



## The Path of Content Innovation and Industrial Upgrading of Liaoning Regional Cultural Industry under the Support of Digital Technology

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**SUMMARY:** *This paper takes 14 prefecture-level cities in Liaoning Province as the research object, focusing on how digital technology drives the upgrading of regional cultural industries, and carrying out empirical explorations from the depiction of network structure to the examination of mechanisms. Social network analysis is applied to quantitatively map the spatial association of cultural industries in Liaoning cities. By calculating the centrality of each city, we verify the small-world and scale-free characteristics of cultural industry agglomeration in Liaoning. Based on this, four major paths are proposed under the support of digital technology to promote the upgrading of the cultural industry through innovative processes, innovative cultural products, optimizing the industry chain structure and generating new business forms. The study reveals that there exists an unbalanced network structure in Liaoning Province with Shenyang and Dalian as the dual core, radiating Anshan, Liaoyang and other sub-nodes, while Fuxin and Chaoyang are at the edge. Digital technology, as the strongest factor of industry development, has an impact coefficient as high as 0.7056. Dynamic impulse response analysis shows that there is a short-term peak effect of about 0.036 of the digital shock on the increase of the share of cultural services. The variance decomposition results show that the contribution of digital technology to structural upgrading increases from 23.9% to 44.8% over time, which jointly dominates the development with the industry's own inertia (47.1%).*

**KEYWORDS:** *liaoning cultural industry; digital technology; industry upgrading; social network; impulse response analysis*

## 1 Introduction

Digitization, as an important form of cultural development, plays an important role in promoting cultural transformation and upgrading, and realizing the development of regional cultural industries [1]. In this context, all places have carried out a cultural construction path mainly based on digitization, starting from the foundation, consolidating the digital infrastructure of culture, relying on existing platforms, and realizing the promotion of regional characteristics of culture [2-4]. As a result, the value of regionality has attracted more and more attention in recent years, and the “digital transformation” of cultural development and the construction of a strong cultural country is the expression of the times to promote the panoramic presentation of Chinese culture in China, which is also the subject of cultural policies of countries around the world.

Liaoning is one of the earlier developed regions in Chinese history, and in the long-term social and historical development, the people of all ethnic groups in Liaoning have created a

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glorious and splendid culture, and the rich and colorful regional culture has also provided a rich soil for digital art creation [5]. In terms of literary styles, Liaoning has Er Renju, Beijing Opera, Peking Opera, Liao Opera, comedy, sketches, Liaoning Ballet, Gaizhou Shadow Play, Haicheng Stilt Rice-planting Songs, big drums and so on [6, 7]. In folklore, there are such excellent representatives as Beipiao folk tales, and a large number of folk songs and proverbs [8]. Among them, the stories of anti-Japanese heroes Lan Tianlin and Li Haifeng, the legend of Daheishan, the “Green Island of Western Liaoning”, and the story of Huining Temple, the holy place of Tibetan Buddhism, have formed a system of their own, are colorful and have high humanistic value [9]. In addition, there are many intangible cultural heritages in Liaoning Province, so far the provincial intangible cultural heritages in Liaoning cover 294 items in 10 categories, and 76 items have entered the national intangible cultural heritages list. Inevitably, there are deficiencies in the digital transformation of Liaoning's regional cultural industry, which can be gradually compensated for by the advancement of technology and the abundance of media nowadays.

In the study on the industrialization of the regional culture of Liaoning, literature [10] reveals the problems of the cultural and creative industry in Liaoning Province, which is insufficiently distributed due to the stereotypical traditional concepts of the region towards the cultural and creative industry and the uneven distribution of cultural resources. Literature [11] points out that the current development trend of the integration of cultural industry and tourism in Liaoning Province has changed from the state of lagging tourism industry to the state of lagging cultural industry, which requires the deep excavation of Liaoning national cultural elements in tourism industry. Literature [12] explored the development strategy of integrating culture and tourism in Xutun Village in Liaoning region, mainly with the help of EEG technology, and a comprehensive approach of trinity and five systems to optimize the environment, create rural IP, develop industries, and share civilization. Literature [13] emphasizes that the combination of Liaoning cultural products and cultural and creative industries with new technologies such as information technology can effectively promote the transformation of the industry, form new business models, and promote the industry and related upgrades and intelligent transformation. Literature [14] establishes a high-quality illustration generation strategy based on intelligent generative adversarial network with Liaoning's regional characteristics and culture, and introduces an attention mechanism to transform the style of characteristic cultural illustrations, which improves the efficiency of illustration design and helps the development of cultural and creative industries. Literature [15] explored the digital dissemination method of Liaoning regional characteristic culture, and pointed out that the information visualization design of digital culture in the design of Liaoning national model database provided the conditions for the revival of regional culture and realized multi-dimensional dissemination, which added materials for the cultural industry. Literature [16] describes the form of tri-industrial fusion of culture + sports + tourism, which creates a variety of intellectual property brands, and has become a competitive advantage and development trend of Liaoning province in China's cultural tourism market. Digitization has become more and more technically diversified and advanced for the content innovation and industrial upgrading of Liaoning's regional cultural industry, allowing Liaoning's regional cultural industry to step into a new chapter.

In addition, a variety of digital technologies provide a variety of boosts to the development of the cultural industry. In the integrated development of cultural industry and other industries, literature [17] introduces multimedia technology combining regional culture and local elements, which can create regional cultural content that attracts customers and is used to realize functional, beautiful and personalized home product design. Literature [18] analyzes the characteristic elements of intangible cultural heritage products such as styling, decoration, and

composition form through artificial intelligence technology, and introduces regional culture and user perception to realize the innovative design of intangible cultural heritage products. Literature [19] uses data mining technology to excavate the cultural and artistic resources of ethnic minority regions, and promotes the innovation of cultural and artistic industries, in order to protect and inherit the national culture, promote the development of regional economy, and realize the cultural exchanges between ethnic groups. Literature [20] utilizes virtual reality and augmented reality technologies to develop a cultural industry strategy that is in line with international standards, reshape the industry structure and presentation forms, and promote digital content dissemination and global promotion to reach international audiences. And literature [21] uses virtual reality and augmented reality technologies to reconstruct industrial and historical heritage in 3D and present it in virtual reality systems in museums to enhance remote visual learning and virtual interaction for the purpose of cultural enrichment. Literature [22] reported that cloud computing technology facilitates the construction of a public cultural cloud platform in China by integrating decentralized heterogeneous resources, coordinating cooperation between different cultures, accurately matching user needs, and balancing services, among other paths, to promote the protection of cultural heritage and the in-depth development of the cultural industry. Literature [23] uses big data technology to process and optimize the industrial restructuring of intangible cultural heritage in the Internet era, providing optimized marketing channels and promotion strategies by formulating product and pricing strategies. Literature [24] proposes an industry chain extension mechanism based on digital technology for the integration method of cultural creativity-rural tourism and value-added effect on the agricultural economy, which extends the industry chain by 3.5 links and promotes the development of the cultural industry. Literature [25] combines artificial intelligence and big data to predict the development of the cultural industry, and constructs a prediction model that can analyze the current hotspots of the cultural industry, the current situation of regional development, investment and financing, and other economic conditions, and provide relevant stakeholders with data references into the path of industrial upgrading. Literature [26] applies blockchain technology to the management of cultural and creative industrial parks, and with its decentralization concept, builds a management system based on smart contracts and distributed ledgers and other forms, realizes the industrial chain and government supervision, and escorts the industrial upgrading.

