Research on The Evaluation Model of Symbiosis Degree in High-tech Industrial innovation Ecosystem-An Empirical Study Based on the Panel Data of China from 2012 to 2018

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Abstract. On the basis of previous symbiotic analysis and research, the scientific and technological activities between symbiotic subjects are included into the evaluation index system of symbiotic network, and the high-tech industry innovation ecosystem evaluation model is established. The symbiosis degree was empirically measured using the entropy method with the data of high-tech industries in 32 provinces, autonomous regions and municipalities in China from 2012 to 2018. Results showed that though a significant development of overall symbiosis degree has been seen, there are still significant differences in the development speed and stage among regional innovation ecosystems. Keywords: Symbiosis Network, Symbiosis Degree, High-tech Industry Innovation Ecosystems, Ecology, Ecosystems.

1 Introduction

Under the background of globalization, the research on industrial innovation and its ecosystem evolution has become the focus[1, 2]. Currently, China has come into a critical transition period of optimizing structure, transforming dynamics, and changing development mode, and its cyclical, institutional, and structural problems are intertwined[3]. Thus, building a major global science and technology center and innovation highland has become a key strategic choice for national development in the new era. Promoting the construction of a regional innovation ecosystem has also become an important goal for the work of central and local governments in China.

However, the current research lacks the investigation of China’s national conditions. Most of China’s high-tech industries are still in the stage of imitation and innovation, facing challenges such as weak core technology capabilities, inadequate industrial chain control, and insufficient cluster advantages. This paper integrates different research perspectives, including industrial cluster theory[4] and system dynamics theory[5], to build an evaluation model of the degree of symbiosis of China’s high-tech industry innovation ecosystem, in order to help the development of China’s innovation ecosystem.

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2 Theoretical Background

Since the paradigm shift of innovation research, the innovation ecosystem concept existed since the 1990s[6, 7], research on the regional innovation ecosystem gradually focuses on the following three aspects.

First, determine the regional innovation ecosystem and its components, as well as the relationship between the components and system functions. Researchers used ecology-related theories to emphasize the importance of symbiosis, synergistic evolution, and interdependence of innovation communities with their innovation environments[8]. According to Estrin, the regional innovation ecosystem consists of three main communities: research, development and application[9]. Gobble points out that regional innovation ecosystems emphasize complexity, nonlinearity and adaptability[10]. Zeng believed that the innovation mode of high-tech industry has gradually changed from industry university research cooperation to multi subject cooperation.

Second is to explore the evolution process of regional innovation ecosystem in practice and update the symbiosis degree model. Li and Zhang summarized the ecological symbiosis mechanism of regional innovation ecosystem from two aspects: the cooperative symbiosis mechanism between agents and the adaptive coordination mechanism between agents and the environment[11]. Wang et al. explored the evolution characteristics and mechanism of regional innovation ecosystem with a new entry point of innovation duality[12].

Thirdly, the measurement method of symbiosis degree is discussed. Durst and Poutanen (2015) believed that the regional innovation ecosystem can be measured from three aspects: resources, culture and regulatory environment. Lei et al. constructed an information entropy model for niche suitability of high-tech industrial innovation system[13]. Li and Zhang established a symbiotic degree model and a symbiotic evolution momentum model integrating the evolution speed state and evolution speed trend, and studied the symbiotic level and symbiotic evolution state of the regional innovation ecosystem.[11] Wu and Tan used niche suitability model to measure the suitability of regional innovation ecosystems in 30 provinces and cities, and studied the impact of their innovation drivers on the collaborative agglomeration of producer services and manufacturing industries.[14]

In conclusion, those studies demonstrate the relationship between high-tech industry development and regional innovation ecosystem, and construct series symbiotic evaluation models from holistic and evolutionary perspectives, which provides a literature basis for this study. However, the existing research lacks the evaluation of symbiosis degree based on high-tech industries, does not combine the high-tech industry innovation ecosystem with the regional symbiosis degree measurement, and lacks the relevant model to include the symbiotic network between symbiotic entities, which is dominated by scientific and technological exchanges, into the measurement systems. In order to fill this gap, this paper combs and constructs the following theoretical framework (as shown in figure 1).

