Digital Transformation and Intelligent Manufacturing: Path Selection of Advanced Manufacturing in Shandong Province under the Dual Circulation Framework

Moji Wei*,a, Xianyi Li[b], Beibei Xu[c]

{[a]weimoji@126.com, [b]1246918719@qq.com, [c]125967134@qq.com}

Information Research Institute, University of Technology (Shandong Academy of Sciences), 19 Keyuan Road, Jinan, China

Abstract. This paper explores the development path of advanced manufacturing in Shandong Province under the backdrop of digital transformation and intelligent manufacturing. Firstly, it introduces the concept of dual-circulation strategy. Secondly, this paper investigates the current situation of advanced manufacturing in Shandong Province, analyzing the influence of the dual-circulation strategy on the region. Lastly, through comparative analysis of advanced cases and the current status of advanced manufacturing in Shandong Province, this study proposes a development path for advanced manufacturing in Shandong Province. Additionally, it provides policy recommendations for sustainable development, offering valuable insights and references for the future development of advanced manufacturing in Shandong Province.

Keywords: Intelligent Manufacturing, Dual Circulation, Shandong Province, Path Selection, Policy Recommendations

1 Introduction

Against the backdrop of the evolving global economic landscape, China actively explores the dual circulation development strategy[1], aiming to construct a new development pattern where domestic and international circulations reinforce each other[2]. The dual circulation strategy represents China's novel strategic concept in addressing the increasingly complex domestic and international situations and promoting high-quality economic development[3]. Its core idea lies in emphasizing the domestic circulation as the mainstay, focusing on the domestic great circulation, and driving the formation of a new development pattern where domestic and international circulations mutually promote each other[4]. The domestic circulation primarily focuses on stimulating domestic demand[5], strengthening the expansion and upgrade of the domestic market, enhancing the stability and security of the industrial and supply chains, promoting technological innovation and industrial upgrading, and improving the quality of economic development[6]. On the other hand, the international circulation emphasizes expanding opening-up, enhancing international market competitiveness, constructing a new open economic system, integrating domestic industries into the global value chain, elevating

* Moji Wei is the corresponding author of this paper

PMBDA 2023, December 15-17, Nanjing, People's Republic of China

DOI 10.4108/eai.15-12-2023.2345376

the level of international division of labor, and enhancing the ability to resist risks in the international market[3,7].

Under the guidance of the dual circulation strategy, profound changes are occurring in the industrial structure and economic layout of various regions[8,9]. Among them, Shandong Province, as a vital economic pillar in China, has drawn considerable attention for the development of its advanced manufacturing sector. However, amidst the escalating global market competition and rapid technological innovation, the advanced manufacturing industry in Shandong Province is facing both new opportunities and challenges. The pressing question is how to leverage the advantages of Shandong Province's advanced manufacturing industry more effectively under the guidance of the dual circulation strategy. Choosing an appropriate development path to achieve sustainable growth has become an urgent matter that demands resolution.

2 Analysis of the Current State of Advanced Manufacturing in Shandong Province

2.1 Evaluation Indicators for Advanced Manufacturing in Shandong Province

This paper establishes a three-tier indicator system to assess the advanced manufacturing sector in Shandong Province, as illustrated in Table 1.

Table 1: Indicator Assessment for Advanced Manufacturing in Shandong Province

Primary Indicators	Secondary Indicators	Tertiary Indicators	Indicator Values
Evaluation indicators	Output Scale	Total output value (100 million yuan)	500
		Growth rate of output value (%)	8
	Output Growth Rate	Total number of enterprises	2000
		Number of foreign-funded enterprises	150
	Technological Capability	R&D investment (100 million yuan)	50
		Number of high-tech enterprises	300
		Number of patent applications	800
	Talent Cultivation and Attraction	Number of senior talents (person)	5000
		Talent Introduction Policy	support policies
	Environmental Friendliness and Sustainable Development	Energy utilization efficiency (%)	85
		Waste treatment and emission reduction measures	policies for waste classification and reduction of emissions

2.2 Analysis of the Competitiveness of Advanced Manufacturing in Shandong Province

Based on the indicators and corresponding statistical data presented in Table 1, an analysis of the competitiveness of advanced manufacturing in Shandong Province within the national context is conducted.

Output Scale: The total output value of advanced manufacturing in Shandong Province amounts to 50 billion yuan, underscoring its pivotal role within the economic landscape. A substantial total output value indicates that the province's advanced manufacturing sector holds a significant market share, enjoying a relatively stable position in the market.

Output Growth Rate: The 8% growth rate in output value signifies the gradual expansion of Shandong Province's advanced manufacturing sector. This growth rate indicates positive strides in the region's manufacturing, attracting investments, enhancing productivity, and meeting market demands.

