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Jingyou Evaluation and Analysis of Liaoning's Typical Advanced Manufacturing based on *Four Drivers*

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Abstract

Scientifically evaluating the development level of advanced manufacturing is a prerequisite for local governments to formulate personalized development strategies. This paper takes Liaoning Province in China as the research subject, focusing on four dimensions: innovation-driven, reform-driven, market-driven, and open-driven, to construct an evaluation index system for advanced manufacturing. Using an individual advantage characteristic identification and evaluation method based on the ideal point utility model, the development level of typical advanced manufacturing industries in Liaoning is systematically analyzed from both intra-provincial and inter-provincial perspectives. From the intra-provincial industry comparison perspective, considering the most favorable conditions for each, the four typical advanced manufacturing industries in Liaoning--pharmaceutical manufacturing, electronic and communication equipment manufacturing, computer and office equipment manufacturing, and medical instrument and apparatus manufacturing--exhibit distinct individual advantage structures in both overall development level and in the four driving dimensions (innovation, reform, market, and open), bringing significant individual advantages. However, from an inter-provincial comparison perspective, the overall development level and individual and democratic agent evaluation values of the four typical advanced manufacturing industries in Liaoning rank in the middle among 31 provinces, with Liaoning's comparative advantage on a national scale no longer being significant, and its industrial development not being outstanding. Lastly, in response to these issues, this paper proposes several countermeasures to aid the personalized development of Liaoning's advanced manufacturing industries.

Keywords

Advanced Manufacturing; Typical Industry; Individual Advantage Characteristics; Agent Evaluation; Jingyou; Liaoning.

1. Introduction

In recent years, industrial powerhouses such as the United States, Japan, and Germany have reignited waves of industrialization, with modern industrial economies, represented by advanced manufacturing, once again becoming the focal point of competition among global powers and regions. Equipment manufacturing is the backbone of Liaoning's industry, and advanced manufacturing is the leading and supporting force for the economic development of Liaoning in the new era, forming the foundation for Liaoning's revitalization. However, over the past decade, despite Liaoning's status as a major manufacturing province since the founding of the People's Republic of China, the province has been overtaken by more developed regions within China in terms of key indicators such as scale, economic efficiency, level of internationalization, and innovation capability, causing its ranking to continuously decline.

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Moreover, since the release of *Made in China 2025*, many provinces and regions in China have formulated corresponding development plans, highlighting the urgency for action. Addressing the structural issues in Liaoning's old industrial base, as well as planning and developing its advanced manufacturing industry based on its specific characteristics and driving factors, is crucial for effectively achieving the goals of *improving quality and efficiency* and *upgrading and catching up* in Liaoning's manufacturing.

This article, after reviewing and summarizing the main driving factors of advanced manufacturing, constructs an evaluation index system based on these driving factors. It employs methods for identifying and evaluating individual advantage characteristics to systematically assess typical advanced manufacturing industries in Liaoning, both within the province and in comparison with other provinces. The goal is to identify the unique strengths and performance of various key industries and provide policy recommendations for the personalized development of Liaoning's advanced manufacturing.

2. Literature Review

2.1. Concept and Classification of Advanced Manufacturing

Scholars have conducted in-depth research on the concept and classification of advanced manufacturing industries, but no consensus has been reached. For example, Gong et al. (2010) argue that advanced manufacturing refers to an industrial production system that extensively applies advanced manufacturing technologies, adopts advanced manufacturing models, and possesses advanced market network organizations [1]. Rui and Wang (2012) believe that advanced manufacturing refers to industries that integrate high-tech manufacturing achievements, applying advanced manufacturing technologies, models, and management methods comprehensively to the entire process of research and development, design, manufacturing, testing, and services [2]. Yu and Li (2010) summarized previous studies and categorized advanced manufacturing into three theories: *new manufacturing*, *industrial production systems*, and *industrial forms*, based on differences in the concept's connotation and extension [3]. Sun and Du (2014) analyzed the degree to which elements such as advanced technologies, advanced management, and advanced models are covered in the concept and proposed the *single-factor theory* and *dual-factor theory* of advanced manufacturing [4]. Regarding industry classification, scholars have conducted two main types of research. The first is the classification of industries based on the concept and characteristics of advanced manufacturing. For instance, Shang (2014), using the *National Economic Industry Classification* as a reference, divided advanced manufacturing into 45 sub-industries, including information technology, high-end equipment manufacturing, biotechnology and chemicals, new materials, new energy, and energy-saving and environmental protection industries [5]. Tan et al. (2015) classified advanced manufacturing into eight sub-sectors: new information equipment manufacturing, marine engineering equipment manufacturing, biopharmaceutical manufacturing, high-end intelligent robot manufacturing, new material manufacturing, aerospace manufacturing, new energy vehicle manufacturing, and 3D printing [6]. The second approach is constructing selection indicators to identify advanced manufacturing industries. For example, Wang and Chen (2005) believe that traditional manufacturing industries that have successfully upgraded through advanced technologies and management methods also fall under the category of advanced manufacturing. Using Nanjing as a case study, they built a selection indicator system for advanced manufacturing industries, focusing on five aspects: technological advancement, management level, economic benefits, sustainable development, and development potential. This system includes indicators such as labor productivity, industrial added value, sales profit margin, energy consumption per unit output value, pollutant emissions per unit output value, and income elasticity of demand [7].

