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Northeast revitalization strategy background below the path analysis of innovation industry driven development

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SUMMARY: *Based on the background of the revitalization strategy of Northeast China and the realistic needs of innovation-driven development of cultural and creative industries, an analysis framework integrating structured indicators, policy texts and industrial data was constructed to systematically investigate the innovation-driven development mechanism of cultural and creative industries in Northeast China. The results show that the innovation-driven development of cultural and creative industries in Northeast China shows a pattern of policy traction, technology empowerment and resource activation. Among them, the technology empowerment path accounts for 27.8%, and the policy traction path accounts for 22.6%, indicating that digital technology embedding and institutional supply have become the main supporting forces, while market transformation and collaborative interaction are still the key links restricting high-quality development. This study could provide reference for the optimization and upgrading of cultural and creative industries and the integrated development of regional culture and economy in Northeast China.*

KEYWORDS: *Northeast revitalization strategy; Cultural and creative industry; Innovation-driven; Path identification model*

1 Introduction

The Northeast revitalization strategy continues to advance, making the restructuring of regional industrial structure, the reconstruction of urban functions and the transformation of cultural resources value into a closer coordination stage. The cultural and creative industry has multiple attributes such as content production, symbol dissemination, consumption drive and space empowerment, and has gradually become an important starting point for cultivating new growth points, rebuilding urban brand image and activating local characteristic resources in Northeast China. With the widespread embedding of big data, artificial intelligence, cloud computing, digital platforms and intelligent terminals, the creative generation method, product development logic, market link mechanism and value diffusion path of the cultural and creative industry have changed significantly. The traditional development model relying on resource endowment and experience judgment has been difficult to adapt to the current cross-media, cross-scene and cross-platform industrial evolution requirements. How to identify the key factors of innovation-driven development of cultural and creative industries under the framework of Northeast revitalization strategy, and then reveal its formation mechanism and realization path, has become a practical research topic.

In recent years, scholars at home and abroad have accumulated rich research results on the relationship between cultural and creative industries and regional development. Kalfas et al.

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pointed out that cultural and creative industries play a significant role in promoting regional rejuvenation and local vitality reconstruction [1]. Ericsson et al. discussed the driving value of cultural and creative industries to regional economic networks from the perspective of innovation performance and spillover effect [2]. Manioudis et al. emphasized that there is a stable linkage between creative economy and regional sustainable growth [3]. Cinar et al. further analyzed the supporting role of universities in cultural creation, knowledge diffusion and regional innovation [4]. Campi et al. verified the economic promotion function of creative industries from the perspective of employment growth [5]. Goya's research on the externalities of creative industry agglomeration shows that knowledge spillovers and urban environment have a strengthening effect on innovation activities [6]. Arcos-Pumarola et al. proposed that the integration of cultural heritage and creative industries can enhance tourism attraction and place recognition [7]. Castaldi et al. connected local brands with the value of intangible resources and expanded the interpretation boundary of regional embedding research in cultural and creative industries [8]. Kitagawa's investigation of Japan's regional revitalization policy shows that local industry renewal is inseparable from institutional guidance and multi-agent collaboration [9]. Erickson et al. research on digital openness and creative innovation revealed the correlation mechanism among digital platform, crowdfunding network and innovation diffusion [10].

Existing research provides an important basis for understanding the growth logic of cultural and creative industries. However, in the case of Northeast China, the existing results still remain at the level of policy discussion, case description or single factor analysis, and the structure identification, data characterization and calculation analysis of the innovation driving path are still insufficient. Especially under the background of Northeast revitalization strategy, the development of cultural and creative industry is not only a problem of repackaging cultural resources, but also involves technology embedding, platform collaboration, talent flow, industrial network reconstruction and regional innovation ecological reconstruction. Based on this, this paper puts the cultural and creative industries in Northeast China into the framework of innovation-driven development, introduces computer methods such as data collection, text mining, feature extraction and path recognition, and analyzes its key impact dimensions and realization paths, in order to provide more explanatory research basis for the quality upgrading of cultural and creative industries in Northeast China, the linkage development of regional culture and economy, and the optimization of relevant policies.

2 Theoretical basis and literature review

2.1 Northeast Revitalization Strategy and Transformation and upgrading of regional cultural and creative Industries

With the continuous promotion of the Northeast revitalization strategy, the regional economic reconstruction has gradually shifted from the traditional factor input leading to the development stage of innovation, coordination and structural optimization. In this process, the cultural and creative industry has special significance not only because of its ability to connect historical culture, industrial heritage and regional symbols with contemporary consumer needs, but also because of its ability to leverage multiple values such as content production, scene renewal, brand building and urban communication with low resource consumption. For Northeast China, the renewal of the old industrial base is not only the replacement of industrial categories, but also involves the reorganization of spatial memory,

the restoration of local image and the cultivation of new consumption formats. It is under this transformation background that the cultural and creative industry is endowed with the practical function of connecting cultural resources, industrial reengineering and regional vitality promotion.

The coupling relationship between knowledge spillover, enterprise capability and industrial environment determines that the regional cultural and creative industry does not rely on a single point of creativity to complete the upgrading, but needs to form a continuous interaction between the innovation subject, platform carrier and market interface [11]. At the same time, shared office space, creative carriers and complex entrepreneurial scenes in medium-sized cities tend to support cultural entrepreneurial activities in peripheral areas, which has a strong inspiring significance for many non-central cities in Northeast China [12]. From the demand side, the rise of creative tourism, cultural experience and local narrative consumption also provides a new entrance for the cultural and creative industry to be embedded in regional renewal [13]. Research on local brands further shows that regional intangible resources are not static assets, but innovative capital that can be re-valued through design translation, platform communication and industrial linkage [14]. Therefore, the transformation and upgrading of cultural and creative industries under the background of the revitalization strategy of Northeast China is no longer a problem of relying solely on policy support to expand the supply scale, but a problem of how to transform regional cultural resources into sustainable innovation drivers with the help of digital technology, platform network and brand construction mechanism.

Table 1: Key supporting dimensions of innovation industry transformation and upgrading in the background of Northeast revitalization strategy

Supporting Dimension	Main Content	Role in Innovation-Driven Development
Cultural resource reorganization	Redevelopment of resources such as industrial heritage, folk culture, red culture, and ice-and-snow culture	Provides content sources and a foundation for local identity recognition
Urban scenario renewal	Renovation of old industrial areas, improvement of public cultural spaces, and construction of culture-tourism integration scenarios	Expands the implementation space and consumer touchpoints for cultural and creative products
Digital platform embedding	E-commerce platforms, short-video platforms, digital display systems, and intelligent recommendation mechanisms	Improves communication efficiency and market matching capability
Collaborative innovation among stakeholders	Linkage among universities, industrial parks, enterprises, government, and maker communities	Strengthens knowledge diffusion and project incubation capacity
Regional brand building	City IP, local narratives, and visualization of cultural symbols	Enhances market recognizability and value transformation capability

As shown in Table 1, the upgrading logic of cultural and creative industries in Northeast China does not unfold linearly, but is the result of the interaction of cultural resources, technological tools, space carriers and organizational networks. This also determines that the subsequent path analysis cannot stay in the experience judgment, but should enter the structure identification and multi-dimensional measurement level.