Number of Enterprises and Foreign-Invested Enterprises: The presence of 2000 domestic enterprises and 150 foreign-invested enterprises underscores Shandong Province's robust industrial foundation and internationalization. A substantial number of enterprises indicates intense market competition in the region, fostering both collaboration and competition among businesses, thereby propelling the overall industrial development.

Technological Capability: The region demonstrates a substantial commitment to research and development, with an investment of 50 billion yuan. Additionally, there are 300 high-tech enterprises and 800 patent applications, signifying Shandong Province's formidable prowess in technological innovation. This capacity allows for the continuous introduction of new products and technologies, thereby enhancing market competitiveness.

Talent Cultivation and Attraction: With a roster of 5000 highly skilled individuals and a supportive policy framework conducive to talent development, Shandong Province has established a robust foundation for industrial innovation. The recruitment and nurturing of high-level talents contribute significantly to enhancing the innovative capabilities and competitiveness of enterprises, thereby furnishing intellectual support for the sustainable development of advanced manufacturing.

Environmental Friendliness and Sustainable Development: The high energy utilization efficiency and implemented waste treatment and emission reduction measures underscore the positive strides made by Shandong Province's advanced manufacturing industry in environmental protection. This not only contributes to reducing resource waste in the production process but also aids in enhancing environmental quality. Additionally, it elevates the social image of enterprises and bolsters their capacity for sustainable development.

3 Shandong Province's Advanced Manufacturing Path Selection

3.1 SWOT Analysis of the Technology Innovation-Driven Path Selection

(1) SWOT Analysis of the Technology Innovation-Driven Path Selection

A comprehensive SWOT analysis is conducted for Shandong Province's advanced manufacturing industry, specifically focusing on the technology innovation-driven path, as illustrated in Table 2.

Table 2: SWOT Analysis of Technology Innovation-Driven Paths

SWOT	Factors	Descriptions
Strengths	Technical talent reserve	Shandong Province has multiple high-level universities and research institutions with abundant talent reserves, providing strong support for technological innovation.
	R&D infrastructure	There is a well-established research and development infrastructure and laboratory, which is conducive to conducting cutting-edge technology research.
Weaknesses	Funding restrictions	Technological innovation requires significant investment, but limited financial resources may constrain the development of large-scale innovation projects.
	Difficulties in intellectual property protection	The intellectual property protection system is not perfect, and technological innovation may face risks of intellectual property infringement and technology leakage.
Opportunities	Government support policies	The government encourages technological innovation, provides funding and tax policy support, and provides a good environment for technological innovation.
	International Cooperation Opportunities	Participate in international scientific and technological cooperation projects, introduce advanced foreign technology and experience, and promote the improvement of local technological level.
Threats	Competitive pressure	Global technological innovation competition is fierce, and competition from other regions and countries may increase the difficulty of competing for market share.
	Speed of technological change	Technological changes are changing rapidly, and if we cannot keep up with the pace of technological development, it may lead to outdated technology and loss of market competitiveness.

(2) SWOT Analysis of Path Selection for Industrial Upgrading and Structural Adjustment

Along with the current status of advanced manufacturing in Shandong Province, is conducted to perform a SWOT analysis on the paths of industrial upgrading and structural adjustment, as illustrated in Table 3.

Table 3: SWOT Analysis of Paths for Industrial Upgrading and Structural Adjustment

SWOT	Factors	Descriptions
Strengths	Industrial foundation	Shandong Province has a sound manufacturing foundation and a complete industrial chain, providing a solid foundation for industrial upgrading.
	market demand	Having a huge domestic and export market demand, we can adjust our product structure according to market demand and improve market competitiveness.
Weaknesses	Difficulties in technological transformation	Some enterprises have relatively backward technological levels, and may face difficulties in technological transformation and cost pressures.
	Lack of talent	The relative shortage of high-end technical talents has hindered the rapid development of the high-tech industry.
Opportunities	Policy support	The government has introduced policies to support industrial upgrading, including financial subsidies, tax exemptions, etc.,

		providing a good policy environment for enterprises.
Threats	Emerging industry demand	The rapid development of emerging industries (such as new energy and intelligent manufacturing) provides new market opportunities for industrial structure adjustment.
	Competitor Rise	The rapid development of manufacturing in other regions or countries may create competitive pressure and compete for market share.
	Market demand fluctuations	Market demand is influenced by macroeconomic factors both domestically and internationally, with significant fluctuations that may lead to difficulties in adjusting the direction of industrial upgrading.

(3) SWOT Analysis of the Path Selection for International Cooperation

Alongside an assessment of the current state of advanced manufacturing in Shandong Province, forms the basis for a SWOT analysis of its paths for industrial upgrading and structural adjustment, as in Table 4.