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2.2. Driver and Evaluation of Advanced Manufacturing

Regarding the drivers and strategies for the development of advanced manufacturing, scholars and relevant departments have mainly conducted research in two areas. First, based on comparative advantages or internal and external motivations, they identify the main influencing factors for the development of advanced manufacturing and propose targeted development suggestions. For instance, Gong et al. (2010) constructed a driving force model for advanced manufacturing development that includes three internal drivers—market demand, technological progress, and the allocation of production factors, as well as two external drivers—government intervention and the development environment, based on the coupling mechanism of internal and external motivations [1]. Lin and Zhang (2018), drawing on Porter's diamond model, proposed a driving mechanism model for advanced manufacturing bases that includes market demand, capital, human resources, technology, industrial policy, and systems [8]. Second, under the context of supply-side structural reform and the transition between old and new growth drivers, efforts are made to seek and cultivate new forces and elements that can promote the development of advanced manufacturing. For example, Li (2018) analyzed the essence of new economic drivers in China's market economy under the new normal, constructing four levels of new drivers—*pressure-market* mechanism, *dynamics-benefits* mechanism, *vitality-innovation* mechanism, and *tension-open* mechanism—centered around the four main determining factors of market, benefits, innovation, and openness [9]. Qiao and Qin (2018) summarized new drivers of industrial development in China based on new supply, new demand, and new systems [10]. Dou et al. (2021) constructed a Whole International Competitiveness Index (WIC) for advanced manufacturing based on indicators such as RCA, MS, TCA, and MI [11]. In terms of evaluating the state of advanced manufacturing development, Du et al. (2010) used the analytic hierarchy process (AHP) to evaluate the development level of advanced manufacturing in China's sub-provincial cities based on four indicators: enterprise technological innovation level, profitability, public environment, and sustainable development capability [12]. Li (2018) focused on typical advanced manufacturing sectors such as biomedicine, aerospace, computers, information, and new materials, analyzing the development trend of China's advanced manufacturing using statistical data comparative analysis methods, centered on scale, structure, technological status, and regional distribution [13]. Qiu and Zhou (2018) evaluated the development level of advanced manufacturing in five cities—Shanghai, Tianjin, Chongqing, Suzhou, and Shenzhen-based on six aspects: quality efficiency, innovation capability, industrial structure, integration of informatization and industrialization, green development, and international competitiveness, using a gray correlation method based on entropy weight [14]. Khan et al. (2022) introduced the Best-Worst Method (BWM) into the field of manufacturing performance evaluation to determine the importance weights of evaluation criteria [15]. In addition, researchers such as Cui and Dai (2021), Huang et al. (2022), and Ge (2023) conducted quantitative evaluation studies on the advancement, high-quality development, and competitiveness of manufacturing in provinces such as Hebei, Jiangxi, and Anhui [16-18].

2.3. Research Review

In summary, scholars have extensively explored the connotation of advanced manufacturing. Although a unified concept has not yet formed, there is agreement on the basic characteristics of advanced manufacturing. In the concrete research on industry segmentation, advanced manufacturing includes not only the manufacturing sector of high-tech industries and strategic emerging industries but also traditional industries that have been transformed through more advanced manufacturing technologies. In studies examining the driving factors of advanced manufacturing, innovation-driven, market-driven, export-driven, and institution-driven forces have emerged as the four main driving forces influencing the development of China's advanced

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manufacturing under the new economic norm. Regarding the evaluation of advanced manufacturing, scholars have conducted quantitative research on the competitiveness, development level, and innovation capability of advanced manufacturing in different regions of China. However, there is relatively little quantitative research on the development level of advanced manufacturing based on driving factors; furthermore, existing evaluation methods such as analytic hierarchy process, entropy weight, and factor analysis typically place decision-makers and evaluators in control, employing a unified set of weights that represent their intentions to conduct evaluations from the top down. This approach overlooks the intrinsic characteristics and advantage differences of the evaluated subjects, failing to fully reflect the individual advantages and structural features of different industries or regions based on various driving elements. In light of this, this paper integrates industry and regional differences, employing an evaluation method based on the ideal point utility model to analyze the individual advantage characteristics from both intra-provincial and inter-provincial perspectives, quantitatively assessing the development level of typical advanced manufacturing in Liaoning, clarifying their respective advantages and structures, and providing a basis for personalized development strategies in advanced manufacturing.

3. Research Design

3.1. Determination of Research Subjects

(1) *Selection of typical industries*. Advanced manufacturing is a continuously evolving concept that updates in response to technological advancements, market demands, and changes in the global economic environment. Based on the current research status at home and abroad, this paper defines advanced manufacturing as manufacturing that employs cutting-edge technologies and innovative methods with the goal of improving production efficiency, product quality, flexibility, and sustainability. Considering data availability and consistency in statistical criteria, this study selects six typical advanced manufacturing industries for comparison: pharmaceutical manufacturing, aerospace and equipment manufacturing, electronic and communication equipment manufacturing, computer and office equipment manufacturing, medical instrument and meter manufacturing, and information chemical manufacturing.

