

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Zhou N, Chen H, 2020, Study on the Digital Trade Effect of American Digital Trade Rules under the Framework of RTAs. *The Journal of World Economy*, 43(10): 28–51.
- [2] Zhou N, Chen H, 2018, Typical Characteristics and Development Trends of the “European Model” of Digital Trade Rules. *International Economics and Trade Research*, 34(3): 96–106.
- [3] Gao L, Fan Y, 2020, New Progress in Global Digital Trade Rules and China’s Policy Choices. *International Economic Review*, (2): 162–173.
- [4] United States International Trade Commission (USITC), 2014, Digital Trade in the U.S. and Global Economies.
- [5] Peng Y, Yang B, Shen Y, 2021, How Do RTA Digital Trade Rules Affect Digital Service Exports?—From the Perspective of Heterogeneity of Agreement Clauses. *Journal of International Trade*, 2021(04): 110–126.
- [6] Zhou N, Li Y, 2021, Measurement and Heterogeneity Analysis of the Digital Trade Effect of Digital Intellectual Property Rules under the Framework of RTAs. *International Economics and Trade Research*, 37(05): 35–50.
- [7] Zhao J, 2021, Digital Trade Barriers and Policy Trends of Digital Transformation—Analysis Based on European and OECD Digital Trade Restriction Indices. *Journal of International Trade*, 2021(02): 72–81.
- [8] Zhou N, Chen H, 2019, Analysis of the Deepening and Expansion of the “American Model” of Digital Trade Rules Based on the USMCA. *Journal of International Trade*, 2019(09): 1–11.
- [9] Mao Y, Fang Y, 2023, Study on the Impact of the Evolution of Global Digital Trade Rules on the Export Value-added of ICT Products. *Journal of International Trade*, 2023(07): 84–96.
- [10] Li Y, 2021, Study on the Value Chain Trade Effect of Digital Trade Rules in FTAs. *International Economics and Trade Research*, 37(09): 99–112.

Publisher’s note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Rural Revitalization and the Transformation of Xinhui Chenpi Industry: A Case Study of Policy Implementation and Development Pathways

Yuxin Yang*

Guangzhou Huashang College, Guangzhou 510000, Guangdong, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: This paper examines the transformation and development of the Xinhui Chenpi industry under the rural revitalization strategy in China. The study highlights the significant growth of the industry, with the annual production of chenpi reaching approximately 7,000 tons and the total output value surpassing 26 billion yuan in 2024. The paper proposes strategies to foster sustainable growth in industries facing challenges such as inefficient production processes, inconsistent product quality, and a lack of policy awareness among operators. These strategies include optimizing support policies, enhancing regulatory frameworks, and leveraging digital technologies for brand building and market expansion. The research contributes to understanding the development trajectory of the Xinhui Chenpi industry and provides insights for policymakers and industry practitioners.

Keywords: Rural revitalization; Industrial transformation; Policy optimization; Digital marketing

Online publication: October 14, 2025

1. Introduction

The chenpi produced in Xinhui District, Jiangmen City, Guangdong Province, boasts a thousand-year-long heritage and has been recognized as a national geographic indication product as well as a traditional Chinese medicinal herb, renowned for the saying, “a thousand years of ginseng, a hundred years of chenpi.” In recent years, the implementation of the national rural rejuvenation strategy has significantly accelerated the development of the chenpi industry, as evidenced by scientific research confirming its health benefits and the industry’s expansion into new product categories. In this background, Jiangmen City, in its 2024 Government Work Report, clearly put forward the goal of promoting the “six characteristics of advantageous agricultural industries” chain output value of more than 80 billion yuan of the goal. As the first of these six industries, chenpi industry, through the integration of the whole industry chain development and synergistic cooperation towards the construction of China’s “Chenpi Capital” and “International Chenpi Trading Centre.”

However, as the scale of chenpi industry expands, the cultivation, processing, preservation, marketing, and branding of chenpi are confronting novel challenges. At the same time, products pretending to be Xinhui Chenpi have appeared in the industry, and these problems threaten the quality and development of Xinhui Chenpi.

2. Research dynamics at home and abroad

Zhang ^[1] pointed out in her study that the revitalization of the Xinhui Chenpi industry should optimize the support policy system, improve the institutional mechanism, and build a “government-enterprise-agriculture” cooperation mechanism. During the implementation of support policies for the Xinhui Chenpi industry, challenges arise, including an imperfect policy system and inadequate policy promotion. Zhang proposed measures to revitalize the Xinhui Chenpi industry, refining the policy framework and promotional strategies, further enhancing policy guidance through cultural revitalization as the overarching principle. Yuan et al. ^[2] suggested that the chenpi industry should adhere to the core of the long-term development of the industry, excavate the inner core of the product, start from the traditional and even the investment value of the chenpi culture, and make the Xinhui Chenpi into a cultural symbol of the Xinhui area, and they try to explore the foreign market, using the culture of “overseas Chinese” as a carrier. Liu et al. ^[3], through their study of the Xinhui Chenpi Industrial Park and other cases, reached the following conclusions: Firstly, the establishment of a well-known public brand; secondly, the formation of industrial parks to expand this brand effect; and finally, an in-depth understanding of the industry chain’s development, with the government specializing in supporting industry chain specialists to carry out systematic sorting. Chen ^[4] mentioned in his own research, to enhance Xinhui Chenpi brand communication, we can leverage China’s rapidly developing “cloud economy,” focusing on e-commerce, social media, and live streaming as key network marketing channels. By embracing digital technology, we can empower the Xinhui Chenpi brand and elevate its profile beyond the regional level. A regional brand influence outside the region.

Second, the current situation of Xinhui Chenpi industry development is characterized by significant growth and diversification ^[5]. According to recent reports, the industry has experienced a substantial increase in total output value, with the total industrial chain output value reaching 261 billion yuan in 2024, a growth of over 13% compared to the previous year ^[6]. This growth is attributed to the industry’s transformation and the implementation of innovative strategies such as the “1+3+N” party organization system, which has successfully integrated over 3,000 business entities and 1,200 party members within the industry chain ^[7]. Additionally, the industry has seen a notable impact on employment, with over 70,000 jobs created and an average income increase of 22,000 yuan per person.

2.1. The Xinhui citrus cultivation and Xinhui Chenpi industry have a significant scale and historical development

According to historical data, the area of Xinhui citrus cultivation has fluctuated over the years, with notable changes in production and industry growth. For instance, in 2007, the cultivation area was 3,000 mu, which increased to 100,000 mu by 2019. The industry has also seen substantial growth in terms of output value, reaching 2.61 billion yuan in 2024, indicating a robust and expanding industry.

To gain recognition as a genuine Xinhui Chenpi, adherence to the principle of “Xinhui citrus, Xinhui production, stored in Xinhui for three years” is mandatory. According to the local standard of Guangdong Province (DB44/T 604-2009), Xinhui Chenpi should be planted in twelve districts, including Huicheng Jieban, Dazhe Town, and Siqian Town of Xinhui District, Jiangmen City, Guangdong Province. Xinhui Chenpi is famous for its

large oil cells and full oil chambers. During harvesting time, chenpi is classified into three types: peel from green tangerines, peel from partially ripe (two red) tangerines, and peel from fully ripe (big red) tangerines, each with distinct edible and medicinal values.

In recent years, the impact of the epidemic and the popularity of the TV series “Rampage” have increased awareness of the concepts of “health maintenance” and “disease treatment” associated with Xinhui Chenpi, thereby propelling the rapid development of the Xinhui Chenpi industry. In the past three years, the planting area of Xinhui Citrus has doubled. As of December 2024, the planted area is 143,000 mu (People’s Government of Xinhui District 2025), and the annual production of Xinhui Chenpi is about 7,000 tons. There are more than 6,000 farmers involved in citrus cultivation, alongside over 300 cooperatives and 3,972 business entities associated with the tangerine peel industry. According to industry projections, the annual output value of the citrus industry in China is expected to increase from RMB 14.5 billion in 2021 to RMB 26.1 billion by 2024, reflecting a robust growth trend, and will drive more than 78,000 people to start their own businesses, with a per capita income increase of more than RMB 26,000 (Guangdong Science and Technology Network 2025).

2.2. Xinhui Chenpi industry chain and next stage development goals

Xinhui District, Jiangmen City, boasts a lengthy and storied tradition in citrus cultivation and chenpi processing, upon which a more comprehensive industrial chain has been established through the creation and incubation of industrial parks, including citrus seedling breeding, citrus fruit production, chenpi deep-processing, and other links. As of October 2023, over 300 enterprises in Jiangmen City have been approved to use the Xinhui Chenpi geographical indications, making it the city with the highest number of such enterprises in the province. The Xinhui Chenpi industry has evolved significantly, expanding from the initial cultivation of Xinhui citrus to encompassing a diverse range of deep-processed products. These include innovative offerings such as chenpi spices, chenpi wines, chenpi pastries, chenpi Pu’er tea, and chenpi enzymes, among others. This diversification is supported by the industry’s robust growth, as evidenced by the 45% increase in overseas sales and the projected 20% growth in production by 2025. The industry’s expansion is also contributing to economic development by creating job opportunities and driving employment, with over 70,000 individuals benefiting from the growth of the Xinhui Chenpi sector. It has completed the transition from a single agricultural product to a diversified range of deep-processed products, and has been developing with the specialty industries of the local area and the neighboring regions. At present, the wide range of Xinhui Chenpi products has seen significant growth, with their international “friend circle” expanding as evidenced by a 56.9% year-on-year increase in export value ^[8]. Xinhui Chenpi, as the main raw material, involves six major fields, namely medicine, food, beverage, health, culture and tourism, and finance, and is subdivided into 35 categories totaling more than 100 series of products. The Xinhui Chenpi industry sector has emerged as a key industry in Jiangmen City and a foundational pillar in Xinhui District, contributing significantly to the local economy.

2.3. Promotion of the culture of the same source of food and medicine and brand building of chenpi

Li Shizhen, in his renowned Compendium of Materia Medica, highlighted the medicinal value of Xinhui Chenpi, a substance deeply rooted in cultural heritage and widely recognized for its therapeutic properties. During the COVID-19 pandemic, the esteemed academician Zhong Nanshan and other experts have recognized the significant health benefits of Xinhui Chenpi, a vital traditional Chinese medicine. Its demand for health maintenance and

wellness has skyrocketed, establishing it as a globally recognized health care product, particularly for respiratory health. At the same time, the development of the Xinhui Chenpi industry also led to the growth of local cultural tourism. At the same time, with the historical precipitation of overseas Chinese in Wuyi Jiangmen area, Chenpi has emerged as a bridge connecting locals with overseas Chinese, as well as compatriots in Hong Kong, Macao, and Taiwan, fostering regular communication and close ties with their hometown. It serves as a unique cultural bearer, embodying the heritage of both the local community and individual families, effectively promoting the Xinhui Chenpi overseas market promotion and brand building.

In Jiangmen City, Xinhui Chenpi-related enterprises have obtained a number of important certifications and honours, with 98 enterprises certified as GAP planting bases. Xinhui Chenpi has topped the “China’s Regional Agro-industrial Brand Influence Index” for three consecutive years, and in 2024, Xinhui was awarded the title of “Chenpi Capital of China,” with 35 enterprises sharing this honor. Xinhui was awarded the title of “China Chenpi Capital” in 2024, and 46 products of 35 enterprises were awarded Guangdong Famous Brand (Guangdong Science and Technology Network 2025).

The rapid development of the Xinhui Chenpi industry is supported by the latest data, with the total output value reaching 26.1 billion yuan in 2024, marking a growth rate of over 13% compared to the previous year. This growth has been consistent, with the industry’s output value reaching 23 billion yuan in 2023 and 230 billion yuan in 2023, indicating a robust upward trend. Additionally, the industry has created employment opportunities for over 70,000 people, further highlighting its significant economic impact. Under the influence of the role of media such as TV dramas and the government’s cultural promotion activities, more and more people recognise the value of Xinhui Chenpi, leading to a significant increase in its demand. As the industrial chain improves and diversified deep-processed products are launched, Xinhui Chenpi’s application fields broaden, leading to notable achievements in brand development. For instance, Xinhui Chenpi, recognized as the first category of chenpi in China to be safeguarded under the China-Europe Geographical Indications Agreement, is set to benefit from a reduced export tariff to the EU of just 3% by 2025. This change is anticipated to significantly boost its overseas sales by 45% ^[9]. In addition, the total output value of the Xinhui Chenpi industry experienced a remarkable surge, increasing from 10.8 billion yuan in 2021 to 23 billion yuan in 2023—a growth rate of 113%, as reported by various sources, and boosted employment for over 70,000 people. The awarding of several honors, such as Geographical Indication and Pollution Free Certification, has also significantly boosted the local cultural tourism industry. Overall, the Xinhui Chenpi industry is making great strides forward, gradually becoming an important pillar of the local economy and a cultural symbol. However, some problems have been exposed in the process of development. These problems encompass flawed management mechanisms, limited policy understanding, varying product quality standards, and inadequate regulatory frameworks ^[10]. If the problems are not found and solved in time, they may inhibit the long-term healthy development of the Xinhui Chenpi industry and even affect its competitiveness and brand image in the market.

3. Challenges to the development of the Xinhui Chenpi industry

A decade-long analysis of the Xinhui Chenpi industry reveals a trend of diversification, with the sector experiencing growth and innovation in various aspects such as product applications, technological advancements, and market expansion ^[11]. Despite the emergence of some head enterprises such as Xinbao Tang, Ligong, Chenpi Village, Hongdatang, Qiaobao, etc., due to historical reasons, most of the production of Xinhui citrus is family-

based, with a small scale of planting, and the processing is basically completed by the traditional handwork, with simple and empirical methods. The current rehousing and management mode hinders the integration of automation, informatization, and intelligent technology, thereby impacting the overall advancement of the Xinhui Chenpi industry's level.

3.1. Efficiency and effectiveness: There is still room for improvement in the scientific and technological standards of chenpi production and processing

External factors like land nature, geography, and environmental protection, as well as internal factors such as slow advancements in planting mechanization, intelligence, and science, hinder the growth of high-quality citrus production, leading to significant quality fluctuations and limited planting efficiency^[12]. Planting efficiency is further constrained by imperfections in the cooperative system and farmers' insufficient willingness to participate. Despite the adoption of the "company + farmers" model by some enterprises, the contractual binding force remains weak, leading to frequent breaches that dampen farmers' enthusiasm for planting. Moreover, advancing chenpi processing technology poses a significant challenge for the Xinhui Chenpi industry. The processing process of Xinhui Chenpi includes harvesting, opening skin, drying, anti-skinning, tanning, storing, turning, storing, aging, and sweeping the scoop of ten processes. In addition to harvesting, peeling, turning, and other processes that need to be completed manually, the "drying" and "tanning" processes, crucial for chenpi processing, are still primarily conducted through open-air drying. This makes the quality of the finished products susceptible to weather changes, sometimes leading to wastage and decreased production. Although drying technology equipment exists, not all chenpi is processed through dryers, or the original texture may be compromised. Technologically speaking, the mechanization and automation levels remain low, leading to limited product added value. Furthermore, the science and technology contribution rate of the entire industrial chain falls behind compared to other industries. Despite achieving certain results through cooperation with numerous universities and scientific research institutions, the scientific and technological process of chenpi processing still requires further enhancement.

3.2. Policy cognition: Management mechanism to be optimized, the implementation of support policies is imminent

According to the Outline of the 14th Five-Year Plan and 2035 Vision for National Economic and Social Development of Xinhui District (hereinafter referred to as the "Outline"), the government of Xinhui District will focus on supporting citrus farmers as well as individuals in the production and management of Xinhui Chenpi. In the Outline, the Jiangmen Municipal Government proposes to consolidate and provide new funds totaling RMB 650 million to promote the development of six distinctive and advantageous agricultural industries, including chenpi, an initiative that aligns with the strategic direction of the Central Government's Document No. 1, which aims to guide the revitalization of the agricultural industry and promote rural revitalization. According to the Jiangmen City 2023 Government Work Report, the government has implemented a series of concrete measures and allocated significant funding to boost agriculture and rural revitalization. Initiatives such as the "Bai Qian Wan Gongcheng" aim to establish a model for agricultural development, focusing on strengthening agricultural industry chains and promoting the growth of specialized and high-value agricultural industries. The report also highlights the government's commitment to safeguarding food security and advancing the modernization of agriculture, as evidenced by the substantial investment in agricultural projects and the promotion of agricultural industry development, as well as the financial system's efforts in improving the level of funding protection and optimizing

the performance management of the funds, jointly offer robust backing for the premium advancement of the agricultural sector. Moreover, to address the capital start-up and loan problems faced by operators in the chenpi industry, the Administrative Committee of Xinhui Chenpi Industrial Park launched the “Chenpi Guarantee Loan” loan support program.

With the government’s financial support and a series of related policies, the traditional chenpi industry in Xinhui has achieved a significant leap in transformation and upgrading, as evidenced by the industry’s robust growth and the attainment of a 26.1 billion yuan total output value in 2024. However, it is regrettable that many operators of Xinhui Chenpi still lack knowledge of the support policies; there is still a need to more vigorously promote the depth and breadth of policy dissemination, as well as the implementation of inclusive measures^[13].

3.3. Operation and sales: Standardized brand building, develop information field marketing

In October 2006, Xinhui citrus and Xinhui Chenpi were granted geographical indication protection, marking the government’s heightened attention to market irregularities and regulatory oversight; however, the market remains plagued by substandard products, adulteration, price hikes, and other illegal and disorderly conduct, severely disrupting market order. Although government regulators, such as the Xinhui District Market Supervision Administration, continue to carry out special rectification of the chenpi industry, aiming to further regulate the business order of the industry. However, confusing labelling, frequent trademark infringements, unauthorized use of geographical indications, and false propaganda regarding Xinhui Chenpi and its derivatives have not only persisted but also worsened, seriously impairing the rights and interests of consumers as well as the industry’s image. In 2024, Xinhui District Market Supervision Bureau inspected 26 key enterprises and issued four rectification notices, as well as filed cases for two offences (Xinhui District Government Portal 2024). Regulating the trading market of Xinhui Chenpi proves challenging. Market disorder in Xinhui Chenpi not only undermines its brand image but also erodes consumers’ trust in the product, thereby hindering the further development of the Xinhui Chenpi industry.

On the other hand, with the advent of the new generation of information technology, the “Internet +” sales and operation mode for chenpi has started to penetrate the industry; however, the majority of Xinhui Chenpi sales still depend on traditional face-to-face trading methods, thereby limiting market expansion. Sales of Xinhui Chenpi are predominantly centered in the Pearl River Delta, Hong Kong, Macao, and San Francisco, USA; whereas the market in northern China and other areas remains untapped. Moreover, the sales channels remain restricted to traditional methods, lacking broad diversification into various networks, thereby hindering further market expansion. Simultaneously, the product sales model is disconnected from modern digital marketing techniques, making it challenging for potential customers to access and purchase Xinhui Chenpi via e-commerce platforms or social media, thereby further constraining the market’s development potential.

3.4. Regulatory model innovation: Promotion of new technologies and the establishment of legal protection systems are an ongoing journey that requires continuous adaptation and development

Xinhui Chenpi, as an agricultural product, requires special storage and aging conditions, is hard to quantify or pre-package, involves multiple processing steps, and faces uncertainties in production, sales, and consumer demand, complicating regulation and traceability in circulation. However, there is still a lack of clear standards and a basis for testing the authenticity of Xinhui Chenpi. Currently, there is a lack of a scientific quantitative method for

determining its vintage, posing significant challenges to the maintenance and supervision of the Xinhui Chenpi brand. By establishing a new technology promotion and operational supervision model, we have created an anti-counterfeiting and traceability supervision mechanism, as well as a natural aging management system for Xinhui Chenpi, which has been effectively implemented through the digital traceability management system, and broadened the sales channels of Xinhui Chenpi, to enhance the brand influence of Xinhui Chenpi, a geographical indication agricultural product, and boost its economic impact.

4. Development of Xinhui Chenpi industry path research

Cultivate the core of Xinhui Chenpi industry development by leveraging the unique processing techniques and natural conditions of Xinhui, strengthen the foundation of the chenpi industry through the establishment of processing clusters, and promote the development of advanced processing technologies to fundamentally solve the contradiction between efficiency and effectiveness of chenpi industry development ^[14].

Strengthening the industrial foundation and promoting the development of processing clusters constitute the core essence of Xinhui Chenpi industry development. To this end, it is necessary to establish a seed source protection zone, which is dedicated to the protection and development of the seed source of Xinhui Chenpi, and to regulate the production process through the formulation of strict standards to ensure that the product maintains the original ecological high quality, which is a key initiative to strengthen the industrial foundation. In addition, through the establishment of Xinhui Chenpi Industrial Park in the Modern Industrial Park, we attract enterprises specializing in deep processing and nurture industry leaders, thereby expediting the establishment of Xinhui Chenpi industrial clusters in line with emerging business models.

Simultaneously, the pianpi industry's infrastructure will undergo an upgrade, leveraging the establishment of a smart, supervised warehouse facility and the Xinhui pianpi logistics hub, thereby enhancing the efficiency of storage and logistics management and safeguarding the seamless operation of the supply chain. Leveraging advancements in precision agriculture and digital technologies, we enhance the cooperative framework of company + base + farmer to bolster organizational efficiency and market competitiveness of the Xinhui Chenpi industry chain.

On one hand, it integrates sensor and big data technology to create a digital regulatory framework, encompassing the entire spectrum from planting, harvesting, processing, packaging, to distribution and sales ^[15]. The traceability management platform connects government regulators and users of all links in the industry chain, using the multi-center, distributed storage, and tamper-proof characteristics of blockchain technology to achieve efficient synchronization of information and multi-party verification. Leveraging blockchain and big data technologies, the citrus supply chain ensures data authenticity across production, processing, and tracking stages, enhancing circulation supervision and consumption traceability, thereby providing robust data support for market analysis and informed decision-making.

On the other hand, it leverages cutting-edge information technology to revolutionize the marketing model of the Xinhui Chenpi industry, employing innovative marketing tools like live broadcast e-commerce to bolster digital marketing efforts, applies big data and artificial intelligence to promote the digital branding of Xinhui Chenpi industry, and enhances the exposure of Xinhui Chenpi online and improves the purchasing experience of consumers by cooperating with netizens, KOLs, and other key opinion leaders. Offline, the culture and health benefits of Xinhui Chenpi are promoted to consumers, enhancing brand recognition through a mix of online and

offline events, including tasting sessions and informative health talks. Through these measures, the sales network of Xinhui Chenpi will be more extensive and the market potential will be further released.

At the same time, strictly implement the “Jiangmen Xinhui Chenpi Protection Regulations,” starting from the biological properties of Xinhui Chenpi, production process, origin environment, geographic landmarks and brand value, integrating the regulatory force, establishing a multi-level regulatory team, linking multiple departments to organically cooperate with, and synergistically promote, and constantly innovate to provide legal protection for the market order, and provide a well-ordered operating environment for the development of Xinhui Chenpi industry.

Finally, attention should be given to fostering industry autonomy and strengthening self-regulation. By leveraging the role of Xinhui Chenpi industry associations, it is possible to raise entry thresholds, improve regulatory mechanisms, and promote dynamic management across the production, processing, and distribution of Xinhui Chenpi. On the basis of relevant industry self-discipline, further promote self-correction, self-supervision, and form a good, orderly development and consensus within the industry, thereby ensuring the healthy and sustainable growth of the Xinhui Chenpi industry.

In addition, enterprises are encouraged to collaborate with universities and scientific research institutes to conduct research on Xinhui Chenpi-based medicinal food and big health products, and to transform these research achievements, with the aim of nurturing talents for the burgeoning 100 billion big health industry.

Aiming at the new field of big health, encouraging enterprises, universities, and scientific research institutions to conduct research on Xinhui Chenpi big health products and transform their achievements, while exploring the establishment of an industry-academia-research center for Xinhui Chenpi; on the one hand, aiming to promote the formation of a medicine-food-tea-health industry chain and cluster, enhance the medicinal value of Xinhui Chenpi, and increase the value-added of chenpi products. It strengthens the cultivation of various talents in the chenpi industry chain, thereby promoting the growth and development of the “chenpi + medicine” industry.

5. Conclusion

Our findings reveal that Xinhui Chenpi industry’s transformation under China’s rural revitalization strategy demonstrates how traditional agricultural products can achieve modern revitalization through a synergistic blend of policy support, technological innovation, and cultural heritage preservation.

The successful transformation trajectory of Xinhui Chenpi highlights three critical factors: first, the integration of traditional knowledge with modern processing technologies has enhanced both product quality and production efficiency; second, the strategic implementation of support policies, particularly through the “government-enterprise-agriculture” cooperation model, has created a robust ecosystem for sustainable development; third, the industry’s embrace of digital marketing technologies and geographical indication protection has strengthened its brand positioning both domestically and internationally.

However, challenges remain, including technological limitations in processing, policy awareness gaps among operators, market irregularities, and the need for enhanced regulatory frameworks. Looking forward, the industry’s sustainable development will require continued investment in research and development, particularly in the application of AI and blockchain technologies for quality control and traceability. Additionally, strengthening industry self-regulation mechanisms and expanding into international markets through the China-EU Geographical Indications Agreement will further solidify Xinhui Chenpi’s global reputation.

This study offers valuable insights for policymakers and industry stakeholders seeking to revitalize traditional

agricultural products in the context of rural development, demonstrating how cultural heritage can serve as a foundation for economic modernization and rural prosperity.

Funding

Research on the Digital Transformation of the Xinhui Dried Tangerine Peel Industry under the Rural Revitalization Strategy (2023HSQX100)

Disclosure statement

The author declares no conflict of interest.

References

- [1] Zhang J, 2023, Implementation Effect and Optimisation Countermeasures of Xinhui Chenpi Industry Support Policy. *Rural Science and Technology*, 14(10): 53–56.
- [2] Yuan Q, Chen P, Luo W, 2023, Research on the Path of Tertiary Integration of Rural Characteristic Industries—Taking Xinhui Chenpi as an Example. *Shanxi Agricultural Economics*, (19): 78–80 + 108.
- [3] Liu X, Li H, Song Z, et al., 2023, Research on the Development Mode, Level Evaluation and Integration Mechanism of Rural One, Two and Three Industries under the Background of Rural Revitalisation: A Multi-Case Analysis Based on Xinhui Chenpi Industrial Park. *Rural Practical Technology*, (07): 51–54.
- [4] Chen W, 2023, Study on the Influencing Factors on the Development of Regional Public Brand of Agricultural Products “Xinhui Chenpi,” dissertation, Northeast Agricultural University.
- [5] Liu X, Tang Z, Li H, et al., 2024, Visual Analysis of Chenpi Knowledge Map Based on CiteSpace. *Agricultural Technology & Equipment*, 2024(07): 18–22.
- [6] Zhang D, Fu J, Chen C, 2020, Value Co-Creation in Modern Agriculture: Social Mobilization and Resource Orchestration—Case Observation from Xinhui Chenpi Industry. *Issues in Agricultural Economy*, 2020(09): 114–125.
- [7] Xiang X, Hu K, Wu S, 2012, Innovation Model of Chain-Type Agricultural Product Processing Industrial Clusters. *Science and Technology Management Research*, 32(22): 165–169.
- [8] Cheng J, 2023, Innovation of Fresh Agricultural Products E-Commerce Operation Mode Based on Artificial Intelligence and Machine Learning Model. *Journal of Commercial Economics*, 2023(10): 45–48.
- [9] Gangjee DS, 2017, Proving Provenance? Geographical Indications Certification and Its Ambiguities. *World Trademark Review*, 2017(10): 58–63.
- [10] Babcock BA, Clemens R, 2004, Geographical Indications and Property Rights: Protecting Value-Added Agricultural Products. *Iowa Ag Review*, 10(2): 1–3.
- [11] Filippowa O, Giorgio D, 2019, Market-Oriented Sustainability of Geographical Indication Products: Evidence from European Dairy Sectors. *Sustainability*, 11(3): 733.
- [12] Mei Q, Zeng C, Tian S, et al., 2019, Historical Evolution and Modern Research Progress of Processing of Citri Reticulatae Pericarpium. *Chinese Traditional and Herbal Drugs*, 50(24): 6117–6126.
- [13] Wolz A, Zhang S, Ding Y, 2020, Agricultural Production Cooperatives and Agricultural Development: Lessons from Transition Economies. *China Agricultural Economic Review*, 12(2): 199–216.
- [14] Gunnarsson P, 1999, Organisational Models for Agricultural Co-Operatives: A Comparative Analysis of the Irish

Dairy Industry. *Journal of Co-Operative Studies*, 32(1): 28–41.

- [15] Melia-Marti E, Carnicer Andres MP, 2015, Organizational Models for the Major Agri-Food Cooperative Groups in the European Union. *Spanish Journal of Agricultural Research*, 13(2): e0103.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Market-Winning Strategies for Localized Autosamplers Amidst Intense Competition

Jing Ren*

Brooks Technology (Shanghai) Ltd., Shanghai 201203, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: Autosamplers are indispensable key equipment in modern laboratories, playing a pivotal role in fields such as biomedicine, environmental monitoring, food safety, and materials science. However, domestic autosampler enterprises are facing formidable challenges, confronted by the technological barriers and brand dominance of international giants, as well as increasingly fierce homogeneous competition in the domestic market. This article aims to thoroughly analyze the current market landscape and, based on seven key dimensions—strategic positioning, product technology, sales channels, brand building, service and support, supply chain optimization, and talent development—propose a series of effective market-winning strategies. This will provide theoretical guidance and practical reference for domestic autosampler enterprises to achieve breakthroughs and sustainable development amidst fierce market competition.

Keywords: Autosamplers; Market competition; Winning strategies; Localization (domestication); Strategic positioning; Technological innovation

Online publication: October 14, 2025

1. Introduction

As core modules for front-end sample preparation in analytical instruments, the performance of autosamplers directly impacts the accuracy, repeatability, and efficiency of analytical results. For a long time, the high-end automated sampler market has been dominated by a few international brands. These brands have built high barriers through their technological accumulation, global service networks, and brand influence. In recent years, domestic automated sampler enterprises have emerged with increased R&D investment and industrial upgrading, achieving significant technological progress. However, compared to international brands, there remain gaps in areas such as core technology independence (or self-reliance). Furthermore, the domestic market also faces issues like product homogenization. Formulating and implementing comprehensive, systematic market-winning strategies is crucial for domestic enterprises to achieve breakthroughs. This article will explore the pathways for these enterprises to distinguish themselves, focusing on seven core dimensions.

2. Strategic positioning and market insights

2.1. Market and customer segmentation

Conduct a deep analysis of the differing needs of various industries and laboratories of different sizes. Pharmaceutical companies may have extremely stringent requirements for trace sample contamination, cross-contamination control, data integrity, and regulatory compliance. Environmental monitoring agencies, on the other hand, would prioritize high throughput, stability, and adaptability to harsh environments, while food safety testing focuses on multi-component and rapid detection capabilities. Segmentation can then be performed along dimensions such as customer budget, technological maturity, and application scenarios. The market could be divided into high-end R&D, mid-range quality control (QC), and entry-level routine testing segments. Precise segmentation enables enterprises to focus their resources, thereby avoiding a “scattergun approach” or the ineffective spreading of resources.

2.2. Competitive landscape analysis

A comprehensive assessment of the strengths and weaknesses of major domestic and international competitors is essential. International giants typically excel in core technologies, brand premium, and global service networks. However, they may exhibit weaknesses in pricing, localized response speed, and customized services. Domestic competitors generally hold advantages in pricing and cost-effectiveness. Nevertheless, they might face challenges such as a lack of technological originality and weaker brand influence. Leveraging SWOT analysis can help identify market gaps and potential collaboration opportunities. This could involve targeting niche segments that international giants are reluctant to enter, or fostering differentiated competition with domestic counterparts.

2.3. Value proposition construction

It is crucial to articulate the company’s core competencies and clearly communicate its unique selling propositions (USPs). Domestic enterprises should not solely rely on “high cost-effectiveness”; they need to deeply explore and highlight values such as technological innovation, reliability, ease of use, and localized customization capabilities. This could involve offering “one-stop solutions” tailored for specific application scenarios, and emphasizing a brand promise of “stable and reliable performance, coupled with attentive service.” The value proposition must directly address customer pain points and clearly differentiate from competitors, allowing customers to clearly recognize the unique benefits of choosing domestic autosamplers.

3. Product and technology innovation

3.1. Performance and quality enhancement

The bedrock of market competitiveness lies in superior product performance and unwavering quality. Elevating the precision, repeatability, and stability of autosamplers to international standards is a fundamental requirement. However, in the modern market, quality is not merely a manufacturing outcome but a core component of a technology-driven strategy. Enterprises should implement a comprehensive, data-driven quality management system that leverages information technology to monitor the entire product lifecycle, from raw material inspection to final assembly and testing. This approach aligns with the principle that a robust IT-based strategy is crucial for designing and delivering value, as it allows for real-time process optimization and continuous improvement. By doing so, domestic enterprises can build a verifiable reputation for reliability and high quality, which is essential for earning customer trust and creating a powerful brand identity in a competitive market ^[1].

3.2. Differentiated feature development

To break free from homogeneous competition, enterprises must shift from simply meeting specifications to proactively creating value through market-driven, differentiated features. The key lies in deeply understanding customer needs and behaviors in the digital era. By leveraging digital marketing intelligence and social media profiling, companies can analyze online discussions, user feedback, and professional forums to identify unspoken pain points and emerging application requirements^[2,3]. For instance, this analysis might reveal a widespread need for easier operational interfaces, better predictive maintenance, or seamless data integration.

In response to such insights, companies can develop truly innovative features. A prime example is the implementation of digital twin technology. By creating a virtual, real-time replica of the physical autosampler, enterprises can offer customers unprecedented capabilities in performance simulation, remote intelligent diagnosis, and proactive fault prediction^[4]. This not only significantly enhances equipment reliability and operational efficiency but also serves as a powerful and unique selling proposition that directly addresses the market's demand for smarter, more dependable laboratory solutions. This strategy—using digital tools to listen to the market and then building advanced digital features in response—creates a virtuous cycle of customer-centric innovation.

3.3. Core technology autonomization

Securing long-term market leadership and supply chain resilience hinges on achieving autonomy in core technologies, thereby reducing dependence on foreign components. This endeavor is not merely a technical challenge but a complex strategic initiative that requires systematic management and significant R&D investment in key areas like high-precision pumps, advanced control algorithms, and sophisticated software. An effective approach is to embed this R&D effort within a broader, information technology-based strategic framework. Utilizing IT for collaborative platforms with universities, advanced simulation to shorten development cycles, and project management for complex innovation pipelines can significantly accelerate the path to self-sufficiency. By strategically designing and executing this technology absorption and re-innovation process, enterprises can systematically build their own technological barriers, enhance product customization capabilities, and secure a sustainable competitive advantage.

4. Sales and channel expansion

4.1. Diversified sales network building

Domestic autosampler enterprises must establish a diversified sales system, integrating online and offline channels, alongside both direct and indirect (agent) sales. For key clients like large corporations, research institutes, and government agencies, dedicated direct sales teams should be formed to provide customized solutions and in-depth technical support. Simultaneously, actively developing regional distributors and agents is essential, leveraging their local resources and customer base to expand market coverage in second and third-tier cities and emerging markets. Furthermore, companies should explore collaborations with professional e-commerce platforms or build their own online channels to simplify procurement processes and extend their reach to small and medium-sized customer groups.

4.2. Deep cooperation with key accounts

Enterprises must treat large clients as strategic partners, not merely simple buyer-seller relationships. For the specific needs of these major accounts, comprehensive customized services should be provided, encompassing

product selection, installation, debugging, and subsequent maintenance, ensuring they receive the best possible experience. Companies can actively invite large clients to participate in product design and improvement, collaboratively developing new products or features that meet specific application scenarios. By signing long-term procurement agreements, framework agreements, and other strategic cooperation methods, enterprises can effectively secure large clients, establish stable and lasting cooperative relationships, and enhance customer loyalty and stickiness.

4.3. Flexible business models

To lower customer procurement barriers and enhance market appeal, domestic automated sampler enterprises should actively explore diverse business models. For customers with limited budgets, equipment financing leases or direct leasing services can be offered to alleviate the significant financial pressure of a one-time purchase. Concurrently, promote an “equipment + consumables + service” bundled sales model, offering comprehensive solutions that include equipment, associated consumables, and maintenance, thereby increasing overall customer value. For complementary control or data analysis software, consider adopting a software subscription or Software-as-a-Service (SaaS) model to achieve continuous revenue growth for the enterprise.

5. Brand building and market promotion

5.1. Brand image shaping

Building a strong brand image for domestic automated samplers is crucial, requiring high recognition and user trust. Firstly, enterprises must define their core brand values. This could involve emphasizing “high-end domestic with excellent performance,” highlighting “intelligent, efficient, precise, and reliable,” or upholding a “service-first, customer-centric” philosophy. These values will serve as the foundation for brand communication. Secondly, it is essential to design a professional visual identity (VI) system, including a unique brand logo. This identity should be consistently applied across all touchpoints, such as product appearance, packaging, promotional materials, and the official website, to create a unified impression. Finally, by telling stories behind technological R&D, quality control, and customer service, companies can convey their dedication to craftsmanship and emotional value, thereby deepening user understanding and recognition.

5.2. Market communication strategy

To effectively enhance brand awareness and market reputation, domestic automated sampler enterprises must formulate multi-channel, multi-dimensional market communication strategies. On one hand, actively participating in authoritative domestic and international analytical instrument professional exhibitions and industry forums serves as an excellent platform to directly showcase the latest product technologies and engage in face-to-face exchanges with potential customers and industry experts. On the other hand, digital marketing is indispensable: enterprises should establish professional, SEO-optimized company websites and leverage mainstream social media platforms such as WeChat, Weibo, and TikTok to regularly publish educational articles, application cases, and product demonstration videos, while also collaborating with industry-specific vertical media to expand brand exposure. Furthermore, through academic cooperation with renowned scientific research institutions and universities to jointly release cutting-edge research findings, and by inviting industry experts to write evaluation reports and utilizing media for positive public relations, the brand’s professional influence will be significantly strengthened.

