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Research Article

Innovation Efficiency and the Spatial Correlation Network Characteristics of Intelligent-Manufacturing Enterprises

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A data envelopment analysis cross-efficiency model was used to measure the innovation efficiency of Chinese intelligent-manufacturing (IM) enterprises. This paper took as samples the number of granted patents and R&D investments of IM enterprises listed from 2015 to 2020. This research used the modified gravity model to determine the innovation efficiency and the spatial correlation of IM enterprises in China and used UCINET software to reveal the innovation efficiency and spatial network characteristics of IM enterprises through a social network analysis. The study found that the relationship was significant and frequently close between innovation efficiency and the spatial correlation network of IM enterprises. The distribution of the spatial association network was "core-edge," and IM enterprises in Eastern China were at the network core and mostly played an intermediary role. The spatial correlation network had four modules. The distribution of the enterprise innovation correlation was uneven within each module, amalgamation was poor among the subgroups, and characteristics of highly cohesive subgroups were present.

1. Introduction

In January 2021, the Ministry of Industry and Information Technology issued the *Report on Intelligent-Manufacturing (IM) Development Index (2020)*, which pointed out that IM has become an important channel for promoting the transformation and upgrading of the manufacturing industry and accelerating its high-quality development, as a new round of scientific and technological and industrial revolutions is constantly deepening. The *Manufactured in China 2025* report issued by the State Council pointed out that IM should be taken as the development core to realize industrial transformation and to upgrade China from a manufacturer of quantity to one of quality. In this critical phase, the Ministry of Industry and Information Technology carried out the special action of an IM pilot demonstration to implement the overall requirements of *Manufactured in China 2025*. At present, China's IM industry is still in the development stage and is at one remove from that in the developed countries. As an emerging industry, China's IM industry is relatively weak in innovative applications and is subject to sensor and control equipment technology. Chinese companies have difficulty developing new products in terms of technology research and development (R&D). At the same time, China's intelligent equipment companies are small in scale and weak in competitiveness. The operation of China's IM of equipment started late, it has not formed a backbone with strong competitiveness, and its industrial organization is small. In the international competitive landscape, enterprises in developed countries still dominate. In addition, China's IM of equipment lacks support, and its foundation is relatively weak. IM has no consistent definition at home or abroad, but China has offered a somewhat comprehensive descriptive definition in *IM Development Planning (2016–2020)*. This definition states that IM is a new production mode based on the deep integration of new-generation information as well as communication and advanced manufacturing technology. It runs through all aspects of manufacturing activities—such as design, production, management, and service—and has the characteristics of being self-sensing, self-learning, self-decision-making, self-executing, self-adaption, etc. Intelligent upgrading refers to the innovation and transformation of the production and development modes. It is also an effective innovation and development path for realizing the transformation of the manufacturing industry. We thus formulate the following research questions: What is the specific innovation efficiency of the upgrading of IM enterprises? What are the spatial network characteristics of the innovation efficiency of China's IM enterprises? This article has a novel research angle. Because China's current IM statistics lack a unified caliber, and related macrolevel statistics are scarce, this article selects as the source microlevel IM enterprise upgrade data. Selected as the sample were the 2015–2020 National Pilot Enterprises of IM, which has high credibility and availability and was officially announced by the Ministry of Industry and Information Technology. The efficiency changes are measured of China's IM pilot enterprises in using such technology to promote the innovation process from 2015 to 2020. Furthermore, the overflow path is analyzed of innovation efficiency in the spatial network of the IM pilot enterprises, and the role and function of each enterprise are studied in the spatial correlation network of IM innovation efficiency. The latter is of great significance for promoting the integration of informatization and industrialization, building a collaborative innovation mechanism of IM and driving regional economic development.

2. Literature Review

Wright and Bourne first proposed the concept [1] of IM in 1988, and a research on IM by domestic scholars has shown "blowout" growth in recent years [2–4]. The IM research focus is its connotation [5], transformation, and upgrade of traditional manufacturing industries [6], production service [7], development strategy [8], performance and influencing factors [9], and other related fields [10–13]. Generally, the current IM research is relatively fragmented [14]. In terms of the innovation efficiency of IM enterprises, Zhao [15] pointed out that it is a means rather than an objective, so it must be evaluated. Li et al. [16] pointed out that this evaluation should focus not only on the technical methods of IM enterprises, but also on their innovation efficiency. To measure the innovation efficiency of enterprises, foreign scholars have mainly used a data envelopment analysis (DEA) [17], the technique for order of preference by similarity to ideal solution (TOPSIS) [18], and a stochastic frontier analysis [19]. Lu et al. [20] pointed out that quantitative methods are seldom used in existing domestic research for this measure. Liu and Ning [21] used the DEA model to measure the technological innovation efficiency of IM enterprises in China. Through a theoretical analysis, Qin [22] believed that the IM industry in China needs to improve its industrial standards and promote the capability for independent innovation. For example, Liao [23] pointed out that the gap of the overall technological innovation capability of the IM industry in China is still large compared with that of the developed regions abroad. Xiao et al. [24] took case study media and concluded that China could further improve the innovation capability of IM enterprises only by breaking through information technology barriers. Regarding the construction and influencing factors of IM networks, Zhou et al. [25] pointed out that IM is a manufacturing network integrated with a human–physical–information system. Through an analysis from the perspective of technical applications, Li et al. [16] found that IM is a complex network that includes application, resource, network, and cloud service platform layers. Jovanovic et al. [26] suggested that the technological progress of IM enterprises would interact with the environment, which is a system undergoing constant development. Zhang [27] analyzed the combination of 5G technology and IM networks to promote regional innovation capability in China. Chen [28] pointed out that IM can not only help enterprises improve production efficiency, but also promote the coordinated development of regional industries. As the research has deepened on the innovation of IM enterprises, a few scholars have analyzed the network problems of IM enterprises from the spatial correlation [29] perspective. For example, Zhang et al. [30] took as the research object the IM cluster of small- and medium-sized enterprises and used a complex network model. Through dynamic evolution, they concluded that the high centrality node in the cluster plays a leading role in the development of its cluster.

Innovation efficiency network structure characteristics can be described from four network aspects: scale, openness, structure holes, and links. Network scale refers to the number of subjects in the network [31, 32]. It represents the most basic characteristics of the network structure and is composed of network nodes. These nodes are mainly characterized by innovation entities such as enterprises, universities, scientific research institutions, and governments. Generally, when the network is larger, there are more opportunities for communication between nodes and for innovation, and the ability to innovate is stronger [33, 34]. Network openness is mainly manifested in the autonomous control of the network connection by the actors, that is, the establishment and interruption of the network connection, its strengthening and weakening, and its communication with other networks [35–37].