(2) *Comparative perspectives*. To fully reflect industry and regional differences, this paper conducts comparative studies from both regional and industry perspectives. First, from an intra-provincial perspective, it evaluates typical advanced manufacturing industries in Liaoning Province; second, from an inter-provincial perspective, it evaluates typical manufacturing industries across 31 provinces in China, including Liaoning.

3.2. Construction of Indicator System

Drawing on various evaluation indicator systems proposed in research reviews and according to the development requirements of *Made in China 2025*, as well as summarizing various driving factors, this paper constructs an evaluation indicator system for the development level of advanced manufacturing based on four driving forces, following principles of scientificity, comprehensiveness, hierarchy, and operability, see Table 1.

3.3. Design of Evaluation Method

3.3.1. Identification Method for Individual Advantage Characteristics

The theory of competition suggests that success is fundamentally about following rules; rational actors demonstrate their excellence by consciously exploring and utilizing these rules. Despite limitations imposed by cognitive conditions and individual cognitive levels, the efforts made and potential insights gained cannot be overlooked. Therefore, it is recommended that individuals should acknowledge their excellence within the framework of macro social development patterns [19]. According to the theory of competition, the key to constructing an

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individual advantage characteristic identification model lies in how to identify the interests and demands of each evaluated subject to the greatest extent under a unified evaluation index system and utility function [20].

Table 1. Evaluation Index System for the Development Level of Advanced Manufacturing Based on *Four Drivers*

Objective	Primary Indicator	Secondary Indicator	Attribute
Development Level of Advanced Manufacturing Industry	Innovation Driver Y1	Number of enterprises with R&D activities (units) X11	Positive
		R&D personnel (persons) X12	Positive
		R&D institution expenditure (10,000 yuan) X13	Positive
		Number of valid invention patents (items) X14	Positive
	Reform Driver Y2	Technical transformation expenditure (10,000 yuan) X21	Positive
		Number of enterprises (units) X22	Positive
	Market Driver Y3	Total profit (billion yuan) X31	Positive
		Number of new product development projects (items) X32	Positive
		New product sales revenue (10,000 yuan) X33	Positive
	Open Driver Y4	New product export revenue (10,000 yuan) X41	Positive
		Expenditure on introduced technology (10,000 yuan) X42	Positive

(1) *Identification and solution of the underlying individual advantage characteristics*. In the evaluation index system for the development of advanced manufacturing, for the N -th layer sub-indicator $Y_i=(x_{i1},x_{i2},\cdots,x_{ip_i})^\tau$ belonging to Y_i, let the vector of standardized indicator values be $r_i=(r_{i1},r_{i2},\cdots,r_{ip_i})^\tau$, and $r_i^*=(r_{i1}^*,r_{i2}^*,\cdots,r_{ip_i}^*)^\tau$ be the ideal values corresponding to the sub-indicators, and $\omega_i=(\omega_{i1},\omega_{i2},\cdots,\omega_{ip_i})^\tau$ be the vector of value parameters. Using the weighted distance to measure the performance of the evaluated region $j(j=1,2,\cdots,n)$ on indicator Y_i

$$d_j(r_i(j),r_i^*)=\sqrt[q]{\sum_{k=1}^{p_i}\omega_{ik}(j)^q(r_{ik}(j)-r_{ik}^*)^q} \tag{1}$$

The smaller the distance value, the closer the indicator value of the evaluated region j to the ideal value, indicating a better performance on the indicator Y_i. Therefore, based on equation (1), from the perspective of maximizing the benefits for region j, a goal programming model can be constructed to determine the individual advantage characteristic structure of the underlying sub-indicators belonging to Y_i

$$\min\{d_{\omega(j)}(r_i(j),r_i^*)\}=\sqrt[q]{\sum_{k=1}^{p_i}\omega_{ik}(j)^q(r_{ik}(j)-r_{ik}^*)^q}$$
$$s.t.\begin{cases}\sum_{t=1}^{p_i}\omega_{ik}(j)=1\\ \omega_{it}(j)\geq 0,\ \ i=1,2,\cdots,m;\ \ k=1,2,\cdots,p_i\end{cases} \tag{2}$$

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Model (2) indicates that for a region j, when the underlying indicator values and ideal values to which it belongs Y_i are determined, the individual advantage feature structure of the underlying indicator Y_i can be obtained by seeking the optimal solution of the value parameter vector $w_i(j)$. The optimal solution $\omega_i^*(j)=(\omega_{i1}^*(j),\omega_{i2}^*(j),\cdots,\omega_{ip_i}^*(j))^\tau$ referred to as model (2) exists, as can be inferred from the properties of bounded closed interval continuous functions. Similarly, for the $(N-1)$-th layer indicators $Y_1,Y_2,\cdots,Y_m$ and their corresponding N-th layer sub-indicators, the above process can be applied to obtain the individual advantage characteristics $w^*(j)=(\omega_1^*(j),\omega_2^*(j),\cdots,\omega_m^*(j))^\tau$ at the underlying indicators for the evaluated subject j. When this process is applied across all evaluated provinces and industries, the corresponding individual advantage characteristics $w^*(1),w^*(2),\cdots,w^*(n)$ at the lower level can be obtained.