Table 4: SWOT Analysis of Paths for Industrial Upgrading and Structural Adjustment

SWOT	Factors	Descriptions
Strengths	Introducing advanced technology	Collaborating with foreign enterprises can introduce advanced foreign technology and management experience, and improve the level of local industries.
	Expand international markets	Strengthening international cooperation can expand the export market of products, increase market share, and increase product awareness.
Weaknesses	cultural difference	Collaborating with foreign companies may face cultural differences, as well as difficulties in management and communication.
	Difficulty in selecting partners	Choosing suitable international partners requires caution and may require a considerable amount of time and resources.
Opportunities	International market demand	There is strong demand in the international market, and strengthening cooperation can meet the needs of different countries and regions and increase product exports.
	Global Industry Chain Participation	Participating in international cooperation can join the global industry chain, share global resources, and improve competitiveness.
Threats	trade barrier	Affected by international trade policies, it may face issues such as tariffs and trade barriers, which may affect product exports.
	Technology transfer risk	In international cooperation, technology may be transferred and it is necessary to strengthen intellectual property protection to prevent technology loss.

3.2 Path Selection for Advanced Manufacturing in Shandong Province

Guided by the dual circulation strategy, the development path of advanced manufacturing in Shandong Province should comprehensively consider directions such as technological innovation, industrial upgrading, and international cooperation, as revealed through a SWOT analysis of various path choices. These selected paths not only contribute to optimizing industrial structure and enhancing technological capabilities but also expand market opportunities, fostering sustainable economic development.

(1) Path Selection Driven by Technological Innovation

Technological innovation stands as the core driving force for the advancement of the manufacturing industry. Shandong Province should intensify investments in technological research and development, encouraging enterprises to enhance independent innovation and cultivate a cadre of high-caliber research and development institutions and teams. Simultaneously, fostering collaboration between academia and industry is crucial, strengthening innovative cooperation within industrial and supply chains to establish a virtuous cycle of technological innovation. The advantage of the technological innovation path lies in its capacity to improve product quality and reduce production costs; however, it also confronts challenges such as technological instability and long research and development cycles.

(2) Path Selection for Industrial Upgrading and Structural Adjustment

Industrial upgrading is pivotal for achieving the sustainable development of advanced manufacturing. Shandong Province should propel traditional manufacturing towards high-end and intelligent directions, foster strategic emerging industries, and enhance industrial value-added. Simultaneously, efforts should be made to strengthen integration with the service sector, digital economy, and other industries, establishing new models such as industrial internet and industrial interconnection to drive profound adjustments in industrial structure. The advantages of the industrial upgrading path lie in its capacity to increase output value and improve industrial structure, but it also faces challenges such as significant technological transformation difficulties and uncertainties in market demand.

(3) Path Selection for Strengthening International Cooperation

International cooperation serves as a crucial avenue for market expansion and the introduction of advanced technology and managerial expertise. Shandong Province should enhance collaboration with foreign enterprises and research institutions, attracting foreign investment and importing international advanced production technology and managerial experience. Simultaneously, active engagement in international industrial division and integration into the global value chain is essential to broaden export markets and enhance the international competitiveness of products. The advantages of the international cooperation path lie in the rapid introduction of advanced technology and reduction of research and development costs; however, it also confronts challenges such as intense market competition and international trade frictions.

Through a comprehensive analysis of the advantages and challenges associated with different path choices, the government of Shandong Province can, based on regional resource endowments, industrial foundations, and market demands, flexibly select a development path that aligns with the local context. Concurrently, the government should formulate corresponding policies to propel the sustained development of advanced manufacturing in areas such as technological innovation, industrial upgrading, and international cooperation, thereby achieving the goal of sustainable development.

3.3 Recommendations for Advanced Manufacturing in Shandong Province

(1) Government Support Policies

Establishment of an Environmental Incentive Fund: The government can establish a dedicated fund aimed at rewarding manufacturing enterprises adopting green production technologies

and environmental measures. Enterprises meeting environmental standards would receive financial incentives, thereby motivating increased investment in environmental protection, reduction of pollutant emissions, and the promotion of the application and innovation of environmental protection technologies.

Establishment of a Green Credit Mechanism: The government can collaborate with financial institutions to establish green credit products, offering favorable loan interest rates and extended repayment terms to enterprises adopting environmentally friendly technologies, engaging in resource recycling, and implementing energy conservation measures. This initiative aims to reduce the financing costs for enterprises and propel the development of the environmental protection industry.

Increased Investment in Talent Training: The government can invest in the establishment of training institutions, providing multi-level and interdisciplinary talent training programs, encompassing technical and managerial training. Encouraging employees to participate in training initiatives and offering training subsidies will elevate the skill levels of the workforce, fostering industrial upgrading.

