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Jingyou Evaluation of Advanced Manufacturing Industry in China's Provinces based on Four Drivers

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Abstract

In the era of economic globalization and rapid technological advancement, the advanced manufacturing has become a critical sector to measure national competitiveness. This research quantitatively assesses the development and competitive strengths of China's advanced manufacturing across its provinces. An evaluation index system was constructed, encompassing innovation, reform, market, and openness four critical dimensions. The ideal point method was utilized to assess individual advantages, complemented by cluster analysis to examine the advanced manufacturing development patterns across China's 31 provinces. The study revealed significant variations and regional characteristics, identifying six distinct developmental patterns: non-equilibrium combinations, equilibrium combinations, foreign investment growth rate leadership, single-strong foreign investment growth rate, total investment growth rate leadership, and single-strong total investment growth rate. These patterns reflect the strategic diversity of provinces in leveraging their strengths and resources.

Keywords

Four Drivers; Advanced Manufacturing; Individual Advantages; Jingyou.

1. Introduction

Globalization and the technological revolution have positioned advanced manufacturing as a critical domain in global economic competition, as well as a key indicator of a nation's or region's overall competitiveness. As a leading manufacturing nation, China stands at a pivotal juncture in its evolution into a powerhouse of manufacturing excellence. The *Made in China 2025* underscores the government's commitment to steering the country's manufacturing sector towards more sophisticated, intelligent, and sustainable practices through technological innovation and sectoral advancement. However, disparities in resources, industrial foundations, and policy frameworks among China's provinces have resulted in uneven development within the advanced manufacturing sector. Thus, conducting a thorough analysis of the current state of advanced manufacturing across different provinces is essential. Identifying their competitive edges and challenges is vital for refining the industrial structure and fostering harmonized regional development.

Researchers globally have conducted extensive studies on the advanced manufacturing sector, primarily focusing on three key areas: Firstly, they have delved into the driving forces behind its development, including factors such as technological innovation, market demand, and capital investment. Secondly, they have assessed the level of advancement and competitive strength of the sector through various quantitative analysis methods and indicators. Thirdly, they have examined the geographical spread and regional disparities within advanced manufacturing, along with strategies for industrial relocation and balanced regional growth. Despite the multidimensional insights offered by current research, there is a notable emphasis

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on macro-level analyses. This has resulted in a gap in the literature regarding in-depth, province-specific studies and the identification of unique competitive traits at the provincial level.

This paper endeavors to establish a evaluation framework for China's provinces advanced manufacturing, grounded in the *four drivers* concept. Firstly, it develops a holistic evaluation index system that spans innovation, reform, market dynamics, and openness, offering a comprehensive assessment of advanced manufacturing's developmental status. Secondly, it employs an ideal point utility model to dissect the unique competitive profiles of each province's advanced manufacturing, highlighting both strengths and vulnerabilities. Lastly, cluster analysis is leveraged to uncover typical patterns of provincial development, laying the groundwork for tailored strategic planning. This study enhances the theoretical underpinnings of advanced manufacturing evaluation and equips practitioners with innovative analytical tools.

2. Literature Review

2.1. Driving Factors for Advanced Manufacturing Development

Research on the development of advanced manufacturing industries has primarily been conducted in two areas. The first area focuses on identifying key factors influencing the industry's growth, considering both industry-specific characteristics and a combination of internal and external drivers. For instance, Gong et al. (2010) constructed an advanced manufacturing industry development dynamics model based on the coupling mechanism of internal and external drivers, including three internal drivers: market demand, technological progress and production factor allocation, and market network organization, as well as two external drivers: government intervention and development environment [1]. Lin and Zhang (2018) proposed a dynamic mechanism model for advanced manufacturing bases, incorporating market demand, capital, human resources, technology, industrial policy, and institutions, drawing on Porter's diamond model [2]. Dou et al. (2021), using the Push–Pull–Mooring (PPM) theory, integrated industry factors to create an evaluation index system for sustainable development in advanced manufacturing, considering technology, economy, and environment [3]. The second area of research, set against the backdrop of supply-side structural reforms, the transition of growth drivers, and the digital economy, aims to identify and foster new forces and elements that can enhance the development of advanced manufacturing. For example, Li (2018) analyzed the essence of new drivers in China's market economy under the new normal, focusing on four main determinants: market, interests, innovation, and openness. Li constructed four dynamic mechanisms: "Pressure-Market," "Power-Interests," "Vitality-Innovation," and "Tension-Openness" [4]. Qiao and Qin (2018) summarized the new drivers of industrial development in China, focusing on three aspects: new supply, new demand, and new institutions [5]. Feng et al. (2024) used panel regression and mediation effect models to study the impact of Foreign Direct Investment (FDI) and technological innovation on the development of advanced manufacturing clusters [6]. Hu (2024), using economic development levels, government control, openness, the information technology industry, technological innovation, productivity, and human capital as antecedents, employed qualitative comparative analysis to explore the integration paths and mechanisms of advanced manufacturing and modern services. Hu identified three highly integrated paths with multiple factor combinations, highlighting that economic development, technological innovation, productivity, and human capital are core elements in these paths [7].