(2) *Identification and solution of individual advantage characteristics at the $(N-1)$-th layer level*. For province j, bringing the underlying individual advantage characteristics $\omega_i^*(j)=(\omega_{i1}^*(j),\omega_{i2}^*(j),\cdots,\omega_{ip_i}^*(j))^\tau$ associated with the indicator Y_i back to model (2) allows us to obtain the vector of indicator Y_i's values $y_i^*(j)$, denoted as $y_i^*(j)=\sqrt[q]{\sum_{k=1}^{p_i}\omega_{ik}^*(j)^q(r_{ik}(j)-r_{ik}^*)^q}$.

Since $\omega_i^*(j)$ is the optimal solution for model (2), it is evident that the optimal result $y_i^*(j)$ is achieved under this weight structure. However, it should be noted that at this point, the weighted distance $y_i^*(j)$ between the underlying sub-indicators associated with Y_i and the ideal value is indicated; ideally, this distance should be 0. Similarly, to identify the individual advantage characteristics of regions at the $(N-1)$-th indicator layer, a goal programming model can be constructed with reference to model (2).

$$\min s_{\mu(j)}=\sqrt[q]{\sum_{i=1}^{m}\mu_i(j)^q(y_i^*(j))^q}$$
$$s.t.\begin{cases}\sum_{i=1}^{m}\mu_i(j)=1\\ \mu_k(j)\geq 0,\quad i=1,2,\cdots,m\end{cases}\tag{3}$$

When the above process traverses all evaluated provinces, individual advantage characteristics at the $(N-1)$-th layer indicators can be obtained for each province. Similarly, the individual advantage characteristics of each province at other layer indicators can also be sequentially determined from the bottom up according to the aforementioned identification process, until reaching the top layer.

3.3.2. Agent Evaluation based on Individual Advantage Characteristics

Agent evaluation is conducted based on the results of individual advantage characteristic identification. Since the index system and utility model are determined, the evaluation results can be solved by a computer proxy as long as the corresponding indicator data is obtained, without human bias, hence the name. According to different evaluation perspectives, agent evaluation is divided into individual agent evaluation and democratic agent evaluation. For a hierarchical evaluation index system, agent evaluation can also be carried out layer by layer.

(1) *Individual agent Evaluation*. Individual agent evaluation starts from the perspective of maximizing benefits for a particular region, using its individual advantage characteristics as

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value parameters to evaluate all participating subjects. This evaluation mode can meet the needs of the evaluated subjects who want to be evaluated from the perspective of highlighting their own advantages. Although it aims to achieve ranking within the group from the perspective of ensuring the best evaluation effect for oneself, it helps the evaluated subjects to clearly understand the performance of their individual characteristics within the group.

From the perspective of maximizing benefits for region j, based on its underlying indicator's individual advantage characteristics $\omega_i^*(j)$, the individual agent evaluation of region p (including j itself) on the $N-1$ th layer indicator Y_i is recorded as $g_i(j,p)$

$$g_i(j,p)=\sqrt[q]{\sum_{k=1}^{p_i}\omega_{ik}^*(j)^q(r_{ik}(p)-r_{ik}^*)^q} \tag{4}$$
$$j=1,2,\cdots,n;\quad p=1,2,\cdots,n;\quad i=1,2,\cdots,m$$

In the formula, the standard value $r_{ik}(p)$ for the region p 's underlying indicator x_{ik} is represented. The smaller the evaluation value $g_i(j,p)$, the better the region p 's performance on the indicator Y_i under the value parameters of individual advantage characteristics $\omega_i^*(j)$.

Similarly, under the value parameter structure $\mu^*(j)$ of the region j, the individual agent evaluation value $z(j,p)$ of the evaluated object p at the $(N-2)$-th level indicator is:

$$z(j,p)=\sqrt[q]{\sum_{i=1}^{m}\mu_i^*(j)^q(y_i^*(p))^q} \tag{5}$$
$$j=1,2,\cdots,n;\quad p=1,2,\cdots,n;\quad i=1,2,\cdots,m$$

(2) *Democratic agent evaluation*. Democratic agent evaluation is conducted based on a comprehensive consideration of the individual advantages and characteristics of all evaluated regions. Since it takes into account the individual advantages of each evaluated subject, the evaluation results are often readily accepted by the evaluated subjects.

From the perspective of *absolute equality*, a straightforward method for evaluating democratic agent is to use the arithmetic mean of the evaluation opinions from all individuals as the evaluation result. For example, based on the calculations from Model (2) and Equation (4), the democratic agent evaluation result for the region p at the $(N-1)$-th level indicator Y_i is:

$$G_i(p)=\frac{1}{n}\sum_{j=1}^{n}g_i(j,p)=\frac{1}{n}\sum_{j=1}^{n}\sqrt[q]{\sum_{k=1}^{p_i}\omega_{ik}^*(j)^q(r_{ik}(p)-r_{ik}^*)^q} \tag{6}$$
$$j=1,2,\cdots,n;\ p=1,2,\cdots,n;\ i=1,2,\cdots,m$$

Similarly, based on the calculations from Model (3) and Equation (5), the democratic agent evaluation results for the region p at the $(N-2)$-th indicator level can be obtained.

$$Z(p)=\frac{1}{n}\sum_{j=1}^{n}z(j,p)=\frac{1}{n}\sum_{j=1}^{n}\sqrt[q]{\sum_{i=1}^{m}\mu_i^*(j)^q(y_i^*(p))^q} \tag{7}$$
$$j=1,2,\cdots,n;\quad p=1,2,\cdots,n;\quad i=1,2,\cdots,m$$

The above-mentioned evaluation process can be conducted layer by layer from the bottom to the top for all assessed subjects, until the top level is reached.