2.2 Connotation, dynamic elements and action mechanism of innovation-driven development of cultural and creative industries

The innovation-driven development of cultural and creative industries is essentially a dynamic evolution process with the core of idea generation, technology embedding, organizational collaboration and market transformation. Its "innovation" is not limited to the update of product form, but also includes the change of content production mode, the reconstruction of communication chain, the reorganization of consumption experience and the redesign of value realization mechanism. Especially in the Northeast region, if the cultural and creative industry is to truly undertake the new growth task under the background of revitalization, it must break through the limitations of traditional souvenir development, single performing arts supply and fragmented brand management, and turn to a compound innovation system supported by data, algorithms, platforms and cross-border integration.

Relevant studies show that the combination of cultural heritage and creative industry can form a dual effect of cultural protection and industrial value-added in the local sustainable development [15]. The success goal of creative entrepreneurs is not only defined by short-term financial returns, but also influenced by social identification, cultural expression, network resources and long-term growth expectations [16]. With the gradual involvement of artificial intelligence in creative production, content generation and user interaction, the internal division of labor, skill structure and innovation rhythm in the cultural and creative industry are also adjusted, which makes the weight of technical factors in the innovation drive continue to rise [17]. From the policy level, the systematic review of cultural and creative entrepreneurship support policies shows that entrepreneurial environment, institutional incentives, financing mechanism and ability cultivation are important conditions affecting the efficiency of cultural innovation [18].

Based on the above understanding, the dynamic elements of innovation-driven development of cultural and creative industries can be summarized into four categories: first, resource elements, including regional culture, historical memory, industrial relics and local symbols; The second is the technical elements, including digital acquisition, intelligent design, platform communication, algorithm recommendation and user portrait. The third is the organizational elements, including the collaboration between enterprises, universities, parks, maker communities and public institutions. The fourth is the market factors, including the change of consumer preferences, the expansion of scene consumption and the improvement of brand value. These elements do not exist side by side, but form a progressive action mechanism in the chain of "digitalization of resources, productization of ideas, communication platform, and value networking". In other words, the innovation driving force of the cultural and creative industry is not a single node, but a networked operation process under the coupling of multiple factors.

2.3 Theoretical basis and technical methods of data-driven innovation development path analysis of the innovation industry below

In traditional research, the judgment of the development path of cultural and creative industries mostly relies on case induction, policy analysis and statistical description. Such methods are helpful to grasp the overall trend, but the description of complex relationships, potential structures and dynamic transmission mechanisms is still insufficient. With the development of data acquisition technology, text calculation methods and intelligent analysis tools, the research of cultural and creative industry path has begun to have stronger computability. The formation of creative hubs and cross-local entrepreneurial ecology shows that cultural and creative activities have been embedded in a wider range of network

connections, and path identification needs to shift from isolated sample analysis to relational network analysis [19]. The five-spiral innovation model suggests that regional development is not only driven by government, enterprises and universities, and natural environment, social culture and public participation will also enter the innovation system, so path analysis must have the ability to integrate multi-source heterogeneous data [20]. Cluster research further shows that the growth of creative and cultural industries is often affected by node aggregation, collaborative division of labor and resource sharing, and it is suitable to use structural models to identify key driving chains [21].

Therefore, the data-driven innovation path analysis of cultural and creative industries can be built on the technical logic of "multi-source data fusion, feature extraction, relationship modeling, and path identification". In the research, statistical indicators, policy texts, industry reports, enterprise information, platform communication data and consumer reviews can be incorporated into the unified data pool, and natural language processing methods can be used to extract policy concerns, industry hotspots and brand narrative features. Regional cultural and creative development types can be identified by clustering analysis, and association rules, social network analysis or path identification models can be further combined. The linkage relationship between innovation drivers is calculated and expressed. The advantage of such processing is that it can not only retain the cultural semantic information that is difficult to be fully quantified in the cultural and creative industry, but also improve the objectivity, stability and reusability of analysis through computer methods.

Table 2: The main technical methods for the analysis of the innovation development path of the innovation industry driven by the data below

Technical Method	Data Objects	Main Functions	Application Value
Text mining and topic identification	Policy texts, news reports, enterprise profiles, and user reviews	Extract high-frequency topics, policy orientations, and market focus points	Identify the structural themes of regional cultural and creative development
Cluster analysis	Urban indicators, enterprise operational data, and industrial park samples	Classify cultural and creative development types and innovation feature groups	Discover regional differences and stratified characteristics
Social network analysis	Enterprise cooperation relationships, platform links, and industrial park collaboration networks	Identify core nodes, linkage strength, and network positions	Determine the flow paths of innovation resources
Path identification model	Multidimensional indicators and feature variables	Measure the direct and indirect effects of key factors	Reveal the realization mechanism of innovation-driven development
Visual analysis	Comprehensive computational results	Present regional distribution, relational structure, and path chains	Improve the intuitiveness of research presentation

As shown in Table 2, the value of data-driven methods does not lie in replacing theoretical judgments in industrial research, but in providing more detailed evidence support for the

analysis of innovation paths in cultural and creative industries. For Northeast China, this method is especially suitable to deal with the research object with obvious regional differences, complex industrial forms, strong policy influence and accelerated digital transformation. Based on this theoretical basis, this paper will further construct the analysis framework of the innovation-driven development path of the cultural and creative industry in Northeast China in the subsequent part, and empirically identify the key driving chain.

3 Research methods and data collection

3.1 Selection basis for analysis method of innovation driving path of cultural and creative industry in Northeast China

The formation process of innovation-driven development of cultural and creative industry in Northeast China is affected by many factors, such as policy supply, cultural resource endowment, digital infrastructure, technology application ability, market transformation efficiency and regional collaborative network. There are direct effects, interactive transmission and threshold differences between the variables. If only descriptive statistics or single linear regression is used, it can only show the average influence of a factor, and it is difficult to reveal the composite structure of innovation path under the condition of multi-source data. Based on this, this paper takes "text mining-feature fusion-random forest path recognition" as the core analysis idea to identify the critical path and its relative strength of the innovation-driven development of the cultural and creative industry in Northeast China.

At the data processing level, the research objects include both structured indicators in statistical yearbooks and unstructured data such as policy texts, industrial reports, park introductions and enterprise cases. In order to enhance the comparability between different data sources, in this paper, the structural features are denoted as S_i, the topic features extracted by text mining are denoted as T_i, and the network correlation features are denoted as N_i, and then the comprehensive input vector is constructed.

$$F_i=\alpha S_i+\beta T_i+\gamma N_i, \qquad \alpha+\beta+\gamma=1 \tag{1}$$

Here, F_i represents the comprehensive feature expression of the ith sample, and α, β, γ are the fusion weights of different data modules. This expression can incorporate policy semantics, industrial structure information and regional coordination characteristics into the same analysis framework, so as to avoid the compression of the complexity of cultural and creative industries by a single index system.