The study builds an analytical framework from two dimensions, namely, network structure and practice path, to explore how the regional cultural industry realizes content innovation and industrial upgrading in the wave of digitization. Firstly, a social network analysis perspective is introduced. Cultural enterprises, universities and governments in the region are visualized as nodes, and the cooperation, knowledge flow and resource sharing among them constitute the innovation network. With the help of average path length, clustering coefficient, degree distribution and other indicators, the degree of network closeness, efficiency of information dissemination and influence of core nodes are measured. We determine whether the regional cultural industry has the small-world characteristics of efficient collaboration and rapid response, and explain the potential of collaborative innovation structurally. Then, focusing on the industrial upgrading path of cultural and technological integration, we clearly quantify a digitization-supporting path for the upgrading of Liaoning's cultural industry with statistical tools such as spatial regression and dynamic impulse response.

## **2 Research on synergistic mechanisms of cultural and scientific integration and regional innovation networks**

### **2.1 Analysis of the effects of regional offloading networks**

The formation of regional innovation networks is the key to the success of enterprises in the region, and the frequent contacts between enterprises, governments, universities and other institutions in the region create conditions for knowledge creation, resource sharing and division of labor. The effects of regional innovation networks are mainly in the following aspects.

#### **2.1.1 Resource sharing and complementarity**

Through the network, enterprises can share complementary resources such as technology, talents, information and capital at lower cost, and realize the optimal allocation of R&D factors. Cooperative innovation not only reduces the R&D investment and risk of each subject, but also improves the possibility of technological breakthrough through resource integration and capacity complementation. Enterprises can focus on core competence construction with advantageous resources, and at the same time make up for their own shortcomings with the help of external resources, so as to accelerate process improvement and product innovation, and enhance the overall innovation efficiency.

#### **2.1.2 Division of labor**

Regional innovation network is essentially a division of labor system for innovation activities, which realizes efficiency enhancement and overall advantage reinforcement through specialized subdivision of industrial chain and technological chain and assigning different subjects to undertake the corresponding links. Geographic proximity promotes frequent interaction and stable collaboration among enterprises, universities, research institutions, financial institutions, etc., so that innovation factors such as talent, knowledge and technology can flow and reorganize rapidly. The division of labor not only promotes the specialization of the innovation process, but also facilitates the natural overflow of knowledge in collaboration. Competition and cooperation among enterprises form a dynamic and synergistic innovation ecosystem, which motivates each subject to continuously improve its own technological capabilities, thus promoting the upgrading of the entire network to high value-added links.

#### **2.1.3 Knowledge spillovers and interactive learning**

Regional innovation networks significantly contribute to the diffusion and transformation of explicit and tacit knowledge. Formal and informal communication mechanisms in the network accelerate the encoding and diffusion of knowledge. Enterprises, universities and research institutions learn continuously through cooperation, forming a collective learning mechanism of “learning by doing” and “learning by using”, which shortens the innovation cycle and improves the success rate of innovation. The network also has dynamic openness, which can absorb new knowledge from outside and continuously update the internal knowledge base. This continuous knowledge overflow and interactive learning enhances the innovation resilience and adaptability of the region as a whole.

#### **2.1.4 Social capital accumulation**

Social capital, including inter-subjective trust, common behavioral norms and network culture, can significantly reduce transaction and coordination costs in cooperation, and promote a

smoother flow and sharing of resources. A deep relationship of trust makes enterprises more willing to carry out long-term R&D cooperation, share innovation risks, and facilitate the transfer and absorption of tacit knowledge. The government can further consolidate social capital by enhancing the standardization and transparency of the network through institutional construction and policy guidance.

## **2.2 Spatial form of virtual agglomeration of cultural industries and its small world analysis**

Regional innovation networks provide knowledge and technological innovation for the cultural industry through mechanisms such as resource sharing, division of labor, knowledge spillover and social capital accumulation. In order to further reveal the structural characteristics of the cultural industry in the context of digitization and networking, this section will introduce social network analysis to explore the spatial pattern of the virtual agglomeration of the cultural industry in Liaoning Province and its small-world characteristics, so as to deepen the understanding of the mechanism of cultural and technological integration from a network perspective.

### **2.2.1 Social network analysis**

A social network is a network system based on inter-subjective relationships. In this network the nodes have a specific relationship with each other, and the goal of the social network is to depict the relevant relationship between the nodes, and this interrelationship has a strong influence on the social behavior of the nodes. These characteristics and laws of the network can be found with the help of social network analysis. A social network is an ensemble of nodes and their relationships. Points and lines are important components of social networks. These nodes mainly include: participants of social behavior throughout the social network. As well as the connecting lines between the social participants.

The measurement of metrics in social networks lies in the hierarchy between network data. Dichotomous relationship data: with the help of two data to represent the establishment or non-establishment of a relationship. E.g., whether a relationship is established or not established between two relationships. Multi-disaggregated data: more than two values are taken. For example, mutual trade between two countries can be represented as: high, medium and low. Ordinal type data, on the other hand, is used to show the closeness of ties between social network participants with the help of data, i.e., closer ties, close ties, fewer ties, and no ties. The patent cooperation relationship among Chinese cultural enterprises is a social relationship. Therefore, with the help of social network method, the spatial characteristics of the virtual agglomeration of cultural industry are displayed, and the network structure attributes of the virtual agglomeration of cultural industry in Liaoning Province are accurately portrayed with the help of index measurement.

### **2.2.2 Small-worldness theory**

Small-worldness is an important property of social networks, a process of conversion of a locally regular system to a stochastic network, which is mainly manifested by increasing aggregation coefficients and decreasing average path lengths. The small-worldness test is applicable to both scale-free and scaled social networks. The Liaoning regional culture industry studied in this paper is a scale-free social network. Therefore, this paper is mainly introduced with scale-free social network. Among them, scale-free social network refers to the existence of power index distribution in the nodes in the social network, the biggest characteristic of the social network is that all the participating subjects in the social network have less relationship

with each other, and only a small number of subjects involved in the social network have a closer relationship with each other, which is similar to the actual social network.

There are three main small world network properties, inequality. This is similar to social development, i.e. the phenomenon of “the rich getting richer”. Subjects outside the social network are more likely to be attracted to the social network by nodes with complex relationships. Robustness. The nature of the social network remains unchanged when some nodes are randomly removed from the social network. This is similar to the real world, in real life, even if you remove some of the more developed nodes will have later nodes to fill in, the impact on the whole society is not great. Vulnerability. When targeted and intelligent attacks on the social network, the social network loses some special connection nodes can easily cause the collapse of the whole social system. Therefore, this paper examines the virtual agglomeration network of cultural industry in Liaoning region with the help of small-worldliness theory to verify whether the virtual agglomeration of cultural industry in Liaoning Province has formed a small-worldliness system.