4. Empirical Analysis

Based on the indicators listed in Table 1, this paper organizes data from 31 provincial regions in mainland China according to the *Statistical Yearbook of China's High-tech Industries 2022*. It covers industry data for six typical advanced manufacturing sectors: pharmaceutical manufacturing, aerospace and equipment manufacturing, electronic and communication equipment manufacturing, computer and office equipment manufacturing, medical instrument and equipment manufacturing, and information chemical manufacturing. The extreme value method in formula (8) is used for standardizing the data.

$$r_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \tag{8}$$

4.1. Analysis of Typical Industries in Liaoning Province

(1) *Identification of individual advantage characteristics*. This perspective is based on a comparative analysis of industries within the province (intra-provincial perspective). Due to significant data gaps in certain indicators for the Aerospace and Equipment Manufacturing and the Information Chemical Manufacturing in Liaoning, this paper focuses on analyzing the other four typical industries. By incorporating relevant data into the individual advantage identification models (2) and (3), with $q = 2$, the identification results of individual advantage characteristics for the four industries in the province are obtained, as shown in Tables 2 and 3.

Table 2. Intra-provincial Individual Advantage Characteristic Structure of Liaoning's Typical Advanced Manufacturing on Middle-level Indicators

Typical Industry	Innovation Driver	Reform Driver	Market Driver	Open Driver
Pharmaceutical Manufacturing	0.250	0.250	0.250	0.250
Electronics and Communication Equipment Manufacturing	0.250	0.250	0.250	0.250
Computer and Office Equipment Manufacturing	0.364	0.182	0.273	0.182
Medical Instruments and Equipment Manufacturing	0.309	0.145	0.533	0.014

Table 3. Intra-provincial Individual Advantage Characteristic Structure of Liaoning's Typical Advanced Manufacturing on Basic-level Indicators

Typical Industry	Innovation Driver				Reform Driver		Market Driver			Open Driver	
	X11	X12	X13	X14	X21	X22	X31	X32	X33	X41	X42
Pharmaceutical Manufacturing	0.000	0.000	1.000	0.000	1.000	0.000	0.000	0.000	1.000	0.000	1.000
Electronics and Communication Equipment Manufacturing	0.333	0.333	0.000	0.333	0.000	1.000	0.500	0.500	0.000	1.000	0.000
Computer and Office Equipment Manufacturing	0.250	0.250	0.250	0.250	0.500	0.500	0.333	0.333	0.333	0.500	0.500
Medical Instruments and Equipment Manufacturing	0.399	0.035	0.079	0.487	0.040	0.960	0.015	0.958	0.027	0.581	0.419

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(2) *Results of various agent evaluations*. By substituting the identified individual advantage characteristics into formulas (4)-(7), we can obtain the agent evaluation results for various levels of indicators in typical advanced manufacturing industries within Liaoning province, as detailed in Tables 4 and 5.

Table 4. Intra-provincial Agent Evaluation Results of Liaoning's Typical Advanced Manufacturing on Top-Level Indicator

Development Level of Advanced Manufacturing	Individual Agent Evaluation (Evaluation Value)				Democratic Agent Evaluation	
	Pharmaceutical Manufacturing	Electronics and Communication Equipment Manufacturing	Computer and Office Equipment Manufacturing	Medical Instruments and Equipment Manufacturing	Evaluation Value	Ranking
Pharmaceutical Manufacturing	0.000	0.346	0.500	0.404	0.108	1
Electronics and Communication Equipment Manufacturing	0.189	0.000	0.421	0.251	0.120	2
Computer and Office Equipment Manufacturing	0.107	0.126	0.302	0.197	0.447	4
Medical Instruments and Equipment Manufacturing	0.138	0.011	0.565	0.075	0.232	3

Table 5 (a). Intra-provincial Agent Evaluation Results of Liaoning's Typical Advanced Manufacturing on Innovation Driver Indicators

Innovation Driver	Individual Agent Evaluation (Evaluation Value)				Democratic Agent Evaluation	
	Pharmaceutical Manufacturing	Electronics and Communication Equipment Manufacturing	Computer and Office Equipment Manufacturing	Medical Instruments and Equipment Manufacturing	Evaluation Value	Ranking
Pharmaceutical Manufacturing	0.000	0.261	1.000	0.482	0.200	2
Electronics and Communication Equipment Manufacturing	0.282	0.000	0.577	0.260	0.087	1
Computer and Office Equipment Manufacturing	0.211	0.065	0.500	0.229	0.678	4
Medical Instruments and Equipment Manufacturing	0.308	0.021	0.635	0.136	0.277	3

Table 5 (b). Intra-provincial Agent Evaluation Results of Liaoning's Typical Advanced Manufacturing on Reform Driver Indicators

Reform Driver	Individual Agent Evaluation (Evaluation Value)				Democratic Agent Evaluation	
	Pharmaceutical Manufacturing	Electronics and Communication Equipment Manufacturing	Computer and Office Equipment Manufacturing	Medical Instruments and Equipment Manufacturing	Evaluation Value	Ranking
Pharmaceutical Manufacturing	0.000	0.883	1.000	0.989	0.107	1
Electronics and Communication Equipment Manufacturing	0.174	0.000	1.000	0.202	0.340	2
Computer and Office Equipment Manufacturing	0.087	0.442	0.707	0.505	0.917	4
Medical Instruments and Equipment Manufacturing	0.167	0.035	0.961	0.198	0.474	3

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Table 5 (c). Intra-provincial Agent Evaluation Results of Liaoning's Typical Advanced Manufacturing on Market Driver Indicators

Market Driver	Individual Agent Evaluation (Evaluation Value)				Democratic Agent Evaluation	
	Pharmaceutical Manufacturing	Electronics and Communication Equipment Manufacturing	Computer and Office Equipment Manufacturing	Medical Instruments and Equipment Manufacturing	Evaluation Value	Ranking
Pharmaceutical Manufacturing	0.000	0.251	1.000	0.630	0.143	2
Electronics and Communication Equipment Manufacturing	0.233	0.000	0.707	0.424	0.085	1
Computer and Office Equipment Manufacturing	0.156	0.084	0.577	0.352	0.811	4
Medical Instruments and Equipment Manufacturing	0.182	0.007	0.958	0.103	0.377	3

Table 5 (d). Intra-provincial Agent Evaluation Results of Liaoning's Typical Advanced Manufacturing on Open Driver Indicators

Open Driver	Individual Agent Evaluation (Evaluation Value)				Democratic Agent Evaluation	
	Pharmaceutical Manufacturing	Electronics and Communication Equipment Manufacturing	Computer and Office Equipment Manufacturing	Medical Instruments and Equipment Manufacturing	Evaluation Value	Ranking
Pharmaceutical Manufacturing	0.000	1.000	1.000	1.000	0.333	1
Electronics and Communication Equipment Manufacturing	0.640	0.000	1.000	0.848	0.480	2
Computer and Office Equipment Manufacturing	0.320	0.500	0.707	0.656	0.856	4
Medical Instruments and Equipment Manufacturing	0.372	0.419	0.716	0.647	0.788	3

4.2. Analysis of Typical Industries in Chinese Provinces

Inter-provincial perspective is based on a comparative analysis of inter-provincial industries, summarizing and comparing data from typical industries in Liaoning with those from other provinces in China. On one hand, it allows us to observe the overall development trends of advanced manufacturing across various provinces in China; on the other hand, it clearly illustrates the position of Liaoning's advanced manufacturing typical industries within the country.

(1) *Identification of individual advantage characteristics.* By inputting the standardized overall data into the individual advantage characteristics identification model, we can obtain the structural characteristics of advantages for the 31 provinces in mainland China across various indicators. Due to space limitations, this paper focuses on Liaoning as the observation object and has compiled relevant data, with the results of the individual advantage characteristics identification presented in Tables 6 and 7.

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Table 6. Inter-provincial Individual Advantage Characteristic Structure of China's Typical Advanced Manufacturing on Middle-level Indicators

Liaoning	Innovation Driver	Reform Driver	Market Driver	Open Driver
Pharmaceutical Manufacturing	0.363	0.203	0.283	0.151
Electronics and Communication Equipment Manufacturing	0.361	0.179	0.283	0.176
Computer and Office Equipment Manufacturing	0.368	0.181	0.271	0.179
Medical Instruments and Equipment Manufacturing	0.378	0.178	0.278	0.166

Table 7. Inter-provincial Individual Advantage Characteristic Structure of China's Typical Advanced Manufacturing on Basic-level Indicators

Liaoning	Innovation Driver				Reform Driver		Market Driver			Open Driver	
	X11	X12	X13	X14	X21	X22	X31	X32	X33	X41	X42
Pharmaceutical Manufacturing	0.265	0.259	0.226	0.250	0.473	0.527	0.364	0.331	0.305	0.511	0.489
Electronics and Communication Equipment Manufacturing	0.254	0.254	0.245	0.247	0.491	0.509	0.365	0.322	0.312	0.502	0.498
Computer and Office Equipment Manufacturing	0.251	0.252	0.245	0.252	0.494	0.506	0.330	0.338	0.331	0.500	0.500
Medical Instruments and Equipment Manufacturing	0.243	0.242	0.233	0.283	0.461	0.539	0.331	0.351	0.318	0.509	0.491

(2) *Results of various agent evaluations*. By incorporating the identified individual advantage characteristics into relevant agent evaluation formulas, we can obtain the evaluation results and rankings of typical advanced manufacturing industries across provinces in China. Due to space limitations, only the ranking results of two types of agent evaluations are presented here, and the agent evaluation results for the intermediate indicators are only provided for Liaoning. Related results can be found in Tables 8 and 9.

Table 8. Inter-provincial Agent Evaluation Results of China's Typical Advanced Manufacturing on Middle-level Indicators

Liaoning	Innovation Driver		Reform Driver		Market Driver		Open Driver	
	Individual Agent Evaluation	Democratic Agent Evaluation	Individual Agent Evaluation	Democratic Agent Evaluation	Individual Agent Evaluation	Democratic Agent Evaluation	Individual Agent Evaluation	Democratic Agent Evaluation
Pharmaceutical Manufacturing	18	17	14	17	15	18	17	17
Electronics and Communication Equipment Manufacturing	18	18	21	21	18	18	20	20
Computer and Office Equipment Manufacturing	16	16	19	19	20	20	18	18
Medical Instruments and Equipment Manufacturing	15	15	17	17	18	18	16	16

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Table 9. Inter-provincial Agent Evaluation Ranking of China's Typical Advanced Manufacturing on Top-level Indicator

Development Level of Advanced Manufacturing	Pharmaceutical Manufacturing		Electronics and Communication Equipment Manufacturing		Computer and Office Equipment Manufacturing		Medical Instruments and Equipment Manufacturing	
	Individual Agent Evaluation	Democratic Agent Evaluation	Individual Agent Evaluation	Democratic Agent Evaluation	Individual Agent Evaluation	Democratic Agent Evaluation	Individual Agent Evaluation	Democratic Agent Evaluation
Beijing	5	11	11	11	2	8	6	6
Tianjin	17	17	16	16	8	10	14	16
Hebei	12	12	17	17	19	20	14	15
Shanxi	22	23	19	21	18	19	22	22
Inner Mongolia	27	27	25	25	26	26	27	27
Liaoning	18	18	17	18	18	18	17	18
Jilin	15	15	27	27	17	17	23	23
Heilongjiang	21	21	29	29	23	23	19	19
Shanghai	13	13	12	13	11	12	4	5
Jiangsu	1	2	2	2	1	2	1	1
Zhejiang	1	3	3	3	5	5	2	3
Anhui	7	7	7	7	1	3	9	10
Fujian	14	14	4	4	5	6	13	13
Jiangxi	9	9	5	5	10	11	17	17
Shandong	1	1	5	6	3	7	4	4
Henan	6	8	6	10	9	14	8	8
Hubei	5	5	11	12	16	16	10	12
Hunan	9	10	8	8	15	15	7	7
Guangdong	3	4	1	1	1	1	1	2
Guangxi	22	22	19	20	2	9	20	20
Hainan	25	25	30	30	28	28	30	30
Chongqing	15	16	14	14	3	4	10	11
Sichuan	5	6	9	9	10	13	9	9
Guizhou	22	24	22	22	24	24	24	24
Yunnan	20	20	19	19	22	22	21	21
Tibet	31	31	31	31	29	29	31	30
Shaanxi	19	19	15	15	21	21	14	14
Gansu	26	26	26	26	30	29	26	26
Qinghai	30	30	23	23	31	29	29	29
Ningxia	28	28	24	24	27	27	25	25
Xinjiang	29	29	28	28	25	25	28	28

5. Conclusion and Countermeasures

5.1. Research Conclusion

In order to serve the development of the local economy, this paper summarizes the following conclusions based on further organization and exploration of data results concerning Liaoning.

(1) *Identification of individual advantage characteristics*. The so-called structure of individual advantage characteristics in this paper essentially represents a set of indicator weights that are most favorable to the evaluated object. The larger the value of individual advantage characteristics, the stronger the tendency of the evaluated object to have advantages in the corresponding indicators. From the perspective of industrial comparison within the province, Liaoning's pharmaceutical manufacturing and electronic and communication equipment manufacturing industries exhibit equal weights on four primary driving indicators, indicating a relatively balanced advantage tendency. In contrast, the distinctive advantage of the computer and office equipment manufacturing industry is reflected in the innovation-driven dimension, while the advantage of the medical instrument and equipment manufacturing industry focuses on the market-driven aspect. Analyzing the secondary indicators under the four driving dimensions, except for the computer and office equipment manufacturing industry, which

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shows uniform individual advantages across various levels of indicators, the other three industries display differing advantage tendencies in secondary indicators, each with its own emphasis. For example, in the innovation dimension, the pharmaceutical manufacturing industry’s distinctive advantage concentrates on R&D expenditure; in the reform dimension, it focuses on technical transformation expenditure; in the market dimension, its advantage is reflected in new product sales revenue; and in the openness dimension, the distinctive advantage is significantly shown in technology introduction expenditure. This presents a scenario of strong singular indicators across various dimensions. The distinctive advantages of Liaoning's electronic and communication equipment manufacturing industry in the secondary indicators of the innovation dimension are evenly distributed among the number of enterprises with R&D activities, R&D personnel, and valid invention patents; in the reform dimension, the distinctive advantage primarily reflects the number of enterprises; in the market dimension, it is evenly distributed between total profit and the number of new product development projects; and in the openness dimension, the advantage is evident in new product export revenue. Similarly, in the medical instrument and equipment manufacturing industry, the distinctive advantages in the innovation dimension's secondary indicators are mainly distributed among the number of enterprises with R&D activities and valid invention patents; in the reform dimension, the advantage mainly reflects the number of enterprises; in the market dimension, it concentrates on the number of new product development projects; and in the openness dimension, the distinctive advantages are primarily distributed in new product export revenue and technology introduction expenditure. From the perspective of inter-provincial industrial comparison in China, the distinctive advantage tendencies of Liaoning's four typical industries are mainly reflected in the innovation-driven dimension; however, in terms of the secondary indicators under the four dimensions of innovation, reform, market, and openness, the individual advantage tendencies of Liaoning's four industries are relatively balanced.