At the path identification level, this paper chooses the random forest model to fit the innovation-driven development level, and its prediction form can be expressed as follows.

$$\hat{Y}_i=\frac{1}{K}\sum_{k=1}^{K} h_k(F_i) \tag{2}$$

where $\hat{Y}_i$ is the innovation-driven development prediction value of the ith sample, $h_k(F_i)$ is the output result of the KTH decision tree, and k is the number of trees. Compared with the traditional linear model, this method does not need to make too strong assumptions on the distribution of variables, and can better adapt to the heterogeneity, nonlinearity and local fluctuation characteristics common in the samples of cultural and creative industries in Northeast China. At the same time, the model can also output the contribution ranking of key impact factors according to the importance of variables, which provides a basis for subsequent

path interpretation. Its path contribution can be further expressed as follows.

$$P_j = \frac{Imp_j}{\sum_{j=1}^{m} Imp_j} \tag{3}$$

Here, P_j is the relative path contribution of the JTH driving factor, and Imp_j is the importance value of this factor.

Table 3: Selection basis for analysis method of innovation driving path of cultural and creative industry in Northeast China

Selection Basis	Specific Description	Applicability
Compatibility with multi-source heterogeneous data	It can simultaneously process statistical indicators, textual features, and network relational data.	High
Nonlinear relationship identification capability	It can capture interaction effects and nonlinear influences among innovation factors.	High
Noise resistance and robustness	It shows strong tolerance to missing values, fluctuations, and local outliers.	High
Interpretability of variable contribution	It can output the importance of key factors, which is helpful for identifying dominant paths.	Medium-High
Convenience of computational implementation	It is convenient to integrate with text mining, feature engineering, and visual analytics.	Medium-High

As can be seen from Table 3, this method is selected in this paper not only for technical novelty considerations, but because of its high suitability to the research object. The development of cultural and creative industry in Northeast China is not only embedded in the regional revitalization strategy, but also deeply affected by the expansion of digital platform, the reconstruction of cultural resources and the change of consumption structure, and the driving process shows obvious multivariate linkage characteristics. The random forest path identification method can calculate and express the key driving chain under the premise of preserving the complex relationship, and provide a method basis for the construction of the innovation-driven path identification model in the following paper.

3.2 Data collection process and method

3.2.1 Research sample, index data and text data collection

In order to improve the pertinence and computability of the analysis of the innovation driving path of the cultural and creative industry in Northeast China, this paper defines the research sample as 36 prefecture-level and above sample units in Liaoning, Jilin and Heilongjiang provinces, and sets the observation period from 2018 to 2024, forming a total of 252 city-year panel observations. On this basis, policy texts, industry reports, enterprise annual reports, park materials and media reports are collected synchronously, and a data system combining "structured indicators + unstructured texts" is constructed. This processing method can avoid information compression caused by relying solely on statistical diameter, and is more conducive to identifying the real transmission chain of innovation industry driven

development under the background of Northeast revitalization strategy.

Table 4 lists the research samples and data composition of this paper. The structured indicator part focuses on five dimensions of innovation input, digital support, market transformation, cultural resources and collaborative environment. Specifically, it includes the operating income of cultural enterprises above designated size, the number of cultural-creative related patents granted, the investment intensity of research and development funds, the Internet broadband access ability, the activity of digital cultural tourism platform, the number of cultural venues, the distribution of art and design majors in colleges and universities, and the scale of cultural tourism consumption. The unstructured text part mainly collects policy documents of cultural and creative industries issued by three provinces and key cities in Northeast China, local "14th Five-Year Plan" cultural development plans, industrial park promotion materials, annual reports of key enterprises, and public communication texts of mainstream platforms, which are used to extract policy concerns, industrial hotspots and regional narrative features.

Table 4: Research sample and data composition

Data Category	Sample Scope	Main Content	Data Sources	Main Purpose
Urban panel data	2018–2024, 36 sample units, 252 observations	Number of cultural and creative enterprises, operating revenue, R&D investment, digital infrastructure, cultural and tourism consumption, etc.	Provincial statistical yearbooks, municipal statistical bulletins, and publicly available cultural and tourism materials	To construct the innovation-driven indicator system
Enterprise sample data	126 key cultural and creative enterprises	Annual report information, number of patents, digital investment, and brand communication performance	Corporate annual reports, publicly available business registration materials, and industrial park materials	To measure enterprise innovation activity and transformation capability
Policy text materials	214 documents	Cultural and creative support policies, digital culture planning, and revitalization-related documents	Government official websites and departmental announcements	To extract policy themes and institutional orientation
Industry and media texts	468 documents	Industry reports, news coverage, industrial park promotion materials, and publicly available platform content	Research report databases, mainstream media, and publicly accessible platform pages	To identify market hotspots and regional narratives

From the perspective of data composition, this paper does not understand the innovation-driven development of cultural and creative industries as the linear change of a single economic indicator, but observes it in the framework of the joint role of policy,

technology, market and cultural resources. Figure 1 shows the data processing and calculation flow of this paper. According to this process, the data collected by the front-end need to be cleaned, transformed and characterized before entering the model, and then used for comprehensive index calculation and path identification analysis.

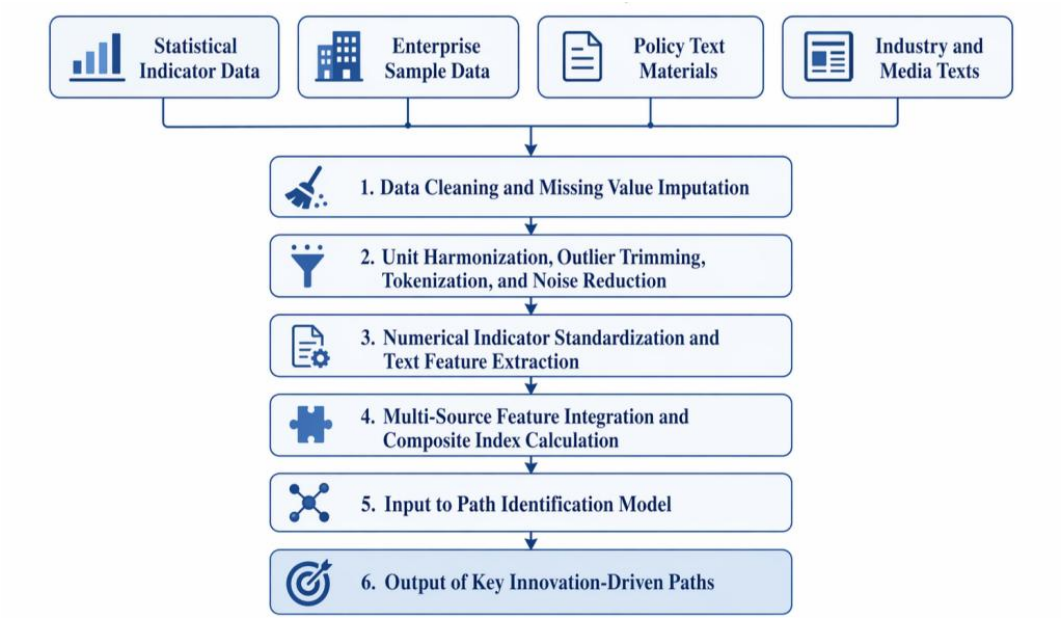

Figure 1: Data processing flow for analysis of innovation driving path of cultural and creative industries in Northeast China

3.2.2 Data preprocessing, feature extraction, and calculation methods

In the stage of raw data collation, this paper firstly performed missing value checking, duplicate deletion and outlier correction for structured indicators. For a small number of missing samples, the mean value of adjacent years was used to interpolate. For the extreme values with excessive fluctuation, 1% quantile tail reduction was used. The data of different dimensions such as currency, quantity and proportion are uniformly converted to a comparable caliber. In order to eliminate the interference of dimensional differences on the model results, the index is standardized by range. For positive metrics, the normalization formula is as follows.

$$z_{ij}=\frac{x_{ij}-\min(x_j)}{\max(x_j)-\min(x_j)} \tag{4}$$

For negative indicators, the reverse transformation is used:

$$z_{ij}=\frac{\max(x_j)-x_{ij}}{\max(x_j)-\min(x_j)} \tag{5}$$

Here, x_{ij} represents the original value of the ith sample on the JTH index, and z_{ij} is the normalized result.