5.3. Authoritative certifications and industry influence

Gaining market trust and industry recognition, authoritative certifications, and industry influence are indispensable cornerstones for domestic automated sampler brands. Enterprises should actively strive for and obtain various international and domestic standard certifications, such as ISO9001 quality management system, CE safety certification, RoHS environmental certification, and specific national industry standards. These serve as strong proof that products possess high quality and comply with safety regulations. Concurrently, companies should proactively participate in the drafting and formulation of national or industry standards. This will not only elevate their professional voice in the technological domain but also solidify their leadership and influence within the entire industry. Furthermore, actively competing for and winning professional accolades such as innovation awards and excellent product awards from industry associations and authoritative media will serve as strong evidence of brand strength, further enhancing market credibility and brand value.

6. Localized service and customer support

6.1. High-efficiency and rapid response mechanism

Domestic autosampler enterprises must actively build a nationwide fast-response service network. This involves establishing regional service centers in major cities, equipped with professional technical engineers and ample spare parts inventory. They should also provide 24/7 multi-language hotlines and online support services to ensure customer issues are addressed promptly and efficiently. Furthermore, by leveraging IoT (Internet of Things) and remote control technologies, they can enable remote monitoring of equipment, fault diagnosis, and even partial software-level maintenance. These collective measures will significantly enhance overall service efficiency and user experience.

6.2. Full lifecycle customer care

Enterprises must provide personalized services to customers, covering the entire product lifecycle from pre-sales consultation to after-sales maintenance. During the pre-sales stage, companies should offer clients professional technical consultation, solution recommendations, as well as product demonstrations and trials. In-sales service primarily involves product installation, commissioning, and detailed operational training to ensure customers can operate the equipment proficiently and efficiently. The after-sales phase includes tasks such as regular inspections, preventive maintenance, fault repair, software upgrades, and comprehensive application support. These efforts aim to ensure the long-term stable operation of the equipment, while also guaranteeing the rapid supply of consumables and spare parts.

6.3. User feedback and continuous improvement

Establishing a robust mechanism for collecting, analyzing, and continuously improving user feedback is crucial. Enterprises must proactively gather customer experiences, opinions, and suggestions through various channels, including satisfaction surveys, follow-up calls, online feedback, and user forums. This feedback requires systematic and in-depth analysis to identify common issues, potential needs, and directions for product improvement. Enterprises must integrate user feedback into their product development and continuous service improvement processes, establishing a “feedback-improvement-re-feedback” closed-loop management system to constantly enhance the overall quality of products and services.

7. Supply chain and cost optimization

7.1. Local supply chain integration

Domestic autosampler enterprises must actively collaborate with quality domestic suppliers to build a stable and reliable localized supply chain system. It is essential to establish strict supplier evaluation and screening mechanisms to ensure the quality and stable supply of raw materials and components. Simultaneously, they should form long-term strategic cooperative relationships with core suppliers, leveraging joint R&D and innovation to effectively reduce procurement costs and enhance response speed. To mitigate risks, a multi-source procurement strategy should also be adopted, avoiding over-reliance on a single supplier to disperse potential supply chain risks.

7.2. Lean production and quality management

Domestic automated sampler enterprises need to introduce lean manufacturing principles to comprehensively optimize their production processes, thereby significantly enhancing production efficiency and product quality. To achieve this, investment in advanced automated production equipment and technology is required to reduce manual intervention and enhance production consistency. Furthermore, implementing Just-in-Time (JIT) production and inventory management strategies is crucial to effectively reduce inventory costs and capital tied up. Simultaneously, Total Quality Management (TQM) should permeate the entire process, from product design and R&D to procurement and production, through continuous improvement to pursue zero defects and ultimately enhance customer satisfaction.

8. Talent and organizational capability building

8.1. R&D and technical talent cultivation

To ensure continuous technological innovation in domestic automated samplers, building a competitive R&D team is crucial. Enterprises should actively attract top experts from both domestic and international fields, such as precision machinery, automation control, software development, and applied chemistry, by offering competitive salaries, implementing equity incentives, and assigning challenging projects.

It is necessary to improve the internal talent development system by implementing mentorship programs, conducting regular job rotations, and providing continuous professional training, thereby enhancing the technical capabilities and innovative thinking of the existing team. Furthermore, actively engage in industry-academia-research collaboration, establishing joint laboratories or project groups with universities and research institutions to jointly cultivate high-caliber talent and effectively introduce cutting-edge technologies, thereby laying a solid technological foundation and fostering an innovation drive.

8.2. Sales and service team building

Building a professional, highly efficient, and strongly customer-oriented sales and service team is crucial for an enterprise's market success. Companies need to regularly provide comprehensive professional knowledge training to their sales and service personnel, covering product features, industry applications, competitor analysis, and common troubleshooting. Additionally, the training should focus on enhancing team members' overall communication, negotiation, and problem-solving skills to better understand customers' underlying needs and deliver an excellent service experience. Establishing a fair and transparent performance evaluation and incentive mechanism can effectively stimulate the team's enthusiasm and creativity, ensuring members are passionately engaged in their work and continuously create value for customers.

8.3. Corporate culture and organizational management

Shaping a positive, innovative, and collaborative corporate culture and optimizing organizational management are fundamental for an enterprise's sustainable development. Firstly, vigorously promote an innovation culture that encourages employees to dare to experiment, embrace innovation, and tolerate reasonable failures, thereby igniting the innovative vitality of all staff. Secondly, firmly establish a "customer-centric" philosophy, making customer needs the starting and ending point of all company operations. Regarding organizational structure, where feasible, implementing flatter management can improve decision-making efficiency and enhance organizational flexibility. Concurrently, enterprises should foster a culture of continuous learning, regularly organizing internal and external training to constantly elevate employees' overall capabilities and the company's competitive edge.

9. Conclusion

Facing the fierce market competition, it is not an overnight thing for international automated sampler enterprises to break through the encirclement and win market share; this requires systematic efforts, including far-sighted strategic positioning and continuous in-depth exploration of product and technology innovation. By accurately perceiving the market to build a differentiated value proposition, continuously innovating core technologies to improve product performance, expanding diversified sales channels, shaping a trustworthy brand image, and optimizing management to cultivate talents, enterprises will undoubtedly stand out in global competition and establish their position as outstanding industry leaders.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Suhartini S, Mahbubah AN, Basjir M, 2021, Marketing Strategy Design Based on Information Technology in Batik Small and Medium-Sized Enterprises in Indonesia. *Eastern-European Journal of Enterprise Technologies*, 6(13): 39–48.
- [2] Forghani E, Sheikh R, Hosseini SMH, et al., 2022, The Impact of Digital Marketing Strategies on Customer's Buying Behavior in Online Shopping Using the Rough Set Theory. *International Journal of System Assurance Engineering and Management*, 13(2): 625–640.
- [3] Mircea F, 2022, Social Media Profiling for the Development of Online Marketing Strategies. *Studies in Business and Economics*, 17(3): 80–89.
- [4] Abouzid I, Saidi R, 2023, Digital Twin Implementation Approach in Supply Chain Processes. *Scientific African*, 21: e01821. <https://doi.org/10.1016/j.sciaf.2023.e01821>

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

The Impact of Female Executives on the Digital Transformation of Enterprises: An Empirical Study Based on Listed Companies

Meixi Zhang*

The University of Warwick, Coventry CV4 8UW, UK

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: This study employs leadership contingency theory and resource dependency theory, utilizing financial data from Shanghai and Shenzhen A-share listed companies between 2012 and 2021. Ultimately, data samples from 4,742 companies were selected to empirically examine the impact and moderating role of female executives on corporate digital transformation. Findings reveal that the proportion of female executives positively promotes corporate digital transformation. Further analysis indicates that female executives drive digital transformation by enhancing corporate innovation investment and risk control capabilities. Supported by the heterogeneity analysis, it shows that this effect is more pronounced in high-tech industries, non-state-owned enterprises, and companies in economically developed regions. This study provides a gender-perspective theoretical explanation for the drivers of digital transformation and offers practical insights for optimizing corporate executive teams.

Keywords: Female executives; Digital transformation; Concentration of shareholding

Online publication: October 14, 2025

1. Introduction

As the core managerial force within enterprises, the role and influence exerted by management have increasingly become factors of significant attention. Whether it be the personal character of managers, their relationship with staff, or their gender, these elements profoundly impact management's strategic decision-making concerning the enterprise, thereby influencing its overall development. In this new era, female executives within corporate management have emerged from a state of non-existence, gradually increasing their representation and assuming greater authority. The distinctive contributions female executives make to organizations have garnered widespread attention^[1]. Based on traditional feminine attributes such as steadiness, inclusivity, and meticulousness, the integration of women into the workplace not only leverages their unique qualities but also injects a singular dynamism into corporate development.

2. Governance characteristics of female executives

Female executives are able to influence digital transformation through the following pathways.

2.1. Innovation-driven

Traditional perceptions suggest female managers lack innovative thinking. With rapid societal advancement, innovation has become an imperative for contemporary enterprises, and managers prioritize innovative decision-making for organizational growth. Furthermore, the professional environment for female executives has evolved, with workplace inequalities mitigated to some extent, creating greater developmental opportunities. In this era of accelerated progress, female managers increasingly cultivate innovative thinking to distinguish themselves from predominant male leadership, thereby proposing more creative ideas and decisions during management processes ^[2].

2.2. Risk balancing

The “networked thinking” characteristic of female managers offers greater integration capabilities than the “linear thinking” of their male counterparts ^[3]. This enables comprehensive consideration of an enterprise’s strengths, weaknesses, opportunities, and threats, alongside potential outcomes. The inherent caution of female managers also compensates for the overconfidence inherent in traditional male management styles, mitigating the pitfalls of reckless advancement. Consequently, when proposing risk-bearing decisions, they demonstrate greater assurance and higher implementation feasibility ^[4]. This facilitates steady corporate operations alongside innovative development, fostering greater adaptability to diversified growth trajectories. The inclusion of female managers introduces fresh perspectives and diverse ideas to management teams, fostering diversified thinking patterns.

2.3. Resource effects

According to resource dependence theory, female managers also play a unique role in promoting resource efficiency. Compared to their male counterparts, their inherent prudence not only curbs excessive investment and ensures rational planning and control of existing resources, but also enables higher resource utilization rates during transformative development ^[5]. Furthermore, it enhances corporate reputation. The steady management style of female executives attracts more collaborative partnerships with other enterprises, facilitating the acquisition of advantageous external resources ^[6].

3. Research design

3.1. Data sources

The data for this study were sourced from the GuoTaiAn Data Service Centre Database, selecting financial data from Shanghai and Shenzhen A-share listed companies between 2012 and 2021. The data underwent the following processing: (1) Financial sector listed companies were first excluded from the sample. (2) Companies with poor performance and consecutive losses, such as ST and PT listed companies, were excluded. (3) Companies listed on the STAR Market and the National Equities Exchange and Quotations (NEEQ) were excluded. (4) Firms lacking key data required for the study were excluded, thereby enabling an examination of the relationship between female executives and corporate digital transformation.

3.2. Model specification

To test the potential impact of female executive participation on corporate digital transformation, the following

model was constructed:

$$DT_{i,t} = \beta_0 + \beta_1 \ln X_{i,t} + \beta_2 \text{Controls}_{i,t} + \varepsilon_{i,t}$$

In the equation, i denotes the firm; t denotes time; β_0 denotes the constant term; β_1 and β_2 denote coefficients; Controls denotes the set of control variables; ε denotes the random disturbance term. The key focus in this model is the coefficient β_1 . If β_1 is significantly positive, it indicates that the participation of female executives promotes the firm's digital transformation.

3.3. Variable selection

The research variables in this paper are defined as follows:

- (1) Dependent variable: Digital transformation. The natural logarithm of the keyword frequency for digital transformation in listed companies' annual reports is taken to measure the degree of corporate digital transformation.
- (2) Independent variable: Proportion of female managers. Data on executive characteristics extracted from the GuoTaiAn database were processed for this study. The proportion of female executives is defined as the ratio of female executives to the total number of executives in the management team.
- (3) Control variables

3.4. Descriptive statistics

Descriptive statistics for key variables are presented in **Table 1**. As shown, the standard deviation of digital transformation level (dt) is 1.401, with a minimum value of 0 and a maximum of 6.301, indicating significant variation in firms' digital transformation levels. The mean proportion of female managers (x) is 0.18, suggesting a low representation of female executives in the sample firms.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Digital transformation	31848	1.414	1.401	0	6.301
Percentage of female executives	30182	0.18	0.171	0	1
Company size	31854	22.158	1.345	14.942	28.636
Capital structure	31854	0.426	0.442	0.008	63.971
Profitability	31854	0.032	0.126	-16.112	0.969
Two jobs in one	31854	0.3	0.458	0	1
Shareholding concentration	31854	34.041	14.973	0	89.991
Ownership of the enterprise	31854	0.319	0.466	0	1
Company age	31854	2.015	0.967	0	3.466

The minimum company size was 14.942, with a maximum of 28.636, indicating significant variation in the selected firms' scale. The average size of 22.158 suggests that, overall, the companies were relatively large in scale. The minimum equity concentration was 0, while the maximum reached 89.991, reflecting considerable disparity in equity concentration among the sample enterprises.

4. The impact of female executives on the digital transformation

Firstly, based on the aforementioned model, the relationship between female executives and corporate digital transformation was examined. The regression results are presented in **Table 2**.

Table 2. Benchmark regression results

Digital transformation	Coef.	St. Err.	t-value	P-value	95% Conf	Interval	Sig
Percentage of female executives	0.436	0.046	9.53	0	0.346	0.526	***
Company size	0.118	0.007	16.50	0	0.104	0.132	***
Capital structure	-0.135	0.028	-4.74	0	-0.19	-0.079	***
Profitability	-0.35	0.098	-3.57	0	-0.543	-0.158	***
Two jobs in one	0.152	0.018	8.54	0	0.117	0.186	***
Shareholding concentration	-0.009	0.001	-15.36	0	-0.01	-0.007	***
Ownership of the enterprise	-0.229	0.02	-11.54	0	-0.268	-0.19	***
Company age	-0.059	0.01	-6.08	0	-0.078	-0.04	***
Constant	-0.75	0.148	-5.08	0	-1.04	-0.46	***
Mean dependent var		1.432		SD dependent var		1.406	
R-squared		0.028		Number of obs		30175	
F-test		109.410		Prob > F		0.000	
Akaike crit. (AIC)		102942.910		Bayesian crit. (BIC)		103017.743	

*** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$

The results indicate that the regression coefficient between the proportion of female executives (x) and digital transformation (dt) is 0.436, significant at the 1% level. This demonstrates that the proportion of female executives can drive corporate digital transformation. Each additional unit of female executives increases digital transformation by 0.436 percentage points. Thus, Hypothesis 1 holds: the proportion of female executives exerts a positive influence on corporate digital transformation.

As demonstrated above, a significant positive correlation exists between female executive representation and corporate digital transformation. To examine this influence, equity concentration is introduced as a moderating variable to further analyze the role of female executives in digital transformation (**Table 3**).

Table 3. Results of moderating effects

Digital transformation	Coef.	St. Err.	t-value	P-value	95% Conf	Interval	Sig
Percentage of female executives	1.329	0.089	15.00	0	1.155	1.503	***
Inter	-0.027	0.002	-11.85	0	-0.031	-0.022	***
Company size	0.127	0.008	16.42	0	0.112	0.142	***
Capital structure	-0.418	0.047	-8.81	0	-0.511	-0.325	***
Profitability	-0.276	0.124	-2.23	0.026	-0.519	-0.033	**
Two jobs in one	0.153	0.018	8.62	0	0.118	0.188	***
Ownership of the enterprise	-0.258	0.02	-13.17	0	-0.297	-0.22	***
Company age	-0.032	0.01	-3.26	0.001	-0.05	-0.013	***
Constant	-1.184	0.159	-7.42	0	-1.496	-0.871	***

Table 3 (Continued)

Mean dependent var	1.432	SD dependent var	1.406
R-squared	0.027	Number of obs	30175
F-test	104.030	Prob > F	0.000
Akaike crit. (AIC)	102984.788	Bayesian crit. (BIC)	103059.621

*** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$

This paper further examines the moderating effect of equity concentration, testing Research Hypothesis 2 by incorporating equity concentration as a moderator variable, with *inter* representing the interaction term between equity concentration and the proportion of female managers. The regression results are presented in **Table 3**. The analysis reveals that, when the moderator interaction term *inter* is added to the baseline model, its coefficient is -0.027 and significant at the 1% level. This indicates that higher equity concentration is associated with a lower likelihood of achieving digital transformation, suggesting that equity concentration exerts a negative moderating effect between the proportion of female executives and corporate digital transformation. Hypothesis 2 is thus supported.

5. Suggestions

In recent years, an increasing number of women have been leveraging their strengths in business management, with the proportion of female executives gradually rising. They are playing an increasingly critical role in corporate development processes and strategic decision-making. Within the context of the digital economy, enterprises are not only encountering new opportunities brought about by technological advancement and industrial upgrading, but emerging industries are also providing female managers, who have historically received limited attention, with a platform for development ^[7]. This study empirically examines the potential influence of female executives on firms' digital transformation and the mechanisms through which this influence operates. The results are as follows:

In light of the demands posed by the digital economy and the persistence of the “glass ceiling” problem widely experienced by women in the workplace, this paper proposes the following practical recommendations:

Firstly, society should devote greater attention to women. In traditional narratives and prior academic literature, women have rarely occupied a central position. Earlier research has often portrayed female managers as embodying traits such as weakness or indecisiveness, thereby objectifying them by attributing socially constructed gendered characteristics while neglecting the managerial competencies they possess and the broader possibilities that emerge once women are empowered.

Second, the government and society should provide support in reducing barriers to women's professional development. Within the framework of China's “talent-driven development strategy”, female talent constitutes a vital component of human capital for advancing the high-quality growth of the digital economy. Yet, many practical challenges remain unresolved, requiring policy-level interventions. Protecting women's legitimate workplace rights from the perspective of female professionals is essential to enabling them to leverage their advantages, thereby creating favorable conditions for female executives to play an active role in driving digital transformation.

Third, enterprises should place greater emphasis on the contributions of women in organizational

management. The inclusion of female executives brings multiple benefits to management teams, as diverse leadership styles are conducive to steady operations and long-term development. Firms must strive to dismantle the “glass ceiling” in the workplace, promote gender diversity at the managerial level, and increase the proportion of female executives. However, a mere numerical increase is insufficient. Only when female executives are granted substantive decision-making power—rather than serving symbolic roles aimed at demonstrating fairness—can they fully realize their managerial potential. This is particularly crucial in areas such as digital transformation, which entail strategic risks. Female executives can help firms achieve their objectives by ensuring decision-making optimization, gaining competitive advantages in emerging markets, strengthening risk management, enhancing firms’ risk-bearing capacity, increasing innovation investment, and improving research and development, as well as scientific innovation capabilities ^[8].

Disclosure statement

The author declares no conflict of interest.

References

- [1] Vial G, 2019, Understanding Digital Transformation: A Review and a Research Agenda. *The Journal of Strategic Information Systems*, 28(2): 118–144.
- [2] Bu Z, Liu Z, 2021, The Impact of Female Leadership Characteristics on Enterprise Innovation Performance. *Journal of Inner Mongolia University of Finance and Economics*, 19(02): 131–135.
- [3] Wang L, Si J, Xing D, 2019, A Review of the Impact of Female Executives on the Performance of Listed Companies in China. *Journal of Hefei Normal University*, 37(02): 59–62.
- [4] Lei X, Wu J, Su T, et al., 2024, Managerial Humility, Performance Expectation Gap, and Strategic Risk-Taking. *Foreign Economics & Management*: 1–15.
- [5] Liu T, Yang Q, 2019, The Rise of “Her Power”: The Impact of Female Executive Participation on Corporate Innovation Strategy. *Economic Theory and Business Management*, 2019(08): 75–90.
- [6] Wu F, Hu H, Lin H, et al., 2021, Corporate Digital Transformation and Capital Market Performance: Empirical Evidence from Stock Liquidity. *Management World*, 37(07): 130–144 + 10.
- [7] Zhang M, 2024, The Impact of Digital Transformation on Enterprise Value from the Perspective of Enterprise Life Cycle, dissertation, Yunnan University of Finance and Economics.
- [8] Li X, Wang J, 2024, The Mechanism of Managers’ Digital Literacy on the Digital Transformation of SMEs. *Science and Technology Management Research*, 44(01): 106–116.

Publisher’s note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Managing Brand Image in the Digital Era: A Strategic Analysis of Dove's Advertising Controversy and Recovery Strategy

Suwen Xuan*

University of Southampton, Southampton SO17 1BJ, United Kingdom

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: Dove's 2017 advertising incident, which sparked widespread debate regarding perceived cultural insensitivity, highlighted a disconnect between the brand's "Real Beauty" positioning and public reception. In response, this study proposes a strategic digital recovery framework, including revised campaign content, transparent communication through social media, and data-driven customer segmentation based on diverse skincare needs and cultural backgrounds. A PESTLE analysis underscores the importance of digital transformation and rising social consciousness in brand management. Findings suggest that inclusive messaging, precision targeting, and omnichannel digital engagement are key to restoring brand trust and reputation in the digital landscape.

Keywords: Brand crisis; Digital marketing; Omnichannel strategy; Precision targeting; Customer segmentation; Inclusive branding

Online publication: October 14, 2025

1. Introduction

1.1. The Dove brand overview

Dove was founded in 1957, and its global expansion began in 1999. Today, Dove is the world's number-one cleaning brand, with sales in more than 80 countries and annual sales of more than 2.5 billion euros. Its success depends not only on the quality of its products but also on years of precise and targeted advertising. As early as 2006, Dove identified the problem of stereotypes that defined women's beauty and used this as a key entry point for marketing, creating the Dove Self-Esteem Project, which conducted several surveys and studies worldwide. Through research, Dove found that more than half of women worldwide have a poor opinion of their appearance, and up to 70% of women worldwide believe that external praise for their appearance and body is more likely to help them build confidence ^[1].

Dove followed up with "The Campaign for Real Beauty," a marketing campaign that emphasizes to

consumers that true beauty is not limited to white skin, long straight hair, and a perfect body, but rather that beauty is real and diverse, that each woman is a unique being full of personality. That true beauty exists in the form of a special person. Each woman is special, and true beauty exists in different shapes, sizes, ages, and skin tones. At the same time, Dove invited nine women who were confident and different from traditional beauty standards to model for the campaign, conveying different forms of beauty to the audience. Dove's anti-stereotyping marketing approach proved successful. This new form of advertising, which overturned the previous use of glamorous appearance to attract consumers' attention, helped women build self-confidence. At the same time, consumers' goodwill towards the brand was also naturally achieved.

1.2. Marketing controversy

In 2017, Unilever's Dove brand released an advertisement on its Facebook page that featured a visual sequence in which an African American woman appeared to transition into a White woman after applying body lotion, followed by a similar transition into an Asian woman ^[2]. This advertisement aimed to portray diverse forms of beauty. However, it provoked a heated online backlash. Many internet users accused Dove of lacking cultural sensitivity in the commercial. More than 3,000 comments under the tweet were overwhelmingly negative, and numerous social media users called for a boycott of the company's products.

It is evident from the public response to the advertisement that Dove's marketing approach encountered significant backlash. The primary causes of this setback appear to include insufficient understanding and consideration of diverse cultural backgrounds, the delivery of content perceived as inappropriate or potentially misleading, and a failure to align with the brand's stated commitment to celebrating diversity in beauty. Although this marketing controversy may not have an immediate impact on Dove's sales performance, the negative effect on brand reputation is apparent. Some consumers from underrepresented ethnic groups may reconsider their purchasing decisions in response to the incident. As a result, it is essential for Dove to implement a comprehensive strategy to restore its brand image. In today's era of rapid digital communication, where individuals consistently use online platforms to access and disseminate information, the effective use of digital media and social networks presents a viable pathway for brand recovery. This study proposes a digital portfolio strategy aimed at addressing the brand reputation challenge arising from this marketing controversy.

2. Digital portfolio

2.1. New advertising campaign

2.1.1. Revised ad content strategies

Timely revisions and replacing ambiguous advertising content would have minimized the damage to the brand's image from the failed campaign. They would have gone some way to calming emotional social media users. The main reason for the failure was that Dove did not truly follow its "Real Beauty" brand promise to consumers. The divisive nature of the campaign, which featured black models turning white after using Dove products, meant that viewers might have thought the campaign sent a signal that white skin was the standard of beauty. Although this may not have been Dove's intention, the lack of thoroughness and consideration in the production and marketing of the ad inevitably gave consumers the illusion of "visual metaphors" and caused strong dissatisfaction. Therefore, the first step in this crisis is to replace ambiguous ads with new ones. The following are two options for new content.

One of the most immediate and straightforward adjustments would be to alter the sequence of model

appearances in the advertisement. For example, the advertisement could begin with a model of lighter skin tone, who then transitions into a model with a darker skin tone, followed by a model with an intermediate skin tone. Such a change might reduce the degree of negative emotional response among certain audience groups and lower the risk of the advertisement being perceived as exhibiting cultural insensitivity. Nevertheless, given that any portrayal involving changes in skin tone may inadvertently lead individuals of specific backgrounds to feel singled out or misrepresented, a more effective approach could be to adopt a creative concept that avoids such associations altogether.

Secondly, an alternative approach could involve dividing the screen into three parallel panels, each featuring a different model with distinct skin tones, where each model is compared only to her own appearance before and after using Dove products. For example, prior to using the products, individuals may feel a need for greater self-confidence due to a perceived skin condition. After product application, the skin may appear more hydrated and radiant, thereby enhancing self-confidence and overall sense of well-being. The accompanying text could emphasize that beauty is diverse and cannot be defined by a single standard. This format not only underscores the functional benefits of the product but also conveys a constructive response to prior criticism, demonstrating the brand's commitment to equitable representation and its willingness to address concerns in a respectful and inclusive manner.

2.1.2. Expanding digital channels

Dove's strategic use of digital media platforms for crisis communication following a marketing controversy can serve as an effective reputational recovery approach. Senior executives could issue formal, empathetic statements via official social media accounts such as Facebook and Twitter, directly acknowledging the shortcomings in the campaign and addressing concerns regarding cultural representation. Such a transparent and proactive response may help preserve existing customer loyalty, as demonstrating a constructive attitude toward problem-solving can mitigate emotionally charged public reactions. Additionally, as discussions on social media gain traction, the heightened visibility may indirectly enhance brand awareness and introduce the company to new audiences, thereby creating opportunities for future market growth. In this sense, digital crisis communication can also function as a supplementary promotional tool.

Furthermore, Dove could consider shifting the emphasis of its promotional strategy from primarily offline channels to a more robust online presence, leveraging social media to foster constructive engagement. Given that online discourse surrounding the incident continues to attract public attention, the brand could utilize this momentum to disseminate content that reinforces its core values—such as the belief that beauty is best expressed through authenticity and should not be constrained by external definitions or physical attributes. Over time, as misconceptions surrounding the controversy diminish, such consistent value-driven messaging has the potential to cultivate a more positive and inclusive brand image for Dove.

2.2. New customer segmentation strategy

2.2.1. Customer understanding through cultural awareness

Customer segmentation and targeted marketing strategies enable Dove to design tailored promotional initiatives that align with diverse consumer needs and motivations. Consumers may engage with similar product categories for varied purposes, and a narrow focus on a single consumer profile risks alienating other segments. To mitigate the adverse effects of prior marketing controversies, Dove should consider re-segmenting its customer base

through structured market research, such as online and offline surveys. This segmentation can group consumers according to factors such as needs, preferences, price sensitivity, and lifestyle characteristics. Given that different demographic groups may exhibit distinct cultural norms, skincare routines, and dermatological needs, it is essential for personal care brands to prioritize product suitability for varying skin conditions and to develop culturally attuned marketing content, thereby avoiding ambiguous or potentially misinterpreted advertising messages.

As an initial step in the recovery strategy, Dove could categorize consumers into three broad demographic clusters based on shared characteristics, followed by direct surveys to identify the primary requirements of each cluster. Key research questions may include: What product attributes are most valued by each group? What functional benefits do consumers expect the product to deliver to their skin? Additionally, leveraging advanced analytics and big data can provide deeper market insights by identifying patterns in online behavior—such as frequently visited websites, common search terms, and purchase histories—within specific geographic regions. This information can be used to refine marketing messages and product positioning. Furthermore, Dove could enhance its online retail platform by incorporating segmented product navigation modules based on criteria such as skin type, sensitivity, and moisturization needs. Such an approach would enable a more personalized shopping experience, increasing the likelihood of meeting diverse consumer expectations. Ultimately, while certain core market preferences may appear uniform, recognizing and addressing nuanced differences is critical to achieving broader customer satisfaction and sustainable brand recovery.

2.2.2. Precision marketing

Compared with traditional offline marketing channels such as print media or public transport advertisements, digital marketing enables more precise audience targeting. Based on insights into consumer preferences, Dove can strategically place promotional content on frequently visited websites or within popular television programs. These campaigns may incorporate messages that emphasize inclusivity and respect for diversity alongside commercial product promotion, thereby aligning brand communication with broader social values. This approach is not intended to replace offline marketing but rather to emphasize the complementary relationship between online and offline strategies. For example, Dove could integrate online promotional activities with in-store experiential programs, enabling consumers to first acquire product knowledge through digital channels and subsequently engage in hands-on trials at physical retail locations. Such a hybrid approach can enhance customer engagement, build trust, and facilitate a more comprehensive understanding of product benefits. This combination of online and offline omnichannel marketing drives brand development ^[3]. This omnichannel marketing approach can take advantage of digital media to spread the brand message quickly. Still, it also allows consumers to enjoy the real feeling of using the product, which can better promote consumption.

3. Literature review

According to Kotler et al. ^[4], the digital era is referred to as the marketing 4.0 era, which is an approach to marketing that combines online and offline interactions between companies and their customers ^[4]. With digital integration into all aspects of business life and the ability of consumers to conduct purchasing activities through many channels, omnichannel marketing has become an emerging strategic phenomenon ^[5]. From the surface meaning of the phrase, omnichannel represents all channels together ^[6]. Companies that adopt omnichannel marketing need to use as many channels as possible to reach their target consumers. Whether it is social media,

email, news studies, or magazines, companies can gain new opportunities through these marketing channels ^[7]. Compared to traditional channel marketing, omnichannel integrates online and mobile in addition to physical and digital, enabling brands' advertising messages to be disseminated and noticed efficiently. Research by Gupta et al. ^[8] and Shah et al. ^[9] indicates that customer-centricity is a characteristic of omnichannel marketing. Whether through online channels or physical stores, consumers can shop for merchandise. High consumer acceptance or ratings are desired. In that case, companies adopting omnichannel marketing need to focus on consumers' search preferences and purchase behavior on online sites, subjective norms, and their perceptions of search behavior on online sites ^[7]. Nakano and Kondo ^[10] focused on purchase channels and media touchpoints to segment consumers. The idea proposed in this study is also to develop customer segmentation strategies regarding consumers' online browsing and purchasing preferences. Mateus ^[11] also showed that companies can offer consumers personalized choices and products in the widest possible way through online channels and reach their target customers through an omnichannel strategy, developing all points of contact with them to optimize the relationship between the brand and the customer.

Even though it is true that omnichannel marketing can bring chances to firms by combining new digital channels, this does not mean that it is ideal. There are still certain drawbacks. Few businesses are truly omnichannel because of the blurred distinction between physical and online in the omnichannel environment ^[12]. Additionally, it is simple for businesses to become immersed in the rapid growth of digital and lose focus, which disrupts the traditional physical environment. According to numerous studies, many businesses cannot profit from the omnichannel market in this environment, instead even appearing to compete ^[13]. For example, most omnichannel merchants operate in siloed structures. In other words, brick-and-mortar and online stores operate independently and compete adversarially rather than fostering complementary relationships ^[14].

In conclusion, it can be observed that even though the omnichannel format is beneficial, it is inevitable that there will be an excessive number of channels from which to pick, which will surely cause the marketing process to become overwhelmed. Therefore, there is still a need to examine how to achieve a healthy balance and stability between channels.

4. Conclusion

4.1. Strengths and limitations

This study examines a case of unsuccessful marketing involving a Dove advertising campaign that was widely perceived as conveying culturally insensitive messages. By analyzing the potential causes and consequences of the incident, this research proposes a digital portfolio to assist Dove in addressing the issue and restoring its brand image. The proposed portfolio consists of three key components: a revised advertising campaign, re-segmentation of the customer base, and refined targeting strategies. Timely replacement of the contentious advertisements with revised versions serves as a form of crisis communication, mitigating the adverse impact of public opinion while attracting renewed consumer attention. The revised segmentation strategy classifies customers according to diverse skin characteristics across different demographic groups, enabling the application of big data analytics to deliver targeted marketing. This integrated approach addresses the immediate reputational challenges arising from the marketing failure while supporting Dove's long-term brand development.

Nevertheless, certain limitations exist within this digital portfolio. Given that the analysis centers on a single case of marketing misjudgment with perceived cultural insensitivity, the initial priority lies in correcting consumer

misconceptions regarding the brand's stance on diversity and inclusion. This can be achieved by providing contextual clarification and illustrative examples. The analysis does not, however, account for other contributing factors that may have influenced the campaign's failure. Furthermore, while the proposed customer segmentation approach enhances precision, it would require additional refinement and careful consideration to ensure effective application in practice.

4.2. PESTLE-based recommendations

In the aftermath of the early-2020s global health crisis, consumer spending in offline channels, such as physical retail stores, has declined, accompanied by a certain degree of global economic slowdown. Conversely, the digital economy experienced rapid growth during this period, with consumers increasingly shifting their purchasing behavior from traditional brick-and-mortar outlets to online platforms. This shift, while creating growth opportunities in e-commerce, has also intensified operational challenges for physical stores. The broader changes in the socio-economic environment have accelerated the adoption of digital consumption as a mainstream trend, presenting opportunities for companies pursuing omnichannel marketing strategies. For brands such as Dove, this transformation provides a pathway to address brand-related misperceptions through digital engagement channels, including social media.

Simultaneously, the process of digital transformation is closely tied to advancements in technology. The recovery strategies outlined in this study can only be effectively implemented with robust technical infrastructure, particularly in optimizing corporate websites and leveraging big data analytics for customer segmentation. However, it is important to note that the pace of regulatory updates may lag behind the rapid evolution of the digital environment, potentially leading to insufficient oversight in certain areas. This regulatory gap can, in some cases, enable enterprises to exploit legal loopholes or engage in unhealthy competitive practices, which may undermine long-term corporate sustainability. In conclusion, to navigate the current marketing challenge and ensure sustainable growth, Dove should capitalize on the opportunities presented by digitalization, employ technology-driven public relations initiatives, and mitigate the impact of reputational risks in a compliant and ethically sound manner.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Dove, 2019, Our Research, Dove US, viewed July 23, 2025, <https://www.dove.com/us/en/stories/about-dove/our-research.html>
- [2] Slawson N, 2017, Dove Apologises for Ad Showing Black Woman Turning into White One. The Guardian, viewed July 23, 2025, <https://www.theguardian.com/world/2017/oct/08/dove-apologises-for-ad-showing-black-woman-turning-into-white-one>
- [3] Manser Payne E, Peltier JW, Barger VA, 2017, Omni-Channel Marketing, Integrated Marketing Communications and Consumer Engagement. *Journal of Research in Interactive Marketing*, 11(2): 185–197.
- [4] Kotler P, 2017, *Marketing 4.0: Moving from Traditional to Digital*, John Wiley & Sons, Hoboken, New Jersey.
- [5] Sutton-Brady C, Spencer R, 2022, Guest Editorial: Interactions, Relationships and Networks in a Digital Era. *Journal*

- of Business & Industrial Marketing, 37(11): 2141.
- [6] Juaneda-Ayensa E, Mosquera A, Sierra Murillo Y, 2016, Omnichannel Customer Behavior: Key Drivers of Technology Acceptance and Use and Their Effects on Purchase Intention. *Frontiers in Psychology*, 7: 1–11.
 - [7] Riantini RE, 2019, The Effect of Omni-Channel Marketing on the Online Search Behavior of Jakarta Retail Consumers with Theory of Planned Behavior (TPB) Approach, 2019 International Conference on Information Management and Technology (ICIMTech), 1.
 - [8] Gupta S, Lehmann DR, Stuart JA, 2004, Valuing Customers. *Journal of Marketing Research*, 41(1): 7–18.
 - [9] Shah D, Rust RT, Parasuraman A, et al., 2006, The Path to Customer Centricity. *Journal of Service Research*, 9(2): 113–124.
 - [10] Nakano S, Kondo FN, 2018, Customer Segmentation with Purchase Channels and Media Touchpoints Using Single Source Panel Data. *Journal of Retailing and Consumer Services*, 41: 142–152.
 - [11] Mateus AF, 2021, Omnichannel Marketing and Consumer Behavior. *Marketing and Smart Technologies*, 205: 347–361.
 - [12] Bucklin RE, Gupta S, 1992, Brand Choice, Purchase Incidence, and Segmentation: An Integrated Modeling Approach. *Journal of Marketing Research*, 29(2): 201.
 - [13] Neslin SA, Shankar V, 2009, Key Issues in Multichannel Customer Management: Current Knowledge and Future Directions. *Journal of Interactive Marketing*, 23(1): 70–81.
 - [14] Rigby D, 2011, The Future of Shopping, *Harvard Business Review*, viewed July 23, 2025, <https://hbr.org/2011/12/the-future-of-shopping>

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Research on the Application of Cash Flow Forecasting Models in Enterprise Investment and Financing Decisions

Chenxu Wang*

Massey University, Palmerston North 4442, New Zealand

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: Cash flow is a core element for enterprises to maintain operations and development. Cash flow forecasting models, through systematic analysis of an enterprise's historical cash flow data, trends in operating activities, and external environmental factors, scientifically predict the scale, direction, and fluctuation of cash flow within a certain period in the future. This article focuses on the application of cash flow forecasting models in enterprise investment and financing decisions, sorts out the types and core functions of the models, analyzes their specific roles in investment project screening, financing plan formulation, risk prevention and control, and fund allocation, points out the existing problems in current applications, and proposes optimization paths. Research shows that the scientific application of cash flow forecasting models can enhance the accuracy and rationality of enterprises' investment and financing decisions, and help enterprises achieve sustainable development.