The existing literature has laid the research foundation for this paper, but the following aspects are still worthy of further exploration. ① Although a small number of scholars have studied the innovation efficiency of IM enterprises in China, most of these studies have used qualitative research methods such as case studies or theoretical analyses. However, the quantitative evaluation method is relatively singular, and the DEA model is applied for most measurements, but a ranking evaluation cannot be carried out since the efficiency value of the DEA model applies to multiple units at the same time. ② The existing research is mainly focused on the construction of IM networks and their influencing factors from the resource, logistics, and technology layers. Research is lacking on the spatial network correlation of the innovation efficiency of IM enterprises, and the scarce existing research lacks pertinence. Therefore, the marginal contributions of this paper lie in the following: first, the innovation efficiencies of 45 IM enterprises were measured by using a DEA cross-efficiency model and exploiting the special action of IM demonstration pilot projects. Furthermore, the model was combined with the data for listed companies to compensate for the lack of a DEA model that cannot rank the units with efficiency, to enrich existing research methods, and to evaluate the innovation efficiency of IM enterprises. Second, this paper used the social network analysis method to construct the spatial correlation network of the innovation efficiency of IM enterprises, studied the influences of and relationships among the subsystems in the spatial correlation network, and filled the theoretical gap of research on the spatial correlation network of the innovation efficiency of IM enterprises. Third, the spatial correlation of the innovation efficiency of IM enterprises is examined from a larger spatial scope, while the existing literature mainly examines the perspective of geographic proximity. Fourth, while the existing literature builds a measurement model based on "attribute" data, the network structure is difficult to describe. This study relies on "relational" data to describe the spatial correlation network structure of the innovation efficiency of IM enterprises.

3. Research Design

3.1. Construction of the DEA Cross-Efficiency Model. In 1986, Silkman first proposed the DEA cross-efficiency evaluation method [38] used in evaluation ranking to evaluate the innovation efficiency of K enterprises. Each enterprise (decision-making unit, DMU) had n input variables and M output variables, in which X_{ik} was the total amount of the i-th input of the k-th enterprise; Y_{sk} was the s-th output variable of the k-th enterprise; and the input and output of the k-th enterprise were expressed as $X_k = (x_{1k}, x_{2k}, \ldots, x_{nk})^T$ and $Y_k = (y_{1k}, y_{2k}, \ldots, y_{mk})^T$, respectively. The weight coefficient vector of input vector X was $Q = (q_1, q_2, \ldots, q_n)^T$, and the weight coefficient vector of output vector Y was $G = (g_1, g_2, \ldots, g_m)^T$.

$$\begin{cases} \max Y_k^T g = E_{ik} \\ Y_k^T g \le X_k^T q, \quad 1 \le k \le n \\ X_k^T q = 1 \\ g \ge 0, q \ge 0, E_{ik} \ge 0. \end{cases} \tag{1}$$

The optimal solutions of the above linear programming were set as g_k^* and q_k^*, and then, optimal $E_{ik} = Y_k T_{gk}^*$ was the efficiency value. When the value of DMU_k was from DMU_1 to DMU_m, m cross-efficiencies could be obtained from any DMU, and the cross-evaluation matrix was finally obtained.

$$E = \begin{bmatrix} E_{11} & \cdots & E_{1m} \\ \vdots & \ddots & \vdots \\ E_{m1} & \cdots & E_{mm} \end{bmatrix}, \tag{2}$$

where the main diagonal element was the efficiency value of self-evaluation, and the other elements were the efficiency values of other evaluations. The average value of each column in the matrix was the final cross-efficiency value of the DMU. When the value was larger, the DMU was better.

3.2. Measurement of the Relationship Efficiency of the Innovation Spatial Network of IM Enterprises. The spatial correlation network of IM enterprises is determined through spatial relationships. Currently, scholars mainly use the vector autoregressive (VAR) Granger causality and gravity models to test the spatial relationship. According to Liu et al. [39], the VAR Granger causality method is too sensitive to the choice of the end of lag, which weakens the accuracy of the characteristic description of the network structure to a certain extent. Therefore, by referring to the modified gravity model of Shao et al. [40], the spatial correlation network of the innovation efficiency of the IM enterprises was constructed in this paper. The modified gravity model was as follows [41]:

$$X_{ij} = R\frac{F_i * F_j}{E_{ij}^2}, \tag{3}$$

where X_{ij} was the spatial correlation strength of the innovation efficiency of the IM enterprises, F_i and F_j were their innovation efficiency, and E_{ij} was the linear distance between two enterprises. This paper used ArcGIS software to calculate and obtain $R = K_i \backslash (KI + Kj)$, in which k_i and k_j were the gross domestic products of the cities, where the IM enterprises were located. The spatial correlation binary matrix of the innovation efficiency of the IM enterprises was calculated by a modified gravity model. To further describe the spatial correlation of their innovation efficiency, the average value of each row of the matrix was taken as critical value P of the correlation degree between the IM enterprise in the row and the other IM enterprises. If $X_{ij} \ge P$, the value was 1, which indicated that those in the row were correlated with the innovation efficiencies of those in the column. Otherwise, the value was 0, indicating that there was no correlation among the enterprises.

3.3. Social Network Analysis. A social network analysis can transform attribute data into relational data. By measuring network indices, the paper analyzed the whole network, individual network, and module characteristics and the intermediary role of the spatial correlation network of the innovation efficiency of IM enterprises in China.

3.3.1. Characteristic Index of the Whole Network. Network correlation refers to an index that can reflect the degree to which two IM enterprises can establish relationships. It can measure the independence and dependence between IM enterprises. The calculation formula was as follows [42]:

$$C = \frac{1 - U}{[N(N-1)/2]}, \tag{4}$$

where C represented network relevance, N was the number of the IM enterprises in the network, and U was the number of those whose innovation efficiency was not discoverable in the correlation network.

Network density refers to the index that measures the density degree of relationships of innovation efficiency correlation among research objects in social networks. It is the ratio of the actual number of relationships in the network to the maximum possible number of relationships in the whole network. When it is higher, the spatial correlation degree is closer to the innovation efficiency of IM enterprises. The calculation formula was as follows:

$$D = \frac{V}{[N(N-1)]}, \quad (5)$$

where D represented the network density, V referred to the actual number of innovation efficiency relationships in the network, and N represented the number of nodes in the whole network.

Network efficiency refers to the extent to which the network has a redundant relationship when the number of research objects is known. It can measure the extent to which the IM enterprises in the spatial correlation network of innovation efficiency have redundant relationships that reduce network stability. Its formula was as follows:

$$\text{GE} = \frac{1-G}{\max(G)}, \quad (6)$$

where G was the redundant relationship in the correlation network of innovation efficiency, and max (G) was the maximum number of possible redundant relationships in the network.

3.3.2. Characteristic Index of the Individual Network. Individual networks can reveal the power of IM enterprises in the spatial correlation network of innovation efficiency and whether one such enterprise is in the core position. Social network scholars use degree, closeness, and intermediary centrality to quantify individual networks from the perspective of "relationships." Degree centrality can measure the node number directly connected with other points. It is applied to the innovation efficiency network of the IM enterprises and can describe the impact of innovation efficiency in each IM enterprise on that of the others. Closeness centrality can measure the distance between two points and can be applied to the innovation efficiency network of IM to describe the stability and independence of the impact of each IM enterprise on the innovation efficiency of the others. Intermediary centrality can measure the ability of a point between two points to control the communication between the two points. It can be applied to the innovation efficiency network of IM enterprises and can describe the ability of IM enterprises to control others. Among the three measurement indices, degree centrality is relatively simple, and closeness and intermediary centrality need to be measured according to formulas.

The calculation formula of closeness centrality was as follows:

$$D_i = \sum_{j=1}^{n} C_{ij}, \quad (7)$$

where D_i was the betweenness centrality of node i, C_{ij} was the shortcut distance between point i and point j, and $i \neq j$.

The calculation formula of the intermediary centrality was as follows:

$$F_{ij} = \frac{\sum_j^n \sum_k^n M_{jk}(i)}{M_{jk}}, \quad (8)$$

where F_{ij} was the betweenness centrality of node i, $M_{jk(i)}$ was the number of shortcuts passing through point i between points k and j, and M_{jk} was the number of shortcuts between points k and j, where $k \neq j \neq i$ and $j < k$.