Adner, R pointed out that the complementary collaboration of a series of subjects within a system could form an innovation ecosystem and then create value[15]. With the deepening of research, research gradually focuses on the national level[16]. Wen et al. analyzed the relationship between symbiosis and innovation system, proposed the concept of symbiotic innovation system, and believed that symbiotic unit, symbiotic matrix, symbiotic interface and symbiotic environment are its basic element set.[17] According to Li, symbiotic network is the relational capital formed by the interaction between symbiotic units and the essence of symbiotic relationship[18]. So high-tech enterprises, scientific research institutions, colleges and universities and other symbiotic subjects rely on symbiotic matrix to build on industrial bases, science and technology incubators and other symbiotic platforms. Bao referred that, the knowledge fusion process in China actually lays the foundation for the improvement of
the overall collaborative innovation level of the regional multi-agent innovation network[19]. The multi-agent innovation network includes universities, research institutes, high-tech enterprises, they could build symbiotic networks to carry out scientific and technological activities. The newly established framework further emphasizes the role of symbiotic network constructed by scientific and technological exchanges as a bridge between symbiotic subjects, which can better reflect the regional innovation ecosystem architecture with high-tech industry as the core, and thus the symbiotic degree measurement model established on this basis is much more fair.

3 Research Method

3.1 Data Collection

In this study, we finally select the period of 2012-2018 as the sample study period and 31 provinces, autonomous regions, and municipalities directly under the control of the central government in China for the analysis, and the data is concentrating on the regional innovation ecosystems centered on high-tech industries.

We calibrate a small number of abnormal values of indicators in the sample by manual query and matching with other relevant authoritative databases, remove the abnormal indicators that cannot be verified.

3.2 Model Setting

According to Ou et al.[20], He et al.[3], Li et al.[13], Chen er al.[21] who measured the symbiosis degree of innovation ecosystems in different regions, this study constructs a symbiosis degree measurement index system (as shown in table 1).

Relating to the symbiotic network, we included more convincing variables and obtained relevant data. Each research object has 21 comprehensive evaluation indicators, which is a typical multi-objective decision problem. To calculate the weights of each indicator, this study uses the entropy method as the objective assignment method, and the weighted average as the proxy variable of regional co-occurrence. According to this method of calculating the entropy weighting, the weights of the indicators are calculated as follows in this study:
Construct the evaluation matrix; that is:

\[
\begin{pmatrix}
 a_{11} & \cdots & a_{121} \\
 \vdots & \ddots & \vdots \\
 a_{311} & \cdots & a_{3121}
\end{pmatrix}
\]

Standardize the raw data by the “range transformation method,” combined with the nature of the indexes.

Calculate the weight of the indicator value of the \(i^{th}\) item under the \(j^{th}\) indicator.

Calculate the entropy value of the \(j^{th}\) indicator \(H_j\).

Calculate the weight of the \(j^{th}\) indicator \(\omega_j\).

Based on these calculations, we determined the weights of the indicators in different regions in different years, and studied their symbiosis of the innovation ecosystem. We define the degree of symbiosis as \(Q\), and constructed following formula:

\[
Q_i = \sum_{j=1}^{n} \omega_j a_{ij}
\]

where \(i\) represents the 31 different regions and \(j\) represents the 21 indicators.

### 4 Analysis and Results

Based on formula 1, the coeval degrees of the 31 regions during 2012-2018 can be calculated (as shown in table 2).

As shown in table 2, the degree of symbiosis between Jiangsu and Guangdong is significantly higher than that of other provinces. With higher growing rate of Guangdong than that of Jiangsu, it surpassed in 2018 and had the highest symbiosis degree. That’s possibly because of the construction of Guangdong-Hong Kong-Macao Greater Bay Area, which has brought more factors conducive to the construction of symbiotic network as well as the prosperity of innovation ecology in this region. Most of the other provinces have improved in different stages with the passage of time, but stagnation and slowly development were seen by provinces as Xinjiang, Tibet, Inner Mongolia, Ningxia, Gansu and other provinces with relatively backward economic development.

From the perspective of geographical orientation, the degree of symbiosis in the eastern region is significantly higher than that in the western region, and the degree of symbiosis in the western region is mostly negative. This is partly because of the benefits brought by geographical position and resources for the development of symbiosis factors. On the contrary, lacking of symbiotic elements and developing vitality, the regional innovation systems of western region were in trouble.
Table 2. Symbiosis in different provinces in China 2012-2018

<table>
<thead>
<tr>
<th>Province</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanghai</td>
<td>0.1938</td>
<td>0.2499</td>
<td>0.3671</td>
<td>0.4311</td>
<td>0.5628</td>
<td>0.5633</td>
<td>0.7574</td>
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<td>Yunnan</td>
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<td>-0.4363</td>
<td>-0.4586</td>
<td>-0.3918</td>
<td>-0.4125</td>
<td>-0.3603</td>
<td>-0.3693</td>
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<td>-0.5082</td>
<td>-0.3823</td>
<td>-0.4255</td>
<td>-0.4449</td>
<td>-0.4184</td>
<td>-0.4326</td>
<td>-0.4563</td>
</tr>
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<td>Beijing</td>
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<td>0.724</td>
<td>0.8704</td>
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<td>1.1344</td>
<td>1.2127</td>
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<td>-0.3787</td>
<td>-0.2988</td>
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<td>-0.2621</td>
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</tr>
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<td>-0.1982</td>
<td>-0.102</td>
<td>0.1156</td>
<td>0.1809</td>
<td>0.2482</td>
<td>0.4042</td>
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<td>Tianjin</td>
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<td>0.1311</td>
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<td>0.7318</td>
<td>0.7948</td>
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<td>Tibet</td>
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<td>-0.0631</td>
<td>-0.1294</td>
<td>-0.1559</td>
<td>-0.2594</td>
</tr>
</tbody>
</table>

