Research on the Evolution of Industry-University-Research Cooperation Hypernetwork in Digital Creative Industry: A Case Study of Beijing

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Abstract. The digital creative industry is a key part of strategic emerging industries, driving the digital economy's growth. This article constructs the topology of the Beijing digital creative industry I-U-R cooperation hypernetwork and analyzes its dynamic evolution through simulation. Empirical results show uneven cooperation distribution, with universities and individual enterprises dominating and weak connectivity between entities. The I-U-R hypernetwork is rapidly developing, with hyperdegree and optimal connection mechanisms driving its evolution. Based on these findings, relevant recommendations are provided.

Keywords: Digital creative industry; I-U-R cooperation; Hypernetworks; patents.

1. Introduction

The digital creative industry is an emerging sector that integrates creativity and content with digital technology, impacting various economic and social fields by engaging human senses through creation, production, dissemination, and service. The '13th Five-Year Plan' of the National Strategic Emerging Industries Development Plan first recognized the digital creative industry as one of five key strategic sectors. However, as a new industry, it faces challenges such as a weak foundation, talent shortages, and limited innovation. Industry-university-research (I-U-R) cooperation can address these issues by leveraging complementary resources for accelerated development. This study uses Python to construct a hypernetwork model based on a weighted hypergraph, measuring I-U-R cooperation through patent collaborations between academic, research, and industrial groups. It examines the current state of Beijing's digital creative industry and analyzes the hypernetwork's vertical evolution.

Compared to other strategic emerging industries, research on the digital creative industry is still in its early stages. Scholars like Deng Lei [1] have analyzed its conceptual connotation, development status, and direction. Others focus on innovation issues, such as Zang Z P et al. [2], who examined enterprise performance based on R&D input. Wei Wei et al. [3] used social network analysis and a modified gravity model to study the evolution of spatial correlation networks and innovation drivers in the digital creative industry. Wang Zhen et al. [4] developed an innovation ecosystem model for the Yangtze River Delta's digital creative industry.

Research on I-U-R cooperation in the digital creative industry is relatively limited. Foreign scholars primarily focus on multi-body collaboration from an enterprise perspective. For example, Santoro [5] notes that enterprises in the digital creative sector can establish innovation networks through I-U-R cooperation to achieve innovation goals. Domestic scholars emphasize strengthening collaboration between industry, academia, and research. Chen Rui et al. [6] proposed creating an integration platform to promote the transformation of technological achievements in the digital creative industry, while Li Wan [7] suggested that I-U-R integration should optimize employment agglomeration in regions like Guangdong, Hong Kong, and Macao.

There are few studies on I-U-R cooperation networks in the digital creative industry. Even fewer use hypernetworks for analysis. Liu Yong [8] developed a hypernetwork equilibrium model for I-U-R collaborative innovation based on financial capital and intermediary roles, offering optimization pathways. Other scholars have applied hypernetworks to industries like Shanghai's

ICT sector [9], the electronic information industry [10], and Beijing's artificial intelligence industry [11].

In summary, studies using the hypernetwork model to analyze the I-U-R cooperation network and its evolution in the digital creative industry have not yet been conducted. Therefore, this study will offer recommendations for I-U-R cooperation in Beijing's digital creative industries, based on an analysis of the collaboration network and its evolution using the hypernetwork model.

2. A Hypernetwork Model of Patent Application by I-U-R Cooperation Based on Weighted Hypergraphs

2.1 Hypernetworks Based on Weighted Hypergraphs

Graph-based hypernetworks are one of two types of hypernetworks; the other is the network-based hypernetwork proposed by Denning [12], typically used for logistic and funding networks. The concept of hypergraph was introduced by Berge in 1970 [13]. Unlike a traditional graph, where an edge connects only two nodes, a hypergraph can connect more than three nodes. Building on Chiang's definition of hypergraph [14], Estrada et al. proposed a hypernetwork based on hypergraph topology [15]. According to this theory, the I-U-R cooperation application hypernetwork represents institutions as nodes, while cooperation among different institutions in academic, research, and industrial clusters forms hyperedges. The strength of cooperation patents within each hyperedge determines the hyperedge weight, with more frequent collaborations leading to higher weights. The topology of the I-U-R cooperation application hypernetwork is shown in the following figure.