3.3.3. Module-Modeling Analysis. A module-modeling analysis classifies each node into a module according to similar characteristics through a cluster analysis in a social network analysis and reacts to the relationship characteristics among modules. With reference to the network module division method of Wasserman and Faust [43], the efficiency spatial correlation network of the IM enterprises could be divided into four modules: two-way benefit, net income, net overflow, and broker. The transmit–receive relationship was generally analyzed between modules, and the image matrix was used to react to the internal structural changes of the network and the correlation relationship changes among modules [44].

3.3.4. Intermediary Analysis. Intermediaries master the "secrets" among multiple groups regardless of whether these comprise the whole network of the innovation efficiency correlation of IM enterprises or individual modules. With reference to the intermediary classification of Gould and Fernandez [45], the IM enterprises were divided into five categories according to the intermediary role: coordinator, gatekeeper, agent, consultant, and contact person. The coordinator agglomerates the internal innovation efficiency correlation of its own module. The agent gives the innovation efficiency of its own module to other modules. The consultant produces the innovation efficiency correlation relationship of different IM enterprises in a certain module. The gatekeeper incorporates the innovation efficiency of other modules into its own module. The contact person both incorporates the innovation efficiency of other modules into its own module and gives the innovation efficiency of its own module to another module, which can drive different modules to build the correlation relationship of innovation efficiency.

3.4. Variable and Data Declaration. For reasons of authority, this paper selected as the data samples the demonstration pilot project of IM enterprises officially announced by the Ministry of Industry and Information Technology. Since 2015, the Ministry of Industry and Information Technology has selected intelligent-upgrading projects of manufacturing enterprises as demonstration pilot projects according to the relevant requirements of the *Element Conditions of the Pilot Demonstration Project of IM*. The pilot demonstration project must have operationalized the transformation of IM enterprises; must have achieved remarkable results in shortening the product development cycle, reducing operating costs, and improving production efficiency; and must continue to improve in future development and exhibit favorable growth. Therefore, the sample selection met the study objective and requirements of this paper. From 2015 to 2018, the Ministry of Industry and Information Technology announced 306 IM demonstration pilot projects. Because obtaining enterprise microdata is difficult, and financial data disclosed by listed companies are highly reliable and available, domestic A-share listed enterprises among the pilot enterprises were selected as typical samples. Moreover, the listed companies experiencing bankruptcy, mergers, and acquisitions or missing important information were eliminated, leaving 103 listed companies. To ensure the data validity and integrity, extreme enterprises whose patent authorization number was 0 were eliminated. Ultimately, 45 effective target enterprises remained. The annual report data were all from the Guotai database, and the number of patent authorizations for each enterprise was searched with the applicant as the search condition yearly on the National Intellectual Property Administration website.

According to the innovation input and output process of IM enterprises, investment in R&D was selected as the input index in this paper. The practice of Su and Li [46] was used in the input stage when measuring the innovation efficiency index by considering the principle of the availability and operability of index selection. The main reasons for using this method are as follows: the enterprise's R&D activities—including personnel, funds, and equipment—include many factors that are difficult to measure, and R&D fund investment is the most direct response to the enterprise's R&D investment. This paper used annual R&D investment/operating income to measure innovation investment. Regarding the output index from the perspective of existing studies, all scholars measure innovation achievements by patent application quantity and the number of granted patents [47, 48]. The quantity of patent applications represents innovation efforts rather than scientific and technological innovation capabilities. The number of granted patents is the number of patents authorized only after strict examination procedures, which can more directly reflect the regional capability of scientific and technological innovation [49]. Therefore, this paper used the number of granted patents rather than the number of applications. The evaluation index system of the innovation efficiency of the IM enterprises is shown in Table 1.

4. Empirical Analyses

4.1. Spatial Distribution of the Innovation Efficiency of the IM Enterprises. This paper used the DEA cross-efficiency model and MaxDEA software to measure the innovation efficiencies of 45 IM enterprises from 2015 to 2020. As shown in Table 2, the development was relatively stable of the innovation efficiency of China's IM enterprises, innovation efficiency has been increasing slowly in the past six years with fluctuations, and the average innovation efficiency was 0.515. In these six years, the average innovation efficiency of Jiangsu CMG Construction Machinery was 0.957, ranking first, and the lowest innovation efficiency was of Shaanxi Xiagu Power in 2015, which was only 0.109. IM enterprises exhibited a large gap in innovation efficiency, which indicated that some of China's IM enterprises made some breakthroughs in recent years, but some of them had low innovation efficiency.

4.2. Analysis of the Characteristics and Evolutionary Process of the Whole Network. Based on the modified gravity model, this section establishes the spatial network of the innovation efficiency of the IM enterprises, draws a topological map of their spatial network by using Netdraw in UCINET, and selects sections of 2015 and 2020 for a comparative analysis (see Figures 1 and 2). The nodes in the figure represent the 45 IM enterprises, and the connections between the nodes represent the correlation relationships between them. As shown in Figures 1 and 2, compared with 2015, the spatial correlation relationships of innovation efficiency, network density, and two-way correlation, represented by thick lines, increased in 2020, and the relationship network of innovation efficiency became more complex then. The innovation efficiencies of many of the IM enterprises not only affected the enterprises in the same provinces, but also broke the geographical restrictions, permitting spatial correlation relationships to occur with neighboring and nonneighboring provinces. To further analyze the overall network characteristics of the spatial correlation of the innovation efficiency of the IM enterprises, this paper calculated the spatial correlation network correlation degree, density, grade, and efficiency of their innovation efficiency based on the spatial correlation matrix. A diagram comparing the network density and relationship number is shown in Figure 3, and one comparing the network grade and network efficiency is shown in Figure 4.

The measurement results showed that the network correlation degree from 2015 to 2020 was 1, which indicated that the network accessibility was good, and the innovation efficiency network of the IM enterprises was closely associated among regions. Figure 3 shows that the network density and the number of relationships decreased slightly in 2020, but the overall trend was still an increase. The quantitative analysis was consistent with the results of the previous topological graph, which indicated that the relationships tended to be close among the spatial correlation network of the innovation efficiency of the IM enterprises. Figure 4 indicates that the network grade showed a downward trend, from 0.7928 in 2015 to 0.686 in 2020, indicating that the spatial correlation network structure of the innovation efficiency of the IM enterprises was broken, the relationship between regional innovation efficiencies was gradually strengthened, and an obvious trend emerged of cross-regional collaborative innovation. The network efficiency decreased from 0.51 in 2015 to 0.4632 in 2020, which indicated that the innovation efficiencies of the IM enterprises were gradually close in the network, and the stability of the spatial network has gradually strengthened.

4.3. Individual Network Characteristics. By measuring degree, closeness, and intermediary centrality, this paper analyzed the individual network characteristics of the spatial

Table 1: Evaluation index system of the innovation efficiency of the IM enterprises.

First-grade index	Second-grade index	Measurement
Input	Investment in R&D	Annual R&D investment/operating income
Output	Number of granted patents	Direct use of the index data

Table 2: Innovation efficiency of 45 IM enterprises from 2015 to 2020.