Keywords: Cash flow forecasting model; Enterprise investment decision-making; Enterprise financing decisions; Capital allocation; Risk prevention and control

Online publication: October 14, 2025

1. Introduction

Investment and financing decisions are at the core of an enterprise's strategy and directly affect its survival, development, and competitiveness. Traditional decision-making relies on experience or a single indicator, is easily influenced by subjective factors, and is difficult to deal with complex risks. Cash flow reflects the actual movement of a company's funds, and its stability determines the feasibility of investment and financing. Cash flow forecasting models, driven by data and featuring dynamic adjustment mechanisms, provide an objective and quantitative basis for decision-making, helping to identify funding gaps, optimize allocation, and avoid risks. In-depth research on its application is of great significance for improving the financial management level of enterprises and enhancing the scientific nature of decision-making.

2. Core types and operating mechanisms of cash flow forecasting models

2.1. The main types of cash flow forecasting models

Cash flow forecasting models can be classified into three categories based on data sources, methods, and scenarios. Trend prediction models take historical cash flow as the core and identify changing trends through time series analysis. They are suitable for enterprises with stable operations and small external fluctuations. The causal prediction model analyzes internal and external driving factors, establishes causal equations for variables, and is suitable for enterprises whose business is closely related to the outside world. The rolling prediction model dynamically updates data, shortens the cycle, and enhances timeliness, making it suitable for enterprises with volatile markets. Enterprises need to select or combine models based on their own characteristics to achieve comprehensive prediction ^[1].

2.2. The operating mechanism of cash flow forecasting models

The operation of a cash flow forecasting model needs to go through four core links: data collection, indicator construction, model operation, and result verification. During the data collection stage, it is necessary to comprehensively collect relevant data on the enterprise's business operations, including detailed historical cash flow, revenue and cost data, information on changes in assets and liabilities, accounts receivable and accounts payable cycle data, as well as external information such as industry development data and macroeconomic indicators, to ensure the completeness and accuracy of the data. During the indicator construction stage, it is necessary to screen key predictive indicators, such as the growth rate of operating cash flow, cash turnover days, and sales cash collection rate, etc., and clarify the logical relationships among the indicators to lay the foundation for model operations ^[2]. In the model operation stage, by applying statistical methods, machine learning algorithms, and other tools, historical data and predictive indicators are substituted into the model to generate the prediction results of future cash flows. At the same time, a fluctuation range is set to reflect the uncertainty of the prediction.

3. Specific applications of cash flow forecasting models in enterprise investment decisions

3.1. Feasibility assessment of investment projects

When enterprises screen investment projects, they need to comprehensively assess the project's income-generating capacity and capital recovery situation. The cash flow prediction model is the core tool for feasibility assessment ^[3]. By predicting the cash inflows and outflows throughout the entire life cycle of an investment project through a model, key data such as the initial investment scale of the project, operating cash flow during the operation period, and residual value recovery at the end of the period can be clearly presented, helping enterprises determine whether the project can achieve net cash inflows. At the same time, based on the prediction results, core evaluation indicators such as net present value, internal rate of return, and payback period of investment are calculated to quantify the profit potential and risk level of the project, avoiding decision-making deviations caused by only focusing on accounting profits while ignoring the time value of funds. For multiple candidate projects, the model can screen out the investment projects that match the enterprise strategy and have the best capital return by comparing the cash flow prediction results and evaluation indicators of different projects, thereby enhancing the scientific nature of investment decisions ^[4].

3.2. Fund planning for investment projects

The implementation of investment projects often requires long-term and continuous capital input. If the capital

planning is unreasonable, it is easy to have a shortage or idleness of funds, which will affect the project progress and the efficiency of capital utilization ^[5]. Cash flow forecasting models provide a basis for enterprises to formulate phased capital investment plans by accurately predicting the capital requirements at each stage of investment projects. For instance, during the project construction phase, the model can predict the time and scale of cash outflows for fixed asset investments such as equipment procurement and engineering construction. During the project operation stage, it is possible to predict operating cash outflows, such as raw material procurement, labor costs, and operating expenses, as well as operating cash inflows, including product sales revenue and service revenue. Based on the prediction results, enterprises can make advanced arrangements for fundraising to ensure that funds are in place in a timely manner at each stage. At the same time, it is necessary to rationally plan the use of idle funds, such as short-term financial investment, to improve the efficiency of fund utilization, reduce capital costs, and ensure the smooth progress of investment projects ^[6].

3.3. Performance monitoring of investment projects

Performance monitoring after the implementation of an investment project is a crucial step to ensure that the project achieves its expected goals. Cash flow prediction models can serve as the core tool for performance monitoring, enabling dynamic tracking and evaluation of the actual operation of the project. By conducting real-time comparisons between the actual cash flow data of the project and the predicted cash flow data, the reasons for the differences are analyzed, such as whether they are caused by changes in the market environment, poor management, or model prediction deviations. If the differences stem from changes in the external environment, enterprises can promptly adjust their business strategies. If the problem stems from the prediction deviation of the model, the model parameters and assumptions can be optimized to enhance the accuracy of subsequent predictions. If it stems from management and operation issues, internal control can be strengthened and operational efficiency improved ^[7]. Through continuous performance monitoring and feedback, enterprises can promptly identify problems in investment projects and take measures to correct them, ensuring that the projects always move towards the expected goals and maximizing investment returns.

4. Specific applications of cash flow forecasting models in corporate financing decisions

4.1. Determination of the scale of financing demand

When enterprises make financing decisions, they first need to clearly define a reasonable scale of financing demand. A financing scale that is too small may not meet the business operation and investment needs of the enterprise, while a scale that is too large will increase financing costs and financial risks. Cash flow forecasting models calculate the company's capital gap or surplus by comprehensively predicting the cash flows from its operating and investment activities within a certain period in the future, thereby determining a reasonable financing scale ^[8]. For instance, the model can predict the operating cash inflows, cash outflows from investment projects, and cash outflows from debt repayment of an enterprise within the next year. By analyzing the difference between cash inflows and outflows, the amount of external financing required by the enterprise can be determined. Meanwhile, the model can take into account the enterprise's demand for safe capital reserves. When calculating the financing scale, it reserves a certain amount of capital buffer space to avoid the breakage of the capital chain due to unexpected situations, ensuring that the financing scale not only meets the actual needs but also avoids idle and wasted funds.

4.2. Selection of financing methods

Enterprise financing methods include various types, such as equity financing, debt financing, financial leasing, and supply chain finance. The costs, risks, terms, and impacts on enterprise control rights of different financing methods vary^[9]. Cash flow forecasting models provide a basis for the selection of financing methods by analyzing the stability, growth trend, and repayment ability of a company's future cash flow. For enterprises with stable future cash flow and strong repayment capacity, priority can be given to debt financing, such as bank loans and bond issuance, to enhance corporate profits through financial leverage without diluting shareholders' control rights. For enterprises with significant cash flow fluctuations and in the growth stage, equity financing can reduce debt repayment pressure and avoid excessive financial risks, making it suitable as the main financing method. For enterprises that need to purchase large-scale equipment, financial leasing can alleviate the pressure of one-time capital expenditure. By paying rent in installments, it can match the cash flow inflow during the equipment usage process and optimize the allocation of funds. Through the simulation and analysis of the cash flow status of enterprises under different financing methods by the model, the most suitable financing method for the current development stage and financial status of the enterprise can be selected^[10].

4.3. Matching of financing terms and control of financing costs

The matching of the financing period with the period of capital demand is the foundation for reducing financing risks and optimizing capital costs, and the cash flow forecasting model is the key tool to achieve this goal. The model helps enterprises precisely match financing terms by predicting the time distribution and duration of capital demands: for short-term demands such as seasonal inventory purchases, it guides the selection of commercial credit, short-term loans, and other methods to avoid the additional costs of long-term financing. For long-term demands such as fixed asset investment, support is provided for the selection of long-term loans, equity financing, and other methods to avoid the risks of the capital chain caused by the maturity of short-term financing and achieve a dynamic balance of terms. Meanwhile, the model can simulate the cash flow expenditures of different financing plans and identify the cost composition and influencing factors. By calculating explicit costs such as loan interest rates and dividend yields, and taking into account implicit costs such as transaction fees and guarantee fees, the actual costs of each plan are comprehensively evaluated^[11]. Based on the prediction results, enterprises can choose the solution with the lowest cost or negotiate the optimization terms. It is also possible to repay high-cost debts in advance based on future cash flow surplus forecasts, further reducing costs and enhancing financial efficiency.

5. Problems and optimization paths in the application of cash flow forecasting models

5.1. Main problems in the application of cash flow forecasting models

At present, when enterprises apply cash flow forecasting models, there are still many problems that restrict the role of the models. Insufficient data quality is the primary issue. The historical cash flow data records of some enterprises are incomplete and inaccurate, and the channels for obtaining external market data and macroeconomic data are limited, resulting in a lack of reliable data support for the model and significant deviations in the prediction results^[12]. The insufficiency of model adaptability is also quite prominent. Many enterprises fail to select the appropriate model type based on their own business characteristics and industry attributes, blindly applying general models while ignoring personalized factors such as business models and cash flow cycles. As a result, the models cannot accurately reflect the actual cash flow situation of the enterprises. The absence of a

dynamic adjustment mechanism for the model also affects the prediction effect. Most enterprises fail to update the parameters and assumptions for a long time after the model is constructed, and thus cannot respond in a timely manner to the impacts brought by changes in the market environment and adjustments in business strategies, resulting in a disconnection between the prediction results and the actual situation ^[13]. In addition, the collaboration between enterprise financial personnel and business personnel is insufficient. Financial personnel lack an in-depth understanding of business processes, and business personnel do not fully participate in the design of model indicators and data provision. This makes it impossible for the model to comprehensively integrate information from the business end, further reducing the prediction accuracy.

5.2. Strategies for improving data quality

Improving data quality is the foundation for optimizing the application of cash flow forecasting models. Enterprises need to establish a complete data management system, standardize the recording standards of historical cash flow data, clarify the scope, frequency, and responsible subjects of data collection, and ensure that cash flow data related to operating activities, investment activities, and financing activities are comprehensively, accurately, and timely entered into the system to avoid data omissions or errors. Strengthen the ability to integrate external data. By connecting with industry databases, macroeconomic information platforms, supplier and customer systems, obtain complete external information such as market demand data, raw material price data, industry competition data, and macroeconomic indicators, and enrich the data sources of the model ^[14]. Establish a data quality review mechanism, regularly verify and clean the collected internal and external data, identify and correct abnormal and duplicate data, and ensure the authenticity and validity of the data. At the same time, data quality evaluation indicators such as data integrity rate, accuracy rate, and timeliness rate are introduced to continuously monitor and improve data quality, providing high-quality data support for the model.

5.3. Model adaptability optimization and collaborative capability building

To optimize the adaptability of the model, it is necessary to combine the operational characteristics of the enterprise, including the business model, cash flow cycle, industry attributes, and development stage, and clarify the core influencing factors to select the appropriate model. Diversified business enterprises can be modeled by sector and then summarized and integrated. For growth-stage enterprises, it is advisable to choose a rolling prediction model to adapt to dynamic changes. At the same time, the best solution can be screened through model testing and comparison of deviations. Regularly evaluate and adjust the model type and indicators to ensure they match actual needs. To ensure the effective application of the model, it is necessary to establish a financial and business collaboration mechanism, break down information barriers, form cross-departmental teams, and clearly define that financial personnel are responsible for model construction and operation, while business personnel participate in indicator design and data verification, promoting the full integration of business information ^[15]. Strengthen personnel training, enhance the data analysis and model optimization capabilities of financial staff, popularize cash flow management knowledge among business personnel, and increase their enthusiasm for participation. Establish a feedback mechanism to encourage all departments to offer opinions on the differences between predictions and actual situations, solve problems in a timely manner, and form a collaborative optimization situation.

6. Conclusion

Cash flow forecasting models are important tools for enterprise financial management and play a crucial role in investment and financing decisions. Scientific application can enhance the efficiency of project evaluation, optimization of financing plans, risk prevention and control, and capital allocation, and promote enterprises to achieve their strategic goals. The problems in the current application need to be solved through data management, model optimization, and collaborative construction. In the future, with the development of technology, models will become more intelligent and dynamic. Enterprises should attach importance to their construction and application, enhance their scientificity and practicality, support decision-making with precise management, strengthen competitiveness, and achieve sustainable development.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Fang Y, 2024, The Role of Optimizing Fund Management in Enterprise Investment and Financing Decisions. *Accounting of Township Enterprises in China*, (16): 61–63.
- [2] Du P, 2024, Risks and Avoidance Strategies of Enterprise Investment and Financing. *Investment and Cooperation*, (08): 41–43.
- [3] Chen Z, 2024, Exploration of Key Points of Cash Flow Management in Private Enterprises. *Sales & Management*, (24): 66–68.
- [4] Lu S, 2024, Analysis of the Management and Control of Small and Micro Enterprises from the Perspective of Investment and Financing. *Modern Audit and Accounting*, (06): 43–45.
- [5] He J, 2024, Risk Assessment and Preventive Measures in Investment and Financing Decisions. *Guangdong Economics*, (11): 73–75.
- [6] Chen Y, 2024, A Brief Analysis of the Impact of Cash Flow Management on the Stability of Business Operations. *Modern Business Research*, (11): 56–58.
- [7] Wang T, 2023, Discussion on Enterprise Cash Flow Management under Internet Finance Model. *Wealth Management*, (11): 38–39 + 42.
- [8] Zheng Y, Wu S, 2023, Research on Bond Default Early Warning Models Based on Financial and Non-Financial Information: Empirical Analysis and Application of Fisher Model and Logistic Model. *Finance and Accounting Monthly*, 44(12): 22–29.
- [9] Research Group of Investment and Financing Professional Committee of China Construction Accounting Society, Ma Y, Qu X, et al., 2023, Research on the Evaluation System of Investment and Financing Capacity in the Engineering Construction Industry. *Architecture*, (02): 48–56.
- [10] Ma Y, Qu X, 2023, Industry Investment and Financing Development Practice and Innovative Exploration. *Construction Enterprise Management*, (02): 68–70.
- [11] Jiang M, 2022, Analysis of Free Cash Flow and Enterprise Value Evaluation. *Business Culture*, (05): 84–85.
- [12] Wen S, Chai M, 2021, Discounted Cash Flow Method: Interpretation and Application Cases. *Friends of Accounting*, (09): 149–155.
- [13] Qiu S, Yang Q, 2020, Research on the Value of Listed Companies Based on Discounted Free Cash Flow Model: A

Case Study of ZTE Corporation. *National Circulation Economy*, (25): 76–79.

- [14] Tang X, Chen C, Xu R, 2020, Analyst Revision Behavior, Cash Flow Forecast and Investor Response: A Study from the Perspective of Unexpected Earnings. *Friends of Accounting*, (12): 13–21.
- [15] Li C, 2020, Research on the Construction of China's Treasury Cash Flow Forecasting System: Macro Thinking and Practical Exploration. *Economic Research Reference*, (03): 39–59.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

A Study on the Risks Associated with On-Balance Sheet Recognition of Data Resources

Xia Xiao*

Shanghai University of Political Science and Law, Shanghai 201804, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: This study focuses on the risks associated with the on-balance sheet recognition of data resources. At the legal level, disputes over ownership often arise due to unclear data property rights, while privacy protection, cybersecurity, and cross-border data flows create additional compliance challenges. In terms of recognition, the subjectivity of traditional valuation methods, the lack of active markets, and the rapid depreciation of data value caused by technological iteration hinder reliable measurement. With respect to disclosure, organizations face a dilemma between transparency and confidentiality. Collectively, these issues exacerbate audit risks. It is therefore imperative to establish an appropriate legal, accounting, and auditing framework to mitigate such risks and remove barriers to the proper recognition of data assets on balance sheets.

Keywords: Data resources; On-balance sheet recognition; Valuation uncertainty; Information disclosure; Risk

Online publication: October 14, 2025

1. Introduction

With the deepening development of the digital economy, data has been widely regarded as the “fifth factor of production.” The volume of data in China has exhibited explosive growth, making the country one of the leaders in the rapid expansion of the digital economy. Under this background, the Chinese government has proposed incorporating data into the national strategic resource system. To promote the deep integration of the digital economy with the real economy, the Ministry of Finance of China issued the Interim Provisions on Accounting Treatment of Enterprise Data Resources (hereinafter referred to as the “Interim Provisions”) in 2023, allowing companies to recognize data resources as assets in their balance sheets, provided that recognition and measurement criteria are met ^[1].

This policy represents the first formal accounting standard worldwide that explicitly permits enterprises to recognize data resources on the balance sheet, marking a milestone in accounting regulation. As of April 30, 2025, among more than 5,000 A-share listed companies in China, 100 had recognized data assets on their balance sheets,

with a total reported amount of 2.164 billion yuan. With the continuous advancement of the digital economy and further implementation of this policy, the number of listed companies recognizing data resources as assets is expected to increase. This institutional innovation not only responds to the practical demands of the digital economy but also raises profound theoretical and practical issues, particularly in the domain of risk identification, which merits in-depth exploration.

Currently, some scholars have attempted to establish theoretical foundations for the identification and measurement of data assets^[2-5]. However, comprehensive risk analyses concerning “on-balance sheet recognition” remain insufficient, especially regarding the systematic review of risks across multiple dimensions, including measurement, legal compliance, information disclosure, and auditing. From the perspectives of accounting and auditing, this paper seeks to systematically identify and analyze potential risks in the recognition of data assets on balance sheets, with the aim of providing theoretical support and policy recommendations for improving relevant accounting standards, enhancing corporate information disclosure, and reducing auditors’ risk exposure.

2. Literature review

2.1. Institutional basis for the on-balance sheet recognition of data resources

At present, major global accounting standard-setting bodies, including the International Accounting Standards Board (IASB), the Financial Accounting Standards Board (FASB), and the Australian Accounting Standards Board (AASB), have not yet issued explicit provisions regarding the recognition of data resources on balance sheets. However, the IASB, in its Conceptual Framework for Financial Reporting (2018), redefined the concept of an asset as “a present economic resource controlled by the entity as a result of past events, where an economic resource is a right that has the potential to produce economic benefits”^[6]. This definition marks a significant departure from previous conceptualizations. First, the new definition explicitly states that an asset is the economic resource itself, rather than the future economic benefits it may generate; second, it no longer emphasizes the expectation of an inflow of economic benefits. Thus, the IASB’s new definition has relaxed the criteria for recognizing assets in terms of rights, control, and economic resources, effectively removing a fundamental obstacle to recognizing data resources as accounting assets^[7].

China’s Basic Standard for Enterprise Accounting Standards defines assets as “resources formed as a result of past transactions or events, owned or controlled by an enterprise, and expected to bring future economic benefits to the enterprise”^[8]. This standard does not redefine the concept of assets but continues to follow the IASB’s 2010 definition. Under the current framework, only when data resources are acquired or transferred in the course of an enterprise’s operations, are actually controlled by the enterprise or its departments, and are expected to generate value, do they meet the criteria for recognition as assets under accounting standards^[9]. Evidently, many data resources fail to meet this definition.

In early 2022, the Ministry of Finance of China initiated research on the on-balance-sheet recognition of data resources. A draft of the Interim Provisions was released for public consultation in December 2022, and the final version was officially issued on August 21, 2023. This policy addresses key issues related to the accounting recognition, measurement, and reporting of data resources on balance sheets. Since the current accounting standards have not expanded the scope of asset recognition within financial statements, the Interim Provisions deliberately adopted the term “data resources” rather than “data assets,” thereby circumventing the definitional constraints imposed by existing Chinese enterprise accounting standards on the concept of assets.

Consequently, a formal institutional basis has been established for recognizing data resources as accounting assets.

2.2. Recognition and measurement of data assets

The Interim Provisions apply to two categories of data resource accounting treatments. The first category includes data resources that can be recognized as intangible assets or inventories under existing accounting standards. The second category comprises data resources that meet the definition of an asset but do not satisfy the recognition criteria for assets. The accounting treatment of data resources involves the application of standards such as Accounting Standard for Business Enterprises No. 1–Inventories, No. 6–Intangible Assets, and No. 14–Revenue, along with their respective implementation guidelines. In applying these standards, the commercial purpose of holding data resources, their formation process, and the associated business models must be considered to determine their recognition, initial measurement, and subsequent measurement.

The China Academy of Information and Communications Technology (CAICT) proposed three principles for data asset recognition in its report *Data Assetization: Research on Data Asset Recognition and Accounting Measurement* (2020): realizability, controllability, and quantifiability^[10]. Therefore, the recognition of data assets first requires identifying data resources that possess economic value for the relevant economic entity. Unlike other assets, the value of data resources depends on the entity that controls them. A dataset recognized as an asset under one entity's control may lose its economic value if transferred to another entity, or even under the same entity, its value may vary depending on business operations. Thus, recognition should carefully consider the controlling entity, the value creation model, and the measurement approach.

Currently, the main valuation methods for data resources include the cost approach, the income approach, and the market approach. In addition, non-arbitrage pricing, Shapley pricing, and Ramsey pricing methods have been proposed^[11]. Regarding accounting measurement, two major perspectives prevail: one advocates a single measurement attribute, allowing data assets to be measured at historical cost, fair value, or present value^[12,13]; the other supports a mixed measurement attribute. For data assets used internally or sold externally with ownership transferred, both initial and subsequent measurements adopt historical cost. For those sold externally with only usage rights transferred, initial measurement uses historical cost, while subsequent measurement applies fair value^[14].

Although both academic and practice have explored various valuation methods for data resources, significant challenges remain, including the subjectivity of traditional valuation approaches and the lack of active markets. Furthermore, consensus has yet to be reached on the selection of appropriate accounting measurement attributes for data resources. Consequently, recognizing data assets on balance sheets under the current conditions entails inherent risks.

3. Risks in on-balance sheet recognition of data assets

3.1. Legal and compliance risks

According to both China's Enterprise Accounting Standards and the International Accounting Standards Board (IASB) definition of assets, one of the core criteria is that the enterprise must "own or control" the resource. This ownership and control essentially reflect the property rights of data resources. In practice, however, the ownership of data is often difficult to clearly define. During multi-party participation in data processing, the rights and boundaries among enterprises, users, and other stakeholders involved in the generation, collection, processing, storage, and utilization of data are frequently ambiguous, creating a high risk of disputes over ownership or control^[15].

Moreover, the realization of data resource value depends on continuous processing, analysis, utilization, and sharing. If the data recognized on the balance sheet contain personal information collected without sufficient user authorization, used beyond its originally intended purpose, or lack necessary security protection measures, the entire data processing activity may be deemed unlawful. This not only could render the data asset valueless but may also trigger severe administrative penalties, civil compensation claims, or even criminal liability. Furthermore, in the event of a data breach or other security incident, companies face reputational damage, user attrition, and related derivative risks.

For enterprises engaged in cross-border operations or reliant on global cloud computing services, their data resources are often subject to cross-border storage or processing. Cross-border data transfer is strictly regulated under statutory procedures. Data transferred abroad in violation of these procedures cannot be legally “controlled” or “utilized,” and recognizing such data as assets entails significant legal risks. For example, before transmitting data resources overseas, enterprises must undergo a security assessment organized by national cybersecurity authorities, sign standard contracts prescribed by those authorities, or obtain personal information protection certification. If any of these legal procedures are bypassed, enterprises may face orders to suspend transmission, mandatory data repatriation, substantial fines, or even revocation of related business licenses. Such penalties not only nullify the value of the affected data assets but may also disrupt the company’s entire international business chain.

3.2. Uncertainty risks of data resources valuation

3.2.1. Subjectivity and limitations of valuation methods

As a unique non-physical asset, the value realization of data resources is heavily dependent on specific scenarios, technological conditions, and market environments. Currently, the assessment of data assets generally adopts the three traditional methods used for intangible assets: the cost approach, the income approach, and the market approach. However, each of these methods exhibits significant limitations.

The cost approach determines the value of data assets by summing up the expenses incurred in acquiring or creating them. However, the value of data often diverges greatly from its historical cost. Enterprises may invest substantial resources in data collection, cleansing, and storage system development, only to find that the resulting dataset has little or no commercial value due to poor quality or lack of application scenarios. Conversely, user behavior data obtained at low cost during service provision may hold substantial commercial value. Thus, the cost approach fails to reflect the true relationship between value and investment, potentially leading to overvaluation or undervaluation. Moreover, the cost structure of data assets is complex, with many joint costs being difficult to allocate accurately, undermining the reliability of this method.

The income approach estimates the current value by discounting the expected future economic benefits generated by the data asset. While this method aligns closely with the essence of asset definition under accounting standards, it poses significant practical challenges. The inflow of future economic benefits from data assets is highly uncertain, making the selection of parameters inherently subjective and increasing the risk of misvaluation. The IASB has also repeatedly discussed the challenges of recognizing and measuring intangible assets due to the difficulty in proving a stable and identifiable stream of future economic benefits.

The market approach estimates value by identifying transaction prices of identical or similar data assets in an active market. However, this method requires the existence of a public, active, and transparent market with comparable transactions. Currently, most data markets suffer from insufficient trading activity, difficulties in

ownership confirmation, and pricing uncertainty, hindering effective price discovery mechanisms.

Consequently, under the current asset valuation framework, data assets bear substantial valuation uncertainty risks. It is debatable whether the data assets recognized on balance sheets using these methods can truly represent an enterprise's actual financial position.

3.2.2. Rapid value depreciation due to technological advancements and business iteration

The value of data assets is highly dependent on the technologies that process them and the associated business models. Due to rapid technological advancements and frequent business iterations, data assets exhibit high time sensitivity. Data value is not static; it tends to decline over time, often at a rate faster than technological obsolescence itself. The value lifecycle of enterprise data assets is thus shortening, making it essential to establish dynamic and continuous mechanisms for valuation and revaluation^[16]. Clearly, there is a misalignment between the current accounting measurement and disclosure framework and the characteristics of data resources, resulting in disclosed data information failing to reflect their true value.

3.3. Information disclosure risks

Information disclosure is essential for reducing information asymmetry. However, the complexity, incompleteness, and valuation uncertainty of data resources create a dilemma for data asset disclosure. These characteristics lead to a decline in the quality of disclosures. The diversity of data resource types, coupled with inconsistent formats, increases the difficulty of integration and processing. During data collection, processing, and storage, limitations of data resources, technical malfunctions, or human errors may prevent the data from fully and accurately reflecting the underlying reality.

As a result, investors and regulators require detailed knowledge of valuation assumptions and measurement models; otherwise, a single figure on the financial statements may mislead investors. This necessitates the disclosure of non-financial information related to data resource valuation. However, excessive disclosure may inadvertently reveal trade secrets or even compromise data security.

Existing research suggests that the market often reacts positively to the disclosure of data assets, interpreting it as a signal of innovation capacity and future profitability^[17,18]. Nevertheless, there is currently no unified framework for data resource disclosure, granting companies significant discretion in determining what to disclose. This may result in selective or strategic disclosure, which neither accurately reflects value nor contributes to market stability, and may even distort market expectations.

3.4. Audit risks

In the current context, where data asset trading and circulation mechanisms are still in their infancy, legal and regulatory systems are under development, and valuation practices face significant limitations, the accounting treatment of data assets is prone to substantial audit risks. These risks primarily arise from challenges in confirming existence, rights and obligations, valuation and allocation, and the occurrence of data asset transactions^[19]. The unique nature and time sensitivity of data assets, which often require specific application scenarios to generate value, make it difficult to determine their existence for audit purposes. To meet the definition of an asset, enterprises must demonstrate lawful, secure, and effective ownership or control over the data resources, as well as their potential to generate future economic benefits. However, the complexity of the interests involved makes this determination challenging.

Moreover, reliable measurement is a prerequisite for recognition, but data asset values are highly dependent on application contexts, and the use of different valuation models may lead to substantial discrepancies. This inevitably complicates valuation and allocation judgments during audits. Additionally, there is significant market demand for data asset transactions, particularly those involving sensitive or core data, which face compliance challenges. Improper handling may lead to privacy breaches or data security incidents, creating further difficulties for auditors in confirming the impact of such transactions on financial statements ^[20]. These factors collectively increase the audit risks associated with data asset recognition.

4. Risk prevention recommendations for on-balance sheet recognition of data resources

4.1. Establishing robust data ownership and compliance mechanisms

The key to incorporating data resources into balance sheets lies in clarifying their ownership and determining their value. First, it is essential to promote the legislation of data property rights and establish a data asset management system that defines the fundamental rights and legal responsibilities of various stakeholders involved in data production. This would provide a legal basis for distinguishing data ownership, operational rights, and usage rights. In addition, a strengthened data security and privacy protection framework should be established, with classified rights protection for different types of data resources and improved rules for determining infringement, thereby ensuring the adequate protection of all stakeholders' interests.

4.2. Improving valuation and information disclosure systems

To address valuation uncertainty, dedicated guidelines for the valuation of data resources should be developed. The Ministry of Finance, in collaboration with industry associations and valuation institutions, should clarify the conditions of application, parameter selection principles, and prioritization of the three main valuation methods, encourage the use of multiple approaches for cross-validation, and require the disclosure of key assumptions and sensitivity analyses.

Regarding information disclosure, a combined framework of mandatory and voluntary disclosure should be established: mandatory disclosure should include the scale of data assets, valuation methods, key assumptions, economic life, and major risks; while voluntary disclosure should encourage the inclusion of non-financial information in management discussions and analyses, such as data quality, application scenarios, and strategic value. Additionally, enterprises should establish a dynamic monitoring mechanism for the value of data assets to regularly assess impairment risks.

4.3. Strengthening audit supervision and risk control

Audit standard-setting bodies should revise relevant auditing standards in a timely manner to provide guidance for the audit of data assets, focusing on auditing procedures related to existence, rights and obligations, valuation, and allocation. Audit institutions should enhance the professional capacity of their auditors by developing professionals who are proficient not only in accounting and auditing but also in data science, information security, and law, or by employing cross-disciplinary expert teams for joint audits ^[21].

Enterprises should cooperate actively with auditors by providing sufficient and appropriate evidence, including documentation of data ownership, compliance statements, and valuation models, to jointly mitigate audit risks.

5. Conclusion

This study demonstrates that the recognition of data resources on the balance sheet is subject to legal compliance risks, information disclosure risks arising from value uncertainty, and audit risks. First, disputes over ownership and compliance deficiencies may fundamentally undermine the legitimacy of asset recognition. Second, traditional valuation methods face limitations, including weak correlation between data value and cost, high subjectivity in revenue forecasting, and the absence of active markets. Coupled with accelerated value depreciation due to technological iterations, these factors make it difficult to reliably measure fair value, resulting in information disclosures that may not accurately reflect the enterprise's actual asset position. Finally, the unique characteristics of data assets pose challenges to traditional audit procedures regarding existence, rights, and valuation. These risks indicate that the recognition of data resources on the balance sheet requires a framework that goes beyond traditional accounting standards. It is necessary to further improve relevant laws and regulations, develop specialized guidelines for data resource valuation, revise existing audit standards, and enhance auditor training to mitigate audit risks.

Disclosure statement

The author declares no conflict of interest.

References

- [1] The Ministry of Finance of China, 2023, Interim Provisions on Accounting Treatment of Enterprise Data Resources, viewed August 1, 2025, https://www.gov.cn/gongbao/2023/issue_10746/202310/content_6907744.html
- [2] Liu G, Zhou D, 2021, Research on Data Asset Standards under the IASB Framework. *Financial and Accounting Monthly*, (21): 66–71.
- [3] Tan M, 2021, On the Conceptual Development and Theoretical Framework of Data Assets. *Financial and Accounting Monthly*, (10): 87–93.
- [4] Xu T, You J, Zeng C, et al., 2022, Exploratory Practice of Enterprise Data Assetization and Construction of Theoretical Model. *Foreign Economics & Management*, 44(06): 3–17.
- [5] Zhang J, Wei Y, Song X, 2020, Accounting Treatment and Information Disclosure of Enterprise Data Assets. *Accounting and Economic Research*, (3): 3–15.
- [6] International Accounting Standards Board, 2018, Conceptual Framework for Financial Reporting, viewed June 23, 2025, <https://www.accaglobal.com/gb/en/student/exam-support-resources/professional-exams-study-resources/strategic-business-reporting/technical-articles/conceptual-framework.html>
- [7] Liu Y, 2023, International Comparison, Challenges and Countermeasures of Data Resource Recognition on the Balance Sheet. *Guangdong Economy*, (11): 37–43.
- [8] Ministry of Finance of China, 2014, Basic Accounting Standards for Enterprises, viewed June 23, 2025, http://tfs.mof.gov.cn/caizhengbuling/201407/t20140729_1119494.htm
- [9] Wu D, Wu Y, Li J, et al., 2023, Prospective Study of Data Asset Accounting Standards: From the Perspective of Data Value Creation Features in the Digital Economy. *Contemporary Accounting Review*, 16(2): 14–33.
- [10] China Academy of Information and Communications Technology, 2020, Data Assetization: Research Report on Data Asset Recognition and Accounting Measurement (2020), viewed June 23, 2025, <http://www.caict.ac.cn/kxyj/qwfb/ztbq/202012/P020201209374734599565.pdf>

- [11] Li D, Liu Y, Deng L, et al., 2023, Data Asset Value Assessment Method and Application Based on the Full Data Lifecycle. *Big Data*, (6): 39–55.
- [12] Lu X, 2019, Discussion on the Measurement Issues of Big Data Assets. *Financial & Accounting Communications*, (10): 59–63.
- [13] Zhang X, Liu Y, Wu W, 2022, Research on Accounting Measurement of Data Assets: The Case of Big Data Enterprises. *Financial & Accounting Communications*, (19): 10–14, 20.
- [14] Huang S, Ye F, Chen C, 2023, Recognition, Measurement and Reporting of Data Assets: From the Perspective of Business Models. *Financial and Accounting Monthly*, (8): 3–7.
- [15] Zhu J, Liu Y, Xu Z, 2024, Discussion on the Risks of Assetizing Data Resources Recognition on the Balance Sheet. *Financial & Accounting Communications*, (13): 91–96.
- [16] Liu Y, 2023, Data, Data Assets, and Their Value Assessment. *China Asset Appraisal*, (5): 51–56.
- [17] Hannila H, Silvola R, Harkonen J, et al., 2022, Data-Driven Begins with DATA: Potential of Data Assets. *Journal of Computer Information Systems*, 62(1): 29–38.
- [18] Yuan Z, Yu X, Li M, 2022, Data Asset Information Disclosure, Heterogeneity of Institutional Investors, and Corporate Value. *Modern Finance and Economics (Journal of Tianjin University of Finance and Economics)*, 42(11): 32–47.
- [19] Zhu J, Shen Z, Bai J, et al., 2025, Research on Audit Difficulties and Countermeasures of Data Assets in Financial Statement Auditing. *Accounting Friends*, (5): 15–24.
- [20] Xiao X, 2024, Research on Audit Risk of Data Assets Recognition. *Proceedings of Business and Economic Studies*, 7(1): 124–131.
- [21] Institute of Chartered Accountants in England and Wales, 2024, Corporate Data: A New Type of Intangible? viewed July 2, 2025, <https://www.icaew.com/insights/viewpoints-on-the-news/2024/may-2024/corporate-data-a-new-type-of-intangible>

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Research on the Impact of International Capital Flows on the Financial Stability of Emerging Economies

Shenghua Feng*

Shenwan Hongyuan Securities Co., Ltd., Shanghai 200031, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: International capital flows play a crucial role in the process of globalization, presenting both opportunities and challenges to the financial stability of emerging economies. This article sorts out the positive effects and potential risks of international capital flows on the financial stability of emerging economies. By combining case studies in recent years, it analyzes the complex relationship between cross-border capital flows and financial stability, and proposes policy paths for emerging economies to cope with the shock of capital flows, providing references for enhancing financial resilience and achieving sustainable development.

Keywords: International capital flows; Emerging economies; Financial stability; Systemic risk; Macroprudential management

Online publication: October 14, 2025

1. Introduction

In recent years, while emerging economies have been promoting economic development by introducing foreign capital, they have also frequently encountered problems such as sudden capital reverses, sharp fluctuations in exchange rates, and financial market turmoil. International capital flows have a “double-edged sword” effect on the financial stability of emerging economies. How to achieve stability through opening up and prevent risks in attracting investment has become a strategic issue that emerging economies urgently need to solve. It is of great theoretical significance to systematically explore the positive effects, potential risks, and response paths of international capital flows, and has practical value for policy-making and practical operation.

2. Positive roles of international capital flows in the financial stability of emerging economies

2.1. Promoting capital formation and economic growth

First, to fill the funding gap and promote investment expansion, emerging economies generally face the contradiction of insufficient capital accumulation and long-term insufficient capital supply. Domestic savings are

difficult to fully support the high-intensity investment demands of industrialization and urbanization. Foreign direct investment and long-term securities investment can effectively fill the funding gap and expand the fixed capital formation rate. For instance, World Bank data shows that during the peak period of capital inflow, the fixed asset investment rate in some Southeast Asian countries increased by 3 to 5 percentage points, accelerating infrastructure construction and industrial expansion, and providing a solid quantitative support for economic growth. Second, it brings about technology spillover, enhances productivity levels, and capital is transferred along with technology, management, and knowledge. When multinational enterprises enter emerging markets, they often introduce advanced production techniques, modern management experience, and strict quality standards, which drive local enterprises to enhance efficiency through the learning effect and competition effect, improve labor productivity, increase total factor productivity, and raise the marginal output rate of capital input. For instance, driven by cross-border investment in information technology and manufacturing between China and India, the productivity growth rate of related industries has been significantly faster than that of non-foreign-dominated industries. Third, optimize the industrial structure and promote economic upgrading. Capital flows have the characteristic of “choosing the best to flow to,” and are more inclined to enter industries and sectors with great potential and high returns. The resources of emerging economies are gradually transferred from inefficient traditional sectors to high-value-added industries, achieving the optimization and upgrading of the industrial structure. The capital flowing into strategic emerging industries such as new energy, information and communication, and digital economy can promote the diversification and modernization of the domestic economy, enhance its position in the global value chain, and form a long-term competitive advantage^[1].