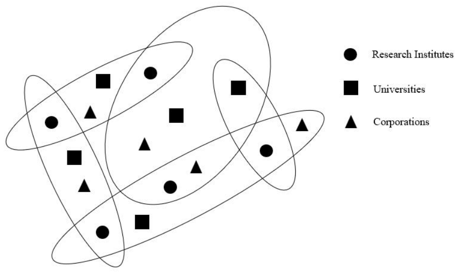

Fig. 1 Topology of the supranet for patent application by I-U-R cooperation

The solid rectangle in the figure is the company, the solid circle is the university, the solid triangle is the research institution, and the ellipse is the hyperedge formed by different institutions cooperating to apply for patents. As can be seen from the figure, the I-U-R cooperation hypernetwork can be expressed as $H = (V, E, W)$, H denotes a weighted hypergraph. Each node in the weighted hypergraph is denoted by $v_i (i = 1,2, \dots, n)$, then all nodes fom a finite set $V = \{v_1, v_2, v_3, \dots, v_n\}$, and each co-operative combination is denoted by $E_j (j = 1,2, \dots, n)$, then all the portfolios participating in the patent application of I-U-R cooperation form a finite set $E = \{E_1, E_2, E_3, \dots, E_m\}$; if $E_j \neq \emptyset$, then the number of patent applications of the combination indicated by each hyperedge can be expressed as a weight $w(E_j)$, then the set of weights of the hyperedges in the hypernetwork can be expressed as $W = \{w(E_1), w(E_2), w(E_3), \dots, w(E_n)\}$.

2.2 Hypernetwork Model Metrics

In this study, based on the existing research, the number of nodes, the number of hyperedges, the degree and degree distribution of nodes, the hyper-degree and hyper-degree distribution, the hyper-strength and hyper-strength distribution, and the hyper-edge hyper-degree, etc., are used as the metrics of the hyper network model based on the weighted hypergraph [16]. The metrics calculation method and practical significance are as Table 1

Table 1 Topological characteristic model metrics

I-U-R Indicator name	calculation method	practical significance
Number of nodes n	can be obtained from the meaning of the definition	Number of all organizations involved in collaborative patenting
Hyperedge m	can be obtained from the meaning of the definition	Number of all organizations involved in collaborative patenting
Degree of nodes d_i	can be obtained from the meaning of the definition	Number of other organizations with which an organization has applied for patents in cooperation with I-U-R
Degree distribution of nodes$P(d_i)$	The degree is the number of d_i nodes/total number of nodes in the supernetwork	Percentage of nodes with reflectivity d_i in the total number of nodes
The nodes are supercharged $d_H(v_i)$	$\sum_{E_j \in E} h(v_i, E_j)$	Number of different teams involved in collaborative patenting at an organization
Distribution of nodes' superdegree$P(d_H)$	The hyperdegree is the number of d_H nodes/total number of nodes in the hypernetwork	Reflects the percentage of nodes with hyper-degree d_H in the total number of nodes
Hyperintensity of nodes$Hd(v_i)$	$\sum_{E_j \in E} w(E_j) h(v_i, E_j)$	The number of teams involved in collaborative patent applications corresponding to this node
Hyperintensity distribution of nodes$P(Hd(v_i))$	Number of nodes with hyperstrength $Hd(v_i)$ / number of nodes in the hypernetwork	Reflecting the number of nodes with hyperintensity $Hd(v_i)$ as a percentage of the total number of nodes
Transborder transcendence $d_s(E_j)$	$\sum_{v_i \in V} h(v_i, E_j)$	Number of applicants filing a particular patent application

2.3 Hypernetwork Structure Measurement

Based on scholarly research, this study uses hypernetwork density, node-weighted centrality, and average distance to measure the hypernetwork structure [9]. Hypernetwork density reflects the level of interaction between subjects in the I-U-R cooperation hypernetwork, represented by the proportion of connecting lines between nodes. Node-weighted degree centrality shows the centrality of nodes within the hypernetwork, helping identify key nodes in I-U-R collaborative invention applications [18]. Average distance measures the connectivity between nodes, calculated as the average distance between any two nodes. The results for hypernetwork density, node-weighted centrality, and average distance are shown in Table 2.