2.2. Evaluation of the Development Status of Advanced Manufacturing

When assessing the development status of advanced manufacturing, researchers have primarily focused on competitiveness, innovation capacity, and sustainability. Li (2018)

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examined typical industries such as biomedicine, aerospace, computing, information technology, and new materials. Through a comparative analysis of statistical data, she evaluated the development trends of China's advanced manufacturing across various dimensions: scale, structure, technological status, and geographical distribution [8]. Qiu and Zhou (2018) assessed the development levels of advanced manufacturing in five cities-Shanghai, Tianjin, Chongqing, Suzhou, and Shenzhen-using the grey correlation method based on the entropy weight method. They considered six aspects: quality efficiency, innovation capacity, industrial structure, integration of informatization and industrialization, green development, and international competitiveness [9]. Dou et al. (2021) developed a Whole International Competitiveness Index (WIC) for advanced manufacturing, incorporating indicators such as RCA, MS, TCA, and MI. They determined the weights of these indicators using the entropy method and conducted regression analysis with panel data to explore the development trends of competitiveness and the factors influencing sustainable development in G20 countries' manufacturing industries from 2010 to 2018 [10]. Khan et al. (2022) applied the Best-Worst Method (BWM) to manufacturing performance evaluation, determining the importance weights of evaluation criteria and providing a comprehensive, real-time data-based tool for this purpose [11]. Ge (2023) used the Analytic Hierarchy Process (AHP) to develop a competitiveness evaluation index system for advanced manufacturing in Anhui Province, focusing on five key dimensions: environment, scale, market, growth, and innovation [12].

In summary, scholarly research suggests that advanced manufacturing encompasses high-tech industries, strategic emerging industry sectors, and traditional industries upgraded with advanced manufacturing technologies. The development of advanced manufacturing in China's new economic paradigm is primarily influenced by four main forces: innovation, market, export, and institutional drivers. These factors together constitute a multidimensional framework for assessing the development level of advanced manufacturing, highlighting its comprehensive and dynamic nature. Monitoring and analyzing these indicators can provide a more holistic view of the manufacturing industry's development status and trends, which is essential for both policy-making and corporate decision-making. Scholars have conducted quantitative studies on the competitiveness, development level, and innovation capabilities of advanced manufacturing across various regions in China. However, there is a scarcity of quantitative evaluations based on driving factors. Furthermore, current evaluation methods such as the analytic hierarchy process (AHP), entropy weight method, and factor analysis often employ a top-down approach with a unified weight system. This approach overlooks the unique characteristics and advantages of the entities being evaluated. It does not adequately reflect the individual advantages and structures of different regions based on their driving factors. In response to this gap, the present study introduces an individual advantage characteristic analysis method based on the ideal point utility model. This method is used for a quantitative analysis of the driving factors' levels in advanced manufacturing across 31 provinces and cities in China. The analysis aims to clarify the distinct advantages and structures of each region, optimize the combination of driving factors, and inform the development of tailored strategies for the future growth of advanced manufacturing.

3. Research Design

3.1. Determination of Research Subjects

Advanced manufacturing is a dynamic and evolving concept that adapts to technological innovations, market demands, and shifts in the global economic landscape. This paper defines advanced manufacturing as industries that employ state-of-the-art technologies and innovative methods to enhance production efficiency, product quality, flexibility, and sustainability. The

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focus is on achieving a high degree of integration and optimization throughout the product lifecycle, from design and production to service.