2.2. Optimizing resource allocation and industrial upgrading

First, enhance the efficiency of resource allocation and promote the optimal flow of factors. As a significant force in the global financial system, international capital flows inherently possess the attribute of “selective allocation.” Capital often flows into areas with high expected returns, relatively complete institutional environments, and greater industrial potential, driving the redistribution of resources within emerging economies. High-efficiency industries that were originally constrained by funds have gained new development opportunities. Low-efficiency sectors have gradually been marginalized, forming an optimized combination of resources at the societal level. Capital inflows can improve the financing conditions of large enterprises and also enable small and medium-sized enterprises to obtain financial support more conveniently through market liquidity improvement and risk dispersion mechanisms. It has alleviated the long-standing problems of “difficult and expensive financing.” Second, promote the upgrading of the industrial structure and facilitate economic transformation and development. When cross-border capital enters emerging economies, it often concentrates on high-value-added, high-tech content and sustainable development in emerging industries. The investment orientation objectively accelerates the modernization process of the industrial structure, enabling emerging economies to gradually get rid of their excessive reliance on low-end processing and resource-intensive industries. The advanced production techniques, corporate governance models, and global market channels brought by foreign capital have enhanced the technological level and management capabilities of local enterprises. Through the forward and backward linkage effect of the industrial chain, it has promoted the formation of regional industrial clusters. For instance, the in-depth participation of multinational capital in the electronic information industry in some East Asian countries has driven the improvement of the industrial chain. It has enhanced the technological content and added value of export products, driving the international competitiveness of the overall economy^[2].

2.3. Promoting the development and internationalization of the financial market

First, it promotes the enhancement of the depth and breadth of the financial market. The continuous inflow of capital increases market liquidity, promotes the development of diversified financial tools such as stocks, bonds, and foreign exchange, enables investors to make choices among a richer asset allocation, and the participation of foreign institutional investors enhances the professionalization level and pricing efficiency of the market ^[3]. They have put forward higher requirements for information disclosure, governance structure, and risk management, which have promoted the improvement of market rules and the enhancement of transparency. Second, promoting the internationalization of the financial market and the integration into the global value chain. The entry of international capital has brought advanced financial products and trading mechanisms, facilitating the alignment with international rules and enhancing the internationalization level of the domestic market. For instance, emerging market currencies such as the RMB and the South Korean won have gradually been incorporated into regional and international settlement systems. Behind this lies the opening up of the capital market and the in-depth participation of international capital. Financial institutions in emerging economies have gradually mastered the design and application capabilities of complex financial instruments through cooperation with international investment banks, rating agencies, and multinational funds, enhancing their positions in the global value chain. The cross-border flow of capital has strengthened the cross-border interactivity of the financial market. It enables emerging economies to participate more directly in global capital allocation and risk diversification, providing strategic support for the sustained development of the economy ^[4].

3. Potential risks of international capital flows to the financial stability of emerging economies

3.1. Intensifying financial market volatility and asset price bubbles

First, the pro-cyclical nature of capital flows intensifies market volatility. International capital flows are highly sensitive and pro-cyclical, often driven by external factors such as global interest rates, US dollar liquidity, and changes in international risk appetite. When global liquidity is loose, a large amount of capital flows into emerging economies, pushing up stock, bond, and real estate market prices. Once the international financial environment tightens or risk aversion sentiment rises, capital rapidly withdraws, causing sharp market fluctuations ^[5]. The financial markets of emerging economies are relatively small in scale and limited in depth, making them vulnerable to large-scale capital flows. For instance, the Asian financial crisis in 1997 revealed the destructive nature of large-scale short-term capital inflows and outflows. During this period, the stock markets of some countries dropped by more than 10% in a single day, and their exchange rates depreciated significantly. Market fluctuations magnified the uncertainty and vulnerability of the real economy. Second, excessive capital inflow triggers asset price bubbles. During the stage of abundant international capital, emerging economies often exhibit a phenomenon of excessive capital concentration in specific fields. This irrational exuberance causes asset prices to deviate from the fundamentals, forming a bubble trend. The short-term profit-seeking behavior of speculative capital accelerates the speed of price increase, making the financial market show the feature of “moving away from the real economy towards the virtual economy.” Once an asset price bubble bursts, it will trigger a reversal of the wealth effect, a break in the credit chain, and impact the banking system and the real economy ^[6].

3.2. Inducing the risk of currency devaluation and capital flight

First, capital outflows have a direct impact on exchange rate stability. Against the backdrop of a tightening

international financial environment, the appreciation of the US dollar, or a rise in global risk aversion, emerging economies are highly vulnerable to large-scale capital outflow pressure. This is because these countries generally have weaknesses such as limited foreign exchange reserves, low levels of currency internationalization, and immature financial markets. Sudden capital withdrawal often leads to a rapid depreciation of the domestic currency exchange rate and even causes an “overshoot effect.” Second, capital flight triggers dual risks for both the financial sector and the real economy. Against the backdrop of expectations of currency depreciation and rising risk premiums, investors tend to shift their assets to safe-haven channels such as the US dollar and gold, accelerating the consumption of foreign exchange reserves and weakening the intervention capabilities of monetary authorities. When foreign exchange reserves are insufficient to maintain market confidence, it may trigger a larger-scale panic flight of capital. The stability of the financial system is seriously threatened. Capital flight will compress domestic credit supply, deteriorate the financing environment for enterprises, dampen investment and consumption confidence, and thus slow down the growth of the real economy ^[7].

3.3. Enhancing systemic financial risks and external dependencies

First, cross-border capital fluctuations may amplify systemic financial risks. The large-scale inflow and outflow of short-term capital will intensify the pro-cyclical fluctuations in the banking system and capital market, leading to the superposition of asset prices, leverage levels, and liquidity risks, triggering a chain reaction. For instance, capital withdrawal is often accompanied by a contraction in bank liquidity and an increase in credit spreads, causing already fragile financial institutions to face asset-liability mismatches and repayment pressure, and ultimately evolving into systemic risk events. When capital inflows are concentrated in sensitive areas such as real estate and the stock market, it is easy to accumulate hidden risks beneath the surface prosperity. If the capital flow reverses or the external environment deteriorates and the price bubble bursts, it will quickly spread to the entire financial system, leading to a chain reaction of “local risk–market panic–systemic crisis.”

Second, excessive reliance on external capital weakens financial autonomy and economic resilience. The excessive outward orientation of the capital structure has made the domestic economic operation highly dependent on external capital supply and the international financial environment, and the independence of monetary policy has been restricted. When global interest rates, liquidity, or risk appetite change, domestic central banks often find themselves in a dilemma between “capital flows and policy goals,” and it is difficult for them to balance exchange rate stability and domestic demand growth simultaneously. The dominant position of foreign capital may lead to the “foreignization” of the financial market, with domestic financial institutions and capital markets losing their say in innovation capabilities and resource allocation, thereby weakening the independent development capacity and long-term resilience of the financial system ^[8].

4. Paths for emerging economies to cope with the impact of international capital flows

4.1. Improving the framework for macroprudential management and capital flow supervision

(1) To effectively prevent the impact of large-scale international capital inflows and outflows, emerging economies first need to establish a cross-border capital monitoring system with wide coverage and transparent information. Under the unified coordination of the central bank and foreign exchange management departments, capital flow data from banks, securities, insurance, funds, and payment and settlement links should be integrated. Form a penetrating real-time statistics platform. By applying methods such as stress testing and network infection

analysis, a full-process mechanism of “monitoring–identification–early warning” is constructed, and multi-level risk thresholds are set. When capital flows exceed the warning level, the system can automatically trigger intervention measures, such as increasing foreign exchange risk reserves, adjusting foreign exchange settlement and sales policies, or restricting the proportion of short-term foreign debt. (2) Improve the combined application of counter-cyclical and structural tools. When there is excessive capital inflow, the foreign currency deposit reserve ratio should be raised or a counter-cyclical capital buffer should be implemented. When capital outflow intensifies, it should be moderately reduced to alleviate liquidity pressure. Structural policies should focus on improving the quality of capital flows, such as setting scale and term requirements for short-term foreign debts, guiding more funds to flow into long-term equity investment and the domestic currency bond market, and promoting the gradual “domestic currency-ization” of the financial system ^[9].

4.2. Strengthening the construction of foreign exchange reserves and the financial safety net

(1) Optimize the scale and structure of foreign exchange reserves. Foreign exchange reserves are the “first line of defense” for emerging economies to deal with the shock of capital flows. Their scale and structure directly affect the resilience of financial stability. It is necessary to dynamically determine a reasonable range in combination with the characteristics of the balance of payments, the scale of short-term foreign debt, and the volatility of capital flows, and avoid excessive reliance on a single currency. To form a balanced combination of “safety, liquidity, and profitability,” in addition to major reserve currencies such as the US dollar and the euro, the proportion of gold, Special Drawing Rights, and regional currency assets can be moderately increased. This can diversify risks when the global financial environment changes suddenly and promote the coordinated operation of central bank reserve management and sovereign wealth funds. Reserves should be divided into “liquidity pools” and “profitability pools.” (2) To build a multi-level financial safety net, it is necessary to establish multiple guarantee mechanisms at the national, regional, and international levels. At the national level, a foreign exchange stabilization fund or a capital market stability fund can be set up, specifically for emergency intervention and market confidence restoration. At the regional level, active participation should be made in currency swap arrangements and regional liquidity mutual assistance mechanisms, such as the “Chiang Mai Initiative Multilateralization” in East Asia, to enhance the overall regional defense capabilities through cross-border liquidity support. At the international level, the precautionary credit lines and short-term liquidity facilities of the IMF should be flexibly utilized to obtain timely financial assistance in the event of severe external shocks ^[10].

4.3. Promoting financial market reform and risk diversification mechanisms

(1) To deepen the reform of the financial market and broaden diversified financing channels, the primary task for emerging economies in responding to the shock of capital flows is to reduce their reliance on a single financing channel and establish a more diversified and resilient financial market system. This requires efforts from three aspects: the bond market, the equity market, and the derivatives market ^[11]. In the bond market, efforts should be made to improve the issuance, rating, and trading systems, encourage enterprises and the government to raise funds through long-term bonds, and reduce the proportion of short-term funds. In the equity market, the construction of a multi-level capital market should be promoted to provide matching financing platforms for enterprises of different scales and development stages, thereby diversifying the risk of single-market fluctuations caused by capital withdrawal. In the derivatives market, efforts should be accelerated to develop foreign exchange, interest rates, and commodity futures and options, enabling enterprises to use financial tools to hedge against price and exchange

rate risks. (2) Improve the risk dispersion mechanism and enhance the market's self-healing capacity. The stability of the financial market depends on financing channels and also relies on the improvement of risk management and dispersion capabilities. We should encourage enterprises and financial institutions to more widely use risk hedging tools, such as forward contracts, swaps, and options, to reduce the uncertainty brought about by fluctuations in exchange rates and interest rates. Establish a cross-institutional and cross-market risk-sharing mechanism, promote collaborative cooperation among banks, insurance companies, funds, and other institutions, and build a pattern where multiple entities jointly bear the impact of capital flows. The regulatory authorities should promote the development of long-term capital tools, such as infrastructure funds, pension funds, and real estate investment trusts, to attract stable funds to weaken the dominant position of short-term speculative capital ^[12].

5. Conclusion

International capital flows, as an important product of globalization, hold both development opportunities and potential financial risks for emerging economies. More attention should be paid to the forward-looking and coordinated nature of policies to strive for greater say in the global governance system and achieve the dual goals of effective capital flows and long-term financial stability.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Cheng L, Li J, 2021, The Heterogeneous Impact of Abnormal International Capital Flows on Economic Growth: A Comparison Between Emerging Economies and Developed Economies. *Financial Forum*, 26(01): 70–80.
- [2] Chen F, Xue W, Zhao Y, 2020, The Degree of Capital Account Openness, the “Sudden Halt” of International Capital Flows and Systemic Banking Crises. *Financial Regulation Research*, (11): 62–82.
- [3] Wang X, 2020, International Capital Flows: Characteristics, Risks and Countermeasures—A Comparison Between Emerging Market Countries and Developed Countries. *National Circulation Economy*, (30): 158–160.
- [4] Xie Y, 2020, International Capital Flows in China's Capital Market. *China Foreign Exchange*, (10): 10.
- [5] An L, 2019, The Role of Capital Flows in the Transmission of US Monetary Policy to Emerging Markets. *International Economic and Trade Exploration*, 35(10): 91–107.
- [6] Zhang L, Zhang Y, Ouyang Y, 2023, Research on the Impact of International Capital Flows on Systemic Financial Risks. *Finance & Trade Economics*, 44(1): 99–115.
- [7] Yuan X, Xu Y, Liu K, 2022, The Dynamic Transmission Effect of Economic Policy Uncertainty in Emerging Economies on the Volatility of Capital Outflows. *Contemporary Economic Science*, 44(5): 16.
- [8] Li X, Tan X, Li X, 2023, Research on the Impact of Digital Technology Development on the Effect of Bilateral Equity Capital Flow Control. *World Economic Research*, 2023(11): 122–134.
- [9] Pang X, Chen Y, 2023, Global External Shocks, Macroprudential Policies and Cross-Border Capital Flows. *Finance and Accounting Monthly*, 44(1): 7.
- [10] Zhan W, Pei P, 2023, The Impact of Global Financial Cycles on Abnormal International Capital Flows. *International Finance Research*, 2023(7): 61–72.

- [11] Tan X, Yu M, Wang X, 2023, New Characteristics, Risks and Policy Recommendations of Cross-Border Capital Flows. *International Finance Research*, 2023(4): 17–28.
- [12] Ding J, Guan J, 2023, Literature Review on Capital Flows and Capital Account Control from the Perspective of Trade-Offs. *International Finance Research*, 2023(10): 62–73.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Traffic Forecast and Business Operation Optimization Strategy of Smart Tourist Attractions Driven by Big Data

Aihan Cao*

Faculty of International Tourism and Management, City University of Macau, Macau, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: In order to improve the competitiveness of smart tourist attractions in the tourism market, this paper selects a scenic spot in Shenyang and uses big data technology to predict the passenger flow of the scenic spot. Firstly, this paper introduces the big data-driven forecast model of scenic spot passenger flow. Based on the traditional autoregressive integral moving average model and artificial neural network model, it builds a big data analysis and forecast model. Through the analysis of data source, model building, scenic spot passenger flow accuracy, and modeling time comparison, it affirms the advantages of big data analysis in forecasting scenic spot passenger flow. Finally, it puts forward four commercial operation optimization strategies: adjusting the ticket pricing of scenic spots, upgrading the catering and accommodation services in scenic spots, planning and designing play projects, and formulating accurate scenic spot marketing strategies, in order to provide references for the optimization and upgrading of smart tourist attractions in the future.

Keywords: Big data; Smart tourist attractions; Passenger flow forecast; Commercial operation

Online publication: October 14, 2025

1. Introduction

With the rapid development of domestic tourism in recent years, how to predict the passenger flow of tourist attractions more accurately is a key task to build smart tourist attractions. The traditional method of forecasting passenger flow is to analyze historical data, which is difficult to accurately reflect the influence of some dynamic factors, such as weather and hot topics on the Internet. Based on this, the driving role of big data technology can be brought into play to build smart tourist attractions and predict passenger flow, so that tourist data can be collected in real time, and the business operation plan can be adjusted through the mining and analysis of big data to meet the diversified needs of tourists ^[1]. Based on this, this paper selects a scenic spot in Shenyang, uses big data to predict the passenger flow of smart tourist attractions, and optimizes the business operation strategy by building a

model to improve the economic benefits of scenic spots.

2. Big data-driven tourist forecast model for scenic spots

There have always been two types of models for predicting tourist attractions, namely qualitative modeling and quantitative modeling. The former is based on the overall analysis of tourist attractions' passenger flow changes, but the disadvantage is that the prediction results lack interpretability. The latter is a more mainstream modeling and forecasting method because of its more detailed prediction process and wide application scope. There are linear and nonlinear models commonly used in quantitative modeling technology, such as the autoregressive integrated moving average (ARIMA) model in linear models, which can clearly describe the changing characteristics of tourist attractions in different seasons, but there may be errors in the ARIMA model when the passenger flow is random ^[2]. Nonlinear models are mainly artificial neural networks, such as RBF and BP neural networks, which are more suitable for random passenger flow characteristics, but different from the ARIMA model, it is difficult to describe seasonal passenger flow, and the actual forecast results will be biased ^[3]. In view of this, this paper improves the passenger flow forecast of a scenic spot in Shenyang based on the above model, and applies big data technology to build a passenger flow forecast model to improve the forecast accuracy and shorten the forecast time.

3. Big data-driven smart tourist attractions passenger flow forecast

3.1. Forecast data sources

In order to ensure the validity of the passenger flow forecast of a scenic spot in Shenyang, the passenger flow of the scenic spot from July 1 to August 1, 2024 was selected as sample data, with a total of 150 samples; 90 training sample sets were used for model construction, and 60 samples were used to test the prediction ability of the model. The big data analysis technology is used to analyze the tourist data of scenic spots, and the factors with strong correlation are screened according to the characteristics of scenic spots. After preliminary screening, the independent variables are obtained as shown in **Table 1**. According to the independent variables sorted out in **Table 1**, this paper presents descriptive statistics on the passenger flow data of a scenic spot in Shenyang from July 1 to August 1, 2024, and the statistical results are also shown in **Table 1**.

Table 1. Independent variables and descriptive statistics

	Variable	Min	Max	Mean	SD
x1	Weather	-1	35	17.6	6.95
x2	Wind power	1	11	4.6	3.26
x3	Hotel booking rate	15	90	42.4	38.1
x4	Keyword index	242	978	410	174.6
x5	Holiday	2	10	3.3	2.4
x6	Economic climate index	94.2	95.3	95.4	0.38
x7	Consumer confidence index	100.1	109.4	101.7	1.15
y	Tourist flow in scenic spots	0.4	8.5	2.1	1.54

Note: The information comes from the public data of scenic spots, the same below.

After descriptive statistics, we can basically grasp the data overview in **Table 1** and randomly carry out correlation analysis. This link mainly uses the Pearson correlation coefficient to judge the linear correlation degree of corresponding variables and independent variables^[4]. Through analysis and judgment, it is found that the linear correlation between x6 and x7 economic factors and y is not significant, and the data change difference is also relatively small. Therefore, these two variables are no longer considered in the subsequent prediction.

3.2. Building a model

Based on the above analysis of scenic spot passenger flow data, a prediction model is constructed, and the Lasso regression algorithm is used to predict parameters and select variables. The regression optimization problem of the Lasso algorithm is expressed by Formula (1):

$$(\hat{\alpha}, \hat{\beta}) = \arg \min \left\{ \sum_{i=1}^N (y_i - \alpha - \sum \beta_j x_{ij})^2 \right\} \quad (1)$$

In the formula (1): $\sum \beta_j \leq t$, $t \geq 0$, this is a harmonic parameter. If $y = 0$, you do not need to consider α .

Then calculate the equation, and the equation solution is:

$$\hat{\beta}_j = \text{sign}(\beta_j^0) (\|\beta_j^0\| - \gamma)^+ \quad (2)$$

The γ in formula (2) is mainly calculated from $\sum |\beta_j| = t$.

3.3. Scenic spot passenger flow accuracy and modeling time comparison

3.3.1. Fitting accuracy

Based on the established prediction model, it is necessary to compare and test the fitting accuracy of scenic spot passenger flow. In this paper, the traditional ARIMA model is selected as the comparison object, and the comparison of fitting accuracy with a scenic spot in Shenyang is shown in **Figure 1**.

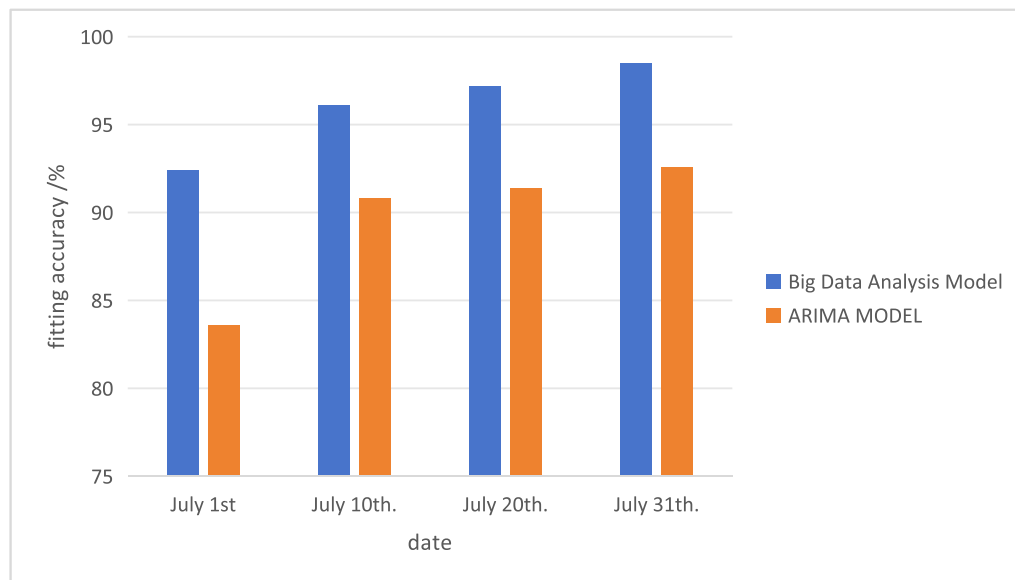


Figure 1. Comparison of fitting accuracy of passenger flow in a scenic spot in Shenyang

According to the numerical results of statistical fitting accuracy in **Figure 1**, the fitting accuracy of the big data prediction model constructed in this paper is higher than that of the ARIMA model, with an average of about 96%; while the average of ARIMA statistics is only 89%, and the fitting accuracy is improved by 7%, which can describe the changes of passenger flow in scenic spots in a more detailed and comprehensive way, thus reflecting the performance advantages of the smart tourist scenic spot passenger flow prediction model driven by big data technology^[5].

3.3.2. Prediction accuracy

During the construction of smart tourist attractions, the fitting results actually obtained by the scenic spot passenger flow prediction model can be used to describe the changes of historical passenger flow data, but it is difficult to describe the changes of passenger flow in the future^[6]. Considering this, this modeling focuses on testing the validation sample set. See **Figure 2** for the sample prediction accuracy of the ARIMA model and the big data passenger flow prediction verification model constructed in this paper.

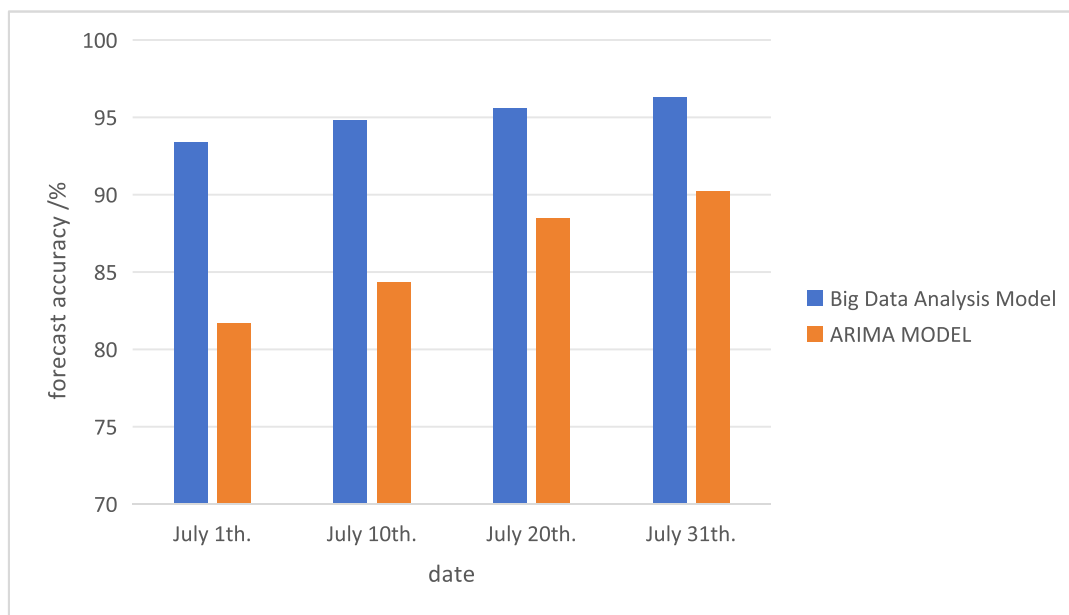


Figure 2. Sample prediction accuracy of scenic spot passenger flow verification model

According to the prediction accuracy sorted out in **Figure 2**, it is found that there is a big gap between the prediction results of the big data model and the ARIMA model. The average accuracy of big data analysis is 95%, while the average accuracy of the ARIMA model is only 86%. It can be seen that the big data model has high accuracy in predicting the passenger flow of smart tourist attractions, which can solve the problem of prediction error.

3.3.3. Modeling time

The construction time of the passenger flow forecast model in smart tourist attractions is also the focus of this analysis. Through the data of prediction time and average fitting time, it is found that the modeling time of building the big data model is better than the ARIMA model. See **Table 2** for a comparison of some modeling

time data. It can be seen that the application of big data analysis technology in the passenger flow modeling of smart tourist attractions can further shorten the passenger flow time and improve the efficiency of modeling and forecasting.

Table 2. Comparison of the construction time of the scenic spot passenger flow model

Data number	Fitting time		Forecast time	
	Big data analysis model	ARIMA model	Big data analysis model	ARIMA model
1	8.15s	12.38s	4.26s	7.32s
2	5.31s	7.66s	2.61s	4.57s
3	4.11s	8.36s	2.25s	4.38s
4	4.63s	5.17s	2.13s	4.46s
5	6.01s	8.06s	2.18s	4.59s

4. Business operation optimization strategies based on passenger flow forecast

4.1. Adjusting the ticket pricing of scenic spots

As a tourist attraction, one of the sources of income is tickets. If the ticket pricing can be guaranteed to be reasonable, it will certainly increase the income of tourist attractions and economic benefits. Especially in the process of upgrading to smart tourist attractions, the application of big data technology to build a scenic spot passenger flow prediction model, managers make dynamic adjustments to ticket prices according to the prediction results obtained by the model, which can improve tourists' satisfaction with the scenic spot on the one hand and increase income on the other^[7]. For example, after the Spring Festival every year to the middle and late March is the off-season. At this time, the ticket price can be appropriately lowered to attract more tourists to visit. After entering the peak season, the manager will raise the price to balance the relationship between supply and demand, and at the same time increase the income of tourist attractions. In the process of forecasting passenger flow, tourists' feedback on ticket pricing is collected through big data technology, and it is suggested to formulate differentiated pricing strategies and refine ticket pricing^[8]. For example, different ticket schemes can be formulated at different time periods, or differentiated fares can be formulated for multiple tourist groups such as students and families. Through the refined and differentiated management of ticket prices, it will give more flexibility to ticket sales, meet the needs of tourists, and give full play to the advantages of big data technology to improve the income of scenic spots.

4.2. Upgrading catering and accommodation services in scenic spots

An important part of the commercial operation of smart tourist attractions is to provide catering and accommodation services for tourists, and the service quality is the key measure of tourists' satisfaction with the scenic spots. By building a passenger flow forecasting model, managers can reconfigure catering and accommodation resources, and when they enter the peak period of tourism, they can still ensure sufficient supply capacity and prevent the waste of resources in the low season of scenic spots. After forecasting the passenger flow, a scenic spot in Shenyang described in this paper prepared catering ingredients in advance, and arranged service personnel at each post to shorten the waiting time of tourists after entering the scenic spot and provide them with high-quality catering and accommodation services^[9]. The forecast of passenger flow in this scenic spot applies big

data analysis technology, and also deeply collects the preference information of tourists in the scenic spot, such as eating habits and requirements for accommodation conditions, so that managers can provide personalized services for tourists. Based on the above analysis, driven by big data, the reconfiguration of catering and accommodation resources in smart tourist attractions can effectively improve the experience of tourists and the competitiveness of the scenic spots themselves in the tourism market.

4.3. Planning and designing play projects

The optimization of the business operation strategy of smart tourist attractions cannot ignore the importance of play items. The key is the opening time and frequency of play items, which is closely related to the experience of tourists after entering the scenic spot and the utilization rate of play items. According to the passenger flow forecast results of the big data analysis constructed in this paper, the managers re-plan the play projects, focusing on the play needs of tourists in different time periods^[10]. According to the forecast, it is found that 9:00 a.m.–12:00 p.m. and 2:00 p.m.–6:00 p.m. are the peak hours of daily passenger flow, so it is necessary to increase the opening frequency of some popular play items in the above two periods, and lower the frequency in other periods, and maintain the play equipment at this stage, which can not only improve the utilization rate of internal resources in the scenic spot, but also ensure the personal safety of tourists. In addition, the application of big data analysis technology to collect tourists' behavior data can also help scenic spots to upgrade the queue management system of each play project. The scenic spots described in this paper add two new functions in the system—intelligent reservation and dynamic adjustment of the queuing route, which greatly shortens the waiting time of tourists in line. To sum up, it is an effective means to improve tourist satisfaction and economic benefits of scenic spots by using big data technology to optimize the planning of play projects and adjust business operation strategies.

4.4. Developing an accurate scenic spot marketing strategy

Making accurate business marketing strategies in smart tourist attractions can improve the attraction to tourists. According to the predicted tourist flow of scenic spots by the model, diversified commercial marketing activities can also be formulated. For example, in the process of forecasting passenger flow in a scenic spot in Shenyang, managers put forward promotion activities for differentiated passenger flow levels. Among them, when the passenger flow is predicted to be low, the scenic spot specially launches several different preferential activities to attract tourists; In order to attract potential tourists, social media such as Xiaohongshu, Weibo, TikTok, and below-the-line are used to make a wide range of publicity when the passenger flow is predicted to be high. In order to locate the target consumer groups more accurately, the scenic spot uses geographic big data technology to collect the location information of tourists, analyze the behavior characteristics of tourists, and enhance the pertinence and personalization of the commercial marketing plan of the scenic spot. In this way, the commercial marketing strategy formulated by smart tourist attractions driven by big data can gain a more ideal publicity effect, and the cost is lower than that of traditional marketing methods, which can improve the utilization rate of scenic resources.

5. Conclusion

To sum up, this paper used big data analysis technology to build a tourist forecast model of smart tourist attractions. Through the analysis of the tourist forecast of a scenic spot in Shenyang, this model solves the problems of randomness, seasonality, and periodicity of the traditional single model, and also optimizes the

commercial operation strategy of the scenic spot. In the long run, it can not only improve tourists' satisfaction with the scenic spot, but also enhance the economic benefits of the scenic spot.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Zhang X, 2025, Research on the Management Path of Tourist Attractions from the Perspective of Smart Tourism. *Vitality*, 43(15): 100–102.
- [2] Guo X, Yu W, Liu Q, et al., 2025, Study on the Planning and Planning of Historical and Cultural Scenic Spots under the Cultural Background of Large Scenic Spots—Taking Jinyang Temple Scenic Spot in Beijing as an Example. *Urban Architectural Space*, 32(7): 69–71.
- [3] Long L, Long S, Xie W, 2025, Research on the Forecasting Method of Parking Demand in Tourist Attractions—Taking Tianmen Mountain Scenic Spot in Zhangjiajie as an Example. *People's Bus*, (12): 17–19.
- [4] Fang F, Liang R, 2025, Study on the Operation and Audience Preference of WeChat in WeChat Official Account——A Case Study of 5A Scenic Spots in Anhui Province. *Journal of West Anhui University*, 41(1): 90–96.
- [5] Yu J, Ye X, He X, et al., 2025, Forecasting Method of GRU-BiLSTM Tourist Flow Based on Seasonal Adjustment. *Journal of China West Normal University (Natural Science Edition)*, 46(03): 318–324.
- [6] Guo X, Liu X, Yao R, 2024, Short-Term Forecast of Jiuzhaigou Scenic Spot Based on SCBANet Model. *Journal of Xinxiang University*, 41(3): 32–38.
- [7] Kang Z, Li X, 2024, Study on Passenger Flow Forecast of Tianchi Scenic Spot in Tianshan Mountain Based on Baidu Index. *Vocational Technology*, 23(2): 99–108.
- [8] Dong M, Jiang W, Wang X, et al., 2023, Research on Passenger Flow Forecast Based on Multi-Attribute Importance Weighted K-Nearest Neighbor Algorithm. *Guangdong Communication Technology*, 43(5): 10–13 + 20.
- [9] Li Y, Li Y, 2022, Study on Tourist Forecast of Scenic Spots Considering the Influence of Holidays-Hybrid Forecasting Method Based on Prophet-NNAR. *System Science and Mathematics*, 42(6): 1537–1550.
- [10] Cui H, Yang X, Yu Y, 2023, Forecast of Tourist Flow Based on EMD-GRU Model—Taking Black Valley Scenic Spot in Chongqing as an Example. *Journal of China West Normal University (Natural Science Edition)*, 44(2): 179–185.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

An Exploration of Performance Appraisal in Human Resource Management of Public Institutions

Famai Ma*

School of Economics and Management, Changchun University of Technology, Changchun 130012, Jilin, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: Public institutions constitute a vital component of China's public service system, playing a significant functional role in the nation's social development and construction. Human resource (HR) management is a vital component of internal administration within these institutions. The integration of performance appraisal is crucial for enhancing the effectiveness of HR management and facilitating the smooth operation of all institutional functions. Based on this premise, this article first briefly outlines the value of applying performance appraisal in the HR management of public institutions. It then explores strategies for implementing performance appraisal within this context, aiming to provide insights for promoting the sustained and healthy development of public institutions.

Keywords: Performance appraisal; Public institutions; Human resource management; Strategies

Online publication: October 14, 2025

1. Introduction

Performance appraisal serves as a vital management tool within the internal governance of public institutions. It comprehensively evaluates and analyzes employee performance to assess the fulfillment of operational objectives across positions and identify existing issues and shortcomings in work processes. This enables the scientific guidance of employee behavior and drives the successful attainment of organizational goals. The appropriate integration of performance appraisal into human resource management (HRM) is crucial for enhancing management efficiency and ensuring the scientific and effective nature of HR decision-making. However, current practices in some public institutions reveal that certain managers undervalue the application of performance appraisal within HRM. They fail to establish clear performance objectives, optimize indicator systems, or develop robust incentive mechanisms tailored to the institution's actual conditions and developmental needs. Low communication efficiency and delayed feedback on appraisal results significantly undermine the effectiveness of HRM operations. To further drive the sustained and stable development of public institutions, relevant leaders and managers should intensify research and practical implementation of strategies for applying performance appraisal within HRM.

2. The value of performance appraisal in public institution human resource management

2.1. Facilitating the achievement of organizational goals

The application of performance appraisal in human resource management holds significant value in advancing the smooth realization of organizational objectives. Specifically, public institutions define specific job tasks and appraisal metrics for each position based on overall organizational goals during performance appraisal. Employees, driven by performance appraisal targets, carry out their work. While achieving individual performance goals, they effectively drive the smooth realization of the organization's overall objectives. Simultaneously, performance appraisal facilitates effective alignment between organizational objectives and individual employee goals. This alignment ensures that organizational and personal objectives move in concert, enabling the achievement of overall organizational targets while also fulfilling employees' personal development needs. This promotes synergistic development between employees and the organization ^[1].

2.2. Stimulating employee motivation

Motivating employees enhances the operational capabilities of public institutions and drives their sustained, healthy development. The application of performance appraisal in human resource management holds significant value for stimulating employee motivation. On one hand, by setting specific appraisal targets, performance appraisal helps employees clarify their work direction and priorities. This enables employees to reasonably set expectations and requirements based on their individual circumstances, understand the rewards they can achieve through diligent work, and thereby boost their motivation. On the other hand, performance evaluation results provide a fair assessment and recognition of employees' work performance and outcomes. Since public institutions typically link these results to employee compensation and benefits, the incentive effect of performance evaluations is further enhanced, encouraging employees to engage more proactively in their job responsibilities.

2.3. Enhancing internal management standards

The application of performance evaluations in human resource management also effectively elevates internal management standards within public institutions. By conducting performance evaluations scientifically, issues within the organization's operations and management can be identified promptly and accurately. For instance, it can reveal inefficiencies in internal workflows or ambiguities in job responsibilities. Through the analysis and application of evaluation results, performance assessments provide a basis for internal management decisions. This enables the scientific adjustment of management strategies, optimization of business processes, and refinement of management systems, ensuring all tasks proceed in an orderly manner and comprehensively elevating the institution's internal management standards ^[2].

3. Application strategies for performance appraisal in public institution human resource management

3.1. Defining performance goals

Establishing clear performance goals is the primary task in implementing performance appraisal within public institution HR management. These goals should be set based on the institution's overall strategic objectives to ensure alignment between performance targets and strategic direction. First, institutions should define strategic objectives and phased development goals based on current realities and developmental needs. These should then

be broken down into specific, quantifiable performance targets. For instance, the strategic goal of enhancing public service quality could be detailed into metrics like service recipient satisfaction and service efficiency, which are then incorporated into the performance target system. Second, during the clarification of performance objectives, attention must be paid to the hierarchical relationships and interconnections among different objectives. On one hand, the performance objectives of various departments and positions should be closely linked to higher-level objectives and organizational strategic goals. On the other hand, performance objectives across different levels should be seamlessly connected to form a complete closed-loop system. This ensures that performance appraisal activities can effectively drive the smooth achievement of organizational goals ^[3]. Third, performance goals must balance challenge and achievability. On one hand, they should be attainable within employees' roles to prevent frustration from unattainable targets. On the other hand, they should possess sufficient challenge to stimulate innovation and enhance work quality and efficiency. Finally, after defining performance goals, emphasize clear communication to ensure all employees understand their specific objectives and recognize how individual goals relate to organizational strategy. This lays the foundation for successful goal attainment.