### 2.2.3 Data sources and indicator selection

#### (1) Data sources

In this section, pajek software is chosen to construct the social network and test the small-worldness of the virtual agglomeration network of cultural industry in Liaoning Province. Since the input file type of this software is .net, firstly, the data of cooperation between cultural enterprises are transformed into a three-column matrix without distinguishing between referencing and referenced relationships. The first column is the enterprise data, the second column is the enterprises with cooperation relationship with the previous column, and the third column is the frequency of cooperation between two enterprises. Then the raw data are converted into file format by excelpajek2, and when the file mode is selected, it is set to mode-1, and the corresponding file is exported, and finally the file in .net format is obtained.

#### (2) Indicator selection

Average access degree: degree is an attribute of complex network nodes and is an important indicator of small-worldness. The higher degree of a node also means that it is more important in the social network. An edge can connect two endpoints and the total degree in the network is half of the sum of the number of each node. N-order average link connectivity is an important parameter for the whole network and the formula is defined as:

$$E = \frac{\sum_i k_i}{2} \quad (1)$$

Mean Path Length: The mean path length is defined as the average of the sum of the shortest distances from any node in the social network to any other node except itself. In performing the average path calculation,  $i$  and  $j$  are used to denote two nodes respectively, and  $D_{ij}$  denotes the shortest path between two nodes.

$$D = \min_{i,j} d_{ij} \quad (2)$$

The average node path and network length in a social network denoted as  $L$  can similarly be defined as a basic feature of a physical network whose path and network length are directly defined as a network average between any two different network-centered nodes, i.e:

$$L = \frac{1}{\frac{1}{2}N(N-1)} \sum_{i \geq j} d_{ij} \quad (3)$$

The average path length is the average of the total length of the shortest node paths between all the nodes in a social network and divided by the number of nodes, this value is the main characteristic of a large network, this metric can be a good measure of the coherence of the nodes of a large network.

Clustering coefficient: the clustering coefficient is an important indicator of the small-world nature of a social network. The higher the clustering coefficient of a particular social network, the stronger the small world of the whole social network. It is assumed that a node  $i$  in a social network can connect other social network nodes into the social network by possessing a new  $k_i$  edge. The  $C_i$  formula is as follows:

$$C_i = \frac{2E_i}{k_i(k_i-1)} \quad (4)$$

Average clustering coefficient. The formula for the average clustering coefficient is:

$$\bar{C} = \sum_k p(k)C(k) \quad (5)$$

Node Degree and Network Degree Distribution: Degree is a property of an individual node. Intuitively, the more connected a node is the stronger and more important its influence on the entire social network.

The average of the access degrees  $k_i$  of all nodes  $i$  participating in a social network is then the average degree of the nodes  $i$  in that social network. The distribution that records the degrees of individual nodes is known as the degree distribution function  $p(k)$ , which represents the probability function corresponding to the degree distribution of any one node. That is, the proportion of the degree of that node in the whole social network. Assuming that the distribution of degree conforms to the Poisson distribution, the distribution function is as follows:

$$p(k) \propto \frac{(k)^k}{k!} e^{-k} \quad (6)$$

### 2.3 The Path of Cultural and Scientific Integration to Promote the Upgrading of the Cultural Industry

After clarifying the characteristics of the network structure of the regional cultural industry, the perspective is shifted to the level of enterprise practice. This section systematically elaborates the four major paths of cultural and technological integration to promote the upgrading of the cultural industry - innovation of process, innovation of cultural products, optimization of the industry chain structure, and generation of new business forms - in order to reveal the intrinsic connection between technology, network and industrial upgrading.

### **2.3.1 Innovative processes**

Innovative process is to make an enterprise's production more efficient by introducing high technology or reorganizing the production system, i.e., to achieve an increase in output and an improvement in production quality with the same inputs. Cultural products manufacturing enterprises through the introduction of advanced technology and equipment to enhance product quality and improve production efficiency. Or by strengthening management to realize the simplification of enterprise business processes, thereby reducing consumption, saving costs and enhancing market efficiency.

### **2.3.2 Innovative cultural products**

Product innovation is the core driving force for the sustainable development of the cultural industry. The integration of culture and technology promotes the evolution of products from low-level and homogenization to high complexity and high value-addedness. Through the introduction of advanced technology, enterprises can realize the iterative updating of products and enhance their artistic expression, user experience and brand value. The optimization of product structure not only extends the life cycle of products, but also promotes the extension of enterprises to the middle and high-end links of the industrial chain, forming differentiated competitive advantages.

### **2.3.3 Optimization of industry chain structure**

China's cultural industry has long been at the low end of the value chain, relying on resource input and low-cost competition. The integration of culture and science and technology promotes the industry to climb up to the high value-added chain by enhancing the technological content and creative design of products. Technology introduction and content innovation work together to promote the decomposition and reconstruction of the original value chain, forming a multi-industry derivation system with intellectual property as the core. For example, pan-entertainment development based on high-quality IP, integrating literature, film and television, games, live broadcasting and other fields, realizing fan economy and cross-industry linkage, and significantly enhancing the profitability and structural elasticity of the overall value chain.

### **2.3.4 Catalyzing New Businesses**

Emerging industries are often born at the intersection of industrial boundaries, and technological integration and policy relaxation jointly promote the dynamic evolution of industrial structure. Cultural and technological integration breaks down industry barriers, promotes the cross-organization of different industrial elements, gradually blurs and even eliminates the original industrial boundaries, and ultimately forms brand-new industrial forms. For example, under the impetus of digital technology, the convergence of communication and media fields has given rise to new industries such as smartphones and virtual reality experience. This dynamic evolution process not only enriches the form of cultural supply, but also promotes the comprehensive transformation of the cultural industry in the direction of digitalization.

After clarifying the theoretical framework of cultural and technological integration and the specificity of Liaoning's geography, a key practical question needs to be answered: how does digitalization technology interact with the existing industrial spatial network and ultimately drive the upgrading of the cultural industry in the specific context of Liaoning? This chapter will provide a systematic response to this question at the level of empirical testing.

### 3 Empirical study on the impact of digital technology based on the network structure of Liaoning's cultural industry development

The third chapter is centered on the logic of network review - power test - impact deepening, and gradually explores how digital technology interacts with industrial spatial networks and eventually drives the upgrading of the cultural industry.

Firstly, with the help of social network analysis, the spatial correlation structure of cultural industry development in 14 prefecture-level cities in Liaoning Province is quantitatively portrayed to reveal its network characteristics.

Secondly, based on the identified network structure, an econometric model is constructed to test the direct impact of digital technology as the core driving force on the development level of cultural industry and its synergistic mechanism with other factors.

Finally, we further explore how the industrial agglomeration based on digital technology, through the spatial network, exerts a heterogeneous influence on the industrial structure upgrading, and dynamically analyze the long- and short-term effects of the digital technology impact on the structural upgrading within the industry by using the vector autoregressive (VAR) model.

#### 3.1 Characteristics of the spatial network structure of cultural industry development in 14 cities in Liaoning Province

The object of the article's research is Liaoning Province, and the characteristics of the spatial network structure of the cultural industry development in its 14 prefecture-level cities (Shenyang, Dalian, Anshan, Fushun, Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Liaoyang, Tieling, Chaoyang, Panjin, and Huludao) are now analyzed.

##### 3.1.1 Network density analysis

In this paper, the interconnection matrix among 14 prefecture-level cities is calculated according to the gravity model in section 2.2, and then the matrix is transformed into a 0-1 directed matrix according to the threshold value. The network structure map of spatial association of Liaoning regional culture industry in 2024 is finally derived as shown in Fig. 1.