There is no universally accepted definition for the scope of advanced manufacturing. However, according to the State Administration of Taxation in China, as of April 2021, the statistical scope of advanced manufacturing includes industries such as non-metallic mineral products, general and special equipment manufacturing, transportation equipment manufacturing, electrical machinery and equipment manufacturing, computer and communication electronics manufacturing, instrumentation manufacturing, pharmaceutical manufacturing, and chemical fiber manufacturing. This provides a clear official definition within China [13]. Taking into account the variations in regional resource endowments, industrial structure characteristics, data accessibility, and statistical standards, this paper selects typical advanced manufacturing industries within high-tech sectors for comparison. These include computers, information technology, biomedicine, new materials, and aerospace. The evaluation of China's 31 provinces is conducted using aggregated data from these industries to facilitate comparative research.

3.2. Construction of the Indicator System

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

Objective	Primary Indicator	Secondary Indicator	Attribute
Development Level of Advanced Manufacturing Industry	Innovation Driver	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	Technical transformation expenditure (10,000 yuan) X21	Positive
		Number of enterprises (units) X22	Positive
		Total investment growth rate (%) X23	Positive
	Market Driver	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	New product export revenue (10,000 yuan) X41	Positive
		Foreign investment growth rate (%) X42	Positive
		Expenditure on introduced technology (10,000 yuan) X43	Positive

This paper constructs an evaluation indicator system for the development level of advanced manufacturing, aligning with the objectives of "Made in China 2025" and adhering to principles of scientific rigor, operability, comprehensiveness, dominance, integration, hierarchy, and balance between dynamics and stability. The system integrates literature on the drivers of advanced manufacturing development and is structured around four key drivers (see Table 1). Innovation driver refers to the enhancement of manufacturing's core competitiveness through technological innovation and product upgrades. It involves R&D activities, investment in talent, financial support, and the establishment and protection of intellectual property rights. Reform driver focuses on optimizing resource allocation and improving production efficiency and market adaptability through technological transformation, enterprise restructuring, and investment growth. It underscores the role of reform in structural optimization and competitiveness enhancement, as well as the benefits of reform for industrial upgrading and economic growth. Market driver emphasizes the use of market mechanisms to direct resources towards high-efficiency areas. It includes profit incentives, new product development, and market sales, which enhance manufacturing's responsiveness to market demand and product design. The market is pivotal in selecting new technologies, products, business formats, and

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models, with a focus on the market's decisive role in resource allocation and the significance of market-oriented activities for meeting consumer needs and improving enterprise efficiency. Openness driver highlights the importance of international engagement for the globalization and technological innovation of manufacturing. It involves participation in international markets, attracting foreign investment, and technology transfer, which are crucial for integrating manufacturing into the global industrial chain, acquiring advanced technology and management expertise, and bolstering international competitiveness.

3.3. Design of Analysis Methods

3.3.1. Individual Advantage Identification Method

The *Jingyou* theory suggests that success is founded on adhering to established principles. Rational actors excel by consciously exploring and applying these principles. Despite cognitive limitations and varying levels of individual cognition, the efforts and potential insights of actors should be recognized [14]. Thus, it is advisable for individuals to recognize their excellence within the context of macro-social development principles.

The development of an individual advantage characteristic identification model, based on *Jingyou* theory, focuses on maximizing the identification of each subject's interests and demands under a unified evaluation index system and utility function. For instance, using the ideal point utility evaluation model, the model from the perspective most favorable to the evaluated subject is given by:

$$\min\{d(f_i, f^*)\} = \sqrt[q]{\sum_{j=1}^{m} \omega_{ij}^q \left| f_j^* - f_{ij} \right|^q}$$

$$s.t. \begin{cases} \sum_{j=1}^{m} \omega_{ij} = 1 \\ \omega_{ij} \geq 0; \quad i = 1,2,\cdots,n; \quad j = 1,2,\cdots,m \end{cases} \tag{1}$$