3.2. Optimizing the indicator system

Implementing performance evaluations in public institutions also requires optimizing and refining the performance evaluation metric system. Establishing a scientific and reasonable metric system is the fundamental basis for high-quality performance evaluation work. First, public institutions should build a performance evaluation metric system based on quantifiable indicators, focusing on designing measurable performance metrics. For example, the traditional metric "work attitude" is a qualitative indicator. During system optimization, it can be transformed into quantifiable metrics such as "attendance rate," "initiative in work," "work enthusiasm," and "execution ability." Simultaneously, corresponding scoring standards should be established for each quantitative indicator. This approach effectively mitigates the influence of subjective factors in performance evaluation, enhancing the objectivity and validity of assessment outcomes. Second, during optimization, prioritize comprehensive and holistic metrics to prevent narrow, one-dimensional indicators from skewing outcomes. For instance, when evaluating employee performance, avoid focusing solely on output volume. Instead, integrate assessments of work quality, efficiency, and innovation to provide a more complete and objective reflection of performance and achievements. Finally, optimizing the indicator system requires recognizing the distinctiveness of assessment metrics across different positions. Public institutions should establish targeted, differentiated indicator systems based on the specific duties and characteristics of each role. This approach enables performance metrics to directly reflect the content and unique aspects of each position, thereby further enhancing the objectivity and fairness of performance evaluation outcomes and maximizing the functional role of performance appraisal in human resource management ^[4].

3.3. Strengthening incentive mechanisms

Performance evaluations possess strong motivational effects. When integrated into human resource management, they can stimulate employees' work enthusiasm and unlock their potential. Public institutions should combine performance evaluations with compensation management within human resource systems. This involves optimizing employee compensation structures by increasing performance-based pay, thereby linking work performance directly to salary levels—where higher performance yields higher compensation—to effectively motivate employees ^[5]. To maximize the motivational impact of performance appraisal, public institutions

should concurrently enhance incentive mechanisms by adopting diversified approaches that address employees' varied needs. For instance, institutions can establish incentive systems combining material and non-material rewards, fostering a people-oriented management philosophy that prioritizes understanding employee needs while innovating and enriching incentive methods. First, compensation incentives remain the most fundamental and crucial method. Institutions should optimize compensation structures, implement scientific compensation management, and refine performance-based pay systems. Second, employees demonstrating strong performance should be provided with corresponding promotion opportunities and training resources to fulfill their career development needs. This fosters a sense of fulfillment and belonging within the organization, thereby enhancing employee loyalty. For instance, public institutions can establish talent pipelines to provide superior employees with enhanced development platforms, allowing their talents to be fully utilized. Additionally, employees should be encouraged to actively participate in training programs organized by the institution to continuously enrich their professional knowledge and skills ^[6]. Finally, when building incentive mechanisms, public institutions must emphasize personalization and fairness in incentives. Unrestricted by age or seniority, all employees should be able to earn corresponding rewards by improving their work performance and outcomes.

3.4. Establishing communication mechanisms

Effective communication is indispensable in performance appraisal processes. Public institutions must therefore prioritize establishing scientific and efficient communication mechanisms. On one hand, institutions should define communication objectives based on appraisal needs, scientifically select communication channels and methods, and ensure timeliness and effectiveness ^[7]. For instance, during the initial stages of performance evaluation, managers should engage in effective communication with employees through face-to-face meetings or online platforms regarding evaluation objectives and performance indicators. This ensures that employees at all positions accurately understand and accept the evaluation targets and performance metrics for their roles, laying the groundwork for successfully achieving expected goals. Throughout the performance appraisal process, managers must communicate with employees in real time while evaluating their performance. This allows managers to understand the difficulties and issues employees face in meeting their targets and provide appropriate assistance. On the other hand, public institutions should establish diverse communication channels, including regularly holding employee forums and setting up anonymous suggestion boxes both online and offline. These channels should be used to collect and organize employee suggestions, with performance appraisal work being adjusted based on reasonable employee feedback ^[8].

3.5. Refining feedback mechanisms

The implementation of performance evaluations in public institution human resource management must emphasize timely feedback and effective utilization of assessment outcomes, establishing a scientifically sound feedback mechanism ^[9]. Following the completion of evaluations, managers should promptly disclose results. They should analyze outcomes tailored to the specific circumstances of employees in different positions, providing timely feedback on both the evaluation results and analytical conclusions. This feedback serves as effective guidance for employees' subsequent job performance. The disclosure and feedback of performance evaluation results must prioritize timeliness. Excessively long feedback cycles may cause employees to lose clarity regarding the evaluation content and process, hindering their ability to utilize the results for refining workflows and methodologies. Furthermore, performance feedback should emphasize conciseness, accuracy, and clarity in

expression. It must present well-reasoned analyses grounded in facts and data, enabling employees to better accept the feedback outcomes.

4. Conclusion

In summary, public institutions should prioritize the rational application of performance evaluations in human resource management. By clarifying performance objectives, optimizing indicator systems, strengthening incentive mechanisms, and establishing communication and feedback channels, institutions can fully leverage the functional role of performance evaluations to enhance the effectiveness of human resource management. Moving forward, performance appraisal in public institutions should further optimize and upgrade its processes and methodologies. This includes adopting multiple evaluation approaches such as 360-degree assessments, comprehensive self-evaluations, peer evaluations, and supervisor evaluations. Such measures will enhance the fairness and transparency of the appraisal process, emphasize the full utilization of results, and integrate advanced information technology tools to comprehensively improve the effectiveness of performance appraisal within human resource management.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Zhao Z, Song L, 2025, Brief Discussion on Performance Appraisal and Incentive Optimization Measures in Human Resource Management of Public Institutions. *Business Economics*, (10): 110–112 + 145.
- [2] Wang L, 2025, Research on the Application of Performance Appraisal in Human Resource Management of Public Institutions. *Market Outlook*, (15): 217–219.
- [3] Xiao X, 2024, Application and Optimization of Performance Management in Public Institution Human Resource Management. *Shanghai Business*, (09): 164–166.
- [4] Zhang J, 2024, Strategies for Enhancing Performance Appraisal in Public Institution Human Resource Management. *Finance News*, (15): 73–75.
- [5] Yin X, 2024, The Role of Performance Appraisal in Human Resource Management. *Finance News*, (19): 59–61.
- [6] Zhang M, 2024, A Brief Discussion on Human Resource Management and Performance Appraisal in Public Institutions. *Today's Wealth*, (25): 83–85.
- [7] Ren J, 2024, The Role of Performance Appraisal in Human Resource Management of Public Institutions. *Sales and Management*, (24): 33–35.
- [8] Guo X, 2023, Research on the Role of Performance Appraisal in Human Resource Management of Public Institutions. *Vitality*, 41(23): 97–99.
- [9] Yu Y, 2023, Research on Performance Appraisal in Human Resource Management of Public Institutions. *Vitality*, (14): 106–108.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Research on the Influence of Enterprise Digital Transformation on Accounting Information Quality and Countermeasures

Yulu Han*

Jinan Foreign Language School, Jinan 250100, Shandong, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: With the progress of information technology, the digital transformation of enterprises has developed into a key strategy to improve competitiveness. This paper studies the influence of digital transformation of enterprises on the quality of accounting information and its countermeasures, discusses how digital transformation reshapes the ability of accounting information processing, transparency, sharing, and decision support, and analyzes the challenges in technology, management, and data security during this period. Through in-depth analysis, this paper puts forward a series of targeted countermeasures, including strengthening technology and system construction, optimizing management and processes, strengthening data security and privacy protection, and promoting the improvement of laws and standards, hoping to provide practical guidance for improving the quality of accounting information in the digital transformation of enterprises.

Keywords: Digital transformation of enterprises; Quality of accounting information; Influence; Countermeasure

Online publication: October 14, 2025

1. Introduction

In the face of increasingly fierce global competition, the digital transformation of enterprises has become an irreversible trend. Digital transformation has not only changed the operation mode of enterprises but also profoundly affected the generation, processing, and utilization of accounting information. Accounting information is the main basis of enterprise management decision-making, and its quality directly affects the financial health and sustainable development of enterprises. For this reason, it is of great significance to study the influence and countermeasures of enterprise digital transformation on the quality of accounting information, which can improve the level of enterprise financial management and enhance market competitiveness, and help enterprises better cope with the challenges brought by digital transformation and improve the quality of accounting information. The above countermeasures include not only strengthening technology and system construction, optimizing management process, but also strengthening data security and privacy protection, and improving regulations and

standards. It is expected that this study can provide references for enterprises to improve the quality of accounting information during the digital transformation.

2. Impacts of enterprise digital transformation on the quality of accounting information

The improvement of data processing efficiency and accuracy: Accounting information is an important means to convey the operating results and financial status of enterprises, and plays a decisive role in the economic development of enterprises. Promoting the digital transformation of accounting can improve the quality of accounting information, send a positive signal to the market for the good development of enterprises, attract investors' attention, and lay the foundation for enterprises to obtain more financing capital. At the same time, digital transformation will increase the difficulty of manual manipulation, promote the realization of "self-audit," and ensure the stability of accounting information. The digital transformation of enterprises has obviously improved the efficiency and accuracy of accounting information processing. In the past, manual accounting processing methods were at risk of human error, and the processing speed was slow, so it was difficult to adapt to the rapidly changing market environment. The digital transformation has realized the rapid collection, classification, recording, and analysis of accounting information by introducing an automatic accounting system and intelligent data processing technology. These technologies can not only greatly reduce human errors and improve the accuracy of data processing, but also significantly improve the speed of data processing, so that enterprises can obtain more accurate and comprehensive accounting information in a short time. This can not only help enterprises make correct financial decisions in time, but also improve their operational efficiency and market competitiveness ^[1].

The transparency and traceability of accounting information: Digital transformation has also significantly enhanced the transparency and traceability of accounting information. In the digital age, the accounting information of enterprises is completely recorded in the system, forming a continuous and traceable data chain. This enables enterprises to consult historical data at any time to understand the changing trend of the financial situation, and also facilitates audit and verification by audit institutions. In addition, enterprises can also present accounting information in a more intuitive and understandable way through digital means, such as making information more transparent and easier to understand through charts, reports, and other forms. This can help improve the credibility and credibility of enterprises and enhance the confidence of investors and stakeholders.

Real-time sharing and collaboration of accounting information: Digital transformation has realized the real-time sharing and collaboration of accounting information. In the digital system, accounting information is stored in the cloud or shared platform, and all departments within the enterprise and external partners can access this information in real time. This can not only help to break the information island and realize the interconnection of information, but also promote the cooperation between departments and improve the overall operational efficiency. At the same time, by sharing accounting information in real time, enterprises can also get market feedback and customer demand in time, so as to formulate and adjust financial strategies more accurately.

The ability to improve decision support: Digital transformation has greatly improved the decision support ability of enterprises. By introducing advanced technologies such as big data analysis and artificial intelligence, enterprises can deeply dig into and analyze accounting information and find potential risks and opportunities. These analysis results can provide a valuable decision-making basis for enterprises, help enterprises to better grasp

market trends and customer needs, and formulate more scientific and reasonable financial strategies. In addition, digital transformation also enables enterprises to establish a more perfect financial early warning system, discover and deal with potential financial risks in time, and ensure the steady development of enterprises.

3. Shortcomings of enterprise digital transformation in accounting information quality management

Technical and system level: Although the digital transformation of enterprises has brought many advantages, there are still some challenges in technology and systems. First of all, the compatibility problem between different systems may lead to the phenomenon of data islands, which makes accounting information unable to flow seamlessly between different systems and affects the integrity and consistency of information. Secondly, the update and maintenance of the digital system is also an important issue. With the continuous progress of technology, the system needs to be upgraded to meet the new business needs, but this process is usually accompanied by risks and costs. In addition, the stability and reliability of the digital system are also a big challenge. System failure or data loss may seriously affect the normal operation of enterprises.

Management and process level: At the level of management and process, the digital transformation of enterprises also faces some shortcomings. First of all, digital transformation needs enterprises to have a corresponding organizational culture and management concepts to support it. However, some enterprises may lack enough awareness of change and innovation ability, which makes it difficult to further promote digital transformation. Secondly, digital transformation requires enterprises to redesign their business processes to adapt to the new digital environment. However, there may be resistance during this period, such as the inadaptability of staff to the new process and the inertia of the old process. In addition, digital transformation also requires enterprises to establish a more perfect internal control system to ensure the accuracy and integrity of accounting information, but the establishment of this system requires the investment of time and resources.

Data security and privacy protection: Data security and privacy protection are issues that cannot be ignored in the digital transformation of enterprises. With the improvement of digitalization, accounting information and other sensitive data of enterprises are increasingly stored in the cloud or digital systems. However, these systems may face risks such as hacker attacks from outside, misoperation of internal staff, or malicious disclosure. If the data is leaked or tampered with, it may cause immeasurable losses to the financial health, reputation, and customer relationships of the enterprise. For this reason, enterprises need to strengthen data security and privacy protection, and establish strict data access control, encryption technology, and a monitoring mechanism to ensure data security and integrity ^[2].

4. Measures to improve the quality of accounting information in the digital transformation of enterprises

Strengthening technology and system construction, and building a comprehensive and efficient digital accounting ecology: In the digital transformation of enterprises, technology and system construction are the cornerstones. First of all, enterprises need to choose or develop highly integrated, intelligent, and compatible accounting information systems. This system should be able to seamlessly connect with the core management systems, such as ERP and CRM, and realize real-time data sharing and collaborative processing, thus effectively avoiding the phenomenon of data islands. At the same time, the system should have a strong data processing ability, which

can efficiently process massive and multi-dimensional accounting information and ensure the accuracy and timeliness of data. Enterprises should upgrade and maintain the system regularly if they want to keep the system advanced and adaptable. Specifically, it includes updating software version, optimizing system architecture, and enhancing system security. In addition, enterprises should also pay attention to the development trend of emerging technologies, such as blockchain and artificial intelligence, and actively explore their applications in accounting information processing. For example, using blockchain technology to realize decentralized storage and traceability of accounting information, and using artificial intelligence technology to improve the intelligence level of data processing and decision support ability. In terms of technology and system construction, enterprises should also pay attention to data governance and metadata management. By formulating a unified data standard and data quality monitoring mechanism, the accuracy and consistency of accounting information are guaranteed. At the same time, a metadata management system is established to record and describe the source, structure, and meaning of data in detail, which provides strong support for the analysis and utilization of data.

Optimizing management and processes, and creating an efficient and collaborative accounting management system: Optimizing management and processes is the key to improving the quality of accounting information in the digital transformation of enterprises. First of all, enterprises need to establish organizational culture and management concepts that are suitable for digital transformation. Specifically, it includes encouraging innovation, advocating change, emphasizing synergy and other values, as well as establishing a matching management system, incentive mechanism, and assessment system. By creating a positive working atmosphere, we can stimulate the enthusiasm and creativity of staff and promote the in-depth digital transformation. In terms of process optimization, enterprises should comprehensively sort out and optimize the existing accounting business processes^[3]. Eliminate unnecessary links and redundant operations through process reengineering and process standardization, and improve the efficiency and quality of the process. At the same time, establish a strict internal control system, including a clear division of responsibilities, a strict examination and approval process, and an effective supervision mechanism to ensure the accuracy and integrity of accounting information. In addition, enterprises should also strengthen cross-departmental collaboration and communication. Through the establishment of cross-departmental cooperation mechanisms and communication channels, information sharing and collaborative processing between departments can be promoted. This can help to break down departmental barriers, improve overall operational efficiency, and also help to improve the accuracy and timeliness of accounting information. In order to improve the professional quality and operational skills of staff, enterprises should also strengthen training and skills improvement. Through regular training and learning activities, the staff can keep abreast of new technologies and knowledge and improve their ability and level of handling accounting information. At the same time, staff are encouraged to participate in all aspects of digital transformation, and actively put forward suggestions and suggestions for improvement to jointly promote the in-depth digital transformation.

Strengthening data security and privacy protection, and building an all-round security protection system: Data security and privacy protection are important issues in the digital transformation of enterprises. In order to ensure the security and privacy of accounting information, enterprises need to take a series of measures to strengthen data security and privacy protection. First of all, enterprises should establish a sound data security management system. This includes formulating data security policies, establishing data security organizations, and defining data security responsibilities and authorities. At the same time, strengthen the control of data access rights to ensure that only authorized personnel can access and process accounting information. In addition, a data backup and recovery mechanism should be established to avoid data loss or damage. Secondly, enterprises should adopt

advanced encryption technology and security protection measures to protect the confidentiality and integrity of accounting information. For example, by encrypting data storage and transmission, it can avoid being stolen or tampered with during data transmission and storage. By deploying security measures such as a firewall, intrusion detection, and virus protection, we can resist external attacks and malware intrusion. At the same time, the system is regularly scanned for security vulnerabilities and assessed for risks, so as to find and repair potential security risks in time. In addition, enterprises should also strengthen staff's awareness of data security and skills training. Through regular safety training and drills, the staff's awareness and attention to data security will be improved, and their awareness and skill level of data security will be improved. At the same time, establish an emergency response mechanism for data security incidents to ensure that data security incidents can be quickly responded to and properly handled ^[4].

Promoting the improvement of regulations and standards, and building a sound regulatory environment: In order to ensure the quality of accounting information in the digital transformation of enterprises, the government and relevant institutions should strengthen supervision and guidance on the quality of accounting information in the digital transformation and promote the improvement of relevant laws and standards. First of all, the government should formulate a clear digital transformation strategy and policy orientation to encourage enterprises to actively promote digital transformation. At the same time, strengthen the supervision of accounting information quality in digital transformation to ensure that enterprises comply with relevant laws and standards. The government can introduce relevant policies, such as tax incentives and financial support, to encourage enterprises to increase investment in digital transformation and improve the quality of accounting information. Secondly, relevant institutions should formulate and improve the standards and norms of accounting information quality in digital transformation. These standards and specifications should include data format, data processing flow, data quality control, and other aspects to ensure the accuracy and consistency of accounting information. At the same time, strengthen the publicity and promotion of these standards and norms, and improve the understanding and compliance of enterprises. Relevant institutions can organize experts to revise and improve the standards, so as to adapt to the rapid development of digital transformation. In addition, the government and relevant institutions should also strengthen supervision and guidance on data security and privacy protection in digital transformation. Through the formulation and improvement of relevant laws and standards, the responsibilities and obligations of enterprises in data security and privacy protection are clarified, and the security and privacy of accounting information are guaranteed. At the same time, strengthen the guidance and training for enterprises, and enhance their awareness and skill level of data security. The government can establish a data security supervision mechanism to supervise and inspect the data security work of enterprises and ensure that enterprises comply with relevant laws and standards ^[5].

5. Conclusion

The influence of digital transformation of enterprises on the quality of accounting information is far-reaching and complex. First of all, digital transformation improves the efficiency and accuracy of accounting information processing by introducing advanced information technology and systems, and provides more reliable data support for enterprise decision-making. Secondly, digital transformation has also brought new challenges to data security and privacy protection, as well as new problems in the adaptability of regulations and standards. In this regard, enterprises should take a series of countermeasures to ensure the quality of accounting information. Including

strengthening technology and system construction, improving data processing capacity, optimizing management and processes, ensuring the accuracy and integrity of accounting information, strengthening data security and privacy protection, building an all-round security protection system, and actively promoting the improvement of regulations and standards to provide a strong institutional guarantee for the digital transformation of enterprises. In short, the impact of digital transformation of enterprises on the quality of accounting information cannot be ignored, but by taking effective countermeasures and measures, enterprises should make full use of the opportunities of digital transformation to improve the quality of accounting information and lay a solid foundation for the sustainable development of enterprises. In the future, with the continuous progress of technology and the gradual improvement of laws and regulations, the positive impact of the digital transformation of enterprises on the quality of accounting information will gradually become obvious.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Huy QP, Phuc KV, 2024, Insight into the Impact of Digital Accounting Information System on Sustainable Innovation Ecosystem. *Sustainable Futures*, 2024: 100377.
- [2] Yang J, Ying L, Xu X, 2024, Digital Transformation and Accounting Information Comparability. *Finance Research Letters*, 2024: 61104993.
- [3] Mohammad ASA, Salim ME, 2023, The Impact of Digital Transformation Towards Blockchain Technology Application in Banks to Improve Accounting Information Quality and Corporate Governance Effectiveness. *Cogent Economics & Finance*, 11(1): 102–103.
- [4] Huy QP, Phuc KV, 2022, Digitalization in Small and Medium Enterprises: A Parsimonious Model of Digitalization of Accounting Information for Sustainable Innovation Ecosystem Value Generation. *Asia Pacific Journal of Innovation and Entrepreneurship*, 16(1): 2–37.
- [5] Oualid M, Latifa B, Zakaria D, 2021, Impact of Digital Transformation on Accounting Information Systems—Evidence from Algerian Firms. *Economics and Business*, 35(1): 249–264.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Impact of the Digital Economy on the Performance of China's Petroleum Enterprises

Mengqi Wang, Ziyang Liu*

Department of Global Business, Kyonggi University, Suwon 16706, Republic of Korea

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: The rapid development of the digital economy profoundly impacts global industries, presenting both opportunities and challenges for traditional sectors like petroleum. This study investigates the impact of the digital economy on the performance of Chinese petroleum enterprises, focusing on the mediating role of total factor productivity (TFP). Utilizing panel data from Chinese petroleum firms (2018–2023), we construct a macro digital economy development index (using the entropy method) and a micro-level enterprise digital transformation index. Empirical analysis employs panel data models and mediation effect models. Findings reveal that regional digital economy development significantly positively affects firms' Tobin's Q (coefficient = 0.516). Enterprise digital transformation significantly enhances Return on Equity (ROE) (coefficient = 27.456). Mediation tests confirm that TFP partially mediates the relationship between digital transformation and firm performance. Heterogeneity analysis shows differences based on ownership: regional digital economy development has a slightly stronger effect on state-owned enterprises' (SOEs) market value, while its effect is statistically more significant for private enterprises. Conversely, digital transformation boosts ROE more significantly in private firms. The study concludes with policy recommendations, including promoting digital governance reform in SOEs, increasing support for private firms' digitalization, building a digital technology innovation ecosystem to enhance TFP, and optimizing digital investment structures for better capital market recognition.

Keywords: Digital economy; Enterprise performance; Total factor productivity; Petroleum industry; China

Online publication: October 14, 2025

1. Background

The global economy is rapidly transitioning into a digital era. The digital economy, driven by technologies like big data, artificial intelligence, and blockchain, has become a new engine for economic growth, significantly altering industrial landscapes and competitive environments. Traditional industries, including the energy sector represented by petroleum enterprises, face an urgent need for digital transformation to adapt and thrive^[1–12].

China's digital economy has experienced substantial growth, reaching CNY 53.9 trillion in 2023. National strategies like the "Digital China" initiative underscore the importance of digitalization. Petroleum enterprises,

being capital-intensive, technologically complex, and strategically vital, are under pressure from volatile global oil prices, geopolitical tensions, and the energy transition. Digital transformation offers avenues for these firms to enhance supply chain agility, production process intelligence, customer relationship management, and overall operational efficiency, ultimately aiming for high-quality development^[13].

While existing research explores the general relationship between the digital economy and firm performance in various sectors, studies specifically targeting the petroleum industry, particularly in China, are limited. Furthermore, the mediating mechanism through which digitalization affects performance, especially via total factor productivity (TFP), remains underexplored. This research gap is critical given the potential of digital technologies to optimize resource allocation and improve efficiency in this traditional sector^[14–20].

2. Research purpose

This study aims to empirically analyze the impact mechanism of the digital economy on the performance of Chinese petroleum enterprises. Specifically, it seeks to:

- (1) Examine the direct impact of regional (macro) digital economy development on petroleum firms' market value (measured by Tobin's Q).
- (2) Investigate the direct impact of enterprise-level (micro) digital transformation on profitability (measured by return on equity, ROE).
- (3) Test the mediating role of TFP in the relationship between digital transformation and firm performance.
- (4) Explore heterogeneity in these effects based on enterprise ownership (state-owned vs. private).
- (5) Provide evidence-based policy recommendations to support the digital transformation and performance enhancement of Chinese petroleum enterprises.

3. Methodology

This research employs a mixed-methods approach, combining theoretical analysis with empirical testing.

3.1. Data sources and sample

The study uses panel data from Chinese A-listed companies in the petroleum and natural gas extraction and processing industries from 2018 to 2023. Data primarily comes from the CSMAR database (firm-level financial and governance data) and the National Bureau of Statistics of China (macroeconomic indicators for constructing the digital economy index). Samples marked ST or ST and those with severe missing data were excluded^[20–35].

3.2. Variable construction and measurement

Dependent variables:

Tobin's Q (Tobin_Q): Market value divided by asset replacement cost, reflecting market valuation and future expectations. Used for analyzing macro-level effects^[35].

Return on equity (ROE): Net income divided by shareholders' equity, measuring profitability and efficiency in using shareholder capital. Used for analyzing micro-level effects.

Core independent variables:

Macro digital economy development index (InDigital): Constructed using the entropy method. This comprehensive index incorporates 19 indicators across three dimensions: information infrastructure (e.g., fiber

optic cable length), internet development level (e.g., internet penetration rate, mobile users), and digital transaction development level (e.g., number of e-commerce enterprises, e-commerce sales). Data was standardized and weighted objectively using entropy values.

Enterprise digital transformation index (DigitalTrans): Measured by the proportion of digital technology-related intangible assets (identified by keywords like “software,” “network,” “client,” “management system,” “smart platform,” and related patents) to total intangible assets for the year ^[10].

Mediating variable:

Total factor productivity (TFP): Calculated using both OLS and fixed effects (FE) methods, following the approach of Xiaodong Lu (2012), to measure output efficiency not attributable to standard inputs (capital, labor) ^[36–38].

Control variables: Include leverage (LEV), current ratio (CR), capital intensity (AI, log of total assets per employee), company growth (growth, revenue growth rate), and company age (lnAge, log of years since establishment) ^[35].

3.3. Empirical models

Panel data models (fixed effects): To assess the direct impact of the macro and micro digital economy variables on firm performance, controlling for firm and time-invariant characteristics ^[39].

Model for macro effect:

$$\text{'Tobin_Q_it} = \alpha + \beta_1 \text{lnDigital_t} + \beta_2 \text{Controls_it} + \lambda_i + \gamma_t + \varepsilon_it\text{'}$$

Model for Micro Effect:

$$\text{'ROE_it} = \alpha + \beta_1 \text{DigitalTrans_it} + \beta_2 \text{Controls_it} + \lambda_i + \gamma_t + \varepsilon_it\text{'}$$

Mediation effect model: Based on the stepwise approach by Zhonglin Wen (2014) to test whether TFP mediates the link between digital transformation (DigitalTrans) and performance (ROE) ^[38,39].

$$1. \text{ROE_it} = \alpha + c \text{DigitalTrans_it} + \beta \text{Controls_it} + \lambda_i + \gamma_t + \varepsilon_it\text{' (Test total effect c)}$$

$$2. \text{TFP_it} = \alpha + a \text{DigitalTrans_it} + \beta \text{Controls_it} + \lambda_i + \gamma_t + \varepsilon_it\text{' (Test effect of IV on mediator a)}$$

$$3. \text{ROE_it} = \alpha + c' \text{DigitalTrans_it} + b \text{TFP_it} + \beta \text{Controls_it} + \lambda_i + \gamma_t + \varepsilon_it\text{' (Test direct effect c' and effect of mediator on DV b)}$$

Mediation is supported if a and b are significant. If c' is insignificant, full mediation; if c' is significant but reduced, partial mediation.

4. Results

4.1. Descriptive statistics and correlation

Descriptive statistics showed variation in all key variables. Correlation analysis indicated significant relationships among some control variables but no severe multicollinearity (all VIFs < 2 for macro analysis, < 1.5 for micro analysis), ensuring reliable regression estimates.

4.2. Impact of regional digital economy (macro)

Regression analysis controlling for firm and year effects showed that the development of the regional digital economy (lnDigital) had a significant positive impact on petroleum enterprises' Tobin's Q value.

Coefficient for lnDigital: 0.516 (significant at the 10% level, $t = 1.807$).

This suggests that improved regional digital infrastructure and environment enhance investor confidence and market valuation of petroleum firms ^[3].

4.3. Impact of enterprise digital transformation (micro)

Enterprise-level digital transformation (DigitalTrans) significantly positively affected profitability.

Coefficient for DigitalTrans: 27.456 (significant at the 5% level, $t = 2.101$).

This indicates that investments in digital technologies directly improve the operational efficiency and profitability of petroleum enterprises^[17,23].

4.4. Mediating role of total factor productivity

The mediation analysis confirmed the hypothesized role of TFP.

Digital transformation \rightarrow TFP: Coefficient $a = 42.135$ (significant at 1% level).

TFP \rightarrow ROE: Coefficient $b = 0.126$ (significant at 1% level).

When including both DigitalTrans and TFP in the model predicting ROE, the direct effect of DigitalTrans became smaller and statistically insignificant (c'), while the effect of TFP remained significant.

This result indicates that TFP fully mediates the relationship between digital transformation and ROE. Digital transformation enhances performance primarily by improving overall productive efficiency^[14,38].

4.5. Heterogeneity analysis: Ownership matters

The effects varied between state-owned enterprises (SOEs) and private enterprises.

Regional digital economy (lnDigital) on Tobin's Q:

SOEs: Coefficient = 0.755 (significant at 10% level). Stronger effect size.

Private: Coefficient = 0.687 (significant at 5% level). Higher statistical significance.

Enterprise digital transformation (DigitalTrans) on ROE:

SOEs: Coefficient = 24.218 (not statistically significant).

Private: Coefficient = 34.842 (significant at 10% level).

This suggests that while the regional digital environment boosts market value slightly more for SOEs, private enterprises are statistically more responsive to it and are significantly more effective at translating their own digital investments into improved profitability (ROE). This might be due to more flexible decision-making and market orientation in private firms^[18].

5. Conclusion

This study demonstrates that the digital economy significantly influences the performance of Chinese petroleum enterprises through both macro-environmental and micro-enterprise level channels. Regional digital development enhances market valuation (Tobin's Q), while firm-specific digital transformation directly improves profitability (ROE). Crucially, the mechanism involves digital transformation boosting total factor productivity (TFP), which in turn drives better financial performance. The impact is heterogeneous: state-owned enterprises see a slightly stronger market value benefit from the regional digital environment, but private enterprises demonstrate a greater ability to convert their own digital investments into higher profitability.

6. Policy recommendations

Based on the findings, the following policy recommendations are proposed:

- (1) Promote digital governance reform in SOEs: SOEs should establish dedicated digital transformation

committees, optimize resource allocation for digital projects, and enhance data asset management to improve TFP and overcome market skepticism about their transformation efficiency.

- (2) Increase digital support for private enterprises: Provide targeted financial and tax incentives (e.g., accelerated depreciation, R&D deductions), facilitate access to specialized loans, and establish public service platforms to lower the barriers and costs of digital transformation for private petroleum firms ^[18,40].
- (3) Build a digital technology innovation ecosystem: Foster industry-academia-research collaboration to develop key technologies relevant to petroleum (e.g., digital twins, smart monitoring). Adjust educational curricula to cultivate talent with dual expertise in digital tech and petroleum engineering, sustaining TFP growth ^[14,40–52].
- (4) Optimize digital investment structure: Encourage firms to balance investments in tangible assets and intangible digital assets. Improve disclosure of digital strategy and outcomes to enhance capital market understanding and valuation of digital transformation efforts.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Xuan Y, 2024, Research on the Relationship Between Manufacturing Transformation Pathways Driven by Digital Economy and Corporate Performance. *Papermaking Information*, 2024(09): 128–130.
- [2] Wu J, Zhou S, Wang G, 2024, The Impact of Digital Transformation on Corporate Performance: An Empirical Analysis Based on the Depth and Breadth of Digitalization. *Shanghai Economic Research*, 2024(09): 49–59.
- [3] Ma Y, 2024, Digital Economy, Resource Allocation and Enterprise Performance. *Industrial Innovation Research*, 2024(15): 140–142.
- [4] Tong J, 2024, Analysis of Digital Transformation Pathways in Steel Manufacturing Enterprises and Their Impact on Performance, dissertation, Inner Mongolia University of Finance and Economics.
- [5] Zhang Z, 2024, The Impact of Digital Technology Innovation on Corporate Performance in Listed Construction Enterprises, dissertation, Guangzhou University.
- [6] Zhang W, 2024, The Impact of Digital Transformation on Manufacturing Enterprise Performance. *Modern Marketing (Lower Monthly Issue)*, (05): 1–3.
- [7] Liu H, 2024, The Impact of Digital Transformation on Manufacturing Enterprise Performance: A Case Study of Goldwind Technology. *Management and Technology of Small and Medium Enterprises*, 2024(09): 135–137.
- [8] Zhang Z, 2024, Research on the Impact of Digital Transformation on Manufacturing Enterprise Performance, dissertation, Central South University of Forestry and Technology.
- [9] Chai J, 2024, Research on the Impact of Digital Technology Innovation on Automotive Enterprise Performance, dissertation, Guangzhou University.
- [10] Shi D, Tang H, Wang P, 2024, Enterprise Digital Transformation, Financing Constraints, and Corporate Performance. *Accounting Friends*, 2024(09): 108–116.
- [11] Barefoot K, Curtis D, Jolliff W, et al., 2018, Defining and Measuring the Digital Economy. *US Department of Commerce Bureau of Economic Analysis*, 15: 210.
- [12] Li K, Kim DJ, Lang KR, et al., 2020, How Should We Understand the Digital Economy in Asia? *Critical Assessment*

and Research Agenda. *Electronic Commerce Research and Applications*, 44: 101004.

- [13] Zhang ML, Chen MS, 2019, China's Digital Economy: Opportunities and Risks, International Monetary Fund.
- [14] Pan W, Xie T, Wang Z, et al., Digital Economy: An Innovation Driver for Total Factor Productivity. *Journal of Business Research*, 2022, 139: 303–311.
- [15] Xun Z, Guanghua W, Jiajia Z, et al., 2020, Digital Economy, Financial Inclusion and Inclusive Growth. *China Economist*, 15(3): 92–105.
- [16] Tan L, 2024, Research on the Impact of Digital Transformation on Manufacturing Enterprise Performance, dissertation, Chongqing University of Technology.
- [17] Wang T, 2024, The Endogenous Mechanisms, Empirical Evidence, and Path Selection of Digital Economy Empowering Enterprise Performance. *Future and Development*, 48(03): 19–28.
- [18] Ren Y, Tian Z, Liu C, et al., 2024, How Does Digital Transformation Affect the Performance of Private Energy Enterprises? Empirical Evidence from Annual Report Text Recognition of Listed Companies in China. *Technoeconomics*, 43(01): 41–54.
- [19] Zhao L, Ji Y, 2023, The Impact of Digital Transformation on Corporate Performance: A Transportation Industry Study. *Science, Technology, Economy & Market*, 2023(12): 77–79.
- [20] Li Z, Qin S, 2023, The Impact of Digital Transformation in Manufacturing Industry on Corporate Performance. *Journal of Modern Business Management*, 2023(24): 114–116.
- [21] Liu J, 2023, The Impact of Digital Transformation on Corporate Performance: A Case Study of Haier Smart Home. *Journal of Modern Marketing*, (23): 119–121.
- [22] Chen L, 2023, Research on the Impact of Digital Transformation on Business Performance in Manufacturing Enterprises, dissertation, Dongbei University of Finance and Economics.
- [23] Chen J, 2023, Analysis of the Impact of Digital Transformation on Manufacturing Enterprise Performance: A Perspective Based on Asset Operation Efficiency. *Journal of Hainan Open University*, 24(03): 124–133.
- [24] Liu Y, Zhou T, Zhao Y, et al., 2023, Research on Performance Evaluation of Logistics Enterprises in the Digital Economy Context. *SME Management & Technology*, 2023(18): 112–114.
- [25] Wu C, Chen W, 2023, Digital Economy, Innovation Capacity and Performance of Manufacturing Enterprises: A Discussion on the Moderating Effect of Supply Chain Integration. *Journal of Beijing University of Chemical Technology (Social Sciences Edition)*, 2023(03): 1–11 + 39.
- [26] Agrawal R, Wankhede V, Kumar A, et al., 2022, Nexus of Circular Economy and Sustainable Business Performance in the Era of Digitalization. *International Journal of Productivity and Performance Management*, 71(3): 748–774.
- [27] Sudrajat AI, Tricahyono D, Yulianti EB, et al., 2023, The Role of Digitalization Performance on Digital Business Strategy in Indonesia MSEMs. *International Journal of Professional Business Review*, 8(6): e02260.
- [28] Ribeiro-Navarrete S, Botella-Carrubi D, Palacios-Marques D, et al., 2021, The Effect of Digitalization on Business Performance: An Applied Study of KIBS. *Journal of Business Research*, 126: 319–326.
- [29] Liu Z, Liu J, Osmani M, 2021, Integration of Digital Economy and Circular Economy: Current Status and Future Directions. *Sustainability*, 13(13): 7217.
- [30] Wang Z, 2023, Impact of Digital Economy Development on the Performance of Plastic Products Enterprises. *Plastics Additives*, 2023(04): 106–108.
- [31] Zhang J, Jing J, Lu Y, 2023, Research on the Impact of Digital Transformation on Corporate Performance: A Mechanism Verification from the Manufacturing Industry. *Contemporary Economics*, 40(08): 38–47.
- [32] Zhang J, Liu J, Huang S, et al., 2023, Digital Transformation and Enterprise Performance: A Review and Outlook.

Accounting & Finance Communications, 2023(14): 3–9 + 44.