In the text data processing part, Chinese word segmentation, stop words elimination and professional dictionary expansion are completed in the Python environment, and high-correlation terms such as "industrial heritage revitalization", "ice and snow tourism", "digital content production" and "animation IP development" are incorporated into the

recognition vocabulary to reduce the deviation of semantic segmentation. The TF-IDF method is then used to measure the discriminative power of terms in the text, which is calculated as follows.

$$w_{t,d}=tf_{t,d}\times \log\left(\frac{N}{df_t+1}\right) \tag{6}$$

where $w_{t,d}$ is the weight of term t in text d, $tf_{t,d}$ is the term frequency, df_t is the number of texts containing the term, and N is the total amount of texts. Based on the weight matrix, this paper further extracts theme features such as policy support, technology embedding, brand communication, cultural tourism integration, and talent support, and incorporates them into the feature library together with structured indicators.

In the comprehensive calculation stage, the entropy method is used to determine the weight of each index to reduce the deviation caused by subjective weighting. Let the proportion of indexes after standardization be p_{ij}, then the information entropy of the JTH index is as follows.

$$e_j=-\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij}\ln p_{ij} \tag{7}$$

Accordingly, the coefficient of difference $g_j=1-e_j$ is obtained, and then the weight $\omega_j=g_j/\sum g_j$ is calculated. After weight determination, the innovation-driven comprehensive index of cultural and creative industry in Northeast China is constructed as follows.

$$D_i=\sum_{j=1}^{m}\omega_j z_{ij} \tag{8}$$

Here, D_i denotes the level of innovation-driven development at the = ith sample. This index does not directly replace the subsequent path identification results, but serves as a core variable to measure the innovation status of the sample, and is input into the model together with text topic features, enterprise innovation features and regional collaboration features. In this way, on the one hand, the cultural semantics and policy signals in the development of cultural and creative industries can be retained, and on the other hand, the identification of regional innovation driving paths can be established on the basis of quantifiable and comparable data.

3.3 Analysis Framework for innovation-driven development path of cultural and creative industries in Northeast China

3.3.1 Path analysis dimension and index selection principle

After sample collection, data cleaning and feature extraction, it is still necessary to organize the scattered indicators, text topics and regional information into a computable and interpretable analysis framework. The development of cultural and creative industry in Northeast China does not show the linear change of a single variable, but the result of the joint action of policy traction, cultural resources, digital technology, innovation subject and market transformation. If the index setting is too scattered, it is easy to cause the accumulation of variables. If the dimension division is too rough, it is difficult to reflect the stage differences of cultural and creative industries in Northeast China under the background

of revitalization strategy. Based on this, this paper divides the path analysis dimension into five levels: policy support dimension, resource transformation dimension, technology empowerment dimension, subject collaboration dimension and market realization dimension, and the overall relationship is shown in Figure 2.

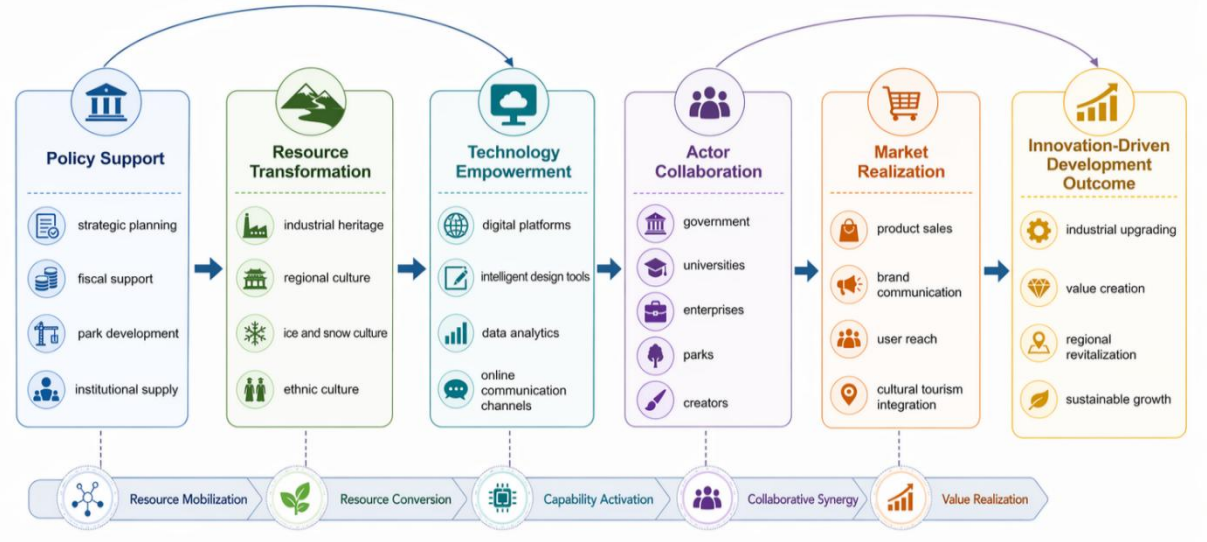

Figure 2: Analysis framework of innovation driving path of cultural and creative industries in Northeast China

Among them, policy support mainly reflects the special planning, financial support, park construction and institutional supply intensity; Resource transformation emphasizes the extent to which resources such as industrial heritage, regional culture, ice and snow culture and national culture enter the cultural and creative production system. Technology empowerment focuses on digital platforms, intelligent design tools, data analysis capabilities and the embedding level of online communication links. Subject collaboration is used to measure the connection strength between government, universities, enterprises, parks and creator groups. Market realization focuses on product sales, brand communication, user reach and the value transformation ability brought by the integration of culture and tourism. The structure shown in Figure 2 is not a simple series relationship, but reflects the transmission logic of the Northeast cultural and creative industry from factor accumulation to innovation output.

