A Study on Innovation Radiation Effects of Shanghai Science and Technology Innovation Center from the Perspective of Field Theory

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Abstract. The way in which science and technology innovation center drives regional innovation capabilities depends on the spillover and radiation of innovation resources. Starting from the connotation of the science and technology innovation center, combined with the electric field theory in physics, the innovative radiation field with the science and technology innovation center as the field source is constructed, and the field source intensity is quantified from four aspects: innovation resources, innovation input, innovation achievements and innovation carrier. Taking the Shanghai science and technology innovation center as the research object, and using 2014 as the base year, the innovative radiation effects of the Yangtze River Delta urban agglomeration before and after construction was measured. The research shows that the radiation intensity of Shanghai has increased significantly since the establishment of the science and technology innovation center, but the overall radiation pattern has changed little and there is still a lot of room for improvement. Finally, the countermeasures for enhancing the innovative radiation effect of the Shanghai science and technology innovation center are proposed.

1. Introduction
Due to the high mobility and spatial agglomeration of innovation resources and activities, the world-class sci-tech innovation center can attract and gather global innovation elements to the greatest extent, develop high-tech industries, and occupy an advantageous position in international competition. With the intensification of international competition and the constant change of competition forms, the government has paid more attention to the construction of sci-tech innovation center. Shanghai has built a sci-tech innovation center with global influence, enabling the city to drive the regional implementation of the strategy of sci-tech innovation-driven development, and driving the factors of regional development to knowledge, information, technology and other aspects [1]. Therefore, it is particularly important to study the innovation radiation effects of Shanghai sci-tech innovation center, especially under the background that the Yangtze River delta regional integration was proposed as a national strategy in 2018.

At present, many scholars have carried out researches on the driving force of sci-tech innovation center. Bo Chen divided the innovation influence of the sci-tech innovation center into three levels: regional, national and global. He believed that it could enhance regional innovation cooperation, lead the country to transform into an innovative economy, and allocate and integrate global innovation
resources [2]. Haiyun Wang et al. constructed the evaluation model of sci-tech innovation center from the perspectives of sci-tech innovation leaders, high-end economic growth poles, preferred places for innovation and entrepreneurship, pilot areas for cultural innovation, and ecological construction demonstration cities [3]. The radiation effect of innovation is not only the manifestation form of sci-tech innovation center from the perspective of space, but also the key factor to measure the importance and influence of sci-tech innovation center. According to the current literature review, most scholars focus on the static evaluation index research on the innovation radiation force of sci-tech innovation center, and few studies are done on the measurement of the innovation radiation effect of sci-tech innovation center from the perspective of space.

Classical physics holds that physical quantities in space can interact and transform energy and information through "fields". With the continuous expansion of "field" theory and research methods, more and more scholars have applied field theory to philosophy, economy, management and other disciplines, put forward the concepts of economic field, logistics field, etc. [4-5], and studied the interaction and spatial connection between subjects by combining physical theories such as electric field, magnetic field and gravitational field [6-8]. The sci-tech innovation center gathers rich human and financial resources. By utilizing, transforming and creating new knowledge, information, technology and other resources from the original resources, it will generate a large number of resource flows and radiate innovation to the surrounding areas. Therefore, field theory can be used for reference in studying the space radiation effect of sci-tech innovation center.

Based on the above research foundation, this paper studies physics field theory in the classical model of electrostatic field combined with the evaluation system of sci-tech innovation center, constructs a model of innovation radiation effect on sci-tech innovation center, Shanghai sci-tech innovation center as the research object, puts forward the construction of Shanghai sci-tech innovation center in 2014 as the base year, measure before and after the construction for the innovation of the Yangtze River Delta urban agglomeration radiation effect, from the perspective of space dynamic study of Shanghai sci-tech innovation center of radiation effect, and explores the ways and methods to enhance its radiation effect.