Here, f_{ij} represents the value of the j-th indicator for the evaluated subject, and $f^* = (f_1^*, f_2^*, \cdots, f_m^*)^\tau$ is the ideal indicator result. The vector $w_i = (\omega_{i1}, \omega_{i2}, \cdots, \omega_{im})^\tau$ represents the value parameter vector, also known as the weight vector. This model characterizes the weighted distance between the evaluated subject and the ideal outcome based on the weight w_i in q-norm, where a smaller distance indicates greater utility (to maintain the fixed effect of the weight coefficient, let w_i appear in the q-th power form). The optimal solution to this model, denoted as $w_i^* = (\omega_{i1}^*, \omega_{i2}^*, \cdots, \omega_{im}^*)^\tau$, is determined based on the entire group. Therefore, $w_i^* (i = 1,2,\cdots,n)$ represents the best value parameter arrangement for the i-th evaluated subject under a given index system and ideal point utility model. This vector structure reflects the individual advantage characteristics of the i-th evaluated subject.

3.3.2. Agent Evaluation Method

Model (1) reveals the individual advantage characteristics of an evaluated subject from their most favorable perspective. However, to determine if these advantages manifest in reality, a comparative analysis within the evaluated group is necessary to reach a definitive conclusion.

Agent evaluation, grounded in individual advantage characteristics, encompasses two primary types: individual agent evaluation and democratic agent evaluation. Individual agent evaluation employs the value parameter w_i^* from Model (1) to objectively assess the i-th evaluated subject. It primarily assesses whether a self-favoring perspective ensures a higher ranking (which can

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be determined by certain principles, such as the 20/80 principle). If this is the case, the individual advantage is significant; otherwise, it is scarce. The individual agent evaluation model is as follows:

$$d_{w_i}(f_i, f^*) = \sqrt[q]{\sum_{j=1}^{m} (\omega_{ij}^*)^q \left| f_j^* - f_{ij} \right|^q} \tag{2}$$

$$i = 1,2,\cdots,n; \quad j = 1,2,\cdots,m$$

Democratic agent evaluation synthesizes all individual agent evaluation results to assess an individual's comprehensive advantage within the group. The democratic agent evaluation model is as follows:

$$z_{w_i}(f_i, f^*) = \frac{1}{n} \sum_{i=1}^{n} \sqrt[q]{(\sum_{j=1}^{m} \omega_{ij}^*)^q \left| f_j^* - f_{ij} \right|^q} \tag{3}$$

$$i = 1,2,\cdots,n; \quad j = 1,2,\cdots,m$$

Since these models represent distance values, the results for both Model (2) and Model (3) are interpreted such that smaller values indicate better performance.

3.3.3. Pattern Recognition Method

Like attracts like, and birds of a feather flock together. To uncover potential typical advantage characteristic patterns within the evaluated subject group and to formulate corresponding adjustment or guidance strategies, it is essential to perform cluster analysis on the set of individual advantage characteristic structures derived from solving Model (1). Let's assume that s types of patterns can be identified through this analysis, with the h-th pattern (for $h = 1,2,\cdots,s$) encompassing l evaluated subjects (members), and t represents the t-th member (for $t = 1,2,\cdots,l$) belonging to the h-th pattern. Following the democratic principle of equality, the value parameter structure corresponding to the h-th typical pattern is given by:

$$w_h^* = (\omega_{h1}^*, \omega_{h2}^*, \cdots, \omega_{hm}^*)^\tau = (\frac{1}{l}\sum_{t=1}^{l} \omega_{t1}^*, \frac{1}{l}\sum_{t=1}^{l} \omega_{t2}^*, \cdots, \frac{1}{l}\sum_{t=1}^{l} \omega_{tm}^*)^\tau \tag{4}$$

4. Empirical Analysis

4.1. Data Sources

This study compiled comprehensive data from the *China High-Tech Industry Statistical Yearbook 2022*, focusing on 31 provincial regions in mainland China. The data encompasses six major advanced manufacturing industries: pharmaceutical manufacturing, aerospace equipment manufacturing, electronic and communication equipment manufacturing, computer and office equipment manufacturing, medical instrument and equipment manufacturing, and information chemical manufacturing. To ensure comparability, the collected data were standardized using the extremum method, given that all indicators are inherently positive. The standardization process follows this formula:

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$$x_{ij} = \frac{f_{ij} - \min(f_{ij})}{\max(f_{ij}) - \min(f_{ij})} \quad (5)$$

4.2. Data Analysis

Identification of individual advantageous features. The standardized indicator data were input into the individual advantageous feature identification model, utilizing the Euclidean distance metric (where q =2). Calculations were performed to determine the advantageous feature structures of the 31 provinces and municipalities across various levels of indicators, as presented in Table 2. In this table, higher values indicate a more pronounced advantageous tendency for the evaluated province in the corresponding indicator. To interpret the data, thresholds were established based on the characteristics of the data distribution: values exceeding 0.5 indicate a prominent advantageous tendency, values between 0.2 and 0.5 suggest a noticeable tendency, and values below 0.2 indicate a lack of advantageous tendency.