Table 2 Hypernetwork structure measurement

structural measure (math.)	Definition	calculation method
hypernetwork density	Used to measure the closeness of intersubjective interactions in a hypernetwork	$\frac{2m}{(C_2^n + C_3^n + \ldots + C_n^n)}$
Node Weighted Degree Centrality	Reflects the degree of centrality of the node's position in the hypernetwork	$C_d^h(i) = \sum_{\substack{j=1 \\ j \neq i}}^{n} \sum_{\substack{k=1 \\ (v_i,\ v_j) \subset E_k}}^{n} w^k$
average distance	The average of the distances between any two nodes	$d = \frac{\sum_{i \neq j} d_{ij}}{2(2^n - 1)}$

3. Empirical Study on Hypernetwork of I-U-R Cooperation in Beijing's Digital Creative Industry

3.1 Data Acquisition and Processing

The patent data of the Beijing Digital Creative Industry I-U-R Cooperation is obtained from the patent database of Patsnap based on The Classification of Strategic Emerging Industries (2021) (for trial implementation).

This study focuses on invention patents, which better represent original technological innovation. The 'State/Province of Current Application (Patentee)' is set to 'Beijing', with the legal status as 'Authorised' and the 'Number of current applicants (patentees)' set to [2-*]. Since it typically takes 18 months for a patent to be disclosed, and many 2021 filings are not yet announced, the data timeframe is 2004-2020. After manually excluding non-I-U-R cooperation patents (e.g., individual applicants or purely academic/industrial collaborations), 768 valid data points were obtained.

3.2 Hypernetwork Composition of I-U-R Cooperation in Beijing's Digital Creative Industry

I-U-RIn the hypernetwork of a patent application by I-U-R cooperation in Beijing's digital creative industry constructed by using the existing data, there are 528 nodes labelled as $v1, v2, \ldots, v29$. Among them, there are 74 nodes representing colleges and universities, 71 nodes representing research institutions, and 383 nodes representing enterprises. The hypernetwork has 416 hyperedges, indicating that there are 416 different forms of cooperation combinations. Each hyperedge is labelled $E1, E2, \ldots, E438$, and each hyperedge contains at least 2 and at most 7 other nodes. The hyperedge weights are used to describe the number of organisations cooperating to apply for patents in each hyperedge species, and the sum of the weights of all hyperedges in the hypernetwork is equal to the total amount of data, i.e., 768 items. The statistical analyses of node degree, hyperdegree and hyperintensity of the hypernetwork of patent cooperation applications in the Beijing digital creative industry are shown in Table 3.

Table 3 Statistical analysis of hypernetwork node degree, hyperdegree, hyperintensity and hyper-edge hyper-degree

Value	Degree	Hyperdegree	Hyperintensity	hyperedge hyperdegree
Max	169	57	148	7
Min	1	1	1	2
Mean	3.568	1.955	3.434	2.481

Table 3 shows significant variation in the degree, hyperdegree, hyper-strength, and hyper-edge hyperdegree of different nodes in Beijing's digital creative industry hypernetwork. On average, each organization has 3.568 cooperative partners, 1.955 participating organizations, and 3.434 patent applications. Each cooperative group includes an average of 2.481 organizations per patent filing.

3.3 Topological Characterisation of the Hypernetwork

3.3.1 Degree and degree distribution of nodes

It can be seen that the node degree value in the hyper network of Beijing's digital creative industry I-U-R cooperation application varies greatly, and there are extreme values. The statistical results show that the number of nodes with d_i=1 is 284, accounting for 53.79% of the total number of nodes. It can be seen that the organisational cooperation heterogeneity in the Beijing digital creative industry I-U-R cooperation to apply for invention patents hyper network is large. Figure 4 shows the cumulative probability distribution of the node degree in double logarithmic coordinates, which is fitted and found to obey a power law distribution, with the fitted power function as follows:

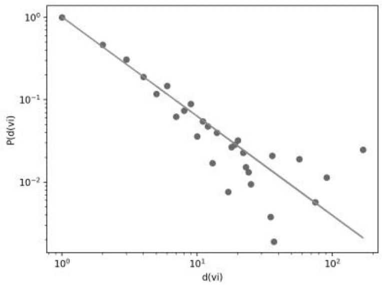

Fig. 4 Cumulative probability distribution of node degree on a double logarithmic scale.
$$y = 1.012x^{-1.204}(R^2 = 0.9918)$$

3.3.2 Node hyper-degree and hyper-degree distribution

The hyper-degree value of nodes in the hypernetwork of Beijing's digital creative industry I-U-R cooperation application varies greatly, among which the hyper-degree of 'Tsinghua University' is the largest, 57. The organisations with the smallest hyperdegree value have 409 organisations, with the hyper-degree value of 1, which accounts for 77.46% of the total number of nodesFig. 5 shows the cumulative probability distribution of node hyperdegree in a double logarithmic coordinate system, which was fitted and found to obey a power law distribution. The fitted power functions are as follows:

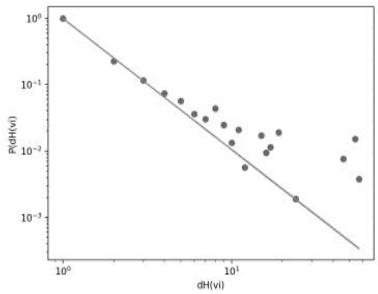

Fig. 5 Cumulative probability distribution of node hyperdegree in a double logarithmic scale

3.3.3 Ultra-strength and ultra-strength distribution of nodes

There are big differences in the value of node hyper strength in the hyper network of Beijing's digital creative industry I-U-R cooperation application, among which the hyper strength of 'Tsinghua University' is the largest (150). There are 321 organisations with the smallest value of hyper strength, with the value of hyper strength of 1, which accounts for 60.70% of the total number of nodes.Fig. 6 shows the cumulative probability distribution of node hyperintensity in a double logarithmic coordinate system, which was fitted and found to obey a power law distribution. The fitted power functions are as follows:

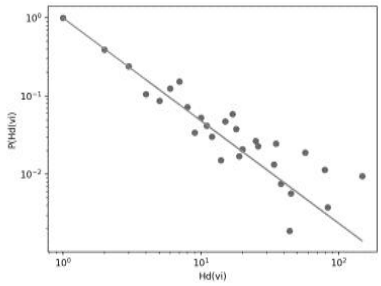

Fig. 6 Cumulative probability distribution of node overstrength on a double logarithmic scale
$$y = 0.995x^{-1.312}(R^2 = 0.9862)$$

The nodes with higher hyperintensity are the key nodes of the I-U-R cooperation hypernetwork of Beijing's digital creative industry and play an important role in the whole I-U-R cooperation hypernetwork. However, there are only 127 nodes with hyperintensity $Hd_{v_i} \geqslant 3$, accounting for about 24.05% of the total number of nodes, while nodes with hyperintensity $Hd_{v_i} \leqslant 2$ account for 75.95% of the total number of nodes. Combined with the statistics in Table 3, it can be seen that most of the organisations are involved in cooperation to apply for a low number of invention patents.

3.3.4 Hyperedge hyperdegree

The hyperedge with hyperedge hyperdegree of 2 accounts for 71.88% of the total number of hyperedges, i.e., most of the patent cooperation application teams include only 2 institutions, and the degree of diversification of team members is low. After further analysing the node categories in the hyperedge, it can be seen that the cooperation between universities and enterprises, research institutes and enterprises applies for more patents, and the tripartite cooperation between industry, academia and research applies for fewer patents.