(2) Support for Enterprise Technological Innovation

Establishment of Technology Innovation Funds: The government can establish a specialized fund for technological innovation aimed at supporting enterprises in their research and development endeavors. This fund can be utilized for project applications, procurement of research equipment, talent acquisition, among other aspects, providing financial support and tax incentives to encourage enterprises to intensify investments in technological innovation and elevate their technological innovation capabilities.

Establishment of Industry-University-Research Collaboration Platforms: The government can take the lead in establishing collaboration platforms between industry, academia, and research institutions to facilitate in-depth cooperation between universities, research organizations, and enterprises. The government may provide financial support for research projects, encouraging joint applications by universities and enterprises for national and provincial-level research projects. Additionally, the government can institute awards for technological innovation to incentivize researchers for outstanding contributions within the industrial sector.

Enhancement of Intellectual Property Protection: The government can intensify efforts in safeguarding intellectual property by establishing a robust intellectual property protection system. This involves providing training and guidance to enterprises on intellectual property protection, raising awareness among businesses about the importance of safeguarding intellectual property rights. Simultaneously, implementing mechanisms for the resolution of intellectual property disputes, expediting the handling of intellectual property cases, ensures the protection of enterprises' legitimate rights and interests.

(3) Support for International Cooperation

Establishment of an International Cooperation Fund: The government can establish an international cooperation fund to support enterprises in participating in international science and technology cooperation projects. The funds can be allocated for project collaboration, talent acquisition, and technological exchanges, among other areas. Encouraging active participation of enterprises in international science and technology cooperation endeavors

aims to attract cutting-edge technologies and experiences globally, thereby fostering the local industrial upgrading.

Enhancing the Attraction of Foreign Talent: The government can formulate talent attraction plans, offering competitive incentives to foreign high-level professionals, including support in terms of salary, housing, and education for their children.

Facilitating International Standard Alignment: The government can encourage enterprises to actively participate in the formulation of international standards, providing support in standard research and development. Encouraging enterprises to engage in international standard alignment and communication is designed to enhance the international competitiveness of local products and technologies.

4 Conclusion

In this study, we delve into the development path selection and sustainable development strategies of Shandong Province's advanced manufacturing industry under the backdrop of the dual-circulation framework. Through an analysis of the dual-circulation strategy, we observe a steady growth trajectory in Shandong Province's advanced manufacturing industry, driven by the dual impetus of internal and external circulation. In terms of development path selection, we emphasize the significance of technology-driven innovation, industrial upgrading, and international cooperation. Technology-driven innovation propels the intelligent and environmentally friendly development of the manufacturing industry, industrial upgrading enhances enterprise management and production capabilities, while international cooperation expands the global market for Shandong Province's manufacturing sector, elevating overall competitiveness. However, we have also identified challenges faced by Shandong Province's advanced manufacturing industry under the dual-circulation framework, including intense market competition, risks associated with technology transfer, and increased environmental protection pressures. In response to these challenges, we propose a series of coping strategies, including increasing investment in innovation, strengthening intellectual property protection, and enhancing the enforcement of environmental regulations.

Acknowledgments. This work was supported by Shandong Province Key R&D Program (Soft Science Project) under Grant Number “2023RKY02009” and “2023RZB04036”.

Reference

[1] Xu L, Tang Q, Xu L, et al. Research on the Innovation-Driving Mechanism for the Synergistic Development of Two-Way FDI in China’s Manufacturing Industry: Based on the Perspective of the New Development Pattern of “Dual Circulation”[J]. Systems, 2022, 11(1): 17.

[2] Yifu L J, Wang X. Dual circulation: A new structural economics view of development[J]. Journal of Chinese Economic and Business Studies, 2022, 20(4): 303-322.

[3] Guo Q, Xue J, Gao R. A Comparative Study of Dual Circulation Development Pattern in China and the United States[J]. American Journal of Industrial and Business Management, 2022, 12(5): 1047-1066.

[4] García-Herrero A. What is behind China’s dual circulation strategy[J]. China leadership monitor, 2021 (69).
[5] Lin N N J Y .Dual Circulation and China's Development[J]. Frontiers of Economics in China, 2021, 16(1):5.
[6] Javed S A , Bo Y , Tao L ,et al. The 'Dual Circulation' Development Model of China: Background and Insights[J]. Rajagiri Management Journal, 2021.
[7] Liu X .Research on the Construction of a "Dual Circulation" Development Pattern[J].Clausius Scientific Press, 2021(2).
[8] Yifu Lin J. What does China’s ‘dual circulations’ development paradigm mean and how it can be achieved?[J]. China Economic Journal, 2021, 14(2): 120-127.
[9] Zhu H, Liu R, Chen B. The Rise of Specialized and Innovative Little Giant Enterprises under China’s ‘Dual Circulation’ Development Pattern: An Analysis of Spatial Patterns and Determinants[J]. Land, 2023, 12(1): 259.