Enterprise abbreviation	2015	2016	2017	2018	2019	2020	Average value
Henei Heis Company Limited	0.726	0.781	0.831	0.884	0.851	0.846	0.820
Shandong Goertek Inc.	0.582	0.559	0.602	0.643	0.685	0.685	0.626
Hunan Zoomlion	0.531	0.564	0.587	0.571	0.639	0.624	0.586
Liaoning Ansteel	0.891	0.784	0.863	0.831	0.783	0.961	0.852
Shanghai Tiandi Science & Technology.	0.761	0.963	0.874	0.767	0.778	0.934	0.846
Zhengjiang Robam	0.873	0.731	0.783	0.731	0.791	0.683	0.765
Henan Yutong Bus	0.741	0.739	0.846	0.883	0.821	0.857	0.815
Hebei CRRC	0.835	0.874	0.887	0.859	0.983	0.973	0.902
Jiangxi Copper	0.783	0.657	0.674	0.895	0.856	0.785	0.775
XCMG Construction Machinery	0.928	0.954	0.961	0.959	0.972	0.968	0.957
Jiangsu HTGD	0.765	0.875	0.931	0.976	0.951	0.874	0.895
Beijing Foton	0.745	0.784	0.734	0.861	0.987	0.943	0.842
China XD Group	0.693	0.646	0.685	0.699	0.751	0.631	0.684
Guangxi Liugong	0.687	0.691	0.682	0.691	0.723	0.703	0.696
Guodian Nanjing Automation	0.735	0.758	0.876	0.831	0.941	0.872	0.836
Chongqing Chuanyi Automation	0.646	0.763	0.735	0.772	0.841	0.864	0.770
Zhejiang Jushi	0.695	0.685	0.821	0.867	0.841	0.871	0.797
Xinjiang TBEA	0.571	0.645	0.682	0.631	0.788	0.793	0.685
Xinjiang West-Construction	0.473	0.482	0.741	0.783	0.732	0.778	0.665
Shandong Sailun Jinyu Group	0.974	0.861	0.967	0.983	0.741	0.865	0.899
Chongqing Yahua	0.651	0.731	0.631	0.689	0.731	0.786	0.703
North China Pharmaceutical	0.573	0.581	0.542	0.514	0.631	0.645	0.581
Gansu Great Wall Electrical	0.463	0.441	0.485	0.463	0.431	0.521	0.467
Xinjiang Goldwind Science & Technology	0.342	0.314	0.381	0.321	0.384	0.351	0.349
Jiangsu Victory Precision	0.351	0.351	0.431	0.463	0.471	0.442	0.418
Jiangsu Tongding Connection	0.319	0.373	0.379	0.365	0.383	0.381	0.367
HT-SAAE	0.341	0.364	0.373	0.361	0.371	0.379	0.365
Hubei Accelink	0.286	0.281	0.265	0.365	0.393	0.345	0.323
CITIC Heavy Industries	0.311	0.382	0.362	0.374	0.375	0.321	0.354
Rapoo Technology	0.331	0.285	0.231	0.351	0.341	0.358	0.316
Guangxi Hytera	0.221	0.252	0.241	0.283	0.261	0.251	0.252
Zhejiang Eastcom	0.156	0.121	0.241	0.271	0.263	0.298	0.225
Fujian Changelight	0.154	0.173	0.196	0.141	0.144	0.131	0.157
Guizhou Space Appliance	0.231	0.274	0.221	0.251	0.267	0.271	0.253
Shanghai Brightdairy	0.151	0.182	0.164	0.171	0.162	0.153	0.164
Jiangxi Changhong Huayi	0.291	0.272	0.263	0.231	0.285	0.221	0.261
Jiangxi JZJT	0.253	0.262	0.241	0.235	0.281	0.284	0.259
Shangdong Doublestar	0.186	0.171	0.184	0.191	0.121	0.132	0.164
Shandong Tianrun Crankshaft	0.257	0.207	0.231	0.221	0.267	0.238	0.237
Zhejiang Wynca	0.178	0.211	0.251	0.268	0.281	0.252	0.240
Jiangsu Hengshun Vinegar Industry	0.191	0.137	0.181	0.189	0.237	0.173	0.185
Zhengjiang Saint Angelo	0.219	0.231	0.298	0.281	0.231	0.235	0.249
Anhui Huamao Group	0.182	0.175	0.238	0.247	0.219	0.183	0.207
Jiangsu Kanion Pharmaceutical	0.178	0.121	0.243	0.189	0.182	0.231	0.191
Shaanxi Xiagu Power	0.109	0.159	0.194	0.114	0.184	0.176	0.156

network of the innovation efficiency of the IM enterprises to determine their positions and roles. This paper measured the in- and outdegrees of each IM enterprise to study the influence and affected situations of the spatial correlation network of certain IM enterprises, and the measurement results are shown in Table 3.

4.3.1. Degree Centrality. Degree centrality can reflect the status of each IM enterprise in the spatial network of innovation efficiency. The five IM enterprises with the highest outdegrees were XCMG Construction Machinery, Jiangsu HTGD, Zhejiang Wynca, Hubei Accelink, and Anhui Huamao Group, which are located in Eastern and Central

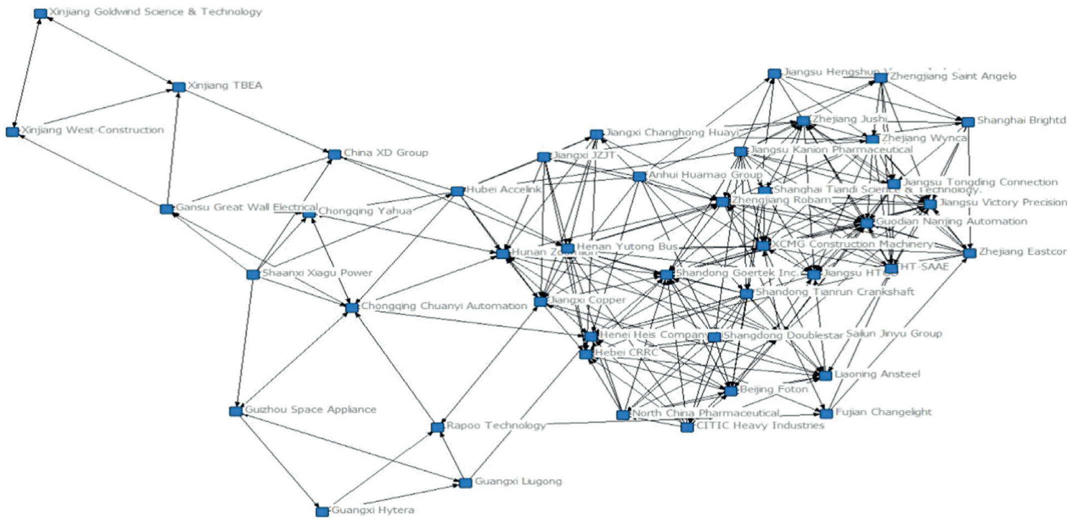

Figure 1: Spatial correlation network of the innovation efficiency of the IM enterprises in 2015.