3.3.5 Link between node degree, hyper-degree and hyper-intensity

Nodal degree, node hyperdegree and node hyper-strength all reflect the ability of organisations to participate in I-U-R cooperation. The linear link between node hyperdegree and node degree and node hyper-strength is shown in Figures 7 . The fitting functions are $y = 2.0767x - 0.4908$ ($R^2 = 0.8367$) and $y = 1.8709x - 0.2231$ ($R^2 = 0.7377$), respectively:

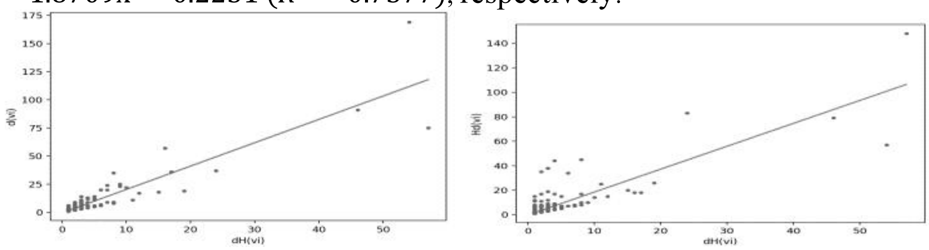

Fig. 7 The link between node hyperdegree and node degree (left) and node hyperstrength (right)

From the fitting function with Figures 6 and 7, it can be seen that there is a positive correlation between node hyperdegree and node degree, and node hyperdegree and node hyperstrength, i.e., the more the number of teams involved in the organisations, the more other organisations with which it cooperates, and the more patents it participates in the collaborative application.

3.4 Hyper Network Structure Measurement

3.4.1 Hypernetwork density

Hypernetwork density can reflect the average strength of the link between nodes and can be used to measure the closeness of the connection between nodes in the hypernetwork. Combined with the formula, the calculation principle is as follows:

$$\text{Density} = \frac{\text{the actual number of hyperedges}}{\text{the maximum number of hyperedges that can be formed by all nodes}}$$

Substituting the number of nodes and the number of hyperedges into the formula, we can get e density is $9.468596631406512\text{e},^{-157}$, which indicates that the connection between the nodes in the whole hypernetwork is relatively weak, i.e., the connection between various organisations and institutions in the hypernetwork of the cooperation between the industry, academia and research of the digital creative industry in Beijing is not strong, and the partnership should be further strengthened.

3.4.2 Hypernetwork node weighted degree centrality

This metric reflects the degree of centrality of individual nodes and measures the key central members of the hypernetwork. A node with high weighted centrality indicates that it is located in the centre of the hypernetwork and is more active and popular. The top 5 nodes of Beijing Digital Creative Industry-Academia-Research Hypernet node weighted centrality are shown in Table 4.

Table 4 Top 5 hypernetwork node weighted degree centrality

Node	Centrality of Node
State Grid Corporation of China	187
Tsinghua University	170
Peking University	138
Beijing University of Posts and Telecommunications	134
New Founder Holdings Development Limited	90

3.4.3 Average distance

The average distance reflects the connectivity of the hypernetwork. Calculations show that the average distance of the I-U-R hypernetwork in Beijing's digital creative industry is ∞, indicating that cooperation between institutions is challenging, and it is difficult for members to establish contact.

4. Analysis of the Evolution Mechanism of Patent Application Hypernetwork for I-U-R Cooperation in Beijing's Digital Creative Industry

4.1 Vertical Static Evolution Analysis of Patent Hypernetwork for I-U-R Cooperation Application in Beijing's Digital Creative Industry

4.1.1 Overall characteristics of Beijing digital entrepreneurship I-U-R cooperation patent application hypernetwork

This study analyses and compares the overall characteristics of the three time windows to determine the evolution and changes of the hypernetwork. As shown in Table 5, the overall scale of the innovation network of Beijing's digital creative industry I-U-R cooperation doubled in the three time windows of 2003-2010, 2011-2015 and 2016-2020, and developed rapidly.