- [33] Zhao S, 2023, Research on the Impact Mechanism of Digital Economy on Manufacturing Enterprise Performance, dissertation, Nanchang University.
- [34] Cao L, 2023, Research on the Impact of Digital Economy on Innovation in Manufacturing Enterprises, dissertation, Henan University.
- [35] Zhang W, 2023, Digital Transformation, Financing Constraints and Corporate Performance, dissertation, Shanxi University of Finance and Economics.
- [36] Guo X, 2023, The Impact of Digital Transformation on the Performance of Manufacturing Enterprises. *Journal of Economic Research*, 2023(09): 22–24.
- [37] Jiang Q, Liu Y, Duan L, 2023, Digital Transformation, Diversified Operations and Corporate Performance. *Techno-Economics*, 42(04): 82–96.
- [38] Liang Y, Wang Z, Guo M, et al., 2023, Research on the Impact of Enterprise Digital Transformation on High-Tech Company Performance: A Mediation Effect Analysis. *Business Observation*, 9(11): 65–69 + 82.
- [39] Chen X, Jiang Y, Xiong Y, 2023, Research on the Mechanism and Pathways of Digital Transformation's Impact on Corporate Performance. *Economic System Reform*, 2023(02): 112–120.
- [40] Skare M, de Obesso MM, Ribeiro-Navarrete S, 2023, Digital Transformation and European Small and Medium Enterprises (SMEs): A Comparative Study Using Digital Economy and Society Index Data. *International Journal of Information Management*, 68: 102594.
- [41] Su J, Su K, Wang S, 2021, Does the Digital Economy Promote Industrial Structural Upgrading?—A Test of Mediating Effects Based on Heterogeneous Technological Innovation. *Sustainability*, 13(18): 10105.
- [42] Wahdiniwaty R, Firmansyah D, Suryana A, et al., 2022, Mystery in Marketing Management Products Post COVID-19 as a Model of Survival Strategy Towards the Awakening of Micro Small and Medium Enterprises (MSMEs) in the Digital Economy Era. *Khazanah Sosial*, 4(1): 187–210.
- [43] Cui L, Zeng F, 2023, The Impact of Digital Transformation on Retail Enterprise Performance. *Journal of Business Economics*, 2023(04): 123–126.
- [44] Zhang S, Hui P, Li Y, 2023, Digital Technology and SME Performance: The Mediating Role of Information Sharing. *Science and Management*, 43(03): 21–30.
- [45] Liang L, Zhang G, 2022, How Digital Transformation Enhances Corporate Performance: The Dual Mediating Role of Innovation Capability and Supply Chain Partnerships. *Journal of Lanzhou University of Finance and Economics*, 38(06): 30–44.
- [46] Gao H, Wu S, 2022, The Pathway Analysis of Digital Transformation's Impact on Corporate Performance. *Accounting*, 2022(22): 20–22.
- [47] Du M, Chen Y, 2022, Empirical Study on the Impact of Digital Economy Development on Corporate Performance. *Financial Economics*, 2022(08): 43–50.
- [48] Liu D, Bai F, Dong K, 2022, Mechanistic Analysis of Digital Transformation's Impact on Corporate Performance. *Accounting & Finance Communications*, 2022(16): 120–124.
- [49] Cao A, Liu X, 2022, Mechanisms of Digital Transformation's Impact on Corporate Performance: A Technological Perspective. *Journal of Wuhan University of Commerce*, 36(03): 34–40.
- [50] Sun Y, Zhou Q, 2022, The Impact of Digitalization Level on Corporate Performance: An Empirical Study Based on Private Listed Companies in Zhejiang Province. *Journal of Zhejiang Industry & Trade Vocational College*, 22(02): 34–38 + 57.

- [51] Chen S, 2022, Impact of Digital Economy on Manufacturing Enterprise Performance. *Journal of Henan Institute of Science and Technology*, 42(05): 37–46.
- [52] Yin J, Wan H, 2021, The Impact of Digital Transformation in Manufacturing Enterprises on Corporate Performance. *Enterprise Reform and Management*, 2021(13): 22–23.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Research on the Application of Blockchain in Supply Chain Finance in Hainan

Tianhao Dong*

Hainan Vocational University of Science and Technology, Haikou 57000, Hainan, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: This paper explores the application of blockchain in Hainan's supply chain finance, analyzing its impact on enhancing market transparency, optimizing processes, and addressing challenges like information asymmetry and inefficient credit transmission. It examines technical and security issues such as scalability and cross-chain interoperability, proposing solutions like layered architectures and privacy computing. The study highlights blockchain's role in empowering cross-border trade, tropical agriculture, and SME financing, aiming to provide a reference for Hainan Free Trade Port's financial digital transformation.

Keywords: Blockchain; Hainan Free Trade Port; Supply chain finance; Cross-border trade

Online publication: October 14, 2025

1. Introduction

With the acceleration of global trade, digital transformation, and the complexity of supply chain finance, traditional financial models face issues such as information asymmetry, lack of trust mechanisms, and redundant processes, particularly pronounced in the financing of small and medium-sized enterprises (SMEs). Blockchain technology, as a distributed ledger technology, offers a novel solution to these supply chain finance pain points by leveraging its characteristics of decentralization, immutability, and transparency with traceability^[1].

Hainan Free Trade Port, as a significant platform for national strategic deployment, has its supply chain finance development deeply intertwined with the construction of the free trade port. Relying on its four leading industries—tourism, modern services, high-tech industries, and tropical high-efficiency agriculture—Hainan has cultivated a unique cross-border supply chain ecosystem. However, challenges such as difficulties in SME financing, low efficiency in cross-border settlements, and risks of trade document forgery hinder industrial upgrading^[2]. Integrating blockchain technology into Hainan's supply chain finance not only enhances the capital flow efficiency of the local industrial chain but also aids in fostering an international, rule-of-law-based, and facilitative financial environment for the Free Trade Port^[3].

This paper focuses on the application of blockchain technology in Hainan's supply chain finance. By

analyzing the compatibility of technical features with Hainan's industrial needs, it explores the application advantages, challenges, and countermeasures, providing theoretical references for supply chain finance innovation in Hainan Free Trade Port. The research combines the policy dividends of Hainan Free Trade Port with the potential of blockchain technology, aiming to construct an optimized supply chain finance path that aligns with regional characteristics ^[4].

2. Blockchain technology and the overview of supply chain finance in Hainan

2.1. Characteristics of blockchain technology

The application of blockchain technology within supply chain finance has garnered increasing scholarly attention, emphasizing its potential to enhance transparency, security, and efficiency in supply chain operations. Zhang and Peng ^[5] specifically investigated how blockchain can be integrated into supply chain finance, highlighting its capacity to streamline financial transactions and improve trust among stakeholders. Similarly, Liu reviewed existing literature on blockchain-based supply chain finance, underscoring its emergence as a significant research hotspot and emphasizing the transformative potential of blockchain in this domain ^[6].

The features of blockchain technology are fundamental to understanding its transformative potential across various sectors. Several studies highlight key characteristics such as decentralization, transparency, immutability, and security as core features that underpin its applications ^[7].

Decentralization is a prominent feature, facilitating distributed data management without reliance on a central authority. This characteristic is particularly advantageous in energy systems, as discussed, where blockchain enables secure energy distribution and trading within microgrids, addressing issues of centralized control and enhancing user autonomy ^[8]. The open nature of blockchain also fosters transparency, which is crucial in supply chain environments. Alabaddi et al. ^[2] demonstrated how blockchain enhances supply chain transparency and resilience, especially in healthcare, by providing an immutable record of transactions accessible to all stakeholders.

Immutability, a feature where once data is recorded, it cannot be altered, is central to blockchain's trustworthiness ^[9]. This feature supports applications requiring high levels of data integrity, such as in trust accounting, where it examines whether blockchain can substitute or complement traditional trust agents by providing a tamper-proof ledger. Furthermore, the technology's ability to manage data in a sequential, chronological manner is highlighted by ^[8], reinforcing its suitability for real-time data management and auditability.

Blockchain's features also extend to enhancing security in Internet of Things (IoT) environments, as discussed, where blockchain's cryptographic and consensus mechanisms bolster IoT security frameworks ^[10]. In the context of cryptocurrencies, describe how interconnected computers form a chain of blocks containing transaction data, illustrating the decentralized and secure nature of blockchain in digital currency systems.

Overall, these studies collectively underscore that blockchain's core features—decentralization, transparency, immutability, security, and open data management—are instrumental in enabling innovative applications across supply chains, energy, healthcare, IoT, and financial sectors. These features not only facilitate enhanced trust and data integrity but also open avenues for replacing traditional intermediaries and improving operational resilience in various industries.

2.2. General situation of supply chain finance in Hainan

Under the grand context of the free trade port construction, the development of supply chain finance in Hainan is

exhibiting a favorable trend, with robust policy support, active market participation, gradually expanding business scale, and continuous emergence of innovative models. However, it also faces numerous challenges.

The continuous enhancement of policy support provides a solid foundation for the development of supply chain finance in Hainan. The Action Plan for Promoting High-Quality Development of Inclusive Finance in Hainan Province (2024–2028) explicitly states the need to deepen the application of the accounts receivable financing service platform, guide “two chains” core enterprises and provincial state-owned enterprises to leverage their “chain leader” advantages in conducting accounts receivable verification, and enhance financing convenience for small and micro enterprises within the supply chain. The development of supply chain finance in Hainan is driven by policy innovation, leveraging the openness advantages of the Free Trade Port and the empowerment of digital technology, and gradually constructing a multi-level service system. According to the 14th Five-Year Development Plan for the Financial Industry in Hainan Province, the provincial government explicitly proposes accelerating supply chain finance innovation, promoting movable property financing services, supporting the real economy and small and micro enterprises, and establishing an accounts receivable financing incentive mechanism (up to 2 million yuan) to stimulate financial institutions’ enthusiasm. The 2025 document Building an Important Practice Base for New Qualitative Productivity further proposes carrying out the “Artificial Intelligence +” initiative, promoting AI-enabled collaborative development of industrial and supply chains, and strengthening technical support.

In terms of business model innovation, Hainan has broken through traditional credit dependencies, forming three typical practices. First is the innovation in credit guarantee models. In 2023, the Industrial and Commercial Bank of China Hainan Branch collaborated with the Hainan Financial Guarantee Fund to launch the first “credit + supply chain financing guarantee” business, issuing 2.9 million yuan in “Hainan Supply Chain Purchase Loans” to a technology company. This model eliminates the need for core enterprise counter-guarantees, using real transaction data as the credit basis to achieve “signing and lending simultaneously.” Second is the breakthrough in asset securitization. In 2023, Ping An Bank Haikou Branch issued Hainan’s first supply chain finance ABS project, with a shelf scale of 2 billion yuan and an initial priority rate as low as 4.98%, dedicated to serving upstream and downstream enterprises in the Sanya Yazhou Bay Science and Technology City, significantly reducing financing costs within the supply chain. Third is the deepening of scenario-based finance. For example, Sunshine Credit Finance introduced an e-commerce supply chain guarantee product, integrating merchant transaction flows and return rates to shorten the capital recovery cycle for small and medium sellers from one month to 1–2 days, cumulatively serving thousands of small and micro e-commerce enterprises.

Cross-border finance has become a prominent feature. Hainan leverages the combined advantages of RCEP and Free Trade Port policies to promote the facilitation of cross-border capital flows. In 2025, enterprises such as Hainan Natural Rubber Group were approved as the first batch of cross-border capital centralized operation centers, achieving coordinated scheduling of domestic and international funds; Zhonglian International Investment Company, relying on the “Cross-border Investment and Financing Connect” digital platform, integrated investment, financing, and settlement services for Chinese-ASEAN enterprises, accelerating its Southeast Asian market layout after receiving 3 million yuan in angel round financing in 2025, and cumulatively facilitating transactions exceeding 50 million yuan. Meanwhile, the optimization of QFLP/QDLP pilot programs and the expansion of EF accounts further enhance cross-border investment and financing capabilities.

Digital infrastructure serves as the underlying support. The Hainan Provincial Smart Financial Integrated Service Platform integrates government data and core enterprise order information to provide a whitelist and risk control service for downstream enterprises in the industrial chain, such as jointly issuing a 1.5 million

yuan loan with Hainan Bank to downstream distributors of Yuehai Feed. Blockchain and AI technologies are deeply integrated into risk control processes, such as data verification rules and cross-border payment big data applications, providing technical assurance for supply chain finance.

3. Impact of blockchain technology application on Hainan's supply chain finance

3.1. Enhancing market transparency and trust

Leveraging core features such as distributed ledgers, immutability, and smart contracts, blockchain technology has established a technology-driven trust mechanism for Hainan's supply chain finance market ^[11]. It fundamentally addresses long-standing issues in traditional models, including information asymmetry and inefficient credit transmission, while systematically enhancing market transparency and trust in multi-party collaboration.

In cross-border trade supply chain finance scenarios, under the traditional model, documents like customs declarations and bills of lading rely on manual verification, which is highly vulnerable to forgery and inefficient in transmission ^[12]. This leads financial institutions to reduce credit limits or extend approval cycles due to doubts about information authenticity. Blockchain digitizes and uploads these documents to the chain, ensuring immutability through hash encryption and timestamps, allowing participants to query in real-time based on their permissions. All data related to products, transportation, and other relevant aspects are stored on the chain, enabling financial institutions to confirm transaction authenticity without on-site verification. This not only reduces risk control costs but also provides small and medium-sized trading enterprises with equal access to financing opportunities.

Targeting the characteristics of Hainan's tropical agricultural supply chains, traditional live collateral valuation relies on manual assessment, resulting in subjective data and delayed supervision. Financial institutions are reluctant to lend or restrict loan amounts due to difficulties in controlling the value of collateral. Additionally, there is a lack of a reliable basis for agricultural product traceability. Blockchain collects real-time growth data (such as weight and health status) of live pigs and deep-sea fish through IoT devices (e.g., smart ear tags and water quality sensors) and uploads it to the chain, with smart contracts automatically updating valuation models. When fluctuations in collateral value exceed thresholds, smart contracts automatically issue warnings, prompting both parties to adjust financing plans. Meanwhile, data on the cultivation, processing, and transportation of fresh products like lychees and durians is fully traceable on the chain. Consumers can verify the entire process by scanning codes, and financial institutions evaluate enterprises' performance capabilities based on traceability data, forming a virtuous cycle of "consumer trust–brand value enhancement–financing convenience."

In the field of SME financing, under the traditional model, core enterprises' payment commitments hardly reach the end of the supply chain, leaving small and medium-sized suppliers struggling with financing due to a lack of credit endorsements. Blockchain, through platforms like "Haikin Cloud Chain," uploads core enterprises' accounts payable confirmation information onto the chain, generating tamper-proof electronic creditor's rights certificates. Small and medium-sized suppliers can secure financing using these on-chain certificates without requiring core enterprises to reconfirm, and enterprises use the platform to confirm rights for upstream and downstream small and medium-sized suppliers, effectively easing their financial pressure.

Moreover, blockchain's hierarchical permission mechanism ensures data security: core enterprises can view the entire chain of creditors' rights circulation, SMEs only access their own transaction data, and financial institutions verify data authenticity via encryption algorithms without gaining access to commercial secrets. This balance between privacy protection and information sharing not only dispels enterprises' concerns about data leakage but also provides financial institutions with a sufficient risk control basis, significantly improving SMEs'

access to financing.

Blockchain also optimizes the overall credit ecosystem through credit information sharing. In the traditional model, enterprises' credit-related data, such as tax payment records, social security contributions, and customs violations, are scattered across various departments, leading financial institutions to underestimate their creditworthiness due to incomplete information. Hainan has integrated government affairs data with on-chain transaction data to build a "government + business" dual-dimensional credit model. For example, after integrating a company's VAT records, on-chain order fulfillment rates, and logistics delivery rates, its credit score is significantly higher than that evaluated based solely on financial data, enabling it to successfully obtain unsecured credit loans. This multi-source data cross-validation model allows well-operated small and medium-sized enterprises lacking collateral to secure financing based on their credit, thereby improving the credit system of supply chain finance.

3.2. Optimizing business processes and efficiency

Blockchain technology, leveraging its decentralized architecture and the automated nature of smart contracts, systematically reconstructs the business processes of supply chain finance in Hainan ^[1]. It breaks the constraints of information silos and manual intervention in traditional models, enabling efficient collaboration throughout the entire financing chain.

In terms of the financing approval process, under the traditional model, SMEs have to go through cumbersome procedures such as confirmation by core enterprises, multi-level reviews by financial institutions, and repeated transmission of paper documents, which are time-consuming and prone to delays due to human errors ^[10]. Blockchain stores trade contracts, order vouchers, logistics records, and other documents on the chain to form tamper-proof digital archives. Smart contracts automatically complete qualification verification and condition matching according to preset rules ^[13]. For example, when a processing enterprise applies for accounts receivable financing, the blockchain platform directly retrieves the on-chain confirmation information of the core enterprise, and smart contracts quickly complete transaction verification and credit calculation without manual document review, significantly shortening the approval process that originally took several days. All parties in the supply chain share data in real-time through the blockchain, avoiding the inefficiency of multiple parties repeatedly entering the same data, and the connection efficiency of each link is significantly improved.

The process innovation in cross-border settlement is particularly crucial. As a free trade port, Hainan's cross-border trade involves multi-currency settlement, multi-department supervision, and adaptation to rules in multiple jurisdictions ^[4]. The traditional model requires layers of verification by correspondent banks, resulting in long document transmission and clearing cycles and high handling fees. The cross-border trade financing platform built on blockchain digitizes and puts letters of credit, bills of lading, foreign exchange verification documents, etc., on the chain to achieve full network visibility ^[7]. When goods arrive at the port, customs inspection data is automatically synchronized to the blockchain, and smart contracts immediately trigger the bank's letter of credit negotiation process, which greatly shortens the settlement time that originally took several days and eliminates intermediate agency fees. This on-chain direct connection model, combined with Hainan's policy of exempting tariffs for processed products with an added value of 30%, accelerates the turnover of cross-border funds and helps foreign trade enterprises seize opportunities.

In the traditional model, enterprises applying for government-supported financing need to submit multiple paper materials such as business licenses and tax certificates, and some certificates need to be issued on-site by multiple departments, resulting in redundant processes and being prone to expired materials. Blockchain puts

government data, such as enterprise operation qualifications, credit ratings, and policy matching degrees, on the chain, and financial institutions can directly retrieve and verify them with authorization, without the need for enterprises to submit repeatedly. When an enterprise applies for a loan, the blockchain platform automatically links its on-chain data to tax or related departments, and smart contracts quickly calculate indicators such as the proportion of R&D investment and the number of patents to match the interest subsidy policy, significantly shortening the total time from application to loan disbursement. This model significantly reduces institutional transaction costs.

In response to the personalized needs of Hainan's characteristic industries, blockchain, combined with the Internet of Things and big data, promotes the upgrading of processes to be scenario-based and dynamic. In the scenario of living collateral, blockchain connects with IoT devices to collect real-time growth data of live pigs and deep-sea fish. Smart contracts dynamically adjust the financing amount according to weight and health indicators, avoiding the rigid data in the traditional model, where one evaluation is used for the whole year^[14]. When the value of the collateral fluctuates beyond the threshold, the system automatically issues an early warning, prompting both parties to adjust the repayment plan, which not only ensures the capital security of financial institutions but also provides financing flexibility for enterprises. In the tourism supply chain, after the transaction data of hotels, scenic spots, and travel agencies are put on the chain, smart contracts can automatically adjust the proportion of advance payment financing according to the passenger flow during peak and off-seasons, making the capital scheduling of small and medium-sized tourism enterprises more in line with the business cycle.

The distributed collaboration feature of blockchain also realizes the process integration of the entire supply chain^[15]. From order generation, raw material procurement to finished product delivery and capital payment, information of each link is uploaded to the chain in real-time and forms a unified data caliber, avoiding reconciliation disputes caused by inconsistent information in the traditional model. Core enterprises store data such as production plans, supplier stockpiles, and logistics scheduling on the chain. When core enterprises adjust the number of orders, smart contracts automatically trigger adjustments in suppliers' financing limits and optimization of logistics routes, improving the response speed of the supply chain. After the goods are inspected and accepted, the system automatically initiates the payment process without manual transfer, achieving seamless connection.

4. Strategies for the application of blockchain technology in Hainan's supply chain finance

4.1. Technical and security challenges faced

Although blockchain technology holds great potential in the application of Hainan's supply chain finance, it also faces a series of technical and security challenges that require systematic solutions. Firstly, scalability is the biggest bottleneck for the large-scale application of blockchain in Hainan's supply chain finance. Despite the certain advantages of consortium blockchains in cross-border trade scenarios of Hainan Free Trade Port, their throughput (TPS) still cannot meet the needs of high-frequency transactions. For instance, the peak transaction volume of cross-border trade in Hainan can reach 12,000 transactions per day, while the performance of existing consortium blockchains (such as Hyperledger Fabric with 3,500 TPS) may fail to ensure the timeliness and reliability of transactions during peak hours. In addition, the balance between the complexity of smart contracts and transaction speed needs further optimization to adapt to the diverse supply chain financial scenarios in Hainan.

Secondly, the issue of cross-chain interoperability is particularly prominent in the multilateral trade of the Hainan Free Trade Port. As an important hub connecting RCEP member states, Hainan's cross-border supply chain

involves data interaction across multiple jurisdictions. The cross-chain technology between different blockchain platforms is not yet mature, especially with conflicts in data formats, privacy protection, and compliance requirements. For example, cross-border data sharing between Hainan and the Guangdong-Hong Kong-Macau Greater Bay Area needs to take into account both the Data Security Law and the privacy protection regulations of Hong Kong and Macau, but there is currently a lack of unified technical and institutional standards.

Thirdly, data privacy and security are of great importance in blockchain applications. Although the decentralized nature of blockchain can enhance transparency, sensitive commercial data and cross-border transaction information still face the risk of leakage. In 2023, global DeFi platforms suffered losses of up to 1.86 billion US dollars due to security vulnerabilities, highlighting the importance of smart contract code auditing and system protection. If the supply chain financial platforms in Hainan Free Trade Port fail to effectively protect enterprises' commercial secrets and transaction data, it may lead to the loss of competitive advantages and legal disputes.

Finally, the issue of energy consumption and sustainability cannot be ignored. The high energy consumption of blockchain consensus mechanisms (such as Proof of Work, PoW) conflicts to a certain extent with the “dual carbon” goals of Hainan Free Trade Port. For example, the annual energy consumption of the Bitcoin network is equivalent to that of a small country, which is inconsistent with Hainan's strategic direction of promoting a green economy. Therefore, priority should be given to energy efficiency and sustainability requirements when selecting blockchain technologies.

4.2. Corresponding solutions and recommendations

To address the aforementioned technical and security challenges, this paper proposes the following specific measures to promote the sustainable application of blockchain in Hainan's supply chain finance.

First, adopt a layered architecture to enhance system performance. At the core transaction layer, Hainan can introduce a “Layer 1 (main chain) + Layer 2 (lightning network)” architecture, diverting high-frequency transactions to the second-layer network to alleviate pressure on the main chain. For example, state channel technology can enable atomic settlement of cross-border payments, reducing transaction confirmation time to seconds. Meanwhile, to meet the demand for complex smart contracts in supply chain finance, a modular design is recommended to separate core logic from auxiliary functions, improving code maintainability and operational efficiency.

Second, improve cross-chain interoperability and data sharing mechanisms. Hainan Free Trade Port should actively promote the application of cross-chain protocols (such as Polkadot's relay chain and parachain architecture) in cross-border trade scenarios to achieve “one chain for multiple uses and multi-chain collaboration.” Specifically, Hainan can collaborate with the Guangdong-Hong Kong-Macau Greater Bay Area to build a “multi-chain interconnection” demonstration project, exploring zero-knowledge proof (ZKP)-based data sharing solutions to realize information mutual recognition among customs, taxation, and financial institutions while protecting privacy. Additionally, it is advisable to formulate the Hainan Free Trade Port Blockchain Data Sharing Standards to clarify cross-chain data formats, transmission rules, and security requirements.

Third, strengthen smart contract security and privacy protection measures. Hainan's supply chain finance platforms should establish strict smart contract code review mechanisms and introduce third-party auditing institutions to detect vulnerabilities in contract logic. For data privacy, multi-party computation (MPC) and homomorphic encryption technologies are recommended to ensure that cross-border transaction data is “usable but not visible.” For instance, in the offshore duty-free supply chain, MPC can enable collaborative data verification among suppliers, logistics enterprises, and banks, reducing the risk of commercial secrets leakage.

Fourth, promote the research, development, and application of green blockchain technologies. Hainan should prioritize low-energy consensus mechanisms such as Proof of Stake (PoS) and Proof of Authority (PoA), gradually phasing out high-energy-consuming PoW algorithms. Furthermore, Hainan can explore the integration of blockchain with digital renminbi, leveraging the controllable anonymity of digital renminbi to enhance payment efficiency and security in supply chain finance. Finally, Hainan Free Trade Port can pilot “green supply chain finance” in Yangpu Bonded Port Area, uploading carbon emission data to the blockchain to promote in-depth integration of carbon credits and financial assets.

The implementation of these solutions will enable Hainan to effectively overcome technical and security barriers in blockchain applications, creating an efficient, secure, and sustainable supply chain finance ecosystem that provides strong technical support for the high-quality economic development of the free trade port.

5. Conclusion

With the characteristics of decentralization and non-tampering, blockchain technology provides an innovative path for Hainan supply chain finance to solve pain points such as information asymmetry and process redundancy. The research shows that it has achieved remarkable results in improving market transparency and trust, and through the construction of a distributed ledger, the data traceability of the whole process of the supply chain can be realized, providing credible support for scenarios such as live mortgage of tropical agriculture and cross-border trade document verification, and helping small and medium-sized enterprises to obtain financing by relying on on-chain credit. In terms of optimizing business processes, the automated execution of smart contracts greatly shortens the financing approval cycle, promotes the efficiency of government financing and cross-border settlement, and promotes the “three-stream” collaboration of the supply chain. Although it faces challenges such as scalability, cross-chain interoperability, and data security, it can be gradually resolved through countermeasures such as hierarchical architecture, cross-chain protocol, and privacy-preserving computing. In the future, with the advancement of the construction of the Hainan Free Trade Port, blockchain technology will be applied in more scenarios, promoting the intelligent and green upgrading of supply chain finance, injecting impetus into the development of the real economy, and providing a practical example for the digital transformation of supply chain finance.

Funding

2024 Hainan Provincial Higher Education Institutions Scientific Research Self-Funded Project “Research on ‘Blockchain + Supply Chain Finance’ and Financing of Small and Medium-sized Enterprises in Hainan Free Trade Harbor” (Hnky2024ZC-23)

Disclosure statement

The author declares no conflict of interest.

References

- [1] Akindotei O, Igba E, Awotiwon BO, et al., 2024, Blockchain Integration in Critical Systems Enhancing Transparency, Efficiency, and Real-Time Data Security in Agile Project Management, Decentralized Finance (DeFi), and Cold

- Chain Management. *International Journal of Scientific Research and Modern Technology (IJSRMT)* Volume, 3(11): 19–35.
- [2] Alabaddi Z, Obidat A, Alziyadat Z, 2023, Exploring the Effect of Blockchain Technology on Supply Chain Resilience and Transparency: Evidence from the Healthcare Industry. *Uncertain Supply Chain Management*, 11(2): 787–798.
 - [3] Almarri S, Aljughaiman A, 2024, Blockchain Technology for IoT Security and Trust: A Comprehensive SLR. *Sustainability*, 16(23): 10177.
 - [4] Bu D, Jiang L, 2025, The Role of Export Competitiveness in Driving Renminbi Cross-Border Settlement: Micro-Level Evidence from China. *PloS one*, 20(4): e0318099.
 - [5] Farhi L, Laila U, Ahmed A, et al., 2022, Application of Blockchain Technology in Energy Sector for Sustainable Future. *VAWKUM Transactions on Computer Sciences*, 10(2): 11–23.
 - [6] Liu Z, 2020, Literature Review of Supply Chain Finance Based on Blockchain Perspective. *Open Journal of Business and Management*, 9(1): 419–429.
 - [7] Pejovic C, Lee U, 2022, Blockchain Bills of Lading: A New Generation of Electronic Transport Documents. *Poredbeno Pomorsko Pravo*, 61(176): 31–62.
 - [8] Secinaro S, Calandra D, Biancone P, 2021, Blockchain, Trust, and Trust Accounting: Can Blockchain Technology Substitute Trust Created by Intermediaries in Trust Accounting? A Theoretical Examination. *International Journal of Management Practice*, 14(2): 129–145.
 - [9] Tan R, Li Y, Zhang J, et al., 2020, Application of Blockchain Technology to the Credit Management of Supply Chain, *Frontiers in Cyber Security: Third International Conference, FCS 2020, Tianjin, China, November 15–17, 2020, Proceedings 3*, Springer Singapore, 121–132.
 - [10] Tang W, 2022, Analysis on the Financing Mode of Small and Medium-sized Enterprises Based on Supply Chain Finance. *Modern Business*, 1(2): 132–135.
 - [11] Wang M, Wu Y, Chen B, et al., 2020, Blockchain and Supply Chain Management: A New Paradigm for Supply Chain Integration and Collaboration. *Operations and Supply Chain Management: An International Journal*, 14(1): 111–122.
 - [12] Xiao L, 2023, Research on Supply Chain Management Models from the Perspective of Cross-Border E-Commerce. *Industrial Engineering and Innovation Management*, 6(6): 54–59.
 - [13] Yan B, Chen Z, Yan C, et al., 2024, Evolutionary Multiplayer Game Analysis of Accounts Receivable Financing Based on Supply Chain Financing. *International Journal of Production Research*, 62(22): 8110–8128.
 - [14] Yu X, 2021, Blockchain-Based Supply Chain Financial Services Using Smart Contract, *Proceedings of the 2021 4th International Conference on Blockchain Technology and Applications, ICBTA 2021, Xi'an, China, December 17–19, 2021, Association for Computing Machinery*, 63–69.
 - [15] Zhang X, Peng J, 2025, Research on the Application of Blockchain Technology in Supply Chain Finance. *Asia Pacific Economic and Management Review*, 2(3): 81–86.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Research on the Evaluation of the Ecological Niche of the Elderly Care Industry Based on the Theory of Situation

Fan Yin^{1,2}, Jing Gu², Ming Liu², Yadong Li², Tingting Zhao², Chunxia Zhao¹

¹Hebei Normal University of Science & Technology, Qinhuangdao 066004, Hebei, China

²Hebei University of Environmental Engineering, Qinhuangdao 066004, Hebei, China

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: The expansion of the scale of the elderly care industry, the acquisition of market share, and the seizure of high profits depend on the consistency between the ecological niche of the elderly care industry and the actual resource and environmental conditions. Based on the situation theory of ecological niche, this paper expands the factor of “energy” and represents the three dimensions of “state,” “potential,” and “energy” from three aspects: market niche, technology niche, and resource niche. Taking 220 listed companies as samples, this paper improves the traditional catastrophe progression evaluation model and uses structural equation modeling to test the validity of the indicator system, thereby conducting evaluation research on the ecological niche of the elderly care industry. From the results of niche potential energy measurement, the three dimensions of market niche, resource niche, and technology niche are unevenly developed, reflecting the lack of competitiveness of the elderly care industry.

Keywords: Elderly care industry; Ecological niche evaluation; Situation theory; Structural equation modeling

Online publication: October 14, 2025

1. Introduction

The “National Medium and Long-Term Planning for Actively Responding to Population Aging” regards responding to the aging population as a major national strategy. How to achieve the integration of meeting the needs of the elderly and high-quality economic development is the key issue to be solved. Currently, the elderly care industry is emerging, but there is a lack of data. The niche method was first applied to the study of ecological environmental systems. The elderly care industry fits the scenarios of ambiguity and species behavioral diversity applicable to niches. This paper treats the elderly care industry entities as various organisms, introduces the concept of niche into the field of population research, and conducts an empirical analysis of the niche level of China’s elderly care industry.

The current application of niche theory mainly focuses on studying the niche breadth, density, and overlap, exploring issues such as the adaptability of enterprises in the environment, enterprise elimination rate, and

niche overlap. Ren analyzed enterprise niche overlap from the perspectives of causes and morphological models, and further studied its correlation with enterprise competition. He believed that niche overlap is the essence of enterprise competition and leads to a relative scarcity of resources in the process ^[1]. In addition, scholars have also introduced niche theory, mainly based on niche situation theory, to evaluate enterprise competitiveness, establishing a comprehensive evaluation index system for assessment. He and Wang specifically proposed an evaluation index system for the core competitiveness of real estate enterprises, encompassing the “state,” “potential,” and interface dimensions of the enterprise niche, which more comprehensively reflects the core competitiveness of enterprises, especially real estate enterprises, than previous studies ^[2]. Yan constructed an evaluation system based on both state and potential aspects, using a combination of the AHP method and catastrophe theory to evaluate enterprise niches in the Chinese context ^[3]. The evaluation framework of niche situation theory is similar to the Yin-Yang theory and the “Qi” and “Blood” theory in traditional Chinese medicine ^[4]. Although the niche composition variables of the pension industry include policies, capital, technology, services, and talent, according to ecological synergy theory, only a few factors play a key role near the critical point of system change. This paper summarizes the key niche factors of the pension industry into three categories: market niche, technology niche, and resource niche. Based on niche situation theory, the “energy” factor is expanded, and the pension industry niche is evaluated from three aspects: market niche, technology niche, and resource niche, representing the three dimensions of “state,” “potential,” and “energy,” as shown in **Figure 1**.

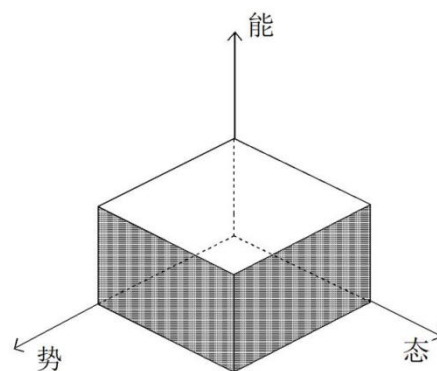


Figure 1. Three-dimensional diagram of “state-potential-energy” of niche in the pension industry

There are mainly two types of traditional situation and trend model evaluation methods. The first type treats the “state” and “trend” of the niche as two separate aspects, measuring them individually through different evaluation methods. However, using two sets of evaluation methods for the same evaluation object may lead to inconsistencies in evaluation scales and large computational workloads, resulting in significant errors ^[5]. The second type of indicator system construction is often based on subjective empiricism, ignoring the specificities of particular problems and lacking validation of whether the indicator system itself is reasonable. The dynamic research method adopted in this paper utilizes a centralized mutation function model and the mutation progression method to fit observations and statistical data of the niche system. This method can capture the primary and secondary relationships of contradictions, suitable for multi-objective comprehensive evaluation. It can conveniently identify mutation points and make decisions about system movements, addressing the limitations of previous static evaluation methods ^[6]. Traditionally, the indicator system for the mutation progression method is often derived subjectively, introducing a certain degree of subjectivity to the indicator system and affecting the

credibility of the comprehensive evaluation conclusions. This issue can be addressed by scientifically validating the effectiveness of the indicator system and improving the mutation progression method using structural equation modeling (SEM).

Therefore, this paper employs the situation and trend theory, collects and summarizes literature, and conducts research and analysis on 220 listed elderly care industry enterprises in 14 industries involving elderly care. It constructs a “state-trend-potential” evaluation index system, measures and analyzes the “state-trend-potential” of the elderly care industry by building an improved mutation progression evaluation model. This provides a theoretical basis and decision-making reference for promoting the development of various industries in China’s elderly care industry, and will facilitate the effective integration and rational allocation of resources in China’s elderly care industry from the institutional and mechanistic perspectives.

2. Construction of an evaluation index system for the elderly care industry niche

The evaluation index system for the elderly care industry niche serves as the structural framework for the development level system of the elderly care industry. The setting of the index system reflects the speed and trend of niche evolution in time, the overall layout and structure of niche evolution in space, the scale and efficiency of niche evolution in quantity, and the function and level of niche evolution in hierarchy. To quantify the elderly care industry niche, an evaluation index system is constructed from three dimensions: “state,” “trend,” and “potential,” corresponding to measurements of the market, technology, and resource niche levels of the elderly care industry.

The market niche factors of the elderly care industry mainly consist of eight indicators across three variables: profitability, operational capability, and social support. The technical niche factor adopts four indicators across two variables: technical research and development investment and technical research and development output. The resource niche factor is specifically divided into 11 indicators across four variables: enterprise scale, capital structure, growth ability, and solvency. The variable types, specific measurement indicators, and calculation formulas for each factor are shown in **Table 1**.

Table 1. Variable decomposition of the evaluation system for the elderly care industry niche

Variable analysis dimension	Variable type	Specific indicator	Meaning	Calculation formula/ notes
Market Niche Factor	Profitability	Sales Gross Margin	Reflects the competitiveness and profit potential of the company’s products	
		Return on Equity (ROE)	Measures the efficiency of a company in utilizing its own capital	
		Earnings Per Share (EPS)	Comprehensively reflects the company’s profit-making ability	
	Operational Capability	Total Asset Turnover	Measures the operational efficiency of enterprise assets	
		Inventory Turnover	Measures the operational efficiency of inventory in production and operation	
		Cash Turnover	Measures the efficiency of cash utilization	
	Social Support	Enterprise Value Growth Rate	Annual average market value, measuring the degree of annual increase/decrease	
		Intangible Assets	Important factors for sustaining enterprise development and establishing corporate image	Year-end Intangible Assets (billion yuan)

Table 1 (Continued)

Variable analysis dimension	Variable type	Specific indicator	Meaning	Calculation formula/ notes
Technology Niche Factor	Technology R&D Input	R&D Personnel Ratio	Represents the software component (personnel aspect) of the enterprise's R&D capability	
		R&D Expense Ratio	Measures the financial intensity of the enterprise's R&D investment	
	Technology R&D Output	Number of Technical Personnel	Represents the software component (personnel aspect) of the enterprise's technical capability	Year-end Number of Technical Personnel (persons)
		Number of Patents	Represents the output results of the enterprise's technology R&D investment	Year-end Number of Authorized Patents (items)
Resource Niche Factor	Enterprise Scale	Total Number of Employees	Measures the software component (personnel aspect) of enterprise scale	Year-end Total Number of On-Duty Employees (persons)
		Total Assets	Measures the stock aspect of enterprise scale	Year-end Total Assets (billion yuan)
		Operating Revenue	Measures the scale of annual revenue	Year-end Total Operating Revenue (billion yuan)
	Capital Structure	Shareholders' Equity Ratio	Reflects the proportion of owner investment in the enterprise's assets	
		Fixed Asset Ratio	Indicates whether there is idle capital in the enterprise's fixed assets	
	Growth Capability	Total Asset Growth Rate	Measures the capital accumulation ability and development capability in the current year	
		R&D Expense Growth Rate	Indicates the momentum of sustained growth in the enterprise's innovation capability	
		Net Profit Growth Rate	Measures the growth rate of the enterprise's current net profit compared to the previous period	
	Solvency	Asset-Liability Ratio (Net Assets)	Measures the security level for creditors granting loans	
		Current Ratio	Measures the ability of current assets to be converted into cash to repay debts before short-term debts mature	
		Quick Ratio	Measures the ability of highly liquid current assets to be immediately converted to repay current liabilities	
		Net Profit Growth Rate	Measures the growth rate of the enterprise's current net profit compared to the previous period	

The selection of the above indicators should objectively reflect reality, be scientific and reasonable, and take into account the availability of statistical data. This article mainly selects 23 indicators from three levels: market niche, technological niche, and resource niche of the pension industry. The pension industry niche is decomposed into an inverted tree-shaped index system, and the overall indicator is decomposed layer by layer into the more specific and quantifiable sub-indicators at the lowest level. When calculating, it is only necessary to know the raw data of the lowest-level sub-indicators.