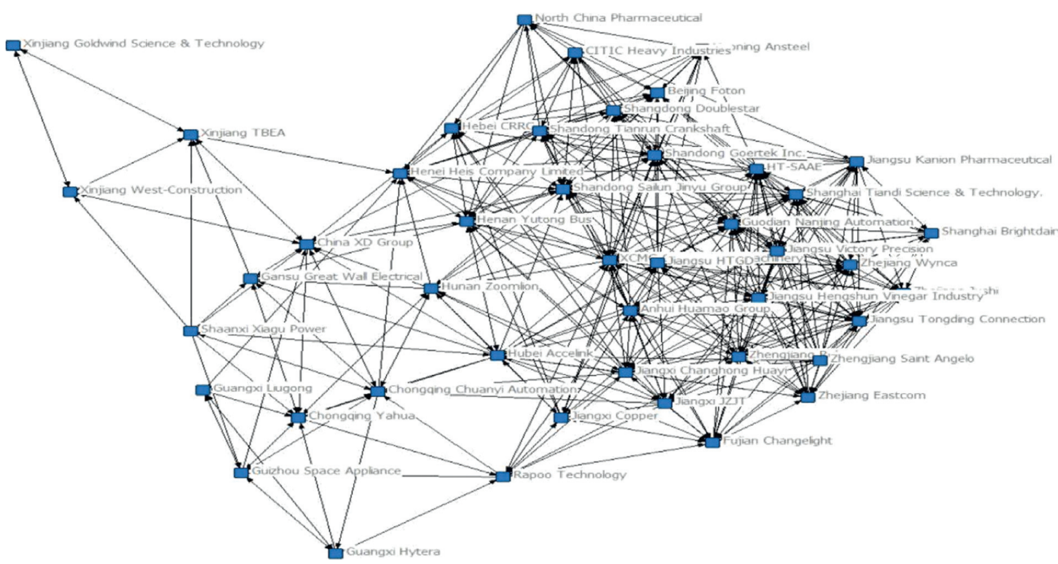

Figure 2: Spatial correlation network of the innovation efficiency of the IM enterprises in 2020.

China. This finding showed that these five IM enterprises had more innovation efficiency overflow, which promoted the innovation efficiency of the other IM enterprises. The five IM enterprises with the poorest outdegrees were Xinjiang Goldwind Science & Technology, Xinjiang West-Construction, Gansu Great Wall Electrical, Xinjiang TBEA, and Guangxi Liugong, which were located in Northwestern China and had little correlation with the other IM enterprises. The five IM enterprises with leading indegrees were XCMG Construction Machinery, Guodian Nanjing Automation, Shandong Goertek Inc., Shandong Sailun Jinyu Group, and Zhejiang Jushi, which were all located in Eastern China. The higher outdegrees indicated that the innovation efficiencies of the other IM enterprises overflowed to these five enterprises. The five IM enterprises with the lowest indegrees were Xinjiang Goldwind Science & Technology, Guangxi Liugong, Shaanxi Xiagu Power, Xinjiang TBEA, and Xinjiang West-Construction, which were located in Northwestern China, indicating that these enterprises undertook fewer network relationships. A further analysis showed that the degree centrality was the highest for the IM enterprises in Eastern China, indicating that these enterprises had a higher degree of external innovation efficiency. In contrast, the degree centrality of the IM enterprises in Western China ranked lower, indicating that these enterprises had a lower degree of external innovation efficiency. According to the *Report on the IM Development Index (2020)*, the IM enterprises in China are unevenly distributed, and more IM enterprises are concentrated in Jiangsu and Zhejiang provinces and other parts of Eastern China. The innovation efficiencies in Eastern China produced a mutual aid effect with a high density, which caused the spatial network relationships to become increasingly closer. However, few IM enterprises were located in Western China, and these were far from the correlation degree of the innovation efficiency of other enterprises in the network.

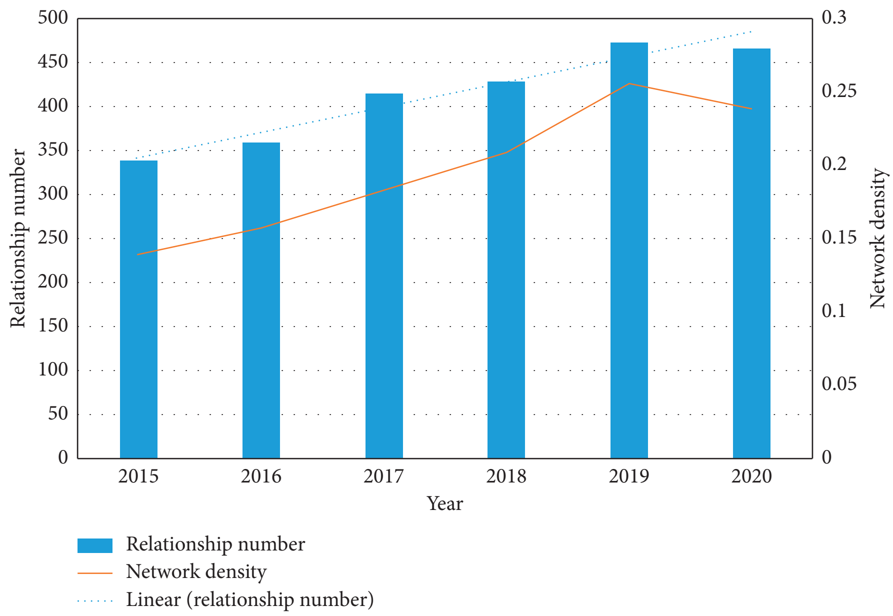

Figure 3: Network density and relationship number.

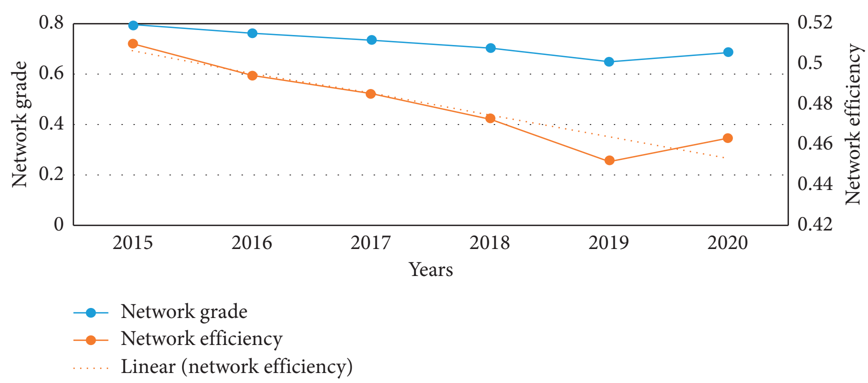

Figure 4: Network grade and efficiency.

Table 3: Analysis of the centrality of the spatial correlation network of the innovation efficiency of the IM enterprises.

Enterprise abbreviation	Outdegree	Ranking	Indegree	Ranking	Degree centrality	Ranking	Closeness centrality	Ranking	Intermediary centrality	Ranking
Henei Heis Company Limited	5	37	15	7	22.222	25	61.972	4	4.526	11
Shandong Goertek Inc.	8	27	19	3	30.000	9	61.111	9	1.604	25
Hunan Zoomlion	10	23	10	22	22.222	25	58.667	15	7.071	4
Liaoning Ansteel	6	36	9	26	16.666	33	50.575	35	1.009	34
Shanghai Tiandi Science & Technology.	13	13	16	6	32.222	4	57.895	17	3.079	17
Zhengjiang Robam	13	13	13	14	28.889	13	57.895	17	1.802	24
Henan Yutong Bus	12	18	15	7	30.000	9	61.972	4	10.161	2
Hebei CRRC	8	27	14	12	24.444	22	58.667	15	2.332	22
Jiangxi Copper	10	23	8	29	20.000	27	55.000	26	2.568	21
XCMG Construction Machinery	19	1	20	1	43.333	1	68.750	1	8.573	3
Jiangsu HTGD	17	2	15	7	35.555	3	65.672	2	3.415	13
Beijing Foton	11	20	12	18	25.555	19	57.895	17	3.242	15
China XD Group	7	32	11	20	20.000	27	56.410	21	12.609	1

Table 3: Continued.