Table 5 Overall Characteristics of I-U-R Cooperation and Innovation Network

	2003-2010	2011-2015	2016-2020
The number of nodes	74	167	378
The number of hyperedges	50	108	287
Maximum node degree	26	38	131
Average node degree	2.30	2.59	3.57
Maximum node hyperdegree	14	25	40
Average node hyperdegree	1.55	1.57	1.89
Maximum node hyperintensity	47	48	58
Average node hyperintensity	4.54	2.66	2.73
Network Density	-∞	-∞	-∞
Average path length	∞	∞	∞

4.1.2 Hypergraph-based analysis of the static evolution of hypernetwork stages

Figure 13 shows that from 2003 to 2010, "Peking University" had the most patent cooperation, followed by "Tsinghua University" and "Beijing University of Posts and Telecommunications." These three were the main nodes, while others were scattered in the hypernetwork. This indicates that during this period, Beijing's creative digital sector was in its early development stage, and the central role of the main nodes was not yet prominent.

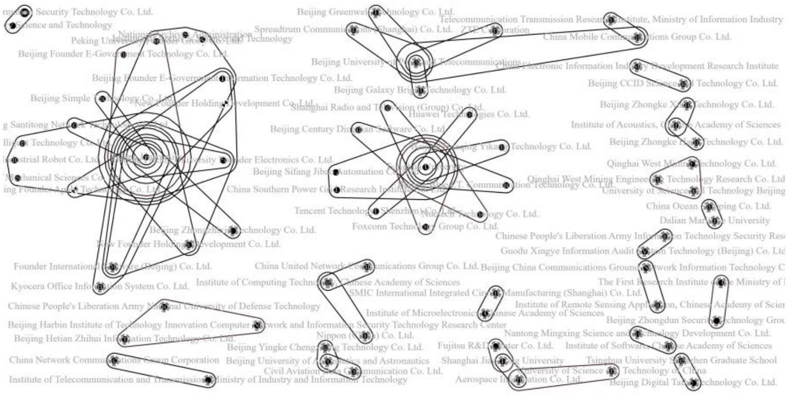

Fig. 13 2003-2010 Beijing Digital Creative Industry I-U-R hypernetwork

From Figure 14, it can be seen that from 2011 to 2015, the scale of Beijing's digital creative industry I-U-R hypernetwork nodes expanded rapidly. ‘Tsinghua University’ became the largest node, and “State Grid Corporation” became the second largest node. The number of small nodes quickly grew, and secondary central nodes began to appear. Thus, from 2011 to 2015, Beijing's digital creative industry I-U-R hypernetwork further developed, the main nodes changed, and its central position was prominent.

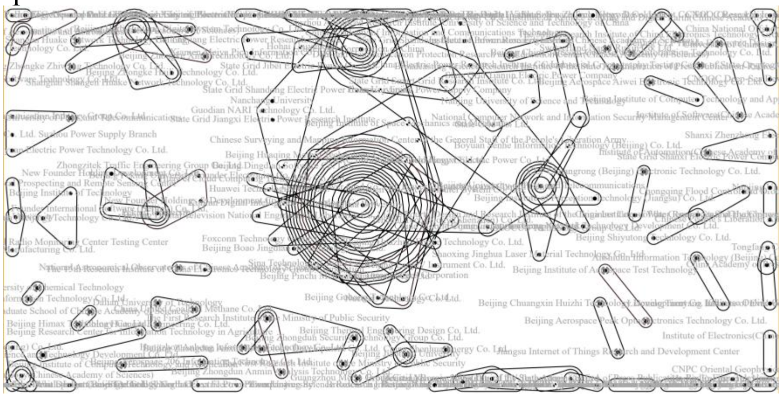

Figure 14 2011-2015 Beijing Digital Creative Industry I-U-R hypernetwork

Topology From Figure 15, it can be seen that the scale of the I-U-R Hypernetwork will further expand in 2016-2020. The "State Grid Corporation" becomes the central node. The number of small nodes continues to grow rapidly, and more secondary nodes appear, and the level of nodes increases. The number of small nodes continues to grow rapidly, and more subordinate nodes appear, increasing the level of nodes. As a result, from 2016 to 2020, the I-U-R hypernetwork will develop rapidly, the main nodes will change, and the central position will become more prominent.