The selection of indicators follows five principles. First, strategic relevance, that is, the indicators must be able to respond to the relationship between the revitalization strategy of Northeast China and the upgrading of cultural and creative industries, rather than a general setting separated from the regional background. Second, structural integrity, that is, each dimension should not only cover the main links driven by innovation in the cultural and creative industry, but also avoid the repeated occurrence of synonymous indicators. Thirdly, quantization and comparability, that is, the selected indicators should have clear statistical caliber or stable extraction rules to ensure the feasibility of cross-region and cross-year comparison. Fourth, computational adaptability, that is, indicators can enter the subsequent feature fusion and model training process to avoid problems that are difficult to encode or standardize. Fifth, dynamic responsiveness, that is, the index not only describes the state of the stock, but also reflects the change direction of the regional cultural and creative industry in the digital transformation. Based on the above principles, let the score of the ith sample on the QTH dimension be G_{iq}, then the dimension aggregation expression is as follows.

$$G_{iq}=\sum_{j=1}^{n_q}\lambda_{qj}\ u_{ij} \tag{9}$$

Here, u_{ij} represents the JTH standardized index value belonging to the dimension, λ_{qj} is the weight of the corresponding index, and n_q is the number of indicators in the dimension. Through this process, multi-source heterogeneous indicators can be compressed into clearly structured dimensional features, and then the path state vector of the sample can be formed:

$$X_i=[G_{i1},G_{i2},G_{i3},G_{i4},G_{i5}] \tag{10}$$

The vector no longer stays in the list of scattered statistical indicators, but integrates the key links of the innovation-driven development of the cultural and creative industry in Northeast China into the unified expression space, which provides the input basis for the subsequent path identification model.

3.3.2 Structure design of innovation-driven path identification model

After the dimension system is determined, the key of research is no longer to describe the level of a certain index, but to identify how different elements are combined into a development path with explanatory power. Considering the obvious regional differences, variable interaction and nonlinear characteristics of cultural and creative industry samples in Northeast China, this paper designs the path identification model as a four-layer structure of "input layer, fusion layer, recognition layer and interpretation layer", and its calculation link is shown in Figure 3.

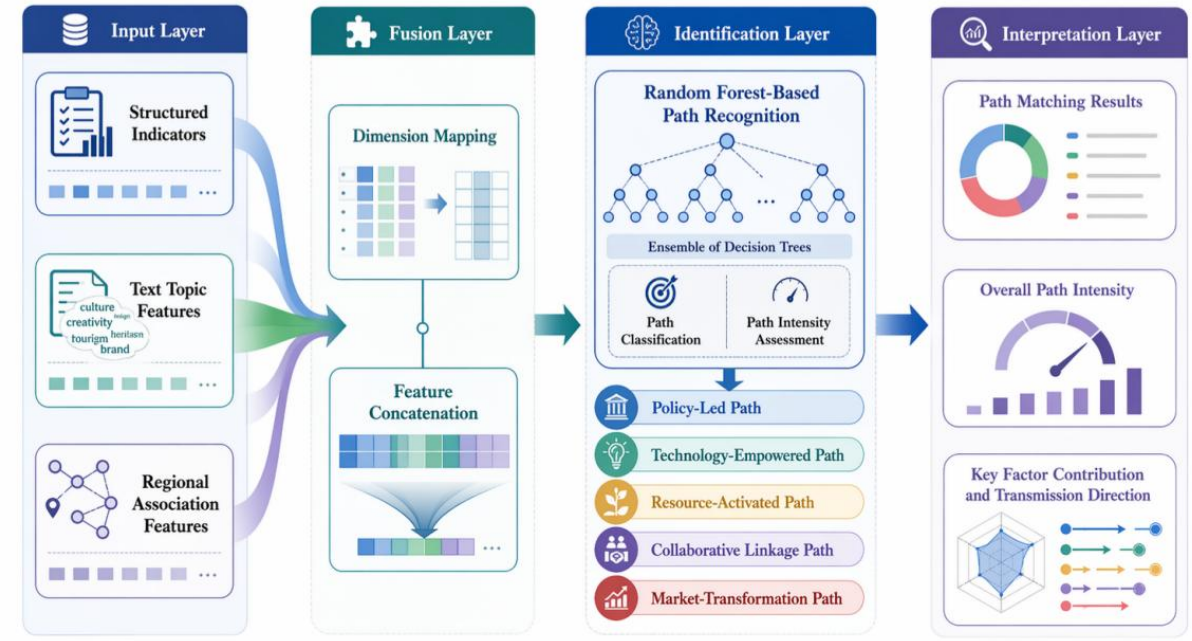

Figure 3: Model structure of innovation-driven path identification

The input layer in Figure 3 receives structured indicators, text topic features, and region association features; The fusion layer completes dimension mapping and feature stitching. The recognition layer uses random forest to complete path classification and intensity judgment. The interpretation layer outputs the contribution degree of the dominant factor and

its conduction direction. In order to improve the interpretability of path identification, this paper divides the innovation-driven development results into five path categories: "policy-driven type, technology-enabled type, resource-activated type, collaborative interaction type, and market-transformed type". For any sample i, the model outputs the probability that it belongs to the KTH path as follows.

$$\pi_{ik}=\frac{1}{T}\sum_{t=1}^{T} I\left(h_t(X_i)=k\right) \tag{11}$$

where T is the number of decision trees,$h_t(X_i)$ represents the classification result of sample i by the t-th tree, and $I(\cdot)$ is the indicator function. If π_{ik} is larger, it means that the sample is more closely matched with the KTH type of innovation driving path. On this basis, in order to measure the overall path strength of the sample, the path comprehensive index is further constructed as follows.

$$R_i=\sum_{k=1}^{5} \pi_{ik}\ \eta_k \tag{12}$$

Here, η_k is the intensity coefficient corresponding to different path types, and R_i represents the overall innovation-driven path level of the sample. The index can transform discrete classification results into continuous measurement values, which is convenient for regional comparison and time series analysis. At the same time, the model also outputs the marginal contribution of each dimension to the path identification results, which is used to determine whether the cultural and creative industries in different cities in Northeast China rely more on policy promotion, technology embedding, or resource translation and market expansion under the background of revitalization strategy.

4 Data analysis

4.1 Application and calculation results of innovation-driven path identification model

In order to test the applicability of the innovation-driven path recognition model constructed in the previous section in the research of cultural and creative industries in Northeast China, this paper inputs the panel data and text features of 36 sample units in Liaoning, Jilin and Heilongjiang provinces from 2018 to 2024 into the model, and divides the training set and the test set according to 7∶3. And set the number of decision trees as 500, the maximum depth as 8, and the minimum number of samples at leaf nodes as 4. In the process of model application, let the set of path categories be:

$$\Omega=\{\omega_1,\omega_2,\omega_3,\omega_4,\omega_5\} \tag{13}$$

Among them, ω_1 represents the policy traction path, ω_2 represents the resource activation path, ω_3 represents the technology empowerment path, ω_4 represents the collaborative linkage path, and ω_5 represents the market transformation path. For any sample x_i, the final recognition result of the model is determined by the majority voting rule:

$$L_i=\arg\max_{\omega_k \square \Omega}\sum_{t=1}^{T} 1\left(f_t(x_i)=\omega_k\right) \tag{14}$$

where $f_t(x_i)$ is the classification output of the t-th tree for sample x_i, T is the total number of trees, and L_i is the category of the dominant innovation-driven path to which the sample belongs. In order to further judge the stability of the recognition results, this paper defines the path confidence as:

$$C_i=\frac{\max_k n_{ik}}{T} \tag{15}$$

Here, n_{ik} represents the number of votes in which sample x_i is judged to be a path of class k, and the closer C_i is to 1, the clearer the dominant path of this sample is.