2. Research Methods

2.1. Innovation Radiation Effect Model Construction

Due to the difference in the distribution of innovation resources in time and space, each innovation subject will carry out the process of overflowing and absorbing innovation resources with “field” characteristics, forming an innovation field. Innovation fields are the environment space for the existence and activities of innovation elements. Innovation subjects utilize, transform and create by gathering abundant human, material and financial information and other innovative resources, so as to form new innovative resources and generate spillover effects on other subjects. The interaction between innovation subjects is similar to the interaction between electric charges in the electric field. Innovation resources radiate from one innovation subject and are absorbed by another. Due to the difference in the total amount of innovation resources between different innovation subjects, the potential energy similar to the electric potential in the electric field will be formed, and the innovation resources will flow under the action of the potential energy. Classical physics holds that the electric field is a vector field, so the innovation field is also a vector field. The radiation and absorption effects of innovation resources form the innovation radiation field and the innovation absorption field respectively.

In the innovation field, the special subjects have strong radiation and influence in the circulation of innovation resources with surrounding areas, and the innovation subjects are relatively static, which is similar to the observation and charge in the static field. Therefore, based on the classical electromagnetic field theory, this paper compares the electrostatic field and the innovative radiation field, and contends that they are similar (as shown in table 1).
### Table 1. Similarity of electrostatic field and innovation radiation field

| Electrostatic Field | Innovation Radiation Field |
|---------------------|----------------------------|
| Point Charge $Q$    | Field Source: Innovation Subject |
| Field: $E$          | Total Innovative Resources of Field Source: $Q$ |
| Space Distance: $r$ | Innovation Radiation Field: $E$ |
| Capacitance Rate: $\varepsilon$ | Innovation Radiation Distance: $R$ |
|                     | Innovation Radiation Field Factor: $k$ |

As a specific innovation subject in the space, the sci-tech innovation center has strong innovation radiation and innovation influence. Based on the above analysis of the innovative radiation field, this paper uses the Shanghai sci-tech innovation center as the source of innovation resources (field source), and the urban group outside the field source of the Yangtze River Delta as a source of innovation resources (site). In the space rectangular coordinate system, the field source coordinates are represented by $(x', y', z')$, and the site coordinates are represented by $(x, y, z)$. The distance vector from the coordinate origin to the field source is represented by $\vec{r}'$, the distance vector from the coordinate origin to the site is represented by $\vec{r}$, and the unit vector is represented by $\hat{e}$. The field source vector is $\vec{r}' = x'\hat{e}_x + y'\hat{e}_y + z'\hat{e}_z$ and the site vector is $\vec{r} = x\hat{e}_x + y\hat{e}_y + z\hat{e}_z$. The distance $\vec{R}$ between the field source and the site is:

$$\vec{R} = \vec{r} - \vec{r}' = (x - x')\hat{e}_x + (y - y')\hat{e}_y + (z - z')\hat{e}_z = R\hat{e}_R$$  \hspace{1cm} (1)

Let the radiation intensity of the innovative radiation field be vector $E(\vec{r})$, and the direction of the innovation resource output points to the point of innovation resources. Combined with the classical electromagnetic field theory and the electric field strength formula, the innovative radiation intensity of the field source to the field at space $\vec{r}$ is:

$$\vec{E}(\vec{r}) = k \frac{Q}{R^2} \hat{e}_R = \frac{Q}{|\vec{r} - \vec{r}'|^2} \hat{e}_R$$  \hspace{1cm} (2)

Where, $Q$ is the total amount of innovation resources of field source, and $k$ is the innovation resource absorption capacity of site.