Table 2. Structure of Individual Strength Characteristics

	Innovation Driver				Reform Driver			Market Driver			Open Driver		
	X11	X12	X13	X14	X21	X22	X23	X31	X32	X33	X41	X42	X43
Beijing	0.059	0.059	0.061	0.066	0.049	0.057	0.233	0.083	0.050	0.065	0.061	0.108	0.049
Tianjin	0.066	0.066	0.066	0.063	0.061	0.066	0.187	0.070	0.061	0.068	0.067	0.096	0.061
Hebei	0.058	0.054	0.054	0.052	0.052	0.058	0.300	0.059	0.051	0.054	0.052	0.106	0.050
Shanxi	0.026	0.027	0.027	0.026	0.026	0.027	0.210	0.026	0.026	0.027	0.028	0.499	0.026
Inner Mongolia	0.004	0.004	0.004	0.004	0.004	0.004	0.898	0.004	0.004	0.004	0.004	0.059	0.004
Liaoning	0.066	0.066	0.062	0.063	0.067	0.066	0.167	0.073	0.061	0.064	0.061	0.123	0.060
Jilin	0.073	0.072	0.072	0.071	0.071	0.074	0.136	0.078	0.070	0.072	0.071	0.070	0.070
Heilongjiang	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
Shanghai	0.052	0.051	0.052	0.052	0.044	0.052	0.162	0.062	0.043	0.050	0.049	0.201	0.132
Jiangsu	0.233	0.054	0.033	0.021	0.028	0.062	0.034	0.227	0.012	0.117	0.111	0.019	0.049
Zhejiang	0.095	0.061	0.075	0.039	0.053	0.067	0.214	0.091	0.031	0.075	0.057	0.082	0.061
Anhui	0.066	0.054	0.051	0.047	0.063	0.060	0.336	0.050	0.043	0.059	0.054	0.075	0.043
Fujian	0.069	0.069	0.067	0.058	0.092	0.064	0.163	0.088	0.052	0.068	0.066	0.073	0.073
Jiangxi	0.080	0.064	0.063	0.055	0.063	0.078	0.159	0.078	0.053	0.074	0.062	0.119	0.052
Shandong	0.071	0.062	0.054	0.046	0.063	0.060	0.264	0.062	0.041	0.070	0.068	0.077	0.063
Henan	0.065	0.060	0.052	0.050	0.052	0.061	0.256	0.057	0.048	0.075	0.087	0.089	0.048
Hubei	0.070	0.068	0.065	0.064	0.064	0.066	0.209	0.060	0.052	0.068	0.057	0.103	0.054
Hunan	0.077	0.062	0.053	0.052	0.063	0.066	0.205	0.062	0.049	0.062	0.053	0.147	0.048
Guangdong	0.063	0.063	0.063	0.063	0.125	0.125	0.000	0.083	0.083	0.083	0.125	0.000	0.125
Guangxi	0.038	0.037	0.036	0.036	0.043	0.038	0.540	0.037	0.035	0.036	0.036	0.052	0.035
Hainan	0.046	0.046	0.046	0.046	0.046	0.046	0.335	0.046	0.046	0.046	0.046	0.158	0.046
Chongqing	0.065	0.063	0.061	0.057	0.057	0.063	0.161	0.072	0.056	0.065	0.071	0.148	0.061
Sichuan	0.071	0.067	0.060	0.058	0.071	0.069	0.222	0.075	0.052	0.064	0.055	0.082	0.053
Guizhou	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
Yunnan	0.012	0.012	0.012	0.011	0.012	0.012	0.858	0.013	0.011	0.012	0.011	0.012	0.011
Tibet	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.137	0.072
Shaanxi	0.073	0.073	0.068	0.068	0.072	0.072	0.141	0.082	0.064	0.072	0.064	0.072	0.078
Gansu	0.065	0.065	0.064	0.064	0.064	0.065	0.219	0.065	0.064	0.065	0.064	0.073	0.064
Qinghai	0.008	0.008	0.008	0.008	0.008	0.008	0.891	0.009	0.008	0.008	0.008	0.016	0.008
Ningxia	0.028	0.028	0.028	0.028	0.029	0.028	0.573	0.029	0.028	0.029	0.028	0.117	0.028
Xinjiang	0.071	0.070	0.070	0.070	0.071	0.071	0.110	0.071	0.070	0.070	0.070	0.114	0.070