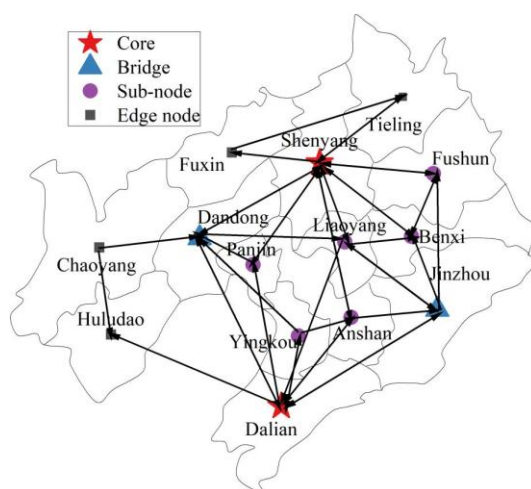


Figure 1: The spatial correlation network of the cultural industry in Liaoning Province

The gathering centers of Liaoning Province are mainly dominated by Shenyang and Dalian. Shenyang, as the provincial capital and political and cultural center, is mainly associated with central Liaoning city clusters, such as Anshan, Fushun, Benxi, Liaoyang, and Tieling, while Dalian, as an open coastal city, mainly overflows to each other with cities along the Bohai Sea, such as Jinzhou, Yingkou, Panjin, and Dandong. Through the spatial association network of cultural industry, these 14 cities are divided into core hubs, sub-nodes, important bridges and edge nodes according to the point degree of connection. Shenyang and Dalian are undoubtedly the two most central hubs, and together they are connected with almost every city in the province, radiating the whole province. Jinzhou and Dandong serve as the bridge of Liaoning Province's cultural industry space, the former being the key to connecting western Liaoning with the Bohai Rim Axis; the latter is related to the external import and export of the coast, and is the two cities with the largest number of entry and exit nodes after Shenyang and Dalian. Anshan, Fushun, Benxi, Liaoyang, Yingkou and Panjin are the six secondary nodes, mainly receiving output from Shenyang or Dalian, and are the relay stations for regional cultural transmission and industrial collaboration. The four edge nodes, Fuxin, Tieling, Chaoyang, and Huludao, have a low level of network participation, receive mostly single-core radiation or are weakly connected to peer cities, and are vulnerable to marginalization.

### 3.1.2 Network Centrality Analysis

The centrality index can reflect what position a region or individual resides in its social network.

The study uses relative mediator centrality for the research, which can avoid overestimation of mediator centrality when the mediator node has a large degree in the network, and more accurately reflect the mediator position of the node in the network. It measures the degree to which an actor has control over resources.

Proximity centrality is an indicator that represents the right of a point; the closer a point is to other points, the easier it is for the point to transmit information, and thus it may reside in the center of the network.

Table 1 shows the centrality analysis of the spatial correlation network of cultural industry in Liaoning Province at 14 municipal levels in 2024. In order to show more clearly the ranking of intermediate centrality and near centrality of each city, Pareto charts of both are also drawn as shown in Figures 2 and 3.

*Table 1: Analysis of Centrality of Cultural Industry Spatial Linkage Network*

	Out-degree	In-degree	Centrality Degree	Betweenness Centrality	Closeness Centrality
Shenyang	7	6	8	0.327	24.758
Dalian	5	5	7	0.241	18.299
Anshan	2	3	4	0.073	8.552
Fushun	3	3	3	0.039	9.212
Benxi	4	2	3	0.091	10.143
Dandong	4	4	6	0.118	15.673
Jinzhou	3	3	5	0.104	9.505
Yingkou	2	1	3	0.045	5.571
Fuxin	1	1	2	0.011	3.373
Liaoyang	5	3	5	0.152	20.758
Tieling	2	1	2	0.024	5.338
Chaoyang	2	0	2	0.000	3.178
Panjin	1	2	3	0.018	5.123
Huludao	0	2	2	0.000	3.178
Average	2.929	2.571	3.929	0.089	10.190

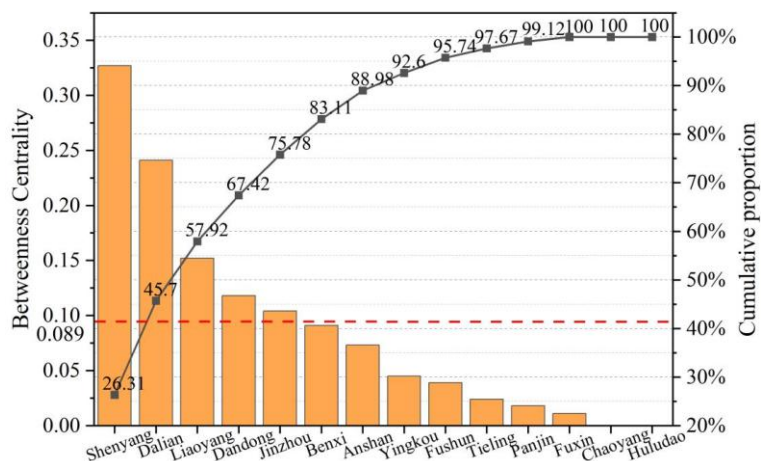


Figure 2: Pareto chart of the betweenness centrality

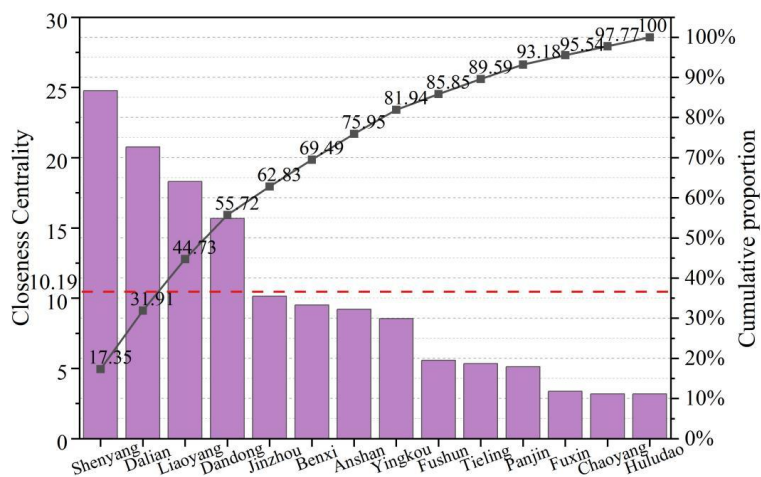


Figure 3: Pareto chart of the closeness centrality

Combined with Table 1 and Figure 1, we can clearly know the specific relationship between out-degree and in-degree of each city. Take the bridge Jinzhou as an example, its point out-degree is 3, i.e., the spillover relationship includes three cities of Dalian, Fushun and Liaoyang, and the point in-degree is also 3, and the gain relationship has Dalian, Anshan and Liaoyang, of which Dalian and Liaoyang have a bi-directional relationship with Jinzhou, and the Fushun-Jinzhou only has an input relationship, i.e., Jinzhou's cultural industry is inputted into Fushun. Similarly, there is only a one-way output between Anshan and Jinzhou. The degree center degree of Jinzhou has only 5 valid paths, so it is 5.