In the specific calculation, the 2024 Changchun sample is selected for demonstration. After standardization and feature mapping, the comprehensive performance of the sample in the five dimensions of policy support, resource transformation, technology empowerment, subject collaboration and market realization is relatively balanced, but the technology empowerment dimension and policy support dimension are significantly higher than other dimensions. Among the 500 decision trees, 241 decision trees judged it as a technology-enabled path, 109 decision trees judged it as a policy-traction path, and 71 decision trees judged it as a resource-enabled path, while the remaining categories had relatively low votes. Therefore, the dominant category of this sample is technology enabling type, and the path confidence is 0.482. This result shows that the current innovation growth of Changchun's cultural and creative industry mainly depends on digital content production, the improvement of platform communication ability, and the enhancement of technological tools to the efficiency of creative transformation, rather than only on the stock of cultural resources itself.

From the overall identification results, the innovation driving path of cultural and creative industry in Northeast China shows a relatively obvious hierarchical feature, and the result distribution is shown in Figure 4. Figure 4 shows that the technology-enabled path accounts for the highest proportion of 27.8%, indicating that digital platform, intelligent communication and data application have become important support for the innovation and expansion of cultural and creative industries in Northeast China. The policy-driven path accounted for 22.6%, reflecting that the institutional supply is still an important condition for the start and expansion of regional cultural and creative industries under the background of revitalization strategy. Resource-activated paths accounted for 18.9%, indicating that local resources such as industrial heritage, regional culture and ice and snow culture still have significant transformation potential. The proportion of collaborative interaction path and market transformation path were 16.3% and 14.4%, respectively, indicating that the cultural and creative industry in Northeast China still has great room for improvement in cross-subject collaboration and market depth development.

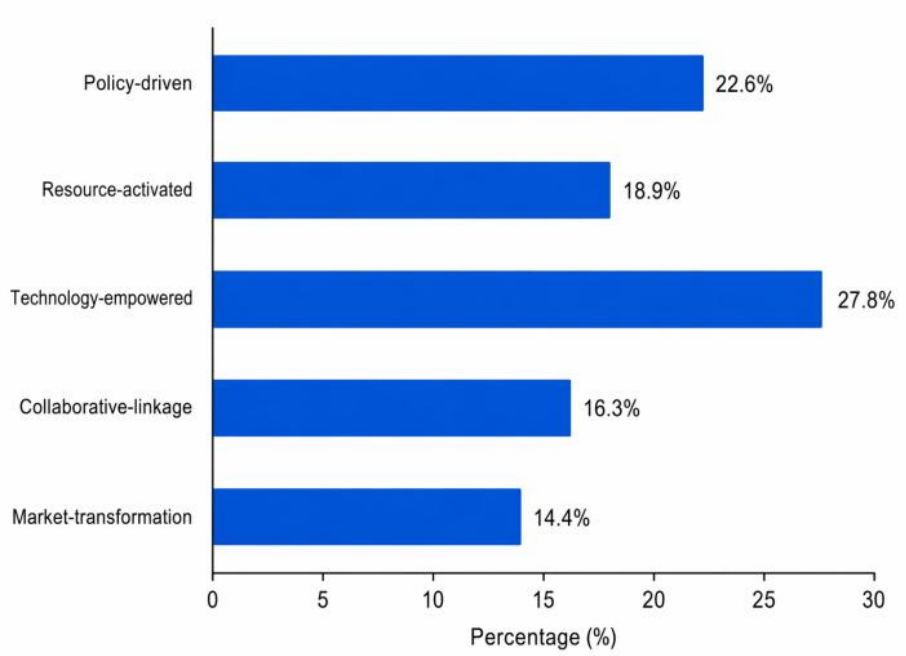

Figure 4: The identification result of innovation driving path of cultural and creative industry in Northeast China

In order to verify the effectiveness of the model results, this paper uses the out-of-bag error to evaluate the recognition accuracy, which is expressed as follows.

$$E_{oob}=1-\frac{1}{N}\sum_{i=1}^{N}1\left(\widehat{L}_i=L_i^*\right) \tag{16}$$

where $\widehat{L}_i$ is the model prediction class and L_i^* is the reference class corresponding to the validation sample. The calculation results show that the out-of-bag recognition accuracy of the model is 0.847, and the Macro-F1 value is 0.823, indicating that the model has good stability and discrimination ability in processing multi-dimensional heterogeneous data of the cultural and creative industry in Northeast China. In general, the application results of the model show that the innovation-driven development of the innovation industry under the background of the revitalization strategy of Northeast China does not have a single path leading the situation, but presents a structural pattern with technology empowerment and policy traction as the core, resource activation as the foundation, synergy linkage and market transformation gradually enhanced.

4.2 Background of Northeast Revitalization Strategy Analysis of the realization path of innovation driven development of innovation industry below

After finishing the training and classification output of the innovation-driven path recognition model in the previous section, the focus of the research has shifted from "can the path be identified" to "how different paths can be transformed into realistic development programs under the background of the Northeast revitalization strategy". The innovation drive of cultural and creative industry is not the natural spillover of a single resource, but the result of the continuous coupling of policy guidance, cultural translation, technology embedding, subject linkage and market feedback. Based on the calculation results of 252 city-year

samples, this paper further analyzes the implementation methods of innovation-driven development of cultural and creative industries in the three northeastern provinces, in order to reveal the differences, advantages and sources of constraints in the path formation of different regions.

As shown in Figure 5, the overall innovation-driven comprehensive scores of cultural and creative industries in the three northeastern provinces showed a continuous upward trend from 2018 to 2024, but there were still obvious gaps between provinces. Liaoning increased from 0.421 in 2018 to 0.642 in 2024, Jilin from 0.389 to 0.587, and Heilongjiang from 0.372 to 0.551. The changes in the scores of the three provinces show that the driving effect of the Northeast revitalization strategy on the cultural and creative industry has gradually extended from the early policy promotion to the deeper links such as the construction of digital platforms, the development of cultural resources and the reconstruction of consumption scenes. However, the magnitude of growth is not exactly the same as the quality of development. The improvement of Liaoning is more dependent on the expansion of the market foundation of urban agglomeration and digital communication network, the growth of Jilin is more closely linked with university resources, animation design and cultural and tourism integration, and Heilongjiang shows strong potential in the transformation of ice and snow culture, frontier culture and industrial memory resources, but the market carrying capacity is weak. It can be seen from the sample calculation results that the cultural and creative industries in the three northeastern provinces all show obvious innovation-driven development characteristics, but their realization paths do not converge to the same model.