Various agent evaluation results. The individual advantage structures were reintroduced into formulas (2) and (3) to perform diverse agency evaluations. The individual agent perspective involves each evaluated entity assessing others from its most advantageous standpoint. These evaluations, when aggregated, form a square matrix with equal rows and columns. However,

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due to space constraints, it is impractical to display all individual agent perspectives and their corresponding values. Therefore, Table 3 selectively presents the individual agent perspectives and overall evaluation results for five provinces and cities, categorized by geographical regions: South China, East China, Northeast China, and North China, specifically Guangdong, Zhejiang, Shandong, Liaoning, and Inner Mongolia. Furthermore, the democratic agent evaluation is calculated as the average of all individual agent evaluations for a particular entity. This average represents the final evaluation outcome, integrating the interests and characteristics of all evaluated provinces. It reflects the comprehensive performance of the evaluated province within the group.

Table 3. Results of Agent Evaluation and Ranking

	Partial individual agent perspectives and evaluation values					Individual agent		Democratic agent	
	Guangdong	Liaoning	Zhejiang	Shandong	Inner Mongolia	Ranking	Individual advantage	Evaluation value	Ranking
Beijing	0.135	0.250	0.174	0.203	0.202	11	general	0.280	18
Tianjin	0.112	0.246	0.174	0.204	0.217	25	lack	0.321	25
Hebei	0.161	0.260	0.177	0.202	0.181	15	general	0.279	17
Shanxi	0.371	0.381	0.310	0.375	0.156	3	significant	0.240	7
Inner Mongolia	0.427	0.539	0.329	0.350	0.062	2	significant	0.195	2
Liaoning	0.118	0.245	0.176	0.207	0.216	25	lack	0.321	26
Jilin	0.082	0.250	0.179	0.210	0.239	29	lack	0.374	29
Heilongjiang	0.717	0.699	0.589	0.719	0.257	1	significant	0.293	21
Shanghai	0.163	0.265	0.194	0.231	0.213	3	significant	0.272	14
Jiangsu	0.021	0.358	0.222	0.293	0.375	2	significant	0.258	10
Zhejiang	0.117	0.254	0.169	0.203	0.221	3	significant	0.221	3
Anhui	0.168	0.270	0.179	0.202	0.181	10	general	0.262	12
Fujian	0.093	0.250	0.175	0.206	0.233	7	general	0.307	24
Jiangxi	0.114	0.247	0.174	0.207	0.221	12	general	0.300	22
Shandong	0.136	0.256	0.172	0.199	0.201	4	notable	0.255	9
Henan	0.137	0.256	0.174	0.200	0.202	12	general	0.278	16
Hubei	0.123	0.248	0.173	0.202	0.209	15	general	0.290	19
Hunan	0.143	0.248	0.176	0.208	0.200	10	general	0.278	15
Guangdong	0.000	0.305	0.220	0.255	0.313	1	significant	0.194	1
Guangxi	0.258	0.347	0.217	0.235	0.128	6	significant	0.262	11
Hainan	0.195	0.273	0.187	0.213	0.159	8	general	0.266	13
Chongqing	0.130	0.246	0.178	0.210	0.212	18	general	0.307	23
Sichuan	0.120	0.250	0.172	0.201	0.211	17	general	0.290	20
Guizhou	0.473	0.599	0.365	0.387	0.066	1	significant	0.240	6
Yunnan	0.406	0.516	0.314	0.334	0.069	4	significant	0.252	8
Tibet	0.104	0.253	0.188	0.221	0.240	27	lack	0.424	31
Shaanxi	0.084	0.250	0.177	0.208	0.237	27	lack	0.352	28
Gansu	0.116	0.250	0.175	0.202	0.214	27	lack	0.330	27
Qinghai	0.422	0.535	0.326	0.346	0.065	3	significant	0.231	4
Ningxia	0.284	0.364	0.230	0.250	0.105	5	significant	0.233	5
Xinjiang	0.097	0.249	0.182	0.213	0.235	29	lack	0.379	30

Development pattern analysis. The preceding analysis has underscored the individual differences and unique advantages of each province. To delve deeper into identifying shared traits, a clustering analysis of the individual advantageous features across all provinces was performed using formula (4). The findings of this analysis are detailed in Table 4.