From the point degree centrality, the average point degree centrality in Liaoning province is 3.93. The core hubs of Shenyang and Dalian undoubtedly have the highest point degree centrality, which is 8 and 7, respectively, and there are four other cities higher than the average value, namely Anshan, Dandong, Jinzhou and Liaoyang. The point centrality of Panjin, Fuxin, Tieling, Chaoyang and Huludao, which are located in the peripheral area, is lower than or equal to 3. The spatial association of cultural industry in Liaoning Province shows an obvious “core-periphery” structure, and most of the association relationships are dominated and carried by a few central cities.

From the analysis of intermediate centrality. The intermediate centrality of Shenyang and Dalian is 0.327 and 0.241 respectively, and the sum of the two accounts for 45.7% of the total

of the 14 cities, which indicates that the twin nuclei have a very strong control over the flow path of cultural resources between cities, and confirms their key hub status once again. The average intermediate centrality in Liaoning province is 0.089, and except for the cities of the Duo, Liaoyang, Dandong and Jinzhou all exceed the average value. The high centrality of Dandong and Jinzhou as key bridges is easy to understand, while Liaoyang has an intermediate centrality of 0.152, indicating that as a relay station of the Shenyang radiation circle, it also plays an indispensable role in connecting other nodes. In contrast, Chaoyang and Huludao have an intermediate centrality of 0, while Fuxin and Tieling have extremely low values, implying that these cities are hardly in any resource circulation paths, and are severely marginalized in the cultural industry network.

Analyzing from the perspective of proximity centrality, it can be found from Figure 1 that Shenyang and Liaoyang are located, and their proximity centrality is undoubtedly the highest, 24.758 and 20.758 respectively, and the cumulative proportion of the two reaches 31.91%, which constitutes the core radiation layer. The Pareto chart shows higher than the average value of 10.190 Shenyang, Liaoyang, Dalian, Dandong cumulative share of more than 55%. These four cities assume the role of key nodes in terms of external spillover. From the perspective of the construction of comprehensive indicators of cultural industry, these cities also possess more human resources and capital engaged in cultural industry, thus playing an important role in controlling the flow efficiency of cultural industry in the province. On the other hand, Yingkou, Tieling, Panjin, Fuxin, Chaoyang and Huludao are at the bottom of the ranking in terms of degree centrality, intermediate centrality and proximity to centrality, and are in a dominated position in the network structure. This further illustrates the unbalanced character of the development of the cultural industry in Liaoning Province. It is mainly due to the remote location, backward infrastructure and low level of economic development of these regions that they are unable to attract more talents and capital inflow, thus leading to the relatively backward development of the cultural industry as a tertiary industry.

### **3.2 Empirical research on the development of cultural industry driven by digital technology**

After understanding the characteristics of the spatial network structure of the cultural industry in Liaoning Province, the perspective is now shifted from the examination of the driving mechanism of digital technology. We empirically analyze how digital technology plays a synergistic role with other key factors, such as scientific and technological innovation and cultural resources, to drive the development level of cultural industries in each region of Liaoning Province, so as to explain the causes of the network structure observed in the previous section at the motivational level.

#### **3.2.1 Selection of indicators**

Five types of influencing factors, namely, digital technology, level of scientific and technological innovation, cultural resources, market demand, and institutional environment, are selected for the development of cultural industry in Liaoning Province. In the selection of specific indicators, (1) the total income of cultural and cultural relic institutions in the current year (yuan) is used to indicate the development status of the cultural industry; (2) the operating income of digital cultural industry (yuan) is used to indicate the degree of application of digitization technology; (3) the level of scientific and technological innovation in each region is used to indicate the level of research and experimental development (internal expenditure of funds (yuan)); (4) the number of museums in each region is used to indicate the cultural resources in each region; and (5) The annual per capita annual expenditure on culture, education and entertainment of urban households (yuan) is used to indicate the market demand for the

cultural industry; (6) The number of patent enforcement cases closed by the departments managing patent work is used to indicate the institutional environment in each region.

To facilitate the analysis of the empirical results, all data are logarithmically processed. Let  $\ln(cul_{it})$  represent the logarithm of the cultural industry development status of each city in each year,  $\ln(dig_{it})$  represent the logarithm of the digital technology application level of each city in each year,  $\ln(tech_{it})$  represent the logarithm of the technological innovation level of each city in each year, and  $\ln(res_{it})$  represent the logarithm of the cultural resources of each city in each year. Let  $\ln(dem_{it})$  represent the logarithm of market demand in each city for each year, and  $\ln(sys_{it})$  represent the logarithm of institutional environment in each city for each year, where  $i$  represents each city and  $t$  represents the year.

### 3.2.2 Overall test situation

The above relevant statistical data for the period of 2015-2024 at the municipal level of Liaoning Province are selected as samples for analysis, and the model estimation results of the driving factors of the development of the cultural industry obtained are shown in Table 2.

Table 2: The model estimation results of the factors for cultural industry development

Independent variable Constant term	Model parameters	Coefficient test	
	Coef	F	P
Independent variable	1.108	2.254	0.021
Technological innovation	0.567	18.217	0.000
Cultural resources	0.195	3.522	0.001
Market demand	0.284	2.395	0.013
Institutional environment	-0.030	-1.147	0.134
Digital technology	0.756	37.029	0
Fitting situation	R <sup>2</sup>	Within the group	0.917
		Between groups	0.848
		Overall	0.772
	Wald	CMIN	67.115
		CMIN/df	1.525
		p	0.000

After estimation, it can be found that the relationship between the main factors affecting the development of science and technology innovation-driven cultural industry in Liaoning Province and the cultural industry can be roughly expressed as follows

$$\ln(cul_{it}) = 1.1083 + 0.756\ln(dig_{it}) + 0.567\ln(tech_{it}) + 0.195\ln(res_{it}) + 0.284\ln(dem_{it}) - 0.030\ln(sys_{it}) \quad (7)$$

Among them, digitization technology is undoubtedly the strongest driving force for the development of cultural industry in Liaoning Province, and its model coefficient is as high as 0.756 and significant at the 1% level, and the scale of cultural industry can grow by about 0.756 units on average for every 1 unit increase in digitization level. The impact of the level of scientific and technological innovation, cultural resources and market demand is also significant, with coefficients of 0.567, 0.195 and 0.284 respectively, but the strength of the impact is far less than that of digitization technology. The coefficient of institutional

environment is -0.0307 and is not significant, indicating that the current institutional environment construction fails to be effectively transformed into a direct promotional force for industrial development, or there is a complex moderating effect. The overall goodness of fit of the model is high, and the  $R^2$  within the group reaches 0.917, indicating that the model has strong explanatory power for the development of the cultural industry, and the choice of variables is reasonable.

### 3.2.3 Analysis of the relationship between digital technology and the development of the cultural industry

In order to show the relationship between digitization technology and cultural industry development in Liaoning Province even further, Figure 4 shows the cultural development level of 14 cities in Liaoning Province over the period of 2015-2024, with the quantitative indicator being the logarithm of the total income of cultural and heritage institutions in the current year (RMB 10,000 yuan), and Figure 5 shows the level of their digitization technology, with the quantitative indicator being the logarithm of the operating income of the digital cultural industry (RMB 10,000 yuan).

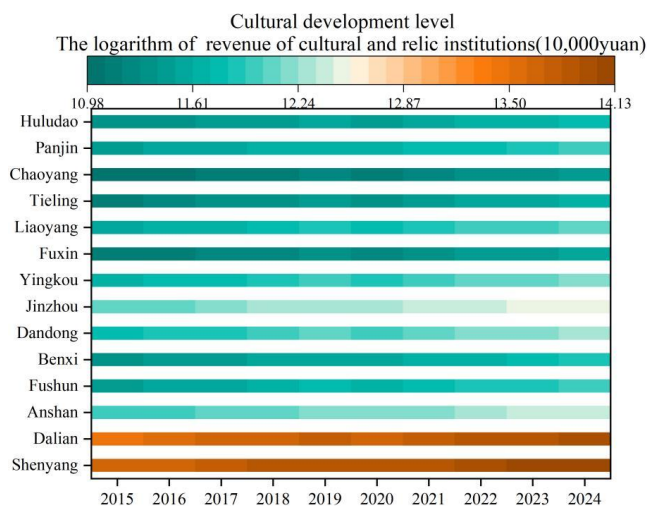


Figure 4: The cultural development levels of 14 cities in Liaoning from 2015 to 2024

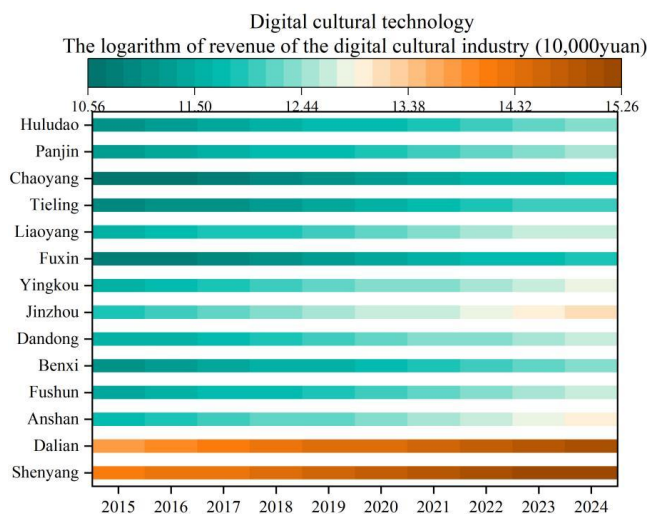


Figure 5: The digitalization level of 14 cities in Liaoning Province from 2015 to 2024

During the period of 2015-2024, the cultural industry and digital technology level of the 14 cities in Liaoning Province as a whole all show a steady growth trend. From Figures 4 and 5, it can be seen that the further to the right, the color of each city almost always deepens to different degrees. Taking the core cities as an example, Shenyang's total income from cultural and heritage institutions increases from 8.564 billion yuan in 2015 to 13.651 billion yuan in 2024, and Dalian increases from 7.216 billion yuan to 11.893 billion yuan. Other cities such as Anshan and Jinzhou have revenues in the 1.5-2.8 billion yuan range, while Fuxin and Chaoyang have less than 1 billion yuan. There is a general short-term pullback of about 5% in 2020 for this indicator, followed by a return to growth.

The operating income of the digital culture industry rose even more dramatically. Shenyang soared from 12.457 billion yuan to 42.029 billion yuan, and Dalian increased from 9.877 billion yuan to 33.323 billion yuan, with an average annual growth rate higher than that of the culture industry section. Cities such as Anshan and Jinzhou also grew from a billion to billions. The strong growth of the digital industry is driving a profound optimization of the province's cultural industry.

In order to further demonstrate the relationship between the two, the logarithmic treatment of the total income of cultural and cultural heritage institutions in the current year as the horizontal coordinate x, the same logarithmic treatment of the operating income of the digital culture industry as the vertical coordinate y, to build the distribution chart of the cultural industry-digitalization technology x-y relationship is shown in Figure 6.

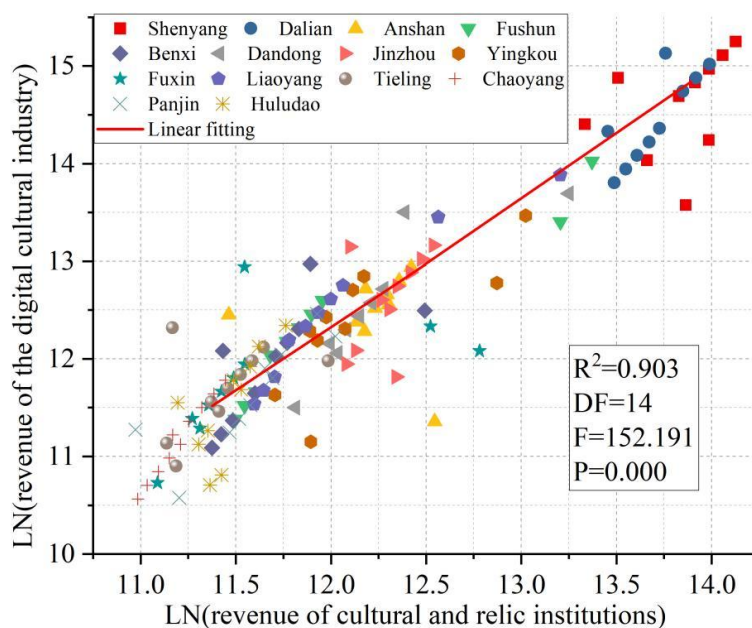


Figure 6: The Relationship Between cultural industry and digital technology

There is a positive linear synergistic relationship between cultural industry development and digitalization technology in 14 cities in Liaoning Province. All sample points are almost in the vicinity of the fitted red straight line. The two core cities of Shenyang and Dalian, as high culture-high digital benchmarks, have their data points clustered in the upper right region of the scatter plot. Sub-nodes such as Anshan, Jinzhou and Liaoyang reside in the central region, while relatively backward cities in the cultural industry such as Fuxin and Chaoyang are relatively concentrated in the lower left. The model fit index  $R^2 = 0.903$ , which again confirms the previous conclusion that digital technology and cultural industry promote each other and together constitute the main axis of industrial upgrading in Liaoning Province.

### 3.3 Impact of cultural industry aggregation based on digital technology on industrial structure upgrading

Based on the theory of small-worldness in section 2.2 and the social network analysis of cultural industry development in 14 cities of Liaoning province in section 3.1, it has been identified that the virtual agglomeration of cultural industry in Liaoning has significant small-worldness and scale-free characteristics, i.e., the cultural industry has already formed a network structure with high connectivity and prominent core nodes in the process of digitization. Section 3.2 also confirms the significant influence of digitization technology on the level of cultural industry development by 75.68% through the regression model. The regression model in section 3.2 also confirms the significant impact of digitalization technology on the level of cultural industry, which is 75.68% of the development. Next, we will further study the impact of cultural industry aggregation on industrial structure upgrading based on digitization technology.

#### 3.3.1 Empirical results of cultural industry agglomeration on industrial structure upgrade

The impact indicators of cultural industry agglomeration include digital technology level (DT) (also using the business income of digital cultural industry as a quantitative indicator), employment (EM), total asset investment (TIS) and residents' consumption level (RC). Two models are constructed with the index of industrial structure upgrading and the upgrading of tertiary industry structure as dependent variables, respectively. Based on the data of each index in the decade of 2015-2024 in 14 cities of Liaoning Province as the research samples, the empirical results of cultural industry agglomeration on industrial structure upgrading are shown in Table 3.

Table 3: The Impact of cultural industry agglomeration on the upgrading of industrial

	Model 1: Industrial Structure Upgrading			Model 2: Tertiary Industrial Structure Upgrading		
	Coef	F	P	Coef	F	P
Constant	-0.3643	-1.898	0.123	-0.1372	-0.146	0.316
CIA	0.1573	4.718	0.000	0.3180	4.253	0.000
DT	0.2130	3.313	0.000	0.1649	3.976	0.000
EM	0.2961	1.952	0.043	1.384	1.419	0.074
TIS	0.2830	2.572	0.000	0.2500	6.785	0.000
RC	0.1147	8.361	0.000	0.1221	1.983	0.033
R <sup>2</sup>	0.917			0.951		
F	156.12			178.04		
P	0.000			0.000		

Whether it is the upgrading of industrial structure in Model 1 or the upgrading within the tertiary industry in the more refined Model 2, digital technology is in the position of the core driving force, and the coefficients reach 0.2130 and 0.1649 respectively and are highly significant. The coefficients are 0.2130 and 0.1649 respectively and highly significant, confirming that digitalization technology is the basis for promoting industrial upgrading. When we focus on the internal upgrading of the tertiary industry in Model 2, we can find that the coefficient of the culture industry cluster index is 0.3180, whose force far exceeds its influence on the overall economic structure (the coefficient in Model 1 is only 0.1573). It shows that the cluster development of cultural industry is particularly good at optimizing the internal business form of service industry and promoting the iterative upgrading of the tertiary industry.

Meanwhile, the number of employment plays a significant role in the structural upgrading of the overall cultural industry, but its importance declines in the refined upgrading of the tertiary industry,  $p=0.074$ , becoming insignificant; while total investment and residents' consumption are stable and significant factors in both models.

### 3.3.2 Analysis of the test of regional heterogeneity

Based on section 3.1, it is clearly known that the development of cultural industry agglomeration in Liaoning Province is unbalanced, therefore, in order to explore the differences in the impact of different levels of cultural industry agglomeration on the upgrading of industrial structure in each region, this paper will further examine the impact of cultural industry on the upgrading of industrial structure in the centers, sub-nodes and edge nodes. The center includes two core hubs, Shenyang and Dalian, and two important bridges, Dandong and Jinzhou; the sub-nodes are six cities, Anshan, Fushun, Benxi, Liaoyang, Yingkou and Panjin; and the edge nodes are Fuxin, Tieling, Chaoyang and Huludao. Based on the above model, it is known that the research on the internal structure of the tertiary industry upgrading impact is more significant, so it is directly carried out on the model 2 cultural industry agglomeration on the internal structure of the tertiary industry upgrading of the empirical analysis of the sub-region, the results are shown in Table 4.

Table 4: Impact of the CIA on the upgrading of the internal of the tertiary industry

	Center			Sub-node			Edge Node		
	Coef	F	P	Coef	F	P	Coef	F	P
Constant	-0.215	-1.124	0.261	-0.382	-1.735	0.083	-0.108	-0.532	0.595
CIA	0.284	4.125	0.000	0.198	2.782	0.007	0.121	2.315	0.035
DT	0.189	3.987	0.000	0.152	3.254	0.001	0.087	1.845	0.066
EM	0.165	1.873	0.062	0.231	2.104	0.036	0.094	1.124	0.262
TIS	0.272	2.891	0.004	0.305	3.125	0.002	0.356	2.874	0.004
RC	0.132	2.543	0.011	0.101	1.987	0.047	0.065	1.542	0.124
R <sup>2</sup>	0.934			0.892			0.763		
F	142.35			98.67			45.23		
P	0.000			0.000			0.000		

The empirical analysis of the cultural industry agglomeration on the internal structural upgrading of the tertiary industry explored in the above sub-regions shows that the coefficients of determination of the samples within the group of the center region, this node region and the edge node R<sup>2</sup> are 0.934, 0.892 and 0.763 respectively, which can explain the changes of internal structural upgrading of the tertiary industry of 93.4%, 89.2% and 76.3% in each region respectively. The significance P is 0.000, and the model coefficients of the cultural industry agglomeration index of the three are greater than 0, indicating that the cultural industry agglomeration of either region is a significant contribution to the structural upgrading of the tertiary industry.

Specifically analyzed, the coefficients of cultural industry agglomeration of the three are 0.284, 0.198 and 0.121, with significance  $P=0.000$ , 0.007 and 0.035, which are significantly correlated at 1%, 5% and 10%, respectively. For the four key central nodes, the model coefficients of all indicators such as digitization, investment and consumption are significantly superior, which indicates that these four core areas in Liaoning Province have formed a mature development pattern of multi-factor synergy; for the six sub-nodes, although the coefficients of all drivers have dropped back, they are still all significant. The coefficient of employment

becomes more significant here than in the core areas,  $\text{Coef}=0.231$ . It shows that for these six industrial cities undergoing transformation, the development of cultural industry has a significant effect on the transfer of job creation from the secondary industry to the tertiary industry. In the fringe region, the digital technology level driving effect becomes less significant here,  $P=0.066$ , but its total investment asset coefficient is the highest among the 3 regions, at 0.356. For the fringe region with weaker links, only increased fixed asset investment can bring the most obvious structural improvement.

### 3.4 Empirical analysis of the impact of VAR-based digital technology on the upgrading of the cultural industry

This paper applies the vector autoregressive (VAR) method to further explore the magnitude of the impact of the development of digitalization technology on the upgrading of the cultural industry. The exploration of cultural industry upgrading in this section centers on two paths: cultural industry structure upgrading and cultural industry chain upgrading. The following three variables are mainly selected for research.

(1) The business (DT) income of the digital culture industry is still selected as the level of digital technology application; (2) The increase in the cultural service industry is used as the level of digital technology application.

(2) The ratio of the value added of cultural service industry to the value added of cultural industry, WFB, is used to indicate the upgrading of cultural industry structure.

(3) The ratio of cultural creativity and design services to the value added of cultural industry WSB describes the upgrading of cultural products. The upgrading of cultural products is a part of the upgrading of cultural industry chain.

The three variables are still treated as logarithms.

#### 3.4.1 Impulse Response Analysis

The  $\text{LN}(\text{DT})$  is first analyzed for its own impulses accordingly, and Figure 7 illustrates the response of the  $\text{LN}(\text{DT})$  to a one-unit standard deviation shock from the  $\text{LN}(\text{DT})$  itself.

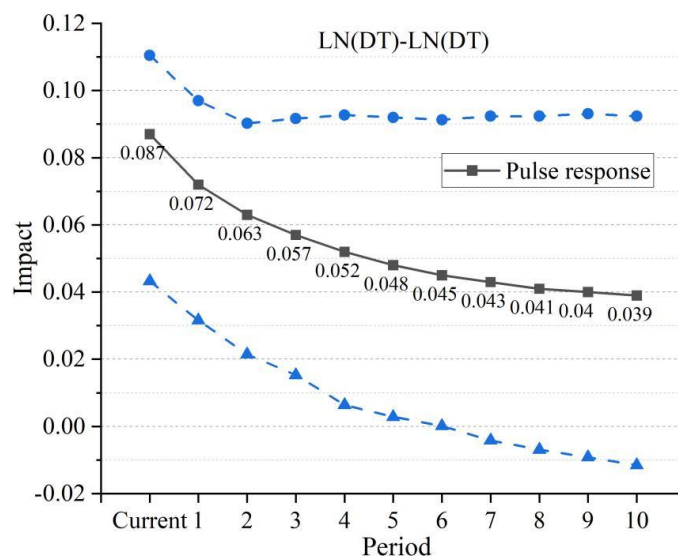


Figure 7:  $\text{LN}(\text{DT}) - \text{LN}(\text{DT})$  pulse response

When a positive shock of one unit standard deviation is given to  $\text{LN}(\text{DT})$  itself in the current period, the impact reaches 0.087, but this impact has been decreasing since that period, dropping

to 0.072 in the first period, 0.063 in the second period... and then stabilizing. It can be seen that the digital technology has a very direct effect on its own promotion. The response value is the highest in the current period. The shock can significantly amplify itself in the short term. However, this self-promotion effect will gradually decay over time, declining significantly from the 1st period, and finally stabilizing at the long-term equilibrium level of about 0.039 after about the 8th period. It reveals that there is a self-reinforcing effect and path dependence in the development of digital culture industry, the marginal effect of a single shock will diminish, and long-term growth requires continuous new kinetic energy injection.

Figure 8 represents the response of LN(WFB) to a one-unit standard deviation shock from LN(DT).

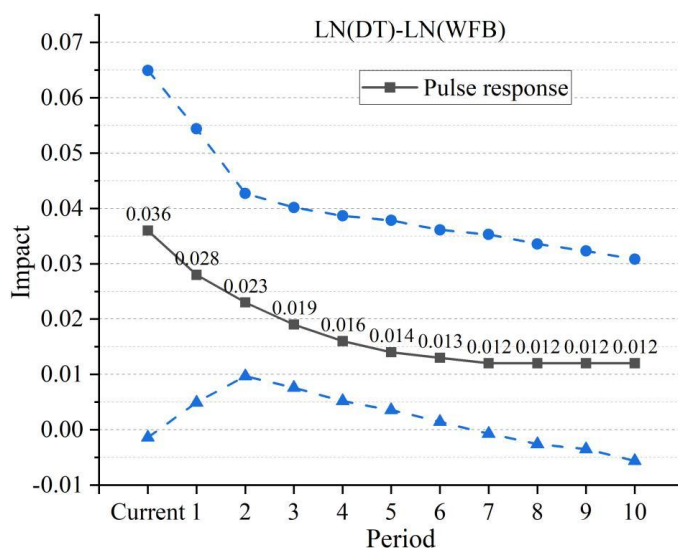


Figure 8: LN(WFB) - LN(DT) pulse response

The impact of the shock of digital technology LN(DT) on the cultural services share LN(WFB) is strong at the beginning and reaches 0.036. Then, the impact of the shock on the cultural services share LN(WFB) diminishes and reaches a stable value of 0.012 around the seventh period, which indicates that the response of the cultural services share LN(WFB) to the shock of digital technology LN(DT) is significant for a short period of time, and with the extension of time the impact of the positive shock diminishes, but still promotes the growth of the cultural services share LN(WFB). The response is significant in the shorter term, and as time lengthens, the positive shock produces a weaker impact, but still contributes to the growth of the cultural services share LN(WFB).

In the short term, the digitization shock directly promotes the rapid agglomeration of capital, technology and other factors to the cultural services industry, thus significantly boosting its industry share. In the long run, digitization has continuously brought out the spillover effect of digital technology by changing the production mode and cultivating new business forms, prompting the adjustment of industrial structure and thus promoting the upgrading of the cultural industry.

### 3.4.2 Analysis of variance decomposition

To further analyze the degree of importance to the structural shocks from digital technology LN(DT), this paper analyzes the contribution of each structural shock to the change in the endogenous variable cultural services LN(WFB) with the help of variance decomposition. Thus, the magnitude of the impact of digital technology LN(DT) on LN(WFB) is obtained. Table 5

shows the results of the variance decomposition of the share of cultural services LN(WFB).

*Table 5: The variance decomposition of the proportion of the cultural service industry*

Lag period	Predicted SD	LN(DT)/%	LN(WFB)/%	LN(WSB)/%
Current	0.0761	23.94	75.92	0.14
1	0.1087	31.42	67.98	0.60
2	0.1226	36.22	62.75	1.03
3	0.1576	40.53	56.54	2.94
4	0.1724	41.71	55.26	3.04
5	0.1807	42.31	53.10	4.59
6	0.1906	43.12	51.15	5.73
7	0.2008	43.43	50.32	6.25
8	0.2139	44.13	49.12	6.75
9	0.2219	44.53	48.11	7.36
10	0.2240	44.85	47.15	8.01

At the beginning, the contribution of LN(DT) to LN(WFB) has reached 23.94%, and the contribution grows faster in the first three periods, and then grows slowly, and finally the contribution stabilizes at about 44.85%. And as the contribution rate of LN(WSB) of the upgraded service industry of the cultural industry chain itself climbs slightly (8.01% in the 10th period), the contribution rate of LN(WFB) of the cultural service industry itself decreases from 75.92% to 47.15% accordingly. This suggests that over time, the internal structure of the cultural industry has become increasingly dependent on digital technology to drive it rather than its own historical inertia, while the upgrading of cultural products also plays a small part. Digital technology has gradually evolved from an external influencing factor to a core explanatory variable driving the industrial structure.

## 4 Conclusion

Social network analysis shows that Shenyang and Dalian constitute the double core of Liaoning's cultural industry spatial structure network, with its intermediate centrality as high as 0.327 and 0.241 respectively, controlling the key path of cultural resources flow in the province. Liaoyang and Dandong, as important bridges, have proximity centrality of 20.758 and 15.673 respectively, while Fuxin and Chaoyang in western Liaoning are at the end of the centrality indicators. The development of Liaoning's cultural industry is uneven.

Every 1% increase in the level of digitalization technology can directly lead to an average growth of about 0.756% in the scale of the cultural industry, and its influence far exceeds that of other factors such as scientific and technological innovation and market demand. However, there is significant regional heterogeneity in its effect, in Shenyang, Dalian and other core areas, the coefficient of its impact on industrial upgrading reaches 0.189; while in Fuxin, Chaoyang and other marginal areas, the impact of digitization becomes insignificant, with a coefficient of only 0.087, and the upgrading of the cultural industry in marginal areas is more reliant on the pull of investment, with a coefficient of 0.356.

Dynamic impulse response analysis shows that a positive shock of digitization can produce a strong short-term upgrading effect on the share of cultural services, with a peak response of about 0.036, and stabilized at a positive level of 0.012 for a long time thereafter. The contribution of digital technology to the structural change of the cultural services industry has continued to rise from 31.4% in the first period to 44.8% in the 10th period, and it is the core

pivot to promote the transformation of the province's cultural industry to modernization.

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