------|-----------------------|
| Pharmaceutical manufacturing industry | 1                    | 0.935                | 0.935                       | 0.943                      | 0.080                 |
| Aviation, spacecraft and equipment manufacturing industry | 0.824                | 0.842                | 0.419                       | 0.374                      | 0.991                 |
| Electronic and communication equipment manufacturing industry | 0.873                | 0.950                | 0.710                       | 0.716                      | 0.255                 |
| Computer and office equipment manufacturing industry | 0.784                | 0.886                | 0.514                       | 0.521                      | 0.584                 |
| Medical equipment and instrument manufacturing industry | 0.813                | 0.867                | 0.477                       | 0.477                      | 0.673                 |
| Information chemicals manufacturing industry | 0.825                | 0.845                | 0.436                       | 0.379                      | 0.974                 |

Analysis of Results

According to the analysis, the most influential index on the comprehensive niche fitness is the environmental niche fitness, which represents the industry's development stamina on the whole. The representative enterprises are the key elements of the industrial innovation ecosystem, and the number of enterprises with R&D activities represents the innovation activity of the industry's ecosystem. The number of invention patents is the basis for new product development to meet market demand. In addition to the second place in demand niche fitness, supply, environment and comprehensive niche fitness of pharmaceutical manufacturing industry ranked the first place. Its comprehensive technical supply strength is strong, market financing ability and the overall level of industrial scientific research input is high. Contrary to pharmaceutical manufacturing industry, the supply and environment of electronic and communication equipment manufacturing industry are relatively high. The niche fitness of environment and comprehensive niche was in the second place, but the niche fitness of demand was in the first place. The market accepted the new product R&D ability of this industry highly. Informational chemicals manufacturing industry is an important branch of the new generation of information technology industry. Its environmental niche fitness is low, but the supply niche fitness is high, and the momentum of evolution is as high as 0.974. The follow-up development has a strong role in fitness. Aerospace, spacecraft and equipment manufacturing industries are relatively backward in all indicators, should be combined with the development of Shandong high-end equipment manufacturing industry, vigorously introduce related enterprises or enhance enterprise R&D capacity and patent ownership.
Conclusions and Countermeasures

Combined with the calculation results, this paper puts forward the following countermeasures and suggestions in order to improve the industrial innovation ecosystem in high-tech industries and accelerate the implementation of “chain building, chain expansion, chain supplement and chain strengthening”.

Shandong’s traditional superior industries, especially the high-end chemical and pharmaceutical industries, should cooperate with the development of modern service industries such as R&D, finance and productive service industries, and realize the high-end links from primary production processing to comprehensive deep processing, brand marketing, technological innovation, capital extension and basic research by improving the industrial innovation system. Transformation makes the development of single industry into a strong industrial cluster with strong innovation ability. Under the conditions of technological revolution and industrial transformation, Shandong needs to seize the opportunity to introduce, upgrade or build new emerging industries. On the basis of existing industries, it is possible and necessary to develop and strengthen new industrial clusters by improving the industrial innovation ecosystem. Shandong traditional disadvantaged industries have a large number and scattered distribution. It is necessary to accelerate the technology spillover effect through park entry, agglomeration development and cluster upgrade, so as to achieve green development and innovative development.

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