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Table 4. Analysis of Jingyou Patterns

Number	Pattern	Advantage Characteristics Structure	Region
1	Non-equilibrium Combination	{0.068;0.063;0.061;0.058;0.062;0.064;0.202;0.069;0.054;0.066;0.062;0.107;0.062}	Jilin, Shaanxi, Fujian, Tibet, Xinjiang, Liaoning, Jiangxi, Chongqing, Hunan, Shanghai, Hebei, Anhui, Hainan, Shandong, Henan, Sichuan, Gansu, Tianjin, Hubei, Beijing, Zhejiang
2	Equilibrium Combination	{0.148;0.058;0.048;0.042;0.077;0.094;0.017;0.155;0.048;0.100;0.118;0.009;0.087}	Jiangsu, Guangdong
3	Foreign Investment Growth Rate Leading	{0.026;0.027;0.027;0.026;0.026;0.027;0.210;0.026;0.026;0.027;0.028;0.499;0.026}	Shanxi
4	Foreign Investment Growth Rate Single-strong	{0;0;0;0;0;0;0;0;0;0;1;0}	Heilongjiang
5	Total Investment Growth Rate Leading	{0.033;0.032;0.032;0.032;0.036;0.033;0.557;0.033;0.032;0.032;0.032;0.085;0.031}	Guangxi, Ningxia
6	Total Investment Growth Rate Single-strong	{0.006;0.006;0.006;0.006;0.006;0.006;0.912;0.007;0.006;0.006;0.006;0.022;0.006}	Yunnan, Qinghai, Inner Mongolia, Guizhou

5. Conclusion and Countermeasures

5.1. Research Conclusions

(1) *Identification of Individual Advantages*. Each province and region possesses unique environmental characteristics and resource endowments that foster the development of advanced manufacturing industries, resulting in distinct individual traits and development models. The higher the value parameter in Table 2, the more pronounced the province's advantage in the corresponding indicator. For instance, in the Northeast region, Heilongjiang's individual advantage in advanced manufacturing is primarily evident in the "foreign investment growth rate" indicator, suggesting a single-factor driven development model. In contrast, Jilin and Liaoning exhibit multi-factor combination development models, with Liaoning showing strengths in both "total investment growth rate" and "foreign investment growth rate," highlighting dual drivers of "reform" and "opening-up." Jilin's advantage is concentrated on the "foreign investment growth rate," indicating a consensus among the three northeastern provinces on leveraging "opening-up" to meet new era development trends, adhering to a B*ring in and Go Global Policy* to explore advanced manufacturing opportunities. Guangdong, as a developed coastal region, differs from the northeastern provinces, showing a balanced development model with value parameters distributed across various indicators, except for "total investment growth rate" and "foreign investment growth rate," where they are zero.

Cluster analysis of the individual advantage characteristics data reveals six general developmental models among China's 31 provinces. These models are characterized by single-factor versus multi-factor and balanced versus individually-led combinations. Key indicators in these models include "foreign investment growth rate" and "total investment growth rate," which can lead to either single-factor dominant or multi-factor combined developmental models. This is particularly evident in provinces with significant individual advantages, as seen in models 3-6 in Table 4. For comparison, using 0.2 as the critical value, models 1 and 2 correspond to unbalanced and balanced multi-factor combination developmental types, respectively. In the balanced type, all indicator factors advance in parallel, as seen in developed provinces like Guangdong and Jiangsu with significant advanced manufacturing advantages. The unbalanced type refers to provinces with average or lacking individual advantages, such as Jilin and Liaoning, where individual factor advantages are slightly higher but not prominent, necessitating re-benchmarking and optimization.