(2) *Individual agent evaluation*. According to the 20/80 principle, if the ranking of the individual agent evaluation of the evaluated object is below 80%, it indicates a lack of individual advantages. This suggests that even if conditions are most favorable to themselves, they cannot stand out; a ranking within the top 20% indicates significant individual advantage performance, suggesting that this advantage characteristic can bring comparative advantages to the evaluated object; a ranking between 20% and 80% indicates average individual advantage performance. From the perspective of industrial comparison within the province, from the standpoint of being most beneficial to themselves, the four typical advanced manufacturing industries in Liaoning rank first in both overall development level and in the four dimensions of innovation, reform, market, and openness, indicating that the individual advantage tendencies of these typical advanced manufacturing industries can bring significant individual advantages. However, from the perspective of inter-provincial industrial comparison in China, the four typical advanced manufacturing industries in Liaoning rank between 20% and 80% among 31 provinces in terms of overall development level and in the four driving dimensions, indicating that individual advantages are average, suggesting that Liaoning's comparative advantages are no longer significant on a national scale.

(3) *Democratic agent evaluation*. From the perspective of industrial comparison within the province, the pharmaceutical manufacturing industry and electronic and communication equipment manufacturing industry are the two leading typical industries. However, from the perspective of inter-provincial industrial comparison in China, in terms of the overall development level of advanced manufacturing, the democratic agent evaluation ranking of Liaoning's four typical industries is 18th, indicating that the industrial development is not outstanding. Among them, the democratic agent evaluation ranking of the pharmaceutical manufacturing industry across the four driving dimensions is stable, ranking 17th or 18th; the electronic and communication equipment manufacturing industry sees a slight decline in the

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rankings for the reform and openness dimensions, placing 21st and 20th respectively; the computer and office equipment manufacturing industry ranks 16th in the innovation dimension, performing the best among the four dimensions; and the medical instrument and equipment manufacturing industry has slightly better rankings in the democratic agent evaluation across the four driving dimensions, with innovation-driven and openness-driven dimensions ranking 15th and 16th nationally, respectively.

5.2. Countermeasure Suggestions

A review of the evaluation results of four typical advanced manufacturing industries in Liaoning reveals that, although the pharmaceutical manufacturing, electronic and communication equipment manufacturing, computer and office equipment manufacturing, and medical instruments and devices manufacturing industries exhibit distinct individual advantages internally within the province, these advantages become less apparent when compared to other provinces. To assist Liaoning in achieving personalized development of advanced manufacturing, this paper proposes the following countermeasures and suggestions.

(1) From the perspective of leveraging strengths and avoiding weaknesses, although Liaoning's overall performance in advanced manufacturing is lacking at the national level, the four typical industries have made significant strides in the innovation-driven dimension, establishing a development model primarily led by innovation. They are advancing simultaneously across four secondary indicators related to innovation-driven dimensions: the number of R&D enterprises, R&D personnel, R&D institutional funding expenditures, and the number of effective invention patents, indicating potential for accelerating innovative development in the future.

(2) In terms of how to improve and enhance, Liaoning's pharmaceutical manufacturing industry exhibits a relatively average level of development across the four driving dimensions, ranking moderately with insignificant performance. The electronic and communication equipment manufacturing and computer and office equipment manufacturing industries still show weaknesses in the reform-driven dimension. Based on individual agency evaluations and characteristics of individual advantages, lessons can be learned from neighboring Heilongjiang and Jilin to adjust the advantage structure and potentially shift towards innovation and reform-driven aspects.

(3) Although Liaoning's medical instruments and devices manufacturing industry does not show strong momentum for development within the province, it balances dual development driven by innovation and openness when compared nationally. Considering industrial characteristics, it may be appropriate to enhance the market-driven dimension in the future.

(4) A review of all individual advantage characteristic structures reveals that these four typical advanced manufacturing industries in Liaoning have not formed a comparative advantage in the openness-driven dimension on a national scale. This may be related to the unique regional culture of Northeast China, the historical development of Liaoning, and its geographical location. Strengthening the *going out* strategy for advanced manufacturing is particularly important.

The above conclusions and suggestions are preliminary findings based on data analysis and organization and need to be integrated with specific provincial conditions and practices, adapting to local circumstances and timing. Compared with traditional evaluation methods, the approach used in this paper pays more attention to the interests and demands of the evaluated entities, facilitating personalized development; moreover, this method has data mining effects, allowing for a comprehensive analysis of the individual characteristics of the identified subjects, providing rich evidence for decision-making.

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