Enterprise abbreviation	Outdegree	Ranking	Indegree	Ranking	Degree centrality	Ranking	Closeness centrality	Ranking	Intermediary centrality	Ran king
Guangxi Liugong	5	37	2	43	7.7775	44	45.361	40	0.559	39
Guodian Nanjing Automation	13	13	20	1	36.666	2	60.274	11	2.671	18
Chongqing Chuanyi Automation	8	27	9	26	18.889	30	56.410	21	6.018	5
Zhejiang Jushi	7	32	17	5	26.667	16	53.012	32	0.435	41
Xinjiang TBEA	4	40	5	37	10.000	41	43.564	41	3.38	14
Xinjiang West-Construction	3	43	4	41	7.778	42	37.931	44	1.468	27
Shandong Sailun Jinyu Group	11	20	18	4	32.222	5	64.706	3	4.894	9
Chongqing Yahua	4	40	9	26	14.444	36	47.312	38	2.009	23
North China Pharmaceutical	7	32	5	37	13.333	37	51.163	34	0.87	36
Gansu Great Wall Electrical	3	43	7	30	11.111	39	48.889	37	1.112	33
Xinjiang Goldwind Science & Technology	2	45	2	43	4.444	45	30.769	45	0	45
Jiangsu Victory Precision	14	10	15	7	32.222	5	60.274	11	1.32	30
Jiangsu Tongding Connection	15	6	12	18	30.000	9	55.000	26	0.643	38
HT-SAAE	15	6	13	14	31.111	8	60.274	11	1.593	26
Hubei Accelink	16	4	7	30	25.556	18	61.972	4	5.366	6
CITIC Heavy Industries	12	18	5	37	18.889	30	54.321	28	1.377	28
Rapoo Technology	7	32	7	30	15.556	35	53.659	31	5.22	8
Guangxi Hytera	4	40	3	42	7.778	42	40.000	43	0.872	35
Zhejiang Eastcom	10	23	14	12	26.666	17	55.696	25	0.518	40
Fujian Changelight	8	27	13	14	25.555	19	56.410	21	1.208	31
Guizhou Space Appliance	5	37	6	35	12.222	38	43.564	41	2.582	20
Shanghai Brightdairy	10	23	5	37	16.666	33	50.575	35	0.123	44
Jiangxi Changhong Huayi	14	10	15	7	32.222	5	61.972	4	4.709	10
Jiangxi JZJT	13	13	10	22	25.555	19	60.274	11	3.701	12
Shangdong Doublestar	11	20	11	20	24.444	23	57.895	17	1.341	29
Shandong Tianrun Crankshaft	13	13	13	14	28.889	13	61.111	9	3.212	16
Zhejiang Wynca	17	2	10	22	30.000	9	56.410	21	1.126	32
Jiangsu Hengshun Vinegar Industry	15	6	7	30	20.000	27	54.321	28	0.169	42
Zhengjiang Saint Angelo	15	6	6	35	18.888	32	52.381	33	0.129	43
Anhui Huamao Group	16	4	10	22	28.889	13	61.972	4	5.302	7
Jiangsu Kanion Pharmaceutical	14	10	7	30	23.333	24	54.321	28	2.653	19
Shaanxi Xiagu Power	8	27	2	43	11.111	40	45.833	39	0.658	37

4.3.2. Closeness Centrality. Closeness centrality can be used as an index to judge the degree of the correlation difficulty of each IM enterprise in the spatial association network. In 2020, the average closeness degree of the IM enterprises was 54.891. The top five enterprises in this regard were XCMG Construction Machinery, Jiangsu HTGD, Shandong Sailun Jinyu Group, Henan Yutong Bus, and Jiangxi Changhong Huayi, which were located in Mideastern China, where IM enterprises were concentrated and had a short network distance from the other IM enterprises in the network. Therefore, they could more easily spatially correlate with the other IM enterprises in the spatial correlation network. The bottom five enterprises were Xinjiang TBEA, Guizhou Space Appliance, Guangxi Hytera, Xinjiang West-Construction, and Xinjiang Goldwind Science & Technology, which were located in Western China at the edge of the network.

Therefore, these enterprises had difficulty obtaining innovation efficiency from the other IM enterprises, and they had no obvious impact and driving effect on the other IM enterprises. Therefore, their independence was stronger in the innovation efficiency correlation.

4.3.3. Intermediary Centrality. Intermediary centrality can be used to measure the ability of IM enterprises to control resources in a spatial correlation network. In 2020, the average intermediary centrality of the IM enterprises was 2.872. The top five enterprises were China XD Group, Henan Yutong Bus, XCMG Construction Machinery, Hunan Zoomlion, and Chongqing Chuanyi Automation, which showed that these IM enterprises were in the middle of the innovation efficiency correlation network and controlled the construction and development of the correlation relationships of the innovation efficiency of the other IM enterprises. Contrary to expectations, the index was insufficient of the IM enterprises located in the economically developed areas of Eastern China, which indicated that the IM enterprises located in economically developed areas had no driving effect on the other IM enterprises.

4.4. Module-Modeling Analysis. To better show the network role and functional rule of the IM enterprises, a social network analysis was introduced in this paper to perform a clustering analysis. In this paper, the CONCOR method in UCINET software was used to study the network structure, and 45 IM enterprises were divided into four modules with a maximum segmentation depth of 2 and a concentration standard of 0.2, as shown in Table 4. Module I had 11 IM enterprises, which were mainly located in Northeastern and Eastern China. Module II had 21 IM enterprises, which were mainly located in Central and Eastern China. Module III had 8 IM enterprises, which were mainly located in Central and Western China. Module IV had 5 IM enterprises, which were mainly located in Western China.

Table 5 shows that the entrepreneurial performance of the IM enterprises in 2020 had 465 spatial network relationships. Of these, 338 were within the module, accounting for 72.69% of the total, and 127 were outside the module, accounting for 27.31% of the total. As a result, intramodule overflow was the primary factor in the spatial network overflow of the innovation efficiency of the IM enterprises. The network module nature was judged by using the Wasserman evaluation method. The number of sending-out relationships in Module I was 104, among which the number of relationships inside the module was 78, that received outside the module was 58, and that overflowing outside was 26; the proportion of expected internal relationships was 22.73%; and the proportion of actual internal relationships was 75%. As a result, Module I had more overflow relationships with the IM enterprises, both inside and outside the module, so it was a "two-way overflow module." The number of sending-out relationships in Module II was 282, among which the number of relationships inside the module was 220, that received outside the module was 34, and that overflowing outside the module was 62; the proportion of expected internal relationships was 45.45%; and the proportion of actual internal relationships was 78.01%. These results indicated that Module II could improve its own innovation efficiency while spilling innovation efficiency to members of other modules. Thus, Module II was designated the "net overflow module." The number of sending-out relationships in Module III was 60, among which the number of relationships inside the module was 27, that received outside the module was 19, and that overflowing outside the module was 33; the proportion of expected internal relationships was 15.91%; and the proportion of actual internal relationships was 45.00%. Thus, the connection between the module and the outside was similar to that within the module, which played the role of a "broker," so Module III was designated the "broker module." The number of sending-out relationships in Module IV was 19, among which the number of relationships inside the module was 13, that received outside the module was 16, and that overflowing outside the module was 6; the proportion of expected internal relationships was 9.09%; and the proportion of actual internal relationships was 68.42%. The number of external relationships received by the module was far greater than that overflowing from the module, so the module was a typical "net income module." Therefore, in 2020, China's IM enterprises were unevenly distributed by region, and each module was composed of enterprises from the same or adjacent provinces. The module regions were geographically concentrated, and when they were closer to each other, they were more likely to have innovation correlation. Module II showed that the Yangtze River Delta and its surrounding economically developed regions accounted for more innovation correlation, and the internal correlation was strong, so they could meet the development needs of their own innovation efficiencies. However, the enterprises in Module IV, located in Western China, needed to absorb the overflow effect of the other modules to develop innovation efficiency, because the module had a small number of enterprises.