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(2) *Evaluation of Individual Advantages and Performance*. Individual advantages are not guaranteed even from the most favorable perspective. The individual agent evaluations in Table 3 serve as a basis for judgment. According to the 20/80 principle, provinces ranked after the 24th in individual agent evaluations have insufficient or lacking individual advantages. Those ranked before the 6th have significant individual advantages, providing a comparative advantage. Provinces between 6th and 24th have general individual advantage performance. Overall, 13 provinces-Shanxi, Inner Mongolia, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Shandong, Guangdong, Guangxi, Guizhou, Yunnan, Qinghai, and Ningxia-show significant advanced manufacturing individual advantages, mostly in China's eastern coastal developed regions. In contrast, 7 regions-Tianjin, Liaoning, Jilin, Tibet, Shaanxi, Gansu, and Xinjiang-lack individual advantages, mostly in remote northeastern and western regions. For example, Heilongjiang's foreign investment growth rate and opening-up effects are ideal, but Jilin and Liaoning's individual development models have not brought group advantages, requiring further adjustments and explorations.

(3) *Evaluation of Democratic Agent*. Only provinces that consistently rank at the top under various development models truly excel. Based on individual agent evaluations across 31 provinces, the top three are Guangdong, Inner Mongolia, and Zhejiang. Inner Mongolia, for example, ranks within the top 14 in individual advantage characteristics for five provinces-Jilin, Fujian, Tibet, Shaanxi, and Xinjiang-at 14th, 14th, 12th, 14th, and 14th, respectively. Additionally, in other provinces, including 6th under the Zhejiang model, Inner Mongolia's individual agent evaluation ranks before the 6th position.

5.2. Countermeasures and Suggestions

The methodology employed in this paper, which emphasizes the individual characteristics and interests of evaluated subjects, is instrumental for tailored development strategies. It also serves as an effective data mining tool, providing a comprehensive analysis of individual traits and a robust foundation for decision-making. Following an in-depth examination of the individual advantages and group performance in China's provinces within advanced manufacturing, the study offers the following policy recommendations to foster the sector's overall growth in China.

(1) Strengthen innovation-driven development to enhance core competitiveness. Innovation is pivotal to the manufacturing industry's evolution. Jiangsu Province exemplifies innovation prowess through extensive R&D initiatives and a robust portfolio of valid invention patents. It is advised that Jiangsu continues to bolster R&D investments, attract and nurture top-tier talent, and foster closer ties with academic and research institutions. This integration of industry, academia, and research should drive industrial advancement through technological innovation.

(2) Optimize reform-driven development to improve resource allocation efficiency. Reform is essential for the structural optimization of the manufacturing sector. Liaoning Province should intensify its focus on technological transformation and corporate restructuring. It is suggested that Liaoning draw on Guangdong Province's successful practices, promoting mergers and reorganizations through policy incentives and market mechanisms. This will optimize resource allocation, enhance production efficiency, and improve market responsiveness.

(3) Stimulate market-driven development to meet consumption upgrading demands. Market demand is a crucial factor guiding manufacturing industry development. Zhejiang Province excels in market-driven growth, marked by substantial total profits and new product sales revenue. It is recommended that Zhejiang further capitalize on its market strengths, enhance brand development, and elevate product quality and design to satisfy consumers' desires for personalized and diverse products.

(4) Expand open-driven development to integrate into the global industrial chain. Openness is vital for increasing the international competitiveness of the manufacturing sector. Heilongjiang

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Province shows notable strengths in open-driven development, particularly in the growth of foreign investment. It is advised that Heilongjiang expand its openness, strengthen international market engagement, attract foreign investment and technology, and elevate the internationalization level of its manufacturing industry.

(5) Implement differentiated development strategies to promote regional coordinated development. Given the varied development levels of advanced manufacturing across China's provinces, it is recommended that each province develop tailored strategies aligned with its resource endowments and developmental foundation. Inland provinces might develop specialized manufacturing by leveraging resource advantages, while coastal provinces could develop export-oriented manufacturing using their geographic benefits.

(6) Enhance policy support and guidance to create a favorable development environment. Governments play a critical role in fostering the growth of advanced manufacturing. It is suggested that governmental bodies at all levels enact policies that support the sector's development, including financial incentives, tax relief, and funding support, while also reinforcing intellectual property rights protection to foster a level playing field in the market.

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