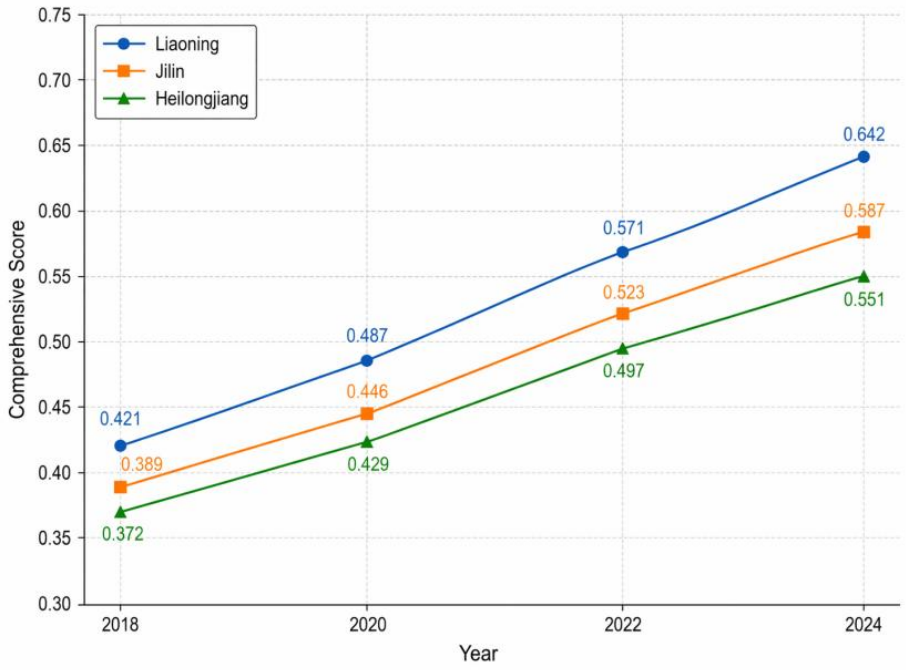

Figure 5: Changes in comprehensive score of innovation-driven of cultural and creative industries in Northeast China (2018-2024)

It can be seen from Figure 6 that the three provinces show a clear differentiation in the dominant path structure. In Liaoning's sample, the technology-enabled path accounted for 31.4%, the policy-driven path accounted for 20.8%, and the market-transformed path accounted for 18.6%, indicating that its cultural and creative industry has gradually shifted from simple policy-oriented to the compound promotion mode of "digital platform + content transformation + consumption access". In the Jilin sample, the policy traction type and

technology empowerment type reached 26.9% and 25.7%, respectively, and the resource activation type accounted for 20.3%, indicating that its path was closer to the promotion logic of "system support - university support - content research and development". The Heilongjiang sample showed 24.6% of resource activation type, 24.1% of technology empowerment type, 22.7% of policy pull type, 19.0% of collaborative interaction type, and only 9.6% of market transformation type, indicating that its innovation drive has a strong foundation of resource development and technology access, but the link of product commercialization and branding is still insufficient. In other words, the key to realize the path of innovation industry under the background of Northeast revitalization strategy is not to simply copy the experience of a certain advanced region, but to form an innovation-driven combination with different focuses according to regional basic differences.

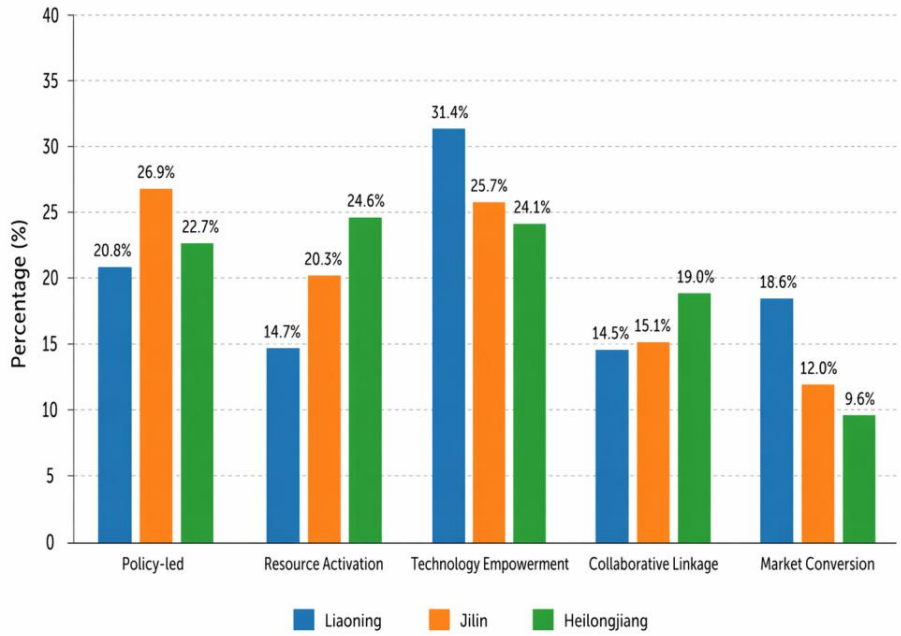

Figure 6: Composition of leading innovation paths of cultural and creative industries in the three Northeastern provinces

In order to further judge the actual performance of different paths, this paper compares the mean results of five types of innovation-driven paths, as detailed in Table 5. Table 5 shows that the comprehensive score of the technology-enabled path is the highest, reaching 0.691, indicating that digital content production, intelligent recommendation, platform communication and data analysis capabilities have become the key forces to promote the efficiency of the cultural and creative industry in Northeast China. The comprehensive score of policy traction path was 0.654, indicating that financial support, park construction and project guidance still had strong starting effects under the background of revitalization strategy. The comprehensive score of resource activation path was 0.618, reflecting that resources such as industrial heritage, ethnic culture, ice and snow culture and local narrative have a good transformation foundation, but the release speed of revenue is still limited if there is no follow-up technology packaging and market amplification. The scores of collaborative interaction path and market transformation path are 0.587 and 0.563 respectively, ranking relatively low, which does not mean that the two are not important, but shows that the current weakest link in Northeast China is precisely focused on the efficiency of cross-subject collaboration and terminal market transformation ability.

Table 5: Comparison of innovation-driven realization paths of cultural and creative industries in Northeast China

Path Type	Composite Score	Dominant Supporting Factors	Main Shortcomings	Adaptation Direction
Technology-Empowered Type	0.691	Digital platforms, algorithmic recommendation, content production tools	The translation of local cultural symbols is not sufficiently stable	Digital content industry agglomeration and platform communication upgrading
Policy-Driven Type	0.654	Special policies, financial support, industrial parks and platform support	The market's endogenous growth capacity is relatively weak	Key project incubation and institutional supply optimization
Resource-Activated Type	0.618	Industrial heritage, local culture, ice and snow resources	The chains of branding and productization are relatively short	Scenario reconstruction, IP development, and cultural-tourism integration
Collaborative-Linkage Type	0.587	Collaboration among universities, enterprises, government, and industrial parks	The stability of the collaboration network is insufficient	Innovation alliances, sharing platforms, and joint research and development
Market-Transformation Type	0.563	Consumer reach, brand communication, channel expansion	The supply of high value-added products is insufficient	Content commercialization and omnichannel operation

It can be seen from Table 5 that the realistic path of realizing innovation-driven development of cultural and creative industries in Northeast China should not stay in the inertial judgment of "resource-rich - natural growth", but should be recombined around the coupling relationship between technology empowerment, policy guidance and resource transformation. For cities with a good digital foundation and strong platform access ability, technology-enabled paths should be prioritized, that is, digital collection, virtual display, intelligent generation and refined communication as the core, to transform local cultural resources into sustainable and iterative digital content products. For regions with a weak industrial base but strong policy support, it is more suitable to start with a policy-driven path and establish a basic innovation ecology through parks, funds, talent programs and pilot projects. For regions with obvious advantages in cultural resources but limited market radius, it is necessary to strengthen the resource activation path, promote the narration of industrial heritage, the visualization of intangible cultural heritage symbols and the scene of ice and snow culture, and expand the conversion efficiency of resources to products, brands and experience consumption.