To further study the overflow relationships and path among the modules, UCINET software was used to calculate the network density and image matrices of each module (see Table 6). Figure 4 indicates that the density of the whole network in 2020 was 0.2383, which was taken as the critical value. A module density greater than 0.2383 indicated a concentration trend in the module. The density value was assigned to 1, and a density value less than 0.2383 was assigned to 0 to convert the density matrix of each module into an image matrix. The evolutionary process showed that the spatial correlation network of the innovation efficiency of the IM enterprises did not show the expected core-edge structure but presented a significant cohesive subgroup characteristic. The IM enterprises within the module were closely connected, while there were fewer external relations. Only Module III sent relationships to Module IV; that is, the innovation efficiency of Broker Module III flowed to Net Income Module IV. Therefore, the IM enterprises in Module IV had to absorb the overflow effects of the other modules to meet the development needs of their own innovation efficiency. However, they could

Table 4: Module members and industries.

Module	Enterprise abbreviation	Economic zone and number	Industry
I	Henei Heis Company Limited., Shandong Goertek Inc., Hebei CRRC, Liaoning Ansteel, Shangdong Doublestar, Shandong Tianrun Crankshaft, Henan Yutong Bus, Hebei CRRC, Shandong Sailun Jinyu Group, Beijing Foton, and North China Pharmaceutical	1 in Northeast and 10 in Eastern China	Electrical machinery and equipment manufacturing, automobile manufacturing, ferrous metal smelting and rolling processing, pharmaceutical manufacturing, and rubber and plastic product
II	XCMG Construction Machinery, Jiangsu Victory Precision, Jiangxi Changhong Huayi, Guodian Nanjing Automation, Shanghai Tiandi Science &Technology, Zhengjiang Robam, Shanghai Brightdairy, Jiangsu Hengshun Vinegar Industry, Jiangxi Copper, Anhui Huamao Group, Jiangsu HTGD, Zhejiang Jushi, Zhejiang Wynca, Rapoo Technology, Jiangsu Tongding Connection, HT-SAAE, Fujian Changelight, Jiangsu Kanion Pharmaceutical, Zhejiang Eastcom, Zhengjiang Saint Angelo, and Jiangxi JZJT	2 in Central and 19 in Eastern China	Electrical machinery and equipment manufacturing; science and technology promotion and application service; computer, communication and other electronic equipment manufacturing; ferrous metal smelting and rolling processing; food manufacturing; chemical raw material and chemical product manufacturing; textile; pharmaceutical manufacturing; nonmetallic mineral product
III	Hunan Zoomlion, Guizhou Space Appliance, Shaanxi Xiagu Power, Guangxi Liugong, Hubei Accelink, Chongqing Chuanyi Automation, Chongqing Yahua, and Guangxi Hytera	1 in Central and 7 in Western China	Electrical machinery and equipment manufacturing, and science and technology promotion and application service
IV	China XD Group, Xinjiang TBEA, Xinjiang West-Construction, Xinjiang Goldwind Science & Technology, and Gansu Great Wall Electrical	5 in Western China	Electrical machinery and equipment manufacturing, science and technology promotion and application service, chemical raw material and chemical product manufacturing

Table 5: Module overflow effect of the spatial correlation network of the innovation efficiency of the IM enterprises.

Module	Receiving relationship matrix				Relationship number received outside the module	Relationship number sent outside the overflow module	Proportion of the expected internal relationship (%)	Proportion of the actual internal relationship (%)
	I	II	III	IV				
I	78	19	3	4	58	26	22.73	75.00
II	49	220	13	0	34	62	45.45	78.01
III	6	15	27	12	19	33	15.91	45.00
IV	3	0	3	13	16	6	9.09	68.42

Table 6: Density and image matrices.

Module	Density matrix				Image matrix			
	I	II	III	IV	I	II	III	IV
I	0.709	0.082	0.034	0.073	1	0	0	0
II	0.212	0.521	0.077	0.000	0	1	0	0
III	0.068	0.089	0.518	0.300	0	0	1	1
IV	0.055	0.000	0.075	0.650	0	0	0	1

only be affected by the innovation efficiency of the IM enterprises in neighboring provinces due to geographical factors. Meanwhile, Eastern China, which has a developed economy and a large number of IM enterprises, had less of an effect on this relationship, which is consistent with the closeness centrality conclusion.

4.5. Role Analysis of the Intermediary. Table 7 shows that the 45 IM enterprises acted as intermediaries in the submodules and internal relationships of the module. Regarding the number of times the IM enterprises acted as intermediaries, XCMG Construction Machinery, Jiangsu HTGD, and Zhejiang Wynca did so more frequently. These three enterprises were all from Module II and were important hubs in both the whole network and Module II. XCMG Construction Machinery, Shandong Goertek Inc., and Shandong Sailun Jinyu Group acted as gatekeepers most frequently and played the role of a gateway and window regarding the overflow of the innovation efficiency of foreign IM enterprises. XCMG Construction Machinery, HT-SAAE, and Jiangxi Changhong Huayi most frequently acted as agents and were important output windows influencing the other modules. Hubei Accelink, Henan Yutong Bus, Jiangsu HTGD, and XCMG Construction Machinery mostly played consultant roles and were the main entry windows in the innovation efficiency relationships of each module. Hunan Zoomlion, Hubei Accelink, and Henan Yutong Bus acted mostly as contacts and played important roles that deepened the innovation efficiency and spatial correlation of China's IM enterprises.

Table 7: Intermediary role.