Figure 15 2016-2020 Beijing Digital Creative Industry I-U-R hypernetwork

Combining Figures 13, 14, and 15, the evolution of Beijing's digital creative industry I-U-R hypernetwork during this period is characterized by: (1) expansion of the hypernetwork scale; (2)

instability of central nodes; (3) rapid growth in the number of small nodes; and (4) a quick rise in node levels. Thus, the I-U-R hypernetwork has shifted from its initial development phase to a rapid growth phase, aligning with the trends in Figures 11 and 12 and the digital creative industry's status as 'the emerging industry among the emerging industries'[2].

4.2 Simulation Analysis of the Dynamic Evolution of Hypernetwork for Patent Application by I-U-R Cooperation in Beijing's Digital Creative Industry

4.2.1 Hyper network evolution mechanism

This study constructs a dynamic evolution model for the hypernetwork of I-U-R cooperation patent applications in Beijing's digital creative industry[24], based on merit connection and hyperedge growth mechanisms. The merit connection mechanism includes technology proximity and hyperdegree merit[18]. Nodes with higher technological proximity are more likely to connect, while new nodes prefer those with greater hyperdegree merit. The hyperedge growth mechanism involves new nodes forming hyperedges with existing nodes based on these factors.

The study assumes that the dynamic evolution of Beijing's I-U-R cooperation patent hypernetwork follows these mechanisms. Using Python, it simulates the evolution process and compares the results with empirical data to verify the existence of the dynamic evolution mechanism.

4.2.2 Comparison between empirical results and simulation results

Most of the current literature uses the individual technology structure vector angle to measure the degree of technology proximity. According to the existing research [26], after analysing the number of patents owned by nodes within the hypernetwork in different technological fields and their proportion as the technological structure vectors of the nodes, constructs a bimodal matrix with the nodes as the horizontal coordinates and the IPC main classification numbers (subclasses) as the vertical coordinates, and divides each element in the matrix by the sum of all the elements in that row to obtain the technological structure vectors of the nodes. Use fi and fj to represent the technical structure vectors constituted by nodes i, and j in different IPC main classification numbers (subclasses), and substitute them into the calculation formula, which is shown as equation (4):

$$P_{ij} = \frac{f_i f_j^{'}}{[(f_i f_i^{'})(f_j f_j^{'})]^{\frac{1}{2}}} \tag{4}$$

The hyper-degree selective connectivity mechanism is manifested as a positive correlation between the node R&D strength and the probability of being selected. When a new node i enters into the hypernetwork, the p likelihood of the old node j being selected Q_j is the ratio of the node's hyperdegree to the sum of the hyperdegrees, and the formula is as follows:

$$Q_j = \frac{d_H(j)}{\sum_j d_H(j)} \tag{5}$$

According to the existing literature [24], the above two selection mechanisms can be integrated as follows: $\prod(j) = \alpha P_j + (1 - \alpha)Q_j$. where $\prod(j)$ is the probability that the new node i selects the old node j.Therefore, the process of the hyperedge growth mechanism is as follows: every time a new node i is added to the network with probability k, m old nodes in the network are selected to form a new hyperedge according to the probability $\prod(j)$ derived from the combination formula. Since n reality, the hypernetwork is anon-homogeneous(each hyperedge contains an unequal number of nodes), the probability m_i is used to express the p probability that the new node i selects t old nodes as $\sum_t m_t = 1$.

The simulation steps are as follows: (1) Initial hypernetwork: take the hypernetwork of the 2003 I-U-R cooperation patent application as the starting point and import the correlation matrix for expansion and the initial hypernetwork contains 3 hyper-edges and 5 nodes. (2) Hyper edge growth: add hyperedges to the hyper network according to the growth of time t $(t = 1,2,3...)$. New nodes i are added with probability k. New nodes are selected to form hyperedges according to the integration formula. k is determined by the total number of nodes and hyperedges in the network. (3) The number of simulations t = total number of specialised profits (768). (4) Adjusting the α parameter to derive the size of the share of the impact of the two mechanisms on the hypernetwork.

The comparison of the simulated and actual hypernetwork node hyperdegree probability distributions is shown in Figure 17. As seen in Fig. 17 and Table 6, when α is small, both the simulated and actual hypernetworks follow a power-law distribution, with similar values for the number of nodes, average hyperdegree, maximum hyperdegree, and standard deviation.