It can be found from Figure 7 that among the five core dimensions, technology empowerment has the highest score of 0.69, policy support is 0.67, resource conversion is

0.61, subject collaboration is 0.58, and market realization is only 0.52. This result shows that the cultural and creative industry in Northeast China has a strong ability to access technology and promote system, but the chain from "creative formation" to "value cashing" is still not fully opened. The low score of subject collaboration means that there is no high-frequency collaboration between university design resources, enterprise development capabilities, local public cultural platforms and communication channels. The lowest market realization score further indicates that cultural and creative products still have obvious shortcomings in brand construction, consumption hierarchical identification, continuous re-purchase and regional diffusion. In other words, under the background of the Northeast revitalization strategy, the focus of innovation-driven development of the innovation industry is not only to continue to increase the number of projects, but to improve the efficiency of the closed-loop from creative research and development, digital packaging to market feedback.

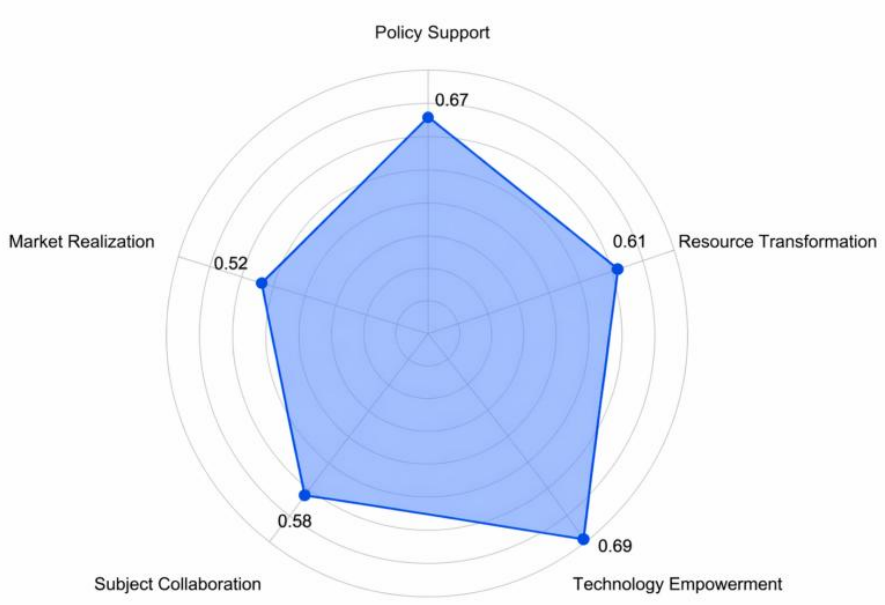

Figure 7: Average score of five dimensions of innovation driving in cultural and creative industries in Northeast China

Based on the above results, the realization path of cultural and creative industry in Northeast China can be summarized as three interrelated promotion directions. One is to reshape the cultural and creative production process with digital technology. Through intelligent design, AIGC auxiliary generation, virtual exhibition, user portrait recognition and platform distribution mechanism, the efficiency of content development and dissemination accuracy are improved, and the technology-enabled path is transformed from local advantages to regional common capabilities. The second is to strengthen the supply of cultural and creative content through the translation of local resources. The Northeast region has unique resources such as industrial civilization memory, frontier culture, multi-ethnic culture and ice and snow culture, which should be transformed into a narrative, visual and interactive cultural content system, rather than staying in the material list. Thirdly, the collaborative network and market loop are used to improve the efficiency of value realization. Relying on colleges, parks, enterprises and cultural and tourism scenes to build a sharing platform, open up the connection between creative incubation, product development, channel operation and consumption feedback, so that the market transformation path and the collaborative linkage

path gradually fill the short board.

4.3 Discussion

Based on the identification results of the above model, it can be seen that the formation of innovation-driven development of innovation industry under the background of Northeast revitalization strategy is not the result of the natural release of single resource advantage, but a phased evolution process under the joint action of policy supply, technology embedding, cultural translation and market feedback. Different from the existing researches that analyze from a single perspective such as policy support, cultural resource development or cultural tourism integration, this paper integrates structured indicators and text data into a unified framework, and reveals the combination relationship between different driving factors through the path identification model. The analysis shows that the model results show that the technology empowerment dimension and policy support dimension have stronger explanatory power for the innovation-driven development of the cultural and creative industries in Northeast China, indicating that the expansion of digital platforms, the application of intelligent communication tools and the support of local institutions have become the core forces promoting the growth of cultural and creative industries. The relatively low scores of the market transformation and collaborative interaction paths also reflect that the cultural and creative industries in Northeast China still have great room for improvement in the efficiency of cross-subject collaboration, continuous operation of brands and value cashing at the consumer end.

The results of this paper also suggest that the development of cultural and creative industries in different provinces cannot simply apply the same model. Liaoning is closer to the path of platform diffusion and market driving, Jilin reflects the characteristics of linkage of university resources, policy guidance and content research and development, and Heilongjiang is more dependent on local cultural resources and scene development. It can be seen that the key to innovation-driven development of cultural and creative industries in Northeast China is not to continue to expand the number of projects, but to optimize the connection mechanism between technology, resources and market according to regional basic differences. Although this paper improves the structure and interpretability of path analysis to a certain extent, the samples are still dominated by public data and accessible texts, and some micro-level enterprise innovation behaviors have not been fully included. Subsequent research can still combine fine-scale platform data and consumption feedback information to further deepen the innovation-driven dynamic evolution process of the cultural and creative industry.

5 Conclusion

Focusing on the realistic needs of innovation-driven development of the innovation industry under the background of the revitalization strategy of Northeast China, this paper constructs a path analysis framework integrating structured indicators and text features, and analyzes the type differentiation and action mechanism of the innovation-driven development of the culture and innovation industry in Northeast China. The results show that the innovation-driven development of cultural and creative industries in Northeast China is not along a single path, but presents a composite pattern of policy traction, technology empowerment, resource activation, collaborative linkage and market transformation interaction. Among them, the driving role of the technology-enabled and policy-driven paths is more prominent, the resource transformation ability constitutes the regional characteristic advantage, and the

synergy efficiency and market realization ability are still the key links restricting the high-quality development. The significance of this paper is that the Northeast revitalization strategy, cultural and creative industry upgrading and data-driven analysis method are brought into the unified research vision, which enhances the structural and explanatory power of path identification. For example, the sample data mainly come from public statistical materials and text information, and some micro-level enterprise innovation behaviors and user feedback have not been fully included. Subsequent research can further expand the sample scope, and introduce platform transaction data, consumption evaluation data, and more fine-grained enterprise innovation data, so as to improve the dynamics and accuracy of the analysis of innovation driving path in the cultural and creative industry.

Fund Project Topic

The "13th Five-Year Plan" Social Science Project of Jilin Provincial Department of Education "Research on the Construction Strategy of Jilin Province's" Changwhite Ground Features "Animation and Cultural Creation Brand under the Background of Rural Revitalization" (JJKH20201228SK)

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