Module	Enterprise abbreviation	Coordinator	Gatekeeper	Agent	Consultant	Contacts	Total
I	Henei Heis Company Limited	5	34	0	0	0	39
	Shandong Goertek Inc.	11	60	3	3	1	78
	Hebei CRRC	17	21	8	0	4	50
	Liaoning Ansteel	4	5	13	3	0	25
	Shangdong Doublestar	7	55	2	1	0	65
	Shandong Tianrun Crankshaft	14	51	9	3	7	84
	Henan Yutong Bus	9	30	42	7	18	106
	CITIC Heavy Industries	7	0	10	0	0	17
	Shandong Sailun Jinyu Group	17	59	20	2	9	107
	Beijing Foton	17	8	42	0	2	69
	North China Pharmaceutical	5	0	5	0	0	10
II	XCMG Construction Machinery	83	84	68	7	9	251
	Jiangsu Victory Precision	41	15	22	1	2	81
	Jiangxi Changhong Huayi	49	12	52	0	3	116
	Guodian Nanjing Automation	35	41	26	2	3	107
	Shanghai Tiandi	37	15	28	1	1	82
	Zhengjiang Robam	53	0	17	0	0	70
	Shanghai Brightdairy	8	0	3	0	0	11
	Jiangsu Hengshun Vinegar Industry	15	8	8	0	2	33
	Jiangxi Copper	8	12	16	2	6	44
	Anhui Huamao Group	49	10	33	1	0	93
	Jiangsu HTGD	67	32	45	7	4	155
	Zhejiang Jushi	29	4	0	0	0	33
	Zhejiang Wynca	59	0	14	0	0	73
	Rapoo Technology	12	10	8	2	0	32
	Jiangsu Tongding Connection	42	0	14	0	0	56
	HT-SAAE	29	0	64	0	0	93
	Fujian Changelight	43	3	0	0	0	46
	Jiangsu Kanion Pharmaceutical	32	11	13	2	0	58
	Zhejiang Eastcom	39	5	0	0	0	44
	Zhengjiang Saint Angelo	19	9	0	0	0	28
	Jiangxi JZJT	36	6	36	0	2	80
III	Hunan Zoomlion	2	16	13	5	26	62
	Guizhou Space Appliance	7	3	3	0	1	14
	Shaanxi Xiagu Power	2	0	4	0	0	6
	Guangxi Liugong	0	0	3	0	0	3
	Hubei Accelink	2	15	22	21	21	81
	Chongqing Chuanyi Automation	11	16	6	0	10	43
	Chongqing Yahua	8	5	3	0	0	16
	Guangxi Hytera	1	0	2	0	0	3
IV	China XD Group	3	17	11	0	14	45
	Xinjiang TBEA	4	1	4	0	1	10
	Xinjiang West-Construction	2	1	0	0	0	3
	Xinjiang Goldwind Science & Technology	0	0	0	0	0	0
	Gansu Great Wall Electrical	0	6	0	0	1	7

5. Main Research Conclusions and Implications

5.1. Research Conclusions. The DEA cross-efficiency model was used in this paper to measure the innovation efficiency of 45 IM enterprises in China from 2015 to 2020. In addition, its spatial correlation network was built through the modified gravity model. Moreover, its structural characteristics were comprehensively analyzed from the aspects of the whole network characteristics and the position, clustering and intermediary roles of various IM enterprises in the network by using a social network analysis. The main conclusions are as follows:

(1) The whole network analysis showed that the spatial network accessibility was favorable for the innovation efficiency of China's IM enterprises from 2015 to 2020. The network density and the number of relationships showed an upward trend in fluctuations, and the network relationships tended to be close. The network grade presented a downward trend in the fluctuations, which indicated that the relationship network of innovation efficiency was more complex and broke the regional restrictions. Finally, the spatial correlation of the innovation efficiency among the enterprises was gradually strengthened.

(2) The analysis of the individual networks revealed that the IM enterprises in Jiangsu Province, which had a high level of economic development and both a high number and an intensive distribution IM enterprises, were in a central position in the innovation efficiency network. However, although they had a high degree of correlation with the IM enterprises in their own and neighboring provinces, they had no strong driving effect on the innovation efficiency of the cross-regional IM enterprises and had overflow benefits only for the IM enterprises in neighboring provinces. However, the IM enterprises in Xinjiang and Shaanxi provinces and other parts of Western China were at the edge of the network. In addition, they were more independent in the innovation efficiency correlation and were not controlled by the other IM enterprises.

(3) The module analysis showed that the 4 modules formed a correlation network for the innovation efficiency of the IM enterprises. The gap between the numbers of IM enterprises in each module was large, which presented obvious characteristics of cohesive subgroups, and the correlation between modules was weak. Module I included the IM enterprises in Eastern and Northeastern China. These enterprises could not only improve their own innovation efficiencies, but also greatly promote that of the other modules. Therefore, Module I was described as a two-way overflow module. Module II had the largest number of members, which were located in Central and Eastern China, mainly including those located in Jiangsu and Zhejiang provinces. The enterprises in this module were closely related and formed highly cohesive subgroups that could meet the development needs of their own innovation efficiency. Therefore, it was described as the net overflow module. The members of Module III were mainly located in Central and Western China and played "bridge" and "intermediary" roles. Module IV—which included enterprises in Xinjiang, Shaanxi, and Gansu provinces—seldom invited outside enterprises to engage in innovation relationships but frequently received invitations to engage with enterprises from nearby Module III. In summary, the regional distribution of IM enterprises in China affected the characteristics of the spatial correlation network structure.

(4) The analysis of the intermediary role showed that, except for enterprises with outstanding innovation capability, the economically developed Yangtze River Delta played the most important role of the intermediary. Henan Yutong Bus, XCMG Construction Machinery, Hunan Zoomlion, and China XD Group were the most active intermediaries among the four modules and played an important role as bridges in establishing the relationship between and within the modules.

5.2. Research Implications. Based on the above analysis, the following four aspects presented in this paper can promote the development of the innovation efficiency network of IM enterprises in China.

(1) The spatial network structure can be optimized of the innovation efficiency of IM enterprises. The spatial network structure has become increasingly complex for the innovation of IM enterprises in China through network analysis. However, compared with the relationship density of Module II, the complexity of the whole network still lags far behind, and the whole network spatial correlation still has much room for growth. Network upgrading for the innovation efficiency of IM enterprises is realized by speeding information construction, optimizing the innovation environment, constructing transportation infrastructure, promoting the regional innovation exchange of IM enterprises, and further breaking regional barriers. On the one hand, IM enterprises must optimize their industrial structure, ensure the rational use of limited independent innovation elements, promote the rational flow of various element resources among different industries of IM enterprises, and achieve the balanced development of IM enterprises' innovation. On the other hand, in the context of coordinated industrial and regional development, it is necessary not only to pay attention to the efficiency problems reflected by attribute data in the innovation process of IM enterprises, but also to place in a prominent position the spatial structure and spillover effects reflected through relational data.

(2) Pay attention to the cyberspace spillover effect of the innovation efficiency of IM companies, in which key leading companies play a leading innovation role. According to previous research, enterprises with high innovation capabilities—such as XCMG Construction Machinery, Jiangsu HTGD, and Zhejiang Wynca—have a small innovation radiation scope and more innovation overflow only to the IM enterprises in their own module. As an innovation resource-clustering area, such enterprises should strengthen the external output capability of their own innovation efficiency and expand their innovation radiation scope while constantly improving their own innovation capability.

(3) Give full play to the role of the government in macro control and balance the development level of IM enterprises in different regions. The module-modeling analysis showed that the four modules in China have an uneven number of members, among which

the 21 members in Module II are four times that in Module IV. Moreover, the innovation and development capability of IM enterprises gradually decreases from economically developed Eastern China to Western China. A new regional pattern must be built of the innovation efficiency of IM enterprises at the national level, and different technological development strategies must be formulated based on the different roles played in their spatial correlation network of innovation efficiency. “Spillover” IM companies must achieve basic, original, critical, and forward-looking technological breakthroughs and spread technology outwards with strong technical strength. “Broker” IM companies should undertake new technologies and improve their own technological innovation capabilities while expanding their technologies. “Net income” IM companies should engage more in the introduction, digestion, absorption, and transformation of new technologies, and special attention should be given to the introduction and cultivation of talent.

A social network analysis was used in this paper to study the overall and individual characteristics and internal structure of the spatial network for the innovation efficiency of IM enterprises, but some shortcomings remain. First, the binary matrix of the correlation structure for the innovation efficiency of IM enterprises can only reveal the relationships of innovation efficiencies among enterprises but cannot describe their strength. Second, all IM enterprises were taken as the research object in this paper, but no further research was conducted on the industry segmentation of IM enterprises. Third, no further research was done on the impact of cyberspace correlations that affect the innovation efficiency of IM enterprises. The author will further explore the above problems in future research.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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