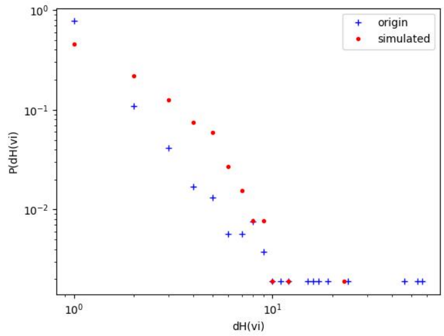

Fig. 17 Comparison of the probability distribution of node hyperdegree between the simulated and the actual hypernetwork in double logarithmic coordinates (α = 0.003)

Table 6 Topology metrics for simulated versus real hypernetworks (α = 0.003)

	Node	The number of hyperdegree	Average Hyperdegree	Maximum value of hyperdegree	Standard Deviation of Hyperdegree
Real Hypernetwork	528	416	1.955	57	4.392
Analogue hypernetwork	527	525	2.349	53	4.297

From the comparison, it can be seen that the technology proximity mechanism has less influence on the I-U-R cooperation hypernetwork. In comparison, the hyper-degree selection mechanism has more impact on the I-U-R cooperation hypernetwork. As shown in Fig. 18 and Table 7, when α is equal to 1, the hyper-degree maximum value and hyper-degree standard deviation of the simulated hypernetwork and the real hypernetwork are more different. In particular, when α=0, the simulated hypernetwork does not fit well with the real hypernetwork either.

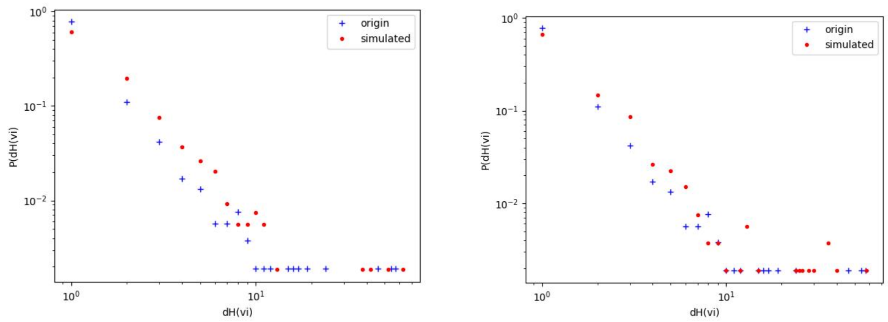

Fig. 18 Comparison of the probability distribution of node hyperdegree between the simulated and the actual hypernetwork in double logarithmic coordinates (α = 1, left) and (α = 0, right)

Table 7 Topology metrics for simulated versus real hypernetworks (α=1)

	Node	The number of hyperdegree	Average Hyperdegree	Maximum value of hyperdegree	Standard Deviation of Hyperdegree
Real Hypernetwork	528	416	1.955	57	4.392
Analogue hypernetwork(α = 1)	537	535	2.270	22	1.803
Analogue	518	516	2.332	87	5.396

hypernetwork(α = 0)					

5. Conclusions and Suggestions

This study uses patent application data from Beijing's digital creative industry I-U-R cooperation (2003-2020) to construct a patent application hypernetwork based on a weighted hypergraph model. By analyzing the topological characteristics, structural measurements, static and dynamic evolution mechanisms, and horizontal comparisons of this hypernetwork, five conclusions were drawn: (1) Development across nodes is uneven, with larger nodes having greater influence. Universities dominate, while some enterprises show strong innovation cooperation capabilities. (2) The connectivity among nodes is low, making cooperation difficult, with significant room for improvement. (3) The network's evolution is driven by the "rich get richer" effect, while technological meritocracy plays a lesser but notable role.

Based on these findings, the study recommends: (1) Universities, as core nodes, should leverage the "rich get richer" effect to enhance their innovation capacity and support weaker nodes. (2) Enterprises, crucial for transforming I-U-R cooperation innovations, should strengthen partnerships with research groups, capitalize on the rapid development of the digital creative industry, and establish long-term innovation mechanisms with universities.

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