From the perspective of spatial heterogeneity, the variation coefficient of symbiosis degree decreased gradually from the east to the middle and then to the west, indicating that the regional differences in the development of regional innovation ecosystems showed a narrowing trend in space.

To conclude, there’s obviously differences between regions, while the overall development of symbiosis degree is growing generally.

5 Conclusions, Theoretical Innovation and Policy Implications

5.1 Conclusions

This study used China’s panel data from 2012 to 2018 for the first time, and used the entropy method to empirically test the symbiosis degree of innovation systems in various regions.
of the country under the high-tech industry environment. It supplements and expands the existing research results, and draws the following important conclusions: the average symbiotic relationship between provinces and regions in China has been increasing in the past ten years, but the differences between regions are still significant, thus balancing development is urgently needed.

5.2 Theoretical Innovation

In terms of innovation ecosystem structure theory, Elias et al. (2010) proposed three helix, four helix, five helix and other innovation ecosystem theories, and Paula et al. (2015) anchored on a systemic perspective of innovation and particularly on the triple helix model, which highlights the state, university and companies as central players[20]. On the other hand, existing studies have used symbiosis and synergy theories, the authors constructed a synergy evaluation index[21], or measured the evolution of symbiosis degree by describing the cooperative symbiosis situation of populations through the ecological features of competitive symbiosis presented by behavioral populations of innovation chains[22]. However, existing theories are lacking in the measurement of the symbiosis degree of regional innovative ecosystems with high-tech industries as the core in our country, and the theoretical penetration degree of the existing model is also lacking. In this article, based on the existing regional ecosystem theory on the relationship between symbiotic agents, symbiotic networks and symbiotic matrix, the scientific and technological activities between the symbiotic agents of high-tech industries are innovative incorporated into the evaluation system of symbiotic network, and the influence of scientific and technological exchanges in the symbiotic network on the symbiotic degree of regional innovation ecosystem is considered. It builds a bridge between the theoretical research of the existing high-tech industrial regional innovation ecosystem and the construction of the existing model of the basic degree of symbiosis, and establishes the model of the high-tech industrial innovation ecosystem symbiosis degree, so as to better reflect the degree of symbiosis improvement brought by the interaction between symbiosis subjects to the regional innovation ecosystem.

5.3 Policy Implications

This study also has the following policy implications:

(1) In the first year of the 14th National Plan, it is urgent to build a regional innovation ecosystem and enhance the independent innovation capacity of high-tech industries. Firstly, a relatively rich and perfect innovation environment should be provided for the construction of the innovation system so as to encourage the interaction among innovation subjects and the formation of cross-regional innovation clusters. Secondly, the construction of regional innovation ecosystem should be taken as an important goal of innovation policy, and all regions should be actively encouraged to build a symbiotic network with good innovation and give play to the symbiotic effect, so as to create a good symbiotic environment.

(2) Encourage all regions to take advantage of China’s institutional advantages, actively follow the requirements of China Symbiosis Evaluation Report, use big data platforms to monitor the development of symbiotic network and the degree of symbiosis in all regions in real time, and formulate differentiated regional innovation ecosystem development plans based on geographical location, resource endowment, innovation resources, industrial base and other actual conditions.

(3) Take more active and effective measures to promote scientific and technological activities among scientific research institutions, universities and high-tech enterprises by improving their information exchange channels, so as to accelerate the construction of a more
high-quality symbiotic network, further balance the development gap between regional innovation ecosystems, provide a good regional innovation ecological environment for high-tech enterprises, and better promote the improvement and balanced development of the overall innovation ecosystem.

6 Limitations and Future Research

Due to current data limitations, there is room to expand this research as follows.

(1) The degree of symbiosis of high-tech industry will change with the overall development of China, the development of China’s high-tech industry and the continuous improvement of regional innovation ecosystem. Therefore, it is necessary to continuously update the database and conduct long-term follow-up research in a more timely manner, so as to provide valuable reference for policy making.

(2) The regional innovation ecosystem is symbiotic, complex and dynamic. In the future, the evolution of innovation ecosystems in some regions can be selected for multi-case comparative study to complement and improve the results of this study.

References