3. Data sources and sample selection

Based on the “Classification and Codes of National Economic Industries” (GB/T4754-2017) used by statistical departments, this study focuses on 14 types of industries in the elderly care industry, including agriculture, forestry, animal husbandry, and fishery (A), manufacturing (C), construction (E), wholesale and retail (H), accommodation and catering (I), information dissemination, software, and information technology services (G), finance (J), real estate (K), leasing and business services (L), scientific research and technology services (M), resident services, repairs, and other services (O), education (P), health and social work (Q), and culture, sports, and entertainment (R).

Listed companies in China involved in the elderly care concept stocks are selected as research samples. On the one hand, from the perspective of supply, listed companies are characterized by large scale, strong financial resources, and strength. Most of them belong to oligopolistic or monopolistically competitive enterprises with economies of scale in the emerging elderly care industry. Therefore, the characteristic of high market share can be used as a typical representative of different industries in the elderly care industry. On the other hand, from the perspective of demand, listed elderly care companies represent the recognition and support of many consumers for the industry and enterprises. The longer the listing time and the higher the financial quality, the more they are favored by consumers and have greater market potential. Therefore, it is feasible to study and judge the development of China’s overall elderly care industry based on the development status of listed elderly care industry companies.

Based on the 2018 annual reports of elderly care industry enterprises in the Wind database, comprehensive data from 229 listed companies with continuous listing status in the Shanghai and Shenzhen stock markets as of the end of 2018 were selected. According to the classification of 14 industries in the elderly care industry, a total of 220 listed companies were selected as samples. All 23 indicators of the sample companies use publicly available data from 2018. The financial data involved comes from the Wind database, and other non-financial data is manually collated from the annual reports of the sample companies.


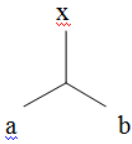
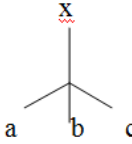
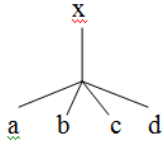
4. Construction of an improved catastrophe progression evaluation model

4.1. Principles of the catastrophe progression model

Catastrophe theory is an emerging mathematical branch that studies discontinuous phenomena. It has developed based on the theory of system structural stability, topology, and singularity theory. Its main idea is to classify critical points according to the potential function, study the characteristics of discontinuous states near various critical points, namely, several primary catastrophes with a limited number, and explore mutation phenomena in nature and society based on this.

By combining the bifurcation set equation in catastrophe theory with fuzzy mathematics, a mutation fuzzy membership function (normalization formula) is derived. The normalization formula converts the different qualitative states of various control variables within the system into a comparable qualitative state. The normalization formula performs comprehensive quantitative calculations, ultimately normalizing to one parameter, namely, calculating the overall membership function. This provides a comprehensive evaluation method for ranking and analyzing evaluation targets. See **Table 2** for specific models and calculation formulas.

Table 2. Catastrophe progression method evaluation model and formulas

Type	Fold catastrophe function	Cusp catastrophe function	Swallowtail catastrophe function	Butterfly catastrophe function
Schematic diagram				
Model	$f(x) = x^3 + ax$	$f(x) = x^4 + ax^2 + bx$	$f(x) = \frac{1}{5}x^5 + \frac{1}{3}ax^3 + \frac{1}{2}bx^2 + cx$	$f(x) = \frac{1}{6}x^6 + \frac{1}{4}ax^4 + \frac{1}{3}bx^3 + \frac{1}{2}cx^2 + dx$
Number of variables	a	a, b	a, b, c	a, b, c, d
Bifurcation set equation	$a = -2x^2$	$a = -6x^2$ $b = 8x^3$	$a = -6x^2, b = 8x^2$ $c = -3x^4$	$a = -10x^2, b = 20x^3$ $c = -15x^4, d = 5x^5$
Normalization formula	$x_a = \sqrt{a}$	$x_a = \sqrt{a}$ $x_b = \sqrt[3]{b}$	$x_a = \sqrt{a}, x_b = \sqrt[3]{b}$ $x_c = \sqrt[4]{c}$	$x_a = \sqrt{a}, x_b = \sqrt[3]{b}$ $x_c = \sqrt[4]{c}, x_d = \sqrt[5]{d}$

4.2. Optimization of the catastrophe progression method based on SEM

The catastrophe progression method decomposes evaluation targets into multi-level contradictions without examining whether the indicator system itself is reasonable. This may lead to significant errors due to the subjectivity of the indicator system construction, affecting the scientific validity and rationality of the conclusions. Therefore, it is necessary to improve and refine the traditional Catastrophe Progression Evaluation Model. SEM is used to test the effectiveness of the indicator system, eliminating evaluation errors caused by subjectivity. SEM can estimate and identify abstract concepts, with the application of covariance as its core. It can also handle average estimations, is suitable for large sample analysis, and has theoretical apriority. Structural equation analysis can be roughly divided into five steps.

5. Measurement of the “state-trend-energy” of the ecological niche in the elderly care industry

Step I: Non-dimensionalization Processing of Raw Data. Based on data from 220 listed companies, the original 23 indicator data points are first weighted and averaged, and then processed using a non-dimensional formula. The calculation formula is as follows:

$$C'_i = \frac{C_i - \min C_i}{\max C_i - \min C_i}$$

Where i represents the sample number, ranging from 1 to 220, and the standardized values range from 0 to 1.

Step II: SEM Indicator System Validation. 23 observed variables and 3 latent variables are identified. The latent variables represent the three analytical dimensions of the ecological niche in the elderly care industry:

market niche factor, technological niche factor, and resource niche factor. The observed variables are the 23 specific indicators selected from these three aspects of the elderly care industry.

The validity of the indicator system is tested using the structural equation method, implemented through the LISREL structural equation modeling software via programming. Additionally, to examine the stability of the improved model, a t-test and a goodness-of-fit test are conducted on the model. See **Table 3** for the LAMBDA-X output results.

Table 3. LAMBDA-X output results

Observable variable	Parameter estimation	Standard error	t value
A1	0.74	0.29	2.17
A2	0.87	0.31	2.31
A3	0.65	0.27	2.01
A4	0.61	0.26	2.00
A5	0.81	0.28	2.18
A6	0.92	0.29	2.14
A7	0.74	0.30	3.31
A8	0.69	0.27	3.01
B1	0.82	0.30	2.87
B2	0.83	0.28	2.92
B3	0.77	0.29	2.84
B4	0.63	0.24	2.51
C1	0.90	0.26	2.60
C2	0.81	0.31	2.05
C3	0.64	0.27	2.32
C4	0.71	0.27	2.77
C5	0.73	0.26	2.49
C6	0.70	0.30	2.35
C7	0.69	0.27	2.01
C8	0.84	0.26	2.08
C9	0.59	0.28	2.32
C10	0.66	0.29	2.11
C11	0.68	0.26	3.04

Based on the output results of the model in **Table 4**, the model's $RMSEA = 0.02 < 0.08$, $GFI = 0.91 > 0.9$, $NNFI = 2.26 > 0.9$, indicating a good fit of the model. Additionally, the model's $CFI = 1.04 > 0.9$, showing that no revision is needed. This suggests that the comprehensive evaluation index system for the ecological niche of the pension industry constructed in this paper is reasonable and highly stable.

Table 4. Test results of goodness-of-fit statistics

RMSEA	GFI	NNFI	CFI
0.02	0.91	2.26	1.04

Step III: Identify the type of catastrophic system. In catastrophe theory, the variables used to describe the system are divided into state variables and control variables. When the system is in a stable state, the value of the function remains constant. However, when parameters change within a certain range, the function may have multiple extrema, causing the system to transition from a stable to an unstable state, known as a catastrophe.

According to **Table 2**, commonly used catastrophe models include the fold catastrophe function, the cusp catastrophe function, the swallowtail catastrophe function, and the butterfly catastrophe function. The measurement of the ecological niche potential energy of the pension industry is a multi-factor system evaluation. In this case, the type of function is determined based on the number of control variables x . As shown in **Figure 2**, the profitability (B_{11}) of the market ecological niche factor has three control variables: gross sales margin (C_1), return on equity (C_2), and earnings per share (C_3), making it a swallowtail catastrophe function. Using statistical data from 220 listed companies in China's pension industry as of the end of 2018, a catastrophic progression evaluation model is constructed, as detailed in **Table 5**.

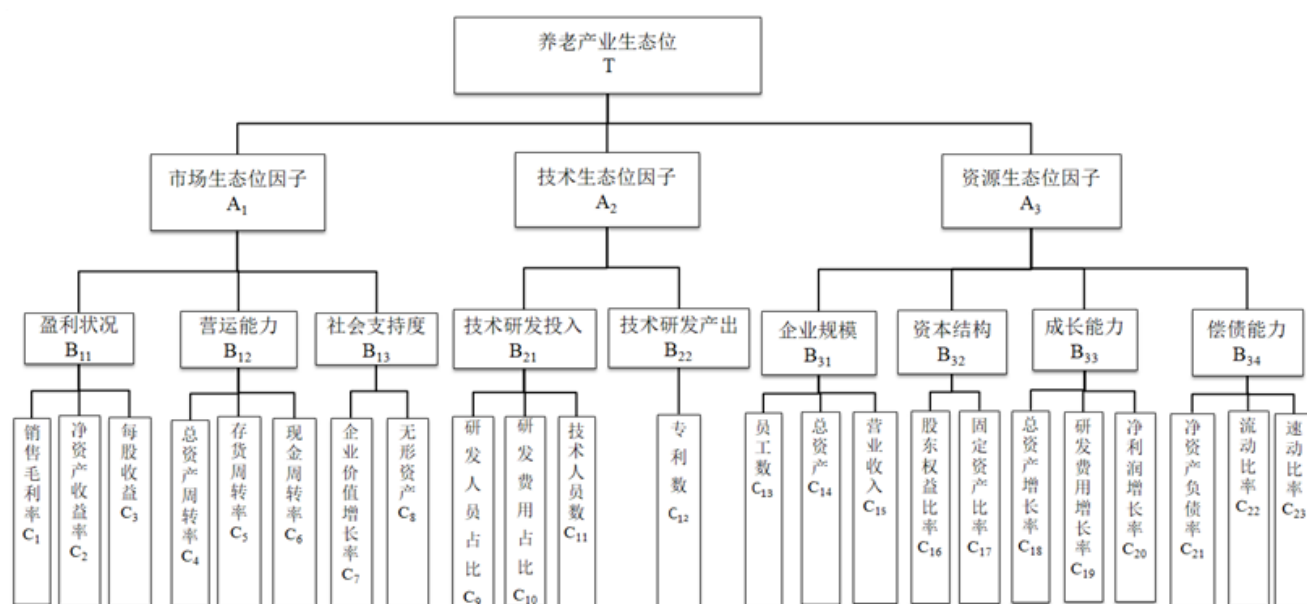


Figure 2. Comprehensive evaluation index system of the ecological niche of the elderly care industry

Table 5. Catastrophic model structure adapted to comprehensive evaluation indicators

T	A1	A2	A3	B11	B12	B13	B21	B22	B31	B32	B33	B34
The swallowtail model	The swallowtail model	The tip model	The butterfly model	The swallowtail model	The swallowtail model	The tip model	The swallowtail model	The folding model	The swallowtail model	The tip model	The swallowtail model	The swallowtail model

Step IV: Derive a normalization formula and use it for evaluation. For simplicity and typicality of the indicator system, complementary indicators are selected to jointly interpret each variable.

The catastrophic progression method is used to calculate the comprehensive strength of the enterprise's

ecological niche from three different dimensions: market, technology, and resource factors. The three ecological niche factors are decomposed layer by layer to the lowest level of quantitative indicators, determining the type of catastrophic function model $f(x)$ between different levels. Finally, the market ecological niche, technological ecological niche, resource ecological niche, and comprehensive ecological niche measurement values and rankings for 14 industry populations are obtained, as shown in **Table 6**.

Table 6. Measurement results of the ecological niche of industry populations in the pension industry

Industry population	Market niche	Ranking	Technology niche	Ranking	Resource niche	Ranking
A Agriculture, Forestry, Animal Husbandry and Fishery	0.77	7	0.46	6	0.71	14
C Manufacturing	0.82	1	0.43	12	0.76	1
E Construction	0.80	3	0.51	2	0.75	2
F Wholesale and Retail Trade	0.78	5	0.50	4	0.75	2
H Accommodation and Catering Services	0.77	7	0.32	14	0.75	2
I Information Transmission, Software and IT Services	0.76	10	0.52	1	0.74	10
J Finance	0.76	10	0.44	9	0.75	2
K Real Estate	0.79	4	0.44	9	0.75	2
L Leasing and Business Services	0.76	10	0.46	6	0.75	2
M Scientific Research and Technical Services	0.76	10	0.51	2	0.73	12
O Resident Services, Repair and Other Services	0.78	5	0.37	13	0.73	12
P Education	0.75	14	0.48	5	0.74	10
Q Health and Social Work	0.81	2	0.44	9	0.75	2
R Culture, Sports and Entertainment	0.77	7	0.46	6	0.75	2

6. Analysis of measurement results for the “state-trend-energy” of the elderly care industry’s ecological niche

Based on **Table 6**, a radar chart comparing the ecological niches of the elderly care industry is drawn, as shown in **Figure 3**. The measurement results are evaluated and analyzed from four aspects: comprehensive evaluation, market niche, technology niche, and resource niche.

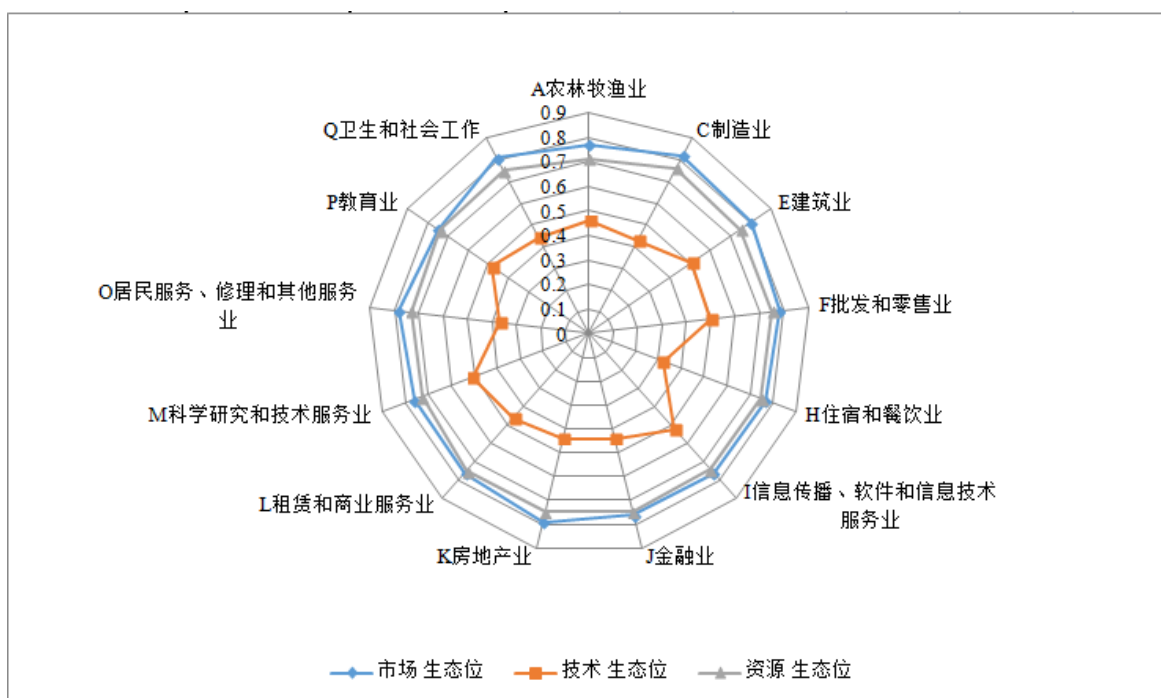


Figure 3. Radar chart comparing the measurement of ecological niches in the elderly care industry

6.1. Analysis of dimensional measurement results for the elderly care industry's ecological niche

From a comprehensive perspective, the elderly care industry's ecological niche is generally at a relatively early stage of development, and the three dimensions are unevenly developed. Among them, the market niche is located on the outermost layer of the circle, with the highest score above 0.75. This indicates that the elderly care industry contributes significantly to the economy, has a large market demand, and can drive China's economic development overall. The elderly care industry is expected to become a pillar, strategic industry, and a major engine of economic growth in China. The middle layer represents the resource niche, with measurement results ranging from 0.70 to 0.80. This suggests that the elderly care industry has a high capacity for sustained development and long-term benefits, indicating significant potential for growth. The innermost layer represents the technology niche, with scores ranging from 0.32 to 0.51. This reflects a lack of competitiveness in the elderly care industry, which currently serves as a bottleneck restricting its development in China. It also represents a direction that the country, as well as industries and enterprises, needs to overcome in the future. Cultivating and improving the technology niche is an urgent priority for the elderly care industry in China.

Based on the results of the market niche measurement (**Figure 4**), it can be observed that the discrimination of measurement outcomes for different industry market niche factors is relatively low, ranging overall from 0.75 to 0.82. Currently, the pension manufacturing industry contributes the most to China's economic development, serving as a pillar industry within the pension sector and positioned at the upstream end of the entire pension industry chain. Listed companies involved in pension manufacturing have the highest number in the entire industry, and in recent years, the market size growth rate of China's pension manufacturing industry has shown an upward trend. Ranked second is health and social work, which is related to the increasing total population of aging individuals in China and the high demand for care among elderly people who are advanced in age or have

difficulties in self-care. The third-ranked industry is construction. With the development of the pension industry, specialized pension healthcare, pension real estate, and integrated medical and nursing care models require accommodation and dining facilities that meet national standards, thus giving rise to a significant demand for pension construction services. In contrast, the pension education industry ranks at the bottom, with a measurement result of only 0.75. Although the government has introduced various policies to promote the development of the pension service industry, such as the Opinions on Promoting the Development of Pension Services issued by the General Office of the State Council in 2019, which emphasizes the need to vigorously develop elderly education as part of efforts to enhance the quality of pension services, overall, the pension education industry has developed slowly compared to other pension-related industries, and its market vitality has not been fully stimulated. In summary, although the scores for the three variables of profitability, operational capability, and social support, which consist of eight indicators calculated from bottom to top using the catastrophe progression method, vary, the final calculated scores for the market niche factors do not differ significantly. Different industry groups contribute roughly equally to the current national economy, with high overall income quantity and quality. The pension industry is a lucrative sector with a promising future, which explains why more and more enterprises are transitioning into this field.

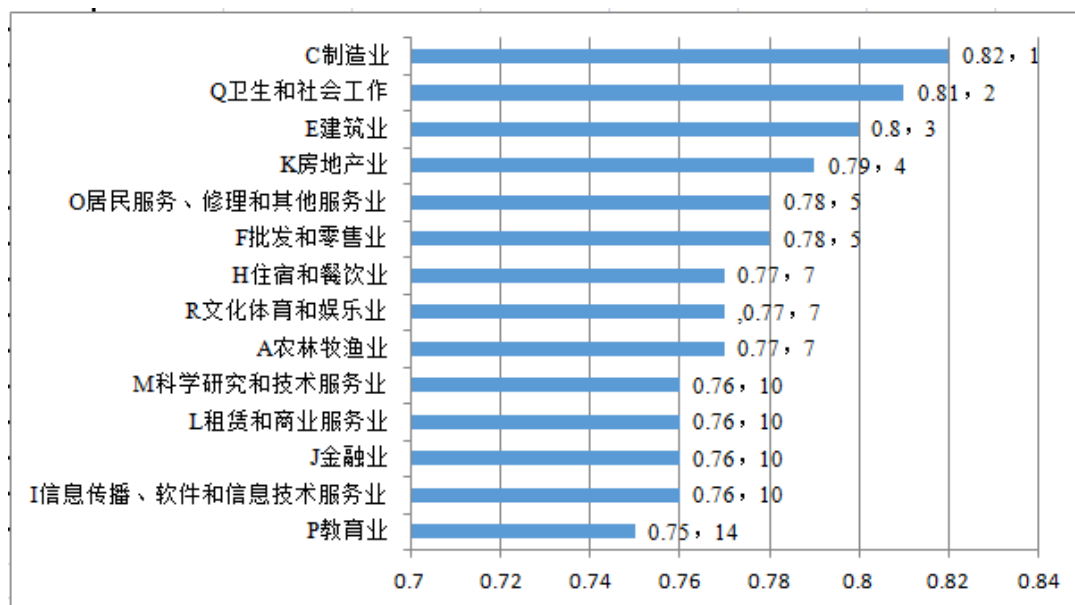


Figure 4. Results of the market niche measurement

Based on the results of the technological niche measurement (**Figure 5**), significant differences can be observed among various industry groups, with overall scores ranging from 0.32 to 0.52. Among these, the information dissemination, software, and information technology service industry ranks first, scoring 0.52. This is followed by the construction industry and the scientific research and technology service industry, both with a measurement result of 0.51. Evidently, to capture the elderly demographic, these industries require cutting-edge technologies to survive in the rapidly developing technological landscape of modern society. Consequently, they occupy the high ground in terms of technology among businesses catering to the elderly, thereby enhancing the overall competitiveness of the industry. The wholesale and retail industry ranks fourth with a score of 0.5. The primary reason for this is that businesses engaged in wholesale and retail for the elderly often operate as composite

enterprises with multiple industries and projects. As national policies increasingly favor businesses catering to the elderly, more companies are emphasizing scientific research input and output. These wholesale and retail enterprises often balance production, processing, and manufacturing, while registering as primarily engaged in wholesale and retail, subsequently expanding their business scope. Therefore, a high level of scientific research input and output leads to strong transformation capabilities of enterprise achievements, further enhancing their competitiveness in the market and forming a virtuous cycle. From the perspective of a technological niche, the manufacturing industry for the elderly has no advantages. Enterprises in this sector, along with their supporting manufacturers, are small in scale, resulting in limited resources for further investment. Globally, there are sixty thousand types of products for the elderly, with Japan offering forty thousand. However, China's manufacturing industry for the elderly provides fewer than three thousand products, indicating a shortage of product categories and a significant lag in technology compared to developed countries. The accommodation and catering industry ranks last with a score of only 0.32, a difference of 0.2 from the top-ranked industry. Enterprises in this sector reflect the varying levels of competitiveness among different industries. Service industries that do not require high technology tend to have weaker competitiveness.

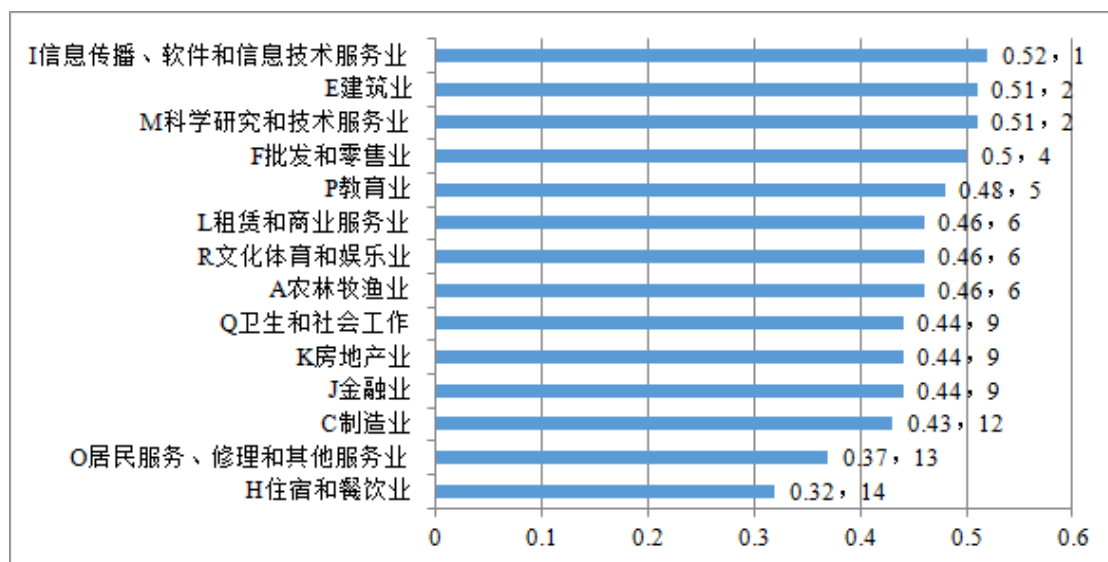


Figure 5. Ranking of measurement results of the technical ecological niche of the elderly care industry

Based on the measurement results of the resource niche (**Figure 6**), it can be seen that the niche evaluation values of various industries are very close, with a small standard deviation, falling into five gradients. The manufacturing industry ranks first with an absolute advantage of 0.76 in total score. This industry has the highest capacity for sustained development and long-term benefits. The second gradient includes eight industries: culture, sports, and entertainment; health and social work; leasing and business services; real estate; finance; accommodation and catering; wholesale and retail; and construction. The measurement results for all eight industries are 0.75. The third gradient comprises education, information dissemination, software, and technical services, with measurement results of 0.74 for both industries. The fourth gradient includes resident services, repairs, and other services. Agriculture, forestry, animal husbandry, and fisheries rank last, as their sustained development capability and long-term benefits are not currently favored. Overall, listed companies in the elderly care industry exhibit good enterprise scale, capital structure, growth capacity, and solvency. The elderly care

industry is showing a positive development trend, with strong, sustained development capability and promising long-term benefits. Although there is currently little overall difference among various industries, in the future, there will be a high degree of overlap among elderly care industries in terms of resource allocation, leading to increased competition.

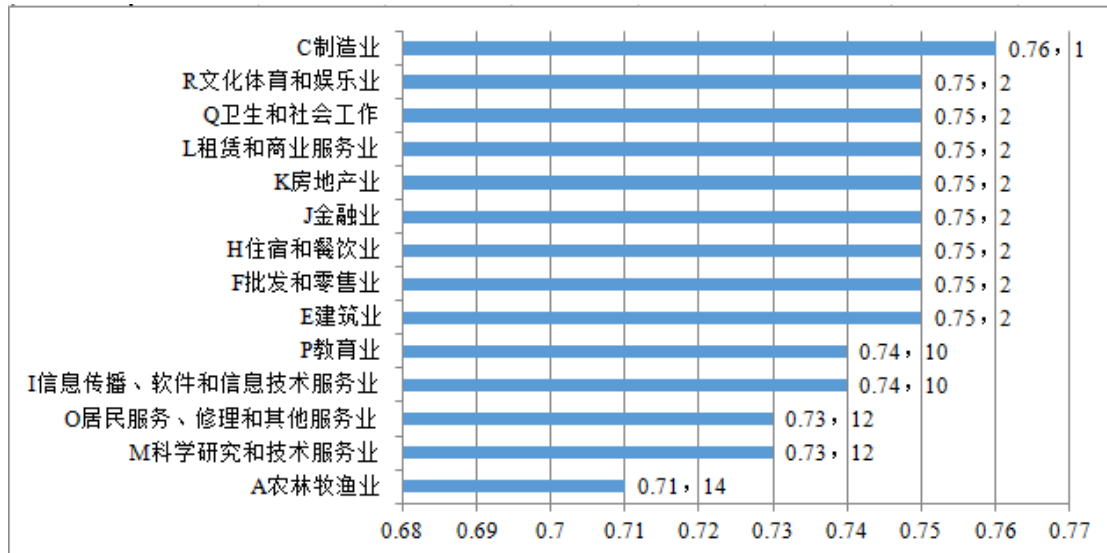


Figure 6. Ranking of measurement results of the resource niche in the elderly care industry

6.2. Analysis of niche measurement results by industry in the elderly care industry

Based on Table 6, which provides niche measurement values for the market niche, technology niche, and resource niche in the elderly care industry, we have plotted the “state-trend-energy” values for the elderly care industry niche in China, as shown in Figure 7.

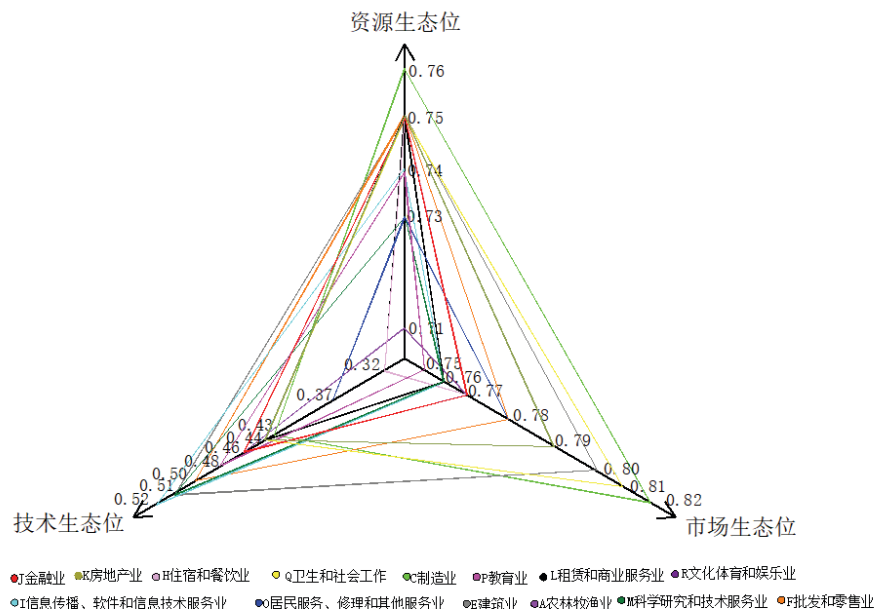


Figure 7. Measurement value of “state-potential-energy” of the ecological niche of the elderly care industry

As seen in **Figure 7**, which shows the “state-trend-energy” measurement values of the ecological niche of the pension industry, China’s pension industry has not yet formed a distinct circle, and the measurement results of various industries are intertwined, without forming a scale effect or a leading industry. The three dimensions of industry development—“state,” “trend,” and “energy”—are shifting. This indicates that there are obvious issues in the development of the pension industry, such as inaccurate industry positioning, low concentration of industrial elements in certain regions, and excessive “hot money” or “fast money” in investments. As a result, on the one hand, pension demand has not been fully released and converted into market demand, and on the other hand, the overall supply of elderly care services shows a low-level involution and lacks sustainable development momentum. This suggests that there are inaccuracies in the policy direction and focus of the development strategy.

Based on the ranking of population measurement values in **Table 6**, various industries are projected into the ecological niche space based on their ranking, as shown in **Figure 8** below, using AutoCAD software.

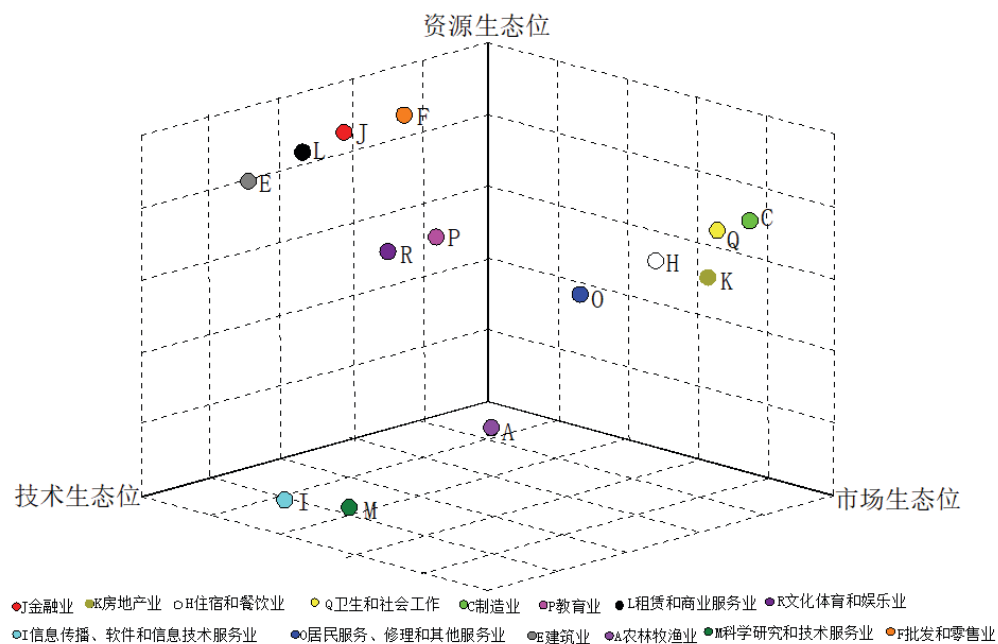


Figure 8. Spatial projection of the “state-trend-energy” ecological niche of the elderly care industry

As can be seen clearly from the figure above, the development of different industries has its own characteristics. Here, the spatial projection points are divided into three categories: market-constrained, technology-constrained, and resource-constrained.

6.2.1. Market-constrained

Market-constrained refers to industries where both the technical ecological niche and resource ecological niche rankings are high, while the market ecological niche ranking is relatively low. Industries with projections on the “resource-technology” ecological niche plane are classified as market-constrained. Among them, the financial industry (J), leasing and business services (L), and education (P) have market ecological niches ranked outside the top 10, which has become a shortcoming for the development of these industries.

The pension construction industry (E) ranks in the top three positions in all three dimensions of ecological niche level. As the country gradually pays more attention to the elderly population, the design specifications for elderly care facility architecture have gradually increased their standards. The leapfrog development of the pension industry in the future will require the driving and radiating effects of the construction industry.

The pension wholesale and retail industry (F) ranks highly in all three dimensions of ecological niche level. There is a wide range of health products, physiotherapy equipment, and daily living aids available on the market, and the sale of daily necessities tailored to the physiological characteristics of the elderly is gradually increasing in the pension wholesale and retail industry. In the future, as the number of elderly people increases, this type of lifestyle service industry will have a huge market and potential.

The pension finance industry (J) only has a resource ecological niche ranked 2nd, while its market and technical ecological niches are both lagging. Only a small number of elderly people are aware of the importance of financial planning for retirement and actively participate in commercial pension insurance and bank financial products, but this group is relatively small. However, China has not yet launched dedicated pension financial products, and some are only individual financial projects.

The leasing and business service industry (L) has the strongest resource ecological niche, ranking 2nd, followed by the technical ecological niche, and the weakest market ecological niche, ranking 10th. Although the overall market contribution of the elderly care service industry is high and its development potential is great, the leasing and business service industry does not occupy a major position, mainly relying on elderly consulting and intermediary services, and the leverage effect of economic growth has not been fully utilized. This industry is also a knowledge-intensive industry that can only provide services to elderly consumers through the professional knowledge of its employees, leveraging the industry's economies of scale.

The pension education industry (P) has the strongest technical ecological niche, ranking 5th; the resource ecological niche ranks 10th; especially the market ecological niche ranks last, which has become a current shortcoming of the industry's development. The development of China's geriatric education industry only stays at the level of public geriatric universities in various regions or activities organized by geriatric associations, and has not formed industrialized operations. There is a serious gap between this and the vast needs of many elderly groups, especially the highly educated elderly groups represented by the post-60s generation.

The cultural, sports, and entertainment industry (R) has a strong resource ecological niche, ranking 2nd; both the market and resource ecological niches are in the middle. Among them, the pension tourism industry has a strong momentum and obvious sustainable development trends. The results of the fourth sample survey of the living conditions of urban and rural elderly people in China show that the elderly have a strong willingness to travel. The better-developed cultural products for the elderly are newspapers, magazines, and books. There is a large demand for cultural supplies in the market, but there is insufficient investment in development and research. Developing high-end cultural products for the elderly is an important growth point for developing the elderly product market in the future and an important choice for vigorously developing the pension cultural industry.

6.2.2. Technology-constrained

The technology-constrained type refers to industries where both market niche and resource niche rankings are high, but the technology niche ranking is relatively low. Points projected onto the "resource-market" plane are classified as technology-constrained.

The manufacturing industry (C) is in good shape overall, with both market niche and resource niche

occupying the top position, but the technology niche lags significantly, ranking 12th. Daily use products, health products, and funeral supplies for the elderly are developing rapidly, but they are mainly limited to low-tech products, or core technologies are held by overseas companies, and there is an urgent need to increase technology research and development and output.

The resource niche of the elderly accommodation and catering industry (H) ranks second, leading the pack, and the overall prospects for future development are promising. The civil affairs security industry, which is most closely related to China's aging population, urgently needs to strengthen its technological level and improve the industry's competitiveness and market recognition.

The core of the elderly real estate business (K) is the sale and leasing of elderly-friendly housing, extending to park development, supporting construction, real estate management, property management, intermediaries, community services, and other businesses, closely related to the construction and finance, and insurance industries. The development of the elderly real estate industry is mainly manifested in three aspects: first, the entire industry entering the market; second, rapid cross-industry development; and third, strong investment appeal.