#### 2.2. Construction of Resource Evaluation System for Science and Technology Innovation Center

Based on the above analysis of the innovation radiation field and the construction of the innovation radiation effect model, the innovation subject of the field source is considered as the sci-tech innovation center. Innovation resources exist in the whole innovation space, which is the embodiment of the intensity of field source. The quantification of the intensity of field source is the measurement of the total amount of innovation resources in the sci-tech innovation center. In combination with the agglomeration and radiation process of the sci-tech innovation center in the innovation radiation field, this paper selects 14 indicators from four levels of innovation resources, innovation input, innovation achievements and innovation carriers to comprehensively measure the intensity of the midfield source of innovation radiation effect (as shown in table 2):
Table 2. Science and Technology Innovation Center resource evaluation index system

| Target layer       | Criteria layer       | Indicator layer                                      |
|--------------------|----------------------|-----------------------------------------------------|
| Science and Technology Innovation Center resource level | Innovation Resources | Number of scientists and technicians                 |
|                    |                      | The number of students in ordinary institutions of higher learning |
|                    |                      | Local government spending on science and technology |
|                    |                      | Three kinds of patent applications                   |
| Innovation Input   |                      | Internal expenditure of R&D expenditure              |
|                    |                      | Expenditure for new product development               |
|                    |                      | Full-time equivalent of R&D personnel                 |
|                    |                      | Number of new product development projects           |
| Innovation Achievements |                      | Number of scientific papers                          |
|                    |                      | Three types of patent grants                         |
|                    |                      | Transaction amount of technical contract             |
|                    |                      | New product sales revenue                            |
| Innovation Carriers |                      | Number of ordinary institutions of higher learning   |
|                    |                      | Number of high-tech enterprises                      |

The total amount of innovative resources of the field source can not only directly reflect the innovation strength of the sci-tech innovation center, but also reflect its ability to drive the development of urban agglomerations. Based on the innovative radiation model constructed above, this paper uses $Q$ to represent the total amount of innovation resources of the field source, and measures it from four aspects:

$$Q = a_1Q_1 + a_2Q_2 + a_3Q_3 + a_4Q_4$$  \hspace{1cm} (3)

Where, $Q$ is the innovation resources, $Q_1$ is the innovation input, $Q_2$ is the innovation achievements, $Q_3$ is the innovation carriers, and $a_i (i = 1, 2, 3, 4)$ is the weight of each part.

In order to dynamically reflect the changes in the total amount of innovation resources from 2011 to 2017, this paper adds the time dimension to evaluate the entropy method. The improved entropy method evaluation model is as follows:

Assume that the indicator system consists of $n$ evaluation indicators, the research object is $m$ cities in $T$ years, $x_{ij}'$ represents the $t$ year data value of the $j$ indicator in the $i$ city, and the initial evaluation matrix is $X = \{x_{ij}'\}_{mT\times n}$.

First, the initial evaluation matrix is standardized:

$$x_{ij}' = \frac{x_{ij}' - x_{j\min}}{x_{j\max} - x_{j\min}} \times 99 + 1, \ i = 1, 2, ..., m; \ j = 1, 2, ..., n; \ t = 1, 2, ..., T$$  \hspace{1cm} (4)

In the formula, $(x_{ij}')'$ represents the data value after the normalization process. $x_{j\max}$ is the maximum value of the $j$ index, and $x_{j\min}$ is the minimum value of the $j$ index.

Then, calculate the entropy value $e_j$ of the $j$ indicator:
\[ e_j = -\frac{1}{\ln mT} \sum_{t=1}^{T} \sum_{i=1}^{m} q_{ij}^t \ln q_{ij}^t, \quad j = 1, 2, \ldots, n \]  

(5)

Finally, the weight \( w_j \) of the \( j \) indicator is obtained:

\[ w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \]  

(6)

In the formula, the closer \( w_j \) is to 1, the greater the weight of the indicator, and the closer is to 0, the smaller the weight of the indicator.

3. Results

This paper takes the Shanghai sci-tech innovation center as a source to study its innovative radiation effects on some cities in the Yangtze River Delta region. Considering the availability of data, the Shanghai sci-tech innovation center uses Shanghai’s statistics. The 2011 and 2017 statistics are derived from the statistical yearbooks of the provinces and cities in 2012 and 2018, and the missing data is supplemented by interpolation. The geographical distance between the center of the field source and the city of the site is obtained by means of Google Maps.

Application (3) – (6) calculates the total amount of innovation resources in 12 cities. The results are shown in Table 3. In 2011 and 2017, the total amount of innovation resources in Shanghai is greater than that of other cities. The difference in resources between Shanghai and the surrounding 11 cities indicates that radiation can be produced.

| City     | In 2011 | In 2017 | City     | In 2011 | In 2017 |
|----------|---------|---------|----------|---------|---------|
| Shanghai | 13 408.066 | 19 466.771 | Huzhou   | 1 107.189       | 2 605.411       |
| Nanjing  | 3 867.619 | 8 291.379 | Shaoxing | 1 616.618       | 4 855.69         |
| Wuxi     | 5 363.037 | 5 541.784 | Jinhua   | 1 752.352       | 2 913.852        |
| Changzhou| 2 279.09  | 3 605.3   | Hangzhou | 5 276.518       | 8 679.526        |
| Suzhou   | 10 874.732| 11 278.756| Ningbo   | 5 624.943       | 7 069.678        |
| Nantong  | 5 060.496 | 4 698.505 | Jiaxing  | 494.607         | 1 405.359        |

With the development of Internet technology and transportation, the spatial distance between the two cities is no longer only geographical distance, but also affected by information and transportation factors. Therefore, this paper uses the total social passenger traffic, the total social freight volume, the number of Internet users and the number of mobile phone users to modify the traditional geographical distance. According to \( R' = (1 - \alpha')D \), the corrected distances between cities and Shanghai in 2011 and 2017 are calculated, as shown in Table 4.
Table 4. Geographic distance and correction distance between cities and Shanghai

| City    | Geographic distance | Correction distance | City    | Geographic distance | Correction distance |
|---------|---------------------|---------------------|---------|---------------------|---------------------|
|         | In 2011             | In 2017             |         | In 2011             | In 2017             |
| Nanjing | 270.1               | 180.33              | 194.13  | Shaoxing            | 133.74              |
| Wuxi    | 114.4               | 91.33               | 96.44   | Jinhua              | 245.67              |
| Changzhou | 155.6               | 136.94              | 138.54  | Hangzhou            | 115.81              |
| Suzhou  | 84.3                | 53.22               | 51.97   | Ningbo              | 111.15              |
| Nantong | 99.6                | 76.85               | 76.54   | Jiaxing             | 78.33               |
| Huzhou  | 137.2               | 126.02              | 124.99  |                     |                     |

The ability of the site to absorb the innovative resources radiated from the field source is related to the innovative resource base between the two cities and the resource utilization capacity of the site city. It is estimated by experts that two indicators are equally important for the ability of the city to absorb innovative resources, that is \( k = 0.5k_1 + 0.5k_2 \). Where, \( k_1 \) represents the ratio of the total amount of innovation resources of the city of the site and the source city, and \( k_2 \) represents the utilization rate of the innovative resources of the site city. This paper selects R&D expenditure, internal expenditure, R&D personnel full-time equivalent, and the number of ordinary higher education institutions as input indicators, the number of scientific papers, three kinds of patent grants, technology contract turnover, new product sales income as output indicators, using the DEA-Solver tool, the innovation resource utilization rate \( k_2 \) of each city is calculated. The results are shown in Figure 1.

Figure 1. Innovative resource utilization rates in cities

According to the formula \( k = 0.5k_1 + 0.5k_2 \), the absorption capacity coefficients of each site city to Shanghai in 2011 and 2017 are calculated, as shown in Table 5.

Table 5. Absorption capacity coefficient of each site city to Shanghai

| City    | In 2011 | In 2017 | City    | In 2011 | In 2017 |
|---------|---------|---------|---------|---------|---------|
| Nanjing | 0.728   | 0.797   | Shaoxing| 0.580   | 0.669   |
| Wuxi    | 0.825   | 0.653   | Jinhua  | 0.793   | 0.588   |
| Changzhou | 0.400  | 0.345   | Hangzhou| 0.754   | 0.724   |
| Suzhou  | 0.970   | 0.845   | Ningbo  | 0.714   | 0.689   |
| Nantong | 0.756   | 0.663   | Jiaxing | 0.528   | 0.589   |
| Huzhou  | 0.112   | 0.400   |         |         |         |
According to formula (2), the innovative radiation effect values of Shanghai for each site city in 2011 and 2017 are calculated, and the scores of each city are imported into ArcGIS 10.6 software, and Shanghai's innovative radiation effects on 11 sites are divided into three types through natural discontinuous grading. These three types are defined as strong innovation radiation effects (2.2036, 6.0962], medium innovation radiation effects (0.7753, 2.2036], and weak innovation radiation effects (0, 0.7753] (as shown in Table 6).

### Table 6. Regional division of innovative radiation effects in Shanghai

| Type       | Innovative radiation effect score | Region                                                                 |
|------------|----------------------------------|------------------------------------------------------------------------|
| Strong     | (2.2036, 6.0962]                 | Suzhou, Suzhou                                                        |
| Medium     | (0.7753, 2.2036]                 | Nantong, Wuxi, Jiaxing, Nantong, Jiaxing, Wuxi, Hangzhou, Ningbo      |
| Weak       | (0, 0.7753]                      | Ningbo, Hangzhou, Shaoxing, Nanjing, Changzhou, Jinhua, Huzhou, Shaoxing, Huazhou, Nanjing, Changzhou, Jinhua |

On the whole, the radiation effect of field source city Shanghai on 11 sites in the Yangtze River Delta in 2017 was significantly enhanced compared with that in 2011, and the areas with strong and medium radiation effect increased from 4 to 6. This is because since 2014 when Shanghai proposed to build a sci-tech innovation center, the Shanghai municipal government has continuously increased the investment in sci-tech innovation, introduced relevant policies to promote the development of high-tech enterprises, continuously improved the ability to transform the achievements of sci-tech innovation, and continuously increased the total amount of innovation resources in Shanghai. From a local perspective, the areas with the strongest radiation effects in 2011 and 2017 were all in Suzhou. This is because the geographical distance between Suzhou and Shanghai is the shortest, and Suzhou has a high degree of external contact, which facilitates the exchange of talents, funds, knowledge, technology and other resources with the Shanghai sci-tech innovation center. In addition, the total amount of innovation resources in Suzhou is much higher than that of the other 10 sites, and the efficiency of innovation resources is relatively high. It can absorb the innovative elements of new knowledge, new technologies and new products radiated by the Shanghai sci-tech innovation center.

### 4. Conclusion

Based on the connotation of sci-tech innovation center as well as the "field" theory in physics, this paper extends the innovation of sci-tech innovation center radiation ability measure to the space level, constructed the sci-tech innovation center for radiation field source of innovation, and at the same time, according to the predecessors' research on evaluation system of sci-tech innovation center, from the innovation resources, innovation input, innovation achievements and innovation carriers to construct the sci-tech innovation center resources assessment system, represented by 2011 and 2017 years, it evaluates the before and after the construction of the construction of Shanghai sci-tech innovation center for the innovation of the Yangtze River Delta urban agglomeration 11 other cities radiation effect. The study finds that since the establishment of the sci-tech innovation center in Shanghai, the level of innovation resources has increased significantly. At the same time, the innovative radiation effect of the field source Shanghai has been significantly enhanced, but the overall pattern of radiation has changed little, and the overall situation is still strong. The pattern is relatively poor in radiation effects in areas with a spatial distance from the edge.

In view of the above conclusions, this paper believes that Shanghai sci-tech innovation center should actively build a first-class innovation platform to strengthen the construction of talent pool, strengthen the construction of transportation and information network infrastructure to enhance the regional external connection, and improve the policy system to improve the innovation efficiency, so as to promote the development of sci-tech innovation in the Yangtze River Delta region.
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