From the measurement results, the market niche of the resident services, repairs, and other services industries (O) is strong, ranking fifth. The main reason is the strong demand for home care, clinical care, and other home services for elderly people with disabilities. However, the technology niche and resource niche rankings of this industry are low. It is difficult to meet the daily care service needs of the elderly. With the trend of high-end and younger aging services in the future, the industry should improve the overall quality of employees and service standards, enhance the industry's resource allocation and utilization capabilities, and competitiveness.

The market niche and resource niche of health and social work (Q) both rank second, but the technology niche is weak. The medical needs of the elderly population are concentrated in healthcare, rehabilitation nursing, and daily care. The pension institutions included in this industry also face many problems. Firstly, the contradiction between supply and demand is very prominent. Secondly, there is an imbalance between public and private development. Thirdly, suburban nursing homes are operating with difficulties, while nursing homes in urban core areas are very scarce. Fourthly, home-based services cannot keep up with market demand. In summary, in addition to policy guarantees in the future, clear technical standards should be established, and the stability of technical services should be improved to enhance the overall development of the industry.

6.2.3. Resource-constrained

The resource-constrained type refers to industries that rank high in both market niche and technology niche but relatively low in resource niche. Points projected onto the "technology-market" niche plane are classified as resource-constrained. This type consists of three industries: agriculture, forestry, animal husbandry, and fishery; information dissemination; software and information technology services; and scientific research and technology services. All three industries rank below 10th in terms of resource niche.

The agriculture, forestry, animal husbandry, and fishery industry (A) has a mid-to-low level of niche measurement for various factors, particularly with the resource niche ranking at the bottom. Enterprises targeting the elderly market are inherently small-scale and have not achieved economies of scale. Such enterprises often require significant investment and have long cost recovery periods, resulting in weak solvency. Consequently, factors related to the resource niche, such as enterprise scale and solvency, have become bottlenecks affecting the industry's development. The overall score for the technology niche in the elderly care industry is relatively low, and technological input and output related to agriculture, forestry, animal husbandry, and fishery involving the

elderly are also areas that need strengthening.

The information dissemination, software, and information technology services industry (I) ranks high in terms of technology niche, occupying the top spot. However, it ranks relatively low in both market niche and resource niche. To ensure sustained competitiveness, it is crucial to build an information platform for elderly care services, improve the elderly information database, and drive development through emerging formats, thereby becoming a new growth point for the industry's economy.

The scientific research and technology services industry (M) has the strongest technology niche, ranking second. However, the measurement results for both market niche and resource niche in this industry are relatively low. As a modern service industry, it has not leveraged its unique technological advantages to achieve market effects. In the future, advanced scientific research advantages should be utilized to intensify research and development efforts for elderly healthcare products, rehabilitation and nursing supplies, assistive listening and vision products, elderly household items, and other in-demand products. This will help promote the overall technological development of the elderly care industry.

7. Conclusion

By introducing niche theory into the field of pension industry research and using multidisciplinary methods and tools, the interaction between populations and their possible trends is measured and evaluated. From the measurement results of niche potential energy, the three dimensions of development are unbalanced, with scores for market niche, resource niche, and technology niche decreasing in order, reflecting the lack of competitiveness in the pension industry. The pension industry has not yet formed a distinct circle as a whole, and the measurement results of various industries are intertwined, without forming a scale effect or a leading industry. The three dimensions of “state-trend-energy” in industry development counteract each other, and the niche ranking of various industries in the three dimensions illustrates their development shortcomings.

The data for measuring the “state-trend-energy” of the pension industry niche comes from listed companies in the pension industry. However, as the pension industry is still in its infancy, the absence of large or representative supply entities may result in data that is not typical enough and accounts for a small overall proportion, leading to errors in the measurement results. In the future, with the development of the pension industry and the improvement of national statistical indicators and measurement methods, the author will conduct key surveys on typical enterprise representatives in the pension industry, continuously improve the pension industry database, scientifically monitor regional industrial structure adjustment and pension industry development, and predict future development trends and key points of industrial structure adjustment in the pension industry.

Funding

Natural Science Foundation Project of Hebei Provincial Science and Technology Department (G2023415001); Humanities and Social Sciences Research Project of Colleges and Universities in Hebei Province (SD2021084); The 2025 Hebei Province Social Science Development Research Project titled “Practical Research on Hebei Province's Undertaking of the Elderly Care Service Industry from Beijing and Tianjin under the Collaborative Development of the Beijing-Tianjin-Hebei Region”

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Yin F, Zhang Y, Liu M, 2019, Hotspot Mapping Analysis and Prospects of the Elderly Care Industry Based on Bibliometrics. *Urban Development Research*, 26(04): 63–68.
- [2] Yin F, Zhang Y, Liu M, 2018, Temporal and Spatial Distribution Characteristics of Zooplankton Community. *Revista Científica-Facultad de Ciencias Veterinarias*, 28(1): 465–474.
- [3] Yin F, Zhang Y, Liu M, 2020, Constraints and Strategic Choices for the Development of China’s Elderly Care Industry from the Perspective of Supply-Side Structural Reform. *Urban Development Research*, 27(04): 1–5.
- [4] Li L, 2016, Evaluation of Energy Enterprises’ Niche and Its Impact on Ecological Strategic Choices—Based on Data from China’s Listed Coal Mining Companies. *Journal of Shanxi Finance and Taxation College*, 18(05): 51–55.
- [5] Xu X, Liu R, Yang S, 2017, Research on the Evaluation of China’s “Urban Mining” Industrial Ecosystem Based on Catastrophe Progression Method. *China Population, Resources, and Environment*, 27(S2): 14–16.
- [6] Yin F, 2016, Research on the Implementation of Grassroots Food Safety Supervision—An Empirical Analysis Based on the SEM Method. *Journal of Hebei Normal University of Science and Technology (Social Science Edition)*, 15(02): 7–12.

Publisher’s note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Research on the Perception and Demand of the Integration of Agriculture, Culture, and Tourism in Farm Stays Based on Tourist Reviews: A Case Study of Chongqing City

Yaqin Dai, Min Kang, Meihong Yang

Chongqing University of Science and Technology, Chongqing 401331, China

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: Against the backdrop of the strategies for rural revitalization and the integration of agriculture, culture, and tourism, farm stay, as a vital carrier, requires a systematic analysis of its resource integration effectiveness and the actual needs of tourists. Taking Chongqing City as an example, this study leverages tourist reviews from the Dianping platform (China's leading consumer review site) and employs a combination of TF-IDF keyword extraction, SnowNLP sentiment analysis, and LDA topic modeling to dissect tourists' perception characteristics and latent demands for agritourism resources from the demand side. The findings reveal that agricultural and tourism elements garner significant attention, while cultural resources are notably underperceived, indicating an imbalanced integration structure. Sentiment is predominantly positive, yet negative feedback highlights issues in service management, transportation, and homogenized experiences. Latent demands converge on three dimensions: deepening agricultural experiences, enhancing cultural participation and interaction, and improving environmental and service quality. Based on these findings, this study proposes integration enhancement strategies, including agricultural branding, cultural vitalization, service intelligence, and multi-faceted collaboration, to drive experience upgrades and sustainable development in farm stays, offering theoretical references and practical pathways for rural tourism integration in similar regions.

Keywords: Integration of agriculture, culture, and tourism; Farm stays; Tourist reviews; Perception characteristics

Online publication: October 14, 2025

1. Introduction

In recent years, the central government has consistently emphasized the crucial role of integrating agriculture, culture, and tourism in driving high-quality rural development. The No. 1 Central Document of 2023 explicitly stated that "new forms of business integrating agriculture, culture, and tourism represent a vital direction for high-quality rural development," and the 2024 document further emphasized the need to "accelerate the construction of a modern rural industrial system that integrates agriculture, culture, and tourism," providing policy guidance

for exploring pathways for the integration of agriculture, culture, and tourism across regions. In recent years, Chongqing has coordinated new urbanization with comprehensive rural revitalization. Strategic plans such as the “14th Five-Year Plan for Rural Leisure Tourism in Chongqing” emphasize the integration of ecological agriculture, pastoral landscapes, and farming culture. However, the integration of agriculture, culture, and tourism in Chongqing still faces challenges such as low product quality and insufficiently distinct characteristics, making it difficult to meet the growing personalized needs of tourists. In particular, the basic business model of farm stays (farm-based tourism) urgently requires innovation and upgrading in its operational model and experiential content through the incorporation of agricultural, cultural, and tourism elements ^[1].

Foreign scholars have independently discussed the sustainable development of different types of farm stays in specific regions within the context of the agricultural tourism industry ^[2,3]. Domestic research has been conducted from the perspectives of economic geography, agricultural economics, tourism management, urban and rural planning, and other disciplines, covering aspects such as the current development status and issues of farm stays ^[4,5], its spatial distribution and influencing factors ^[6,7], integrated development ^[8,9], and sustainable development research ^[10,11]. Current research on the integration of agriculture, culture, and tourism primarily focuses on the connotations ^[12], influencing factors ^[13,14], mechanisms ^[15], pathways ^[16,17], and effects ^[18] of such integration, predominantly employing qualitative research methods and gradually incorporating quantitative approaches such as the Analytic Hierarchy Process (AHP) ^[19] and entropy value method ^[20] to evaluate integration effects. However, existing research predominantly focuses on macro-level policies or industrial aspects, lacking empirical analysis of the effects of integrating agriculture, culture, and tourism in farm stays from the perspective of tourist needs. In particular, there is a noticeable deficiency in exploring the perceived characteristics of resource integration, tourist emotional attitudes, and potential needs during the integration process.

The farm stay industry in Chongqing is relatively well-developed, with abundant and representative online review text data, providing favorable conditions for conducting empirical research from the demand side. This study takes farm stay venues in Chongqing as the research object, utilizing data from customer reviews on the Dianping platform. By comprehensively employing methods such as TF-IDF keyword extraction, sentiment analysis, and LDA topic modeling, the study systematically identifies tourists’ perception characteristics, emotional attitudes, and underlying needs regarding the integration of agriculture, culture, and tourism resources. Subsequently, targeted strategies for integrated development are proposed. This research not only contributes to expanding the theoretical perspectives and methodological frameworks for the integration of agriculture, culture, and tourism but also provides practical references for enhancing the quality, upgrading, and sustainable development of farm stay venues in Chongqing and similar regions across the country.

2. Data sources and research methods

2.1. Data sources

The research data were sourced from the Dianping app. Using Python, a web crawler program was developed to capture online review data for 3,507 farm stay venues in Chongqing from January 1, 2023, to August 31, 2024. To ensure the accuracy and representativeness of the study, farm stays with the highest user review activity, representativeness, and normal operation were selected. Ultimately, 312 farm stays in Chongqing were chosen as the sample, yielding a total of 21,706 valid review data entries.

2.2. Data preprocessing

The review texts underwent preprocessing, including the removal of duplicates, meaningless characters, and stop words, as well as text standardization (e.g., “tea picking” and “tea frying” were unified as “tea culture”). Chinese word segmentation was performed using the Jieba word segmentation tool, and custom dictionaries and sentiment dictionaries were introduced to enhance analysis accuracy.

2.3. Research methods

2.3.1. Sentiment analysis

SnowNLP is a Python library specifically designed for Chinese text processing, offering functionalities such as Chinese word segmentation, keyword extraction, sentence segmentation, sentiment analysis, and text similarity calculation^[21]. By utilizing the SnowNLP library, we can assess the sentiment orientation of reviews, calculate the sentiment score for each review (ranging from 0 to 1), and classify them into positive, neutral, or negative sentiments to identify the overall emotional attitude of tourists.

2.3.2. TF-IDF keyword extraction

TF-IDF (Term Frequency-Inverse Document Frequency) is a commonly used text feature extraction method in information retrieval and text mining^[22]. This method employs TF-IDF to identify high-frequency feature words in reviews, measuring the importance of words in a corpus by combining term frequency (TF) and inverse document frequency (IDF). This approach allows us to analyze the core resources and experience dimensions that tourists focus on. The formula is as follows:

$$TF-IDF_w = \frac{count(w)}{|D_i|} \times \log \frac{N}{1 + \sum_{i=1}^N I(w, D_i)} \quad (1)$$

where w represents the occurrence frequency of keywords in the document, D_i represents the total number of words in the document, N represents the total number of reviews, and I represents whether the review contains keywords (1 if it does, 0 otherwise).

2.3.3. LDA topic model

The LDA (Latent Dirichlet Allocation) model is used to uncover hidden topics within a document collection, with perplexity serving as a measure of its predictive ability (lower values indicate better performance)^[23]. In this study, we employed the LDA model to mine latent topics from review data, determining the optimal number of topics through perplexity evaluation. Subsequently, we extracted representative keywords under each topic to reveal the underlying demand structure of tourists.

3. Findings

3.1. Identification of integrated development of agriculture, culture, and tourism

This study employed the TF-IDF method to extract high-frequency keywords from tourist reviews that are related to agricultural resources, cultural resources, and tourism experiences. The results are presented in **Tables 1 to 3**.

Table 1. Sample TF-IDF results for agricultural resources

Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF
Strawberry	0.1197	Fresh	0.0282	Farm	0.0109	Loquat	0.0072	Camping	0.0032
Barbecue	0.0594	Cherry	0.0216	Blueberry	0.0098	Ecological	0.0060	Fruit	0.0030
Picking	0.0487	Grape	0.0123	Firewood chicken	0.0081	Season	0.0038	Ingredients	0.0028
Fishing	0.0482	Variety	0.0111	Vegetable	0.0074	Self-service	0.0032	Agricultural products	0.0002

In terms of agricultural resources, tourists show a high level of interest in experiential activities such as “strawberries,” “barbecue,” “picking,” and “fishing” (TF-IDF values > 0.04), reflecting the central role of agricultural experiences in the operation of farm stays. Additionally, the presence of terms like “fresh,” “variety,” and “ecology” indicates that tourists have a certain awareness of the quality and ecological attributes of agricultural products. However, the expression of agricultural resources predominantly focuses on basic, seasonal activities, lacking the integration of deep cultural connotations.

Table 2. Sample TF-IDF results for cultural resources

Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF
Chess & card room	0.0256	French style	0.0012	Wine culture	0.0006	Handicraft	0.0005
Team building	0.0221	Tea culture	0.0010	Rural scenery	0.0005	Farming culture	0.0003
Photography	0.0088	European style	0.0007	Study tour	0.0005	History	0.0003
Hot pot	0.0045	Classic elegance	0.0006	Sketching	0.0005	Wellness	0.0002

Regarding cultural resources, the weights of keywords are generally low, with the highest being “chess and card room” (0.0256) and “team building” (0.0221). The TF-IDF values for culturally rich terms such as “wine culture,” “tea culture,” “farming culture,” and “handicrafts” do not exceed 0.001. This indicates that cultural resources are relatively weak in tourists’ perceptions and have not effectively formed differentiated experiential advantages.

Table 3. Sample TF-IDF results for tourism experiences

Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF	Keyword	TF-IDF
Traffic	0.1088	Experience	0.0624	Tea garden	0.0156	Cost-effective	0.0121	Manor	0.0049
Boss	0.0964	Family	0.0471	Air	0.0147	Animals	0.0110	Entertainment	0.0034
Dishes	0.0775	Friends	0.0416	Accommodation	0.0143	Fireflies	0.0080	Tickets	0.0030
Environment	0.0698	Service	0.0254	Activities	0.0126	Facilities	0.0062	Convenience	0.0020

In the realm of tourism experiences, terms like “transportation,” “owner,” “dishes,” “environment,” and “experience” have significantly higher weights, showing that tourists place a high level of attention on fundamental tourism elements such as infrastructure, service quality, and environmental atmosphere. The overall

perception of tourism experiences is relatively positive, but it also reveals deficiencies in cultural experiences and in-depth agricultural participation.

3.2. Tourist perception analysis

This study employed the SnowNLP sentiment analysis tool to identify emotional tendencies and conduct word frequency statistics on the review data. Positive sentiment reviews accounted for 83.08%, neutral sentiment reviews 10.23%, and negative sentiment reviews 6.69%. Overall, tourists' emotional attitudes towards Chongqing's farm stays were predominantly positive, with the word frequency of positive emotions significantly higher than that of neutral and negative emotions. The results of high-frequency words for each emotional dimension are shown in **Tables 4 to 6**.

Table 4. Positive emotions and word frequency in the integration of agriculture, culture, and tourism in Chongqing's farm stays

Positive emotion	Frequency	Positive emotion	Frequency	Positive emotion	Frequency
Not bad	7167	Picking	2713	Like	1874
Strawberry	6166	Children	2679	Air	1861
Boss	5086	Delicious	2671	Traffic	1802
Friends	5080	Convenient	2294	Cost-effective	1707
Environment	4556	Fishing	2228	Enthusiastic	1562
Very good	4180	Weekend	2087	Activities	1555
Many	3684	Service	2076	Worth it	1326
Recommend	3212	Parking	2028	Happy	1286
Flavor	3158	Fresh	1893	Comfortable	1244
Barbecue	2851	Very large	1882	Next time	1092

From a positive emotional perspective (**Table 4**), tourists' positive perceptions were concentrated in three main dimensions: agricultural experiences, tourism facilities, and service attitudes. In terms of agricultural experiences, high-frequency words such as "strawberries," "picking," "fishing," and "barbecue" reflected the core appeal of farming activities to tourists. Regarding tourism facilities, words like "environment" and "air" highlighted the natural ecological advantages, while "transportation" and "parking" indicated the accessibility advantages of farm stays in the main city and nearby suburbs. In terms of service attitudes, words like "owner," "service," "enthusiasm," and "cost-effectiveness" suggested that service quality and reasonable pricing were well-received. Words like "recommend" and "next time" also reflected tourists' willingness to revisit and their tendency to spread positive word-of-mouth.

Table 5. Neutral emotions and word frequency in the integration of agriculture, culture, and tourism in Chongqing's farm stays

Neutral emotion	Frequency	Neutral emotion	Frequency	Neutral emotion	Frequency
Average	1262	Fishing	287	Weekend	149
Acceptable	566	Environment	272	Service	146
Suggestion	548	Flavor	234	Mahjong	137
Boss	441	Picking	181	Activities	116
Not many	434	Feeling	177	Dining	103
Slightly	375	Parking	171	In advance	99
Strawberry	352	Price	168	A bit	93
Place	341	Hour	165	Indeed	74
Friends	320	Really	163	Not considered	53
Barbecue	303	Traffic	152	Rainy	53

The word frequency of neutral emotions in **Table 5** revealed tourists' cautious attitudes towards some integrated resources, with the core issues being homogenized experiences and inadequate supporting details. Words like "average" and "okay" became high-frequency evaluations. The low frequency of words related to single entertainment items, such as "activities" and "mahjong," reflected the homogenized model of most farm stays, which primarily offered "picking + dining" experiences. The combination of words like "parking" and "transportation" with modifiers like "slightly" and "not much" suggested issues such as limited parking spaces and inadequate transportation guidance in remote areas. The word "suggestions" directly reflected tourists' expectations for more family-friendly, interactive, and cultural experience projects.

Table 6. Negative emotions and word frequency in the integration of agriculture, culture, and tourism in Chongqing's farm stays

Negative emotion	Frequency	Negative emotion	Frequency	Negative emotion	Frequency
Boss	1906	Picking	658	None	273
Strawberry	1343	Remote	609	Ticket	253
Place	1302	Traffic	606	Bad taste	251
Barbecue	1187	Not good	579	Roadside	239
Service	906	Location	469	Disappointing	223
Flavor	845	Dishes	457	Inconvenient	187
Environment	819	Weather	430	Regret	160
Feeling	780	Attitude	427	Not recommended	156
Price	731	Fee	367	Boring	111
Parking	720	Only	285	Accommodation	107

The frequency of negative emotional words (**Table 6**) highlights three core issues, with the most prominent being deficiencies in service and management. Words like "boss," "service," and "attitude" have emerged as high-

frequency terms associated with negativity, while the controversy over “ticket prices” has also exposed issues regarding pricing rationality. In terms of transportation and location disadvantages, terms such as “location,” “remote,” and “transportation” reflect poor accessibility in remote areas, with “inconvenience” being a primary complaint from tourists. Regarding agricultural experiences and seasonal limitations, words like “strawberry,” “barbecue,” “dishes,” and “unpalatable” point to the unstable quality of agricultural products and homogenization in catering services. Meanwhile, terms such as “weather,” “nothing to do,” and “boring” highlight the lack of experience caused by seasonal limitations.

3.3. Analysis of potential demand themes

A deep analysis of tourist reviews was conducted using the LDA topic model. The LDA model’s perplexity curve was plotted using Matplotlib (**Figure 1**), showing that as the number of topics increases, perplexity gradually decreases and the rate of decrease slows down. Therefore, eight topics were selected to prevent overfitting (**Figure 2**).

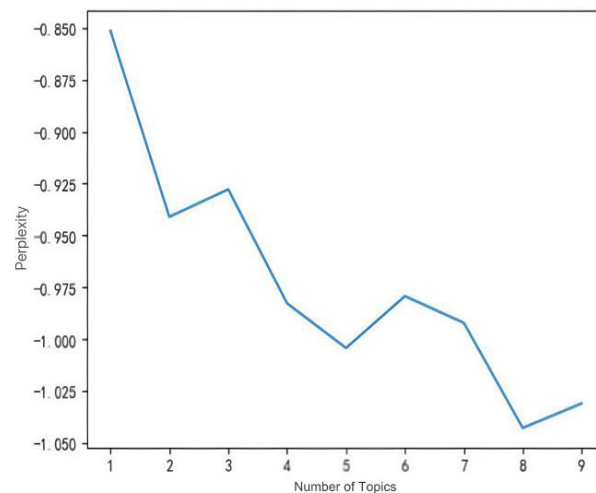


Figure 1. Perplexity line chart

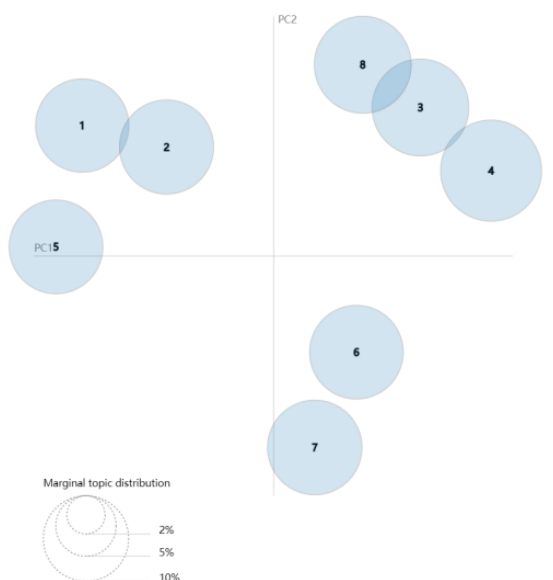


Figure 2. Topic distance chart

By substituting the number of topics into the LDA model, the top 10 core keywords for each topic were extracted. The meanings of the keywords within each topic were identified, and the logical relationships among these words were analyzed, as shown in **Table 7** below.

Table 7. Topic classification and topic keywords

Theme 1	Theme 2	Theme 3	Theme 4	Theme 5	Theme 6	Theme 7	Theme 8
Strawberry	Barbecue	Not bad	Children	Flavor	Accommodation	Environment	Navigation
Picking	Boss	Fishing	Place	Delicious	Room	Special	Traffic
Per pound (0.5 kg)	Environment	Suitable	Experience	Price	Homestay	Air	Driving
Basket	Farm Stay	Weekend	Team building	Feature	Facilities	Scenery	Location
Variety	Taste	Hour	Friends	Grape	Clean	Mountain	Parking
Very sweet	Many	Navigation	Kids	Cherry	Comfortable	Clean	Self-driving
Blueberry	Dishes	Driving	Weekend	Loquat	Service	Season	In advance
Fresh	Firewood chicken	Indeed	Service	Fresh	Recommend	Photo	Nearby
Base	Self-service	Villa	Activities	Chongqing	Downtown	Yard	Base
Next time	Camping	Mountain villa	Programs	Ingredients	Parking	Comfortable	Fun

In terms of agricultural experiences, Theme 1 focuses on high-frequency words such as “strawberry,” “picking,” and “per pound,” reflecting tourists’ concerns about quantified fruit and vegetable picking, standardized experiences, and visible output. Theme 2 highlights outdoor dining and leisure activities such as “barbecue,” “firewood chicken,” “camping,” and “self-service,” demonstrating a preference for scenic and socialized agricultural leisure activities. Theme 5 centers around words like “taste,” “delicious,” “specialty,” “ingredients,” and “freshness,” indicating tourists’ demand for tasting and purchasing high-quality agricultural products. This suggests that tourists are no longer satisfied with basic farming activities but expect agricultural resources to upgrade towards in-depth experiences, quality consumption, and scenic extensions.

There is a significant demand for cultural participation and social experiences. In Theme 4, words such as “children,” “kid,” “experience,” “team building,” and “activity” appear frequently, indicating a strong demand for interactive and educational cultural projects among parent-child families and corporate team-building groups. In Theme 8, although words like “navigation,” “transportation,” “driving,” “location,” and “parking” fall under the category of infrastructure, their co-occurrence with terms like “self-driving,” “base,” and “enjoyment” reflects tourists’ expectations for the accessibility of cultural attractions and the organization of themed tour routes. This suggests that cultural resources need to transition from static displays to dynamic participation and must be enhanced in coordination with transportation guidance systems.

The improvement of environmental and service quality constitutes the third core demand. Keywords in Theme 3, such as “good,” “suitable,” “weekend,” and “villa,” reflect tourists’ emphasis on the overall adaptability of leisure environments and their weekend getaway functions. Theme 6 focuses on “accommodation,” “room,” “homestay,” “cleanliness,” and “comfort,” highlighting a concern for the quality of living facilities and service details. Theme 7 centers around “environment,” “air,” “scenery,” “mountain,” “season,” and “photography,” reflecting tourists’ high demand for natural ecological environments, seasonal landscapes, and aesthetic

experiences. This indicates that tourism services need to transition from functional assurance to quality, personalization, and value-added experiences.

4. Research conclusion

Based on the review data of visitors to farm stays in Chongqing, this study employs TF-IDF keyword analysis, SnowNLP sentiment analysis, and LDA topic modeling to identify the perceived characteristics and potential demands of the integration of agriculture, culture, and tourism from the perspective of tourist needs. The main conclusions are as follows:

- (1) The structure of resource integration is unbalanced, with a notable lack of cultural integration. Agricultural and tourism resources have garnered significant attention, with prominent keyword weights, particularly for experiential and service-related terms such as “picking,” “barbecue,” and “environment.” In contrast, cultural keywords like “tea culture” and “farming culture” have extremely low weights, indicating that cultural resources have not been effectively transformed into perceivable experiences for tourists, resulting in a shallow level of integration.
- (2) The overall emotional attitude is positive, but negative feedback points to shortcomings in experience and management. Positive emotions account for 83.08%, indicating widespread recognition of agricultural experiences and natural settings. Neutral and negative reviews primarily highlight issues such as unstable services, inconvenient transportation, homogenized projects, and a lack of cultural experiences, revealing that the current integration model has not fully met the diverse and high-quality demands of tourists.
- (3) Potential demands are trending toward depth, interactivity, and quality. LDA topic modeling has identified three major demand dimensions: deepening agricultural experiences, cultural participation and social integration, and environmental and service enhancement. Tourists are no longer satisfied with basic farming activities but expect localized agricultural products, scenario-based activities, dynamic cultural experiences, and refined services. The demand structure is shifting from “functional” to “experiential.”

In summary, the integration of agriculture, culture, and tourism in Chongqing’s farm stays remains in a developmental stage characterized by “agriculture as the core, tourism as the framework, and culture as the weak link.” There is a need to advance the integration model from superficial overlap to deep symbiosis through resource enhancement, cultural empowerment, and service innovation.

5. Development strategies

5.1. Promoting the experiential and brand-oriented upgrade of agricultural resources

Leveraging Chongqing’s mountainous agricultural characteristics, focus on developing a differentiated agricultural product system with “one district, one specialty,” such as Wushan crisp plums, Fengjie navel oranges, and Rongchang braised geese (geographical indication products). Transition agricultural products from mere picking and consumption to processing experiences and cultural gifts. Enhance the design of seasonal farming activities and integrate digital technologies to create traceable and participatory immersive agricultural settings, elevating the perceived value and consumption depth of agricultural resources.

5.2. Strengthening the dynamic utilization and educational functions of cultural resources

Explore local folk culture and agricultural traditions, transforming them into tourism projects that are both

experiential and educational. Encourage farm stays to collaborate with intangible cultural heritage bearers and rural communities to conduct regular cultural performances, handicraft workshops, and research courses, emphasizing the locality and interactivity of cultural narratives to enhance visitors' cultural identity and emotional connections.

5.3. Establishing a demand-oriented service innovation and smart management mechanism

Target niche markets such as families with children, elderly groups, and corporate team-building activities, offering thematic and customized experience packages, such as family kitchens, eco-camping, and rural wellness programs. Strengthen the digital transformation of infrastructure, introducing smart service systems such as online reservations, intelligent guides, and visitor behavior data analysis to optimize reception efficiency and personalized service levels. Focus on improving transportation accessibility, parking facilities, and hygiene conditions to address management shortcomings highlighted by negative visitor feedback.

5.4. Promoting collaborative development among multiple stakeholders and regional linkages

Guide farm stays to transition from “single-point operations” to “clustered collaborations,” strengthening partnerships with travel agencies, e-commerce platforms, agricultural cooperatives, and cultural institutions to jointly create high-quality integrated agritourism routes and regional public brands. The government should play a guiding role in policy support, standard setting, and marketing promotion, fostering a symbiotic development pattern characterized by resource sharing, complementary themes, and market coordination.

6. Future prospects

This study has certain limitations, and future research can delve deeper into the following aspects: Firstly, the data is primarily sourced from online platforms, necessitating the incorporation of multi-source data, such as surveys and interviews, in the future to enhance the universality of the conclusions. Secondly, the conclusions are based on a case study in Chongqing, and their applicability in other regions requires further validation through cross-regional comparative studies. Additionally, the current analysis is a static cross-sectional study, and future research could conduct long-term tracking to reveal the dynamic evolution mechanisms of agritourism integration, providing stronger theoretical support and practical references for the high-quality development of rural tourism.

Funding

Chongqing University of Science and Technology Graduate Innovation Program Project (YKJCX2420802)

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Yu R, Chen H, Chen G, et al., 2018, Spatial Distribution and Influencing Factors of Rural Tourism Destinations in Hubei Province: A Case Study of High-Star-Rated Farm Stay Venues. *Economic Geography*, 38(06): 210–217.
- [2] Popescu CA, Iancu T, Popescu G, et al., 2023, The Impact of Agritourism Activity on the Rural Environment:

Findings from an Authentic Agritourist Area—Bukovina, Romania. *Sustainability*, 15(13): 10294.

- [3] Grillini G, Sacchi G, Streifeneder T, et al., 2023, Differences in Sustainability Outcomes Between Agritourism and Non-Agritourism Farms Based on Robust Empirical Evidence from the Tyrol/Trentino Mountain Region. *Journal of Rural Studies*, 104: 103152.
- [4] Yang J, 2018, Research on the Development of Farm Stays Tourism Industry in Shangluo Region, Shaanxi Province. *Northeast Agricultural Science*, 43(05): 55–59.
- [5] Wang L, Li H, Du H, 2017, Research on the Development Dilemmas and Countermeasures of Rural Tourism Homestays. *Agricultural Economy*, (03): 141–142.
- [6] Xiao Z, Mohtar P, An C, 2022, Research on the Spatial Distribution Characteristics and Influencing Factors of Xinjiang Farm Stays Based on POI Data. *Journal of Southwest University (Natural Science Edition)*, 44(04): 144–154.
- [7] Wang J, Li Y, Chen Z, 2022, Research on the Spatial Distribution Characteristics and Influencing Factors of Beijing Farm Stays Based on POI Data Mining. *Research on Agricultural Modernization*, 43(02): 340–350.
- [8] Li S, 2010, Opportunities and Challenges Brought by Tourism for the Elderly to “Farm Stays.” *Jiangsu Business Theory*, (09): 118–119.
- [9] Ji G, Wang L, Peng Y, et al., 2016, Research on the Integrated Innovation of Farm Tourism from the Perspective of Supply-Side: A Case Study of Jurong City. *Jiangsu Agricultural Sciences*, 44(08): 553–556.
- [10] Cai B, Wang M, Chen Y, 2024, Sustainability of Rural Tourism Operations in the Suburbs of Beijing from the Perspective of Operators: A Case Study of Lianhuachi Village in Huairou District. *Human Geography*, 39(03): 92–104.
- [11] Liu X, Xiao R, 2014, Discussion on the Sustainable Development of Leisure and Sightseeing Agriculture: A Case Study of Peach Blossom Village Farm Tourism in Taihu, Jingzhou. *Hubei Agricultural Sciences*, 53(05): 1206–1209.
- [12] Tu W, Huang Q, 2017, Promoting Better Development of Rural Tourism in Hubei through the Integration of Rural Roots and Agricultural Tourism. *Theory Monthly*, (12): 124–127.
- [13] Ge S, Chen X, Chen W, et al., 2025, Research on the Influencing Factors and Mechanisms of Revisit and Recommendation Intentions for Rural Cultural and Tourism Projects under the Background of Agricultural-Cultural-Tourism Integration. *Modern Business*, (14): 113–117.
- [14] Zhao B, Zhan S, 2025, Spatiotemporal Evolution and Influencing Factors of the Coupling and Coordination Degree between Agricultural-Cultural-Tourism Integration and Rural Revitalization: A Case Study of Shaanxi Province. *Chinese Journal of Agricultural Resources and Regional Planning*, 1–14.
- [15] Liu J, 2021, Analysis of the Driving Mechanism for Rural Tourism Development from the Perspective of Industrial Integration. *Hubei Agricultural Sciences*, 60(04): 44–49.
- [16] Zhang Y, Yang J, 2025, Research on the Mechanism and Path of Digital Empowerment in the Integration of Agriculture, Culture, and Tourism: From the Theoretical Perspective of Spatial Production. *Journal of Yunnan Nationalities University (Philosophy and Social Sciences Edition)*, 42(04): 92–98.
- [17] Zhao P, Guo J, 2024, Operational Models and Practical Paths for Empowering Agricultural and Rural Modernization through Agricultural-Cultural-Tourism Integration: A Case Study of Three Typical Villages. *Rural Economy*, (06): 132–142.
- [18] Yuan Z, 2013, Dynamic Effects and Development Trends of the Coupling between Rural Tourism and Large-Scale Agriculture. *Tourism Tribune*, 28(05): 80–88.
- [19] Chang J, 2020, Evaluation of the Integrated Development of Agriculture and Tourism in Sichuan Province and

Analysis of Obstacle Factors. Chinese Agricultural Science Bulletin, 36(11): 149–156.

- [20] Li X, Xu S, 2021, Rural Industrial Integration: Level Measurement and Spatial Distribution Pattern. Chinese Journal of Agricultural Resources and Regional Planning, 42(12): 60–74.
- [21] Wang T, Yang W, 2021, A Review of Text Sentiment Analysis Methods. Computer Engineering and Applications, 57(12): 11–24.
- [22] Zhang J, 2014, An Intelligence Keyword Extraction Method Based on Improved TF-IDF Algorithm. Journal of Information, 33(04): 153–155.
- [23] Liang C, Li R, 2020, Analysis of Image Perception in Lijiang Ancient Town Based on Integrated LDA and Feature Dimensions. Progress in Geography, 39(04): 614–626.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

The Belt and Road from a Global Perspective

Zeju Zhao*

University of Illinois Urbana-Champaign, Champaign, 61820, U.S.

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: The Belt and Road Initiative (BRI) is a project that has heavy emphasis on basic infrastructure and is sponsored by the government of the People's Republic of China. It deeply impacts Africa's economy in terms of its transport infrastructure investments. Railways, ports, and transnational infrastructure have been made not only as tools for economic integration and trade expansion between countries but also as ways of including people in development processes. Out of many BRI promises, one of them entails the potential to uplift peripheral areas, with the hope of giving these areas that have traditionally been expensive capitals and government investors a chance. Though the claims surrounding this initiative are robust, an interview with current practitioners on the ground brings to the fore a problematic concern: precisely to what extent have the rural poor across the wealthiest subregions of Africa, the continent's least fortunate and most underserved populations, benefited to any significant degree from these infrastructure projects? An exploration of a central contradiction about the BRI: inevitably, it involves the fact that through BRI infrastructure, regions are connected to a better, easier trade system. However, sociopolitical benefits fully tend to be in the hands of the ruling elite, foreign contractors, and the urban centers. However, the majority of those citizens who most need economic injection will stand aside from either the decision-making process or be cut off from partaking in the ongoing benefits. Therefore, projects that should reverse existing disparities might actually maintain or even worsen the old problems. The research topic spans three transport works under the BRI in Africa, which are Tanzania Zambia Railway (TAZARA), Addis Ababa Djibouti Railway, and the Port of Djibouti, with the aim of assessing any poverty alleviation carried directly by these works among marginalized demographics. This paper collects data on project outcomes in more neutral and local indicators, such as job creation, market access, skills development, and recovery of tourist attractions. Pro-poor tourism literature as well as the theory of development are being discussed, and the point is made that the investment size is not the key to solving everything that will end all poverty. Instead, it is about the careful consideration behind each and every project's design and execution as to whether it addresses the systemic poverty that has existed for a long period of time. Participatory planning, transparent governance, and common ownership of capacity building and community, as the last part of policy offerings, are the suggestions provided. These will determine if BRI infrastructure can be turned from a bilateral, top-down pattern of integration and interaction to a real field of multidimensional and accountable development in Africa.

Keywords: Belt and Road; Tanzania Zambia Railway; International trade

Online publication: October 14, 2025

1. Introduction

The Belt and Road Initiative (BRI), which China initiated in 2013, has since proved to be one of the most far-reaching global strategies for development cooperation and infrastructure investment, covering more than 140 countries. The initiative seeks to realize the concept of connectivity and economic integration through infrastructure investments in transport, energy, telecommunication, and other key areas. China's financial and technical assistance under the BRI has been simultaneously welcomed and criticized in Africa, where the lack of infrastructure has always been a barrier to regional growth and human development.

Another pillar of the BRI is transportation infrastructure projects, such as railways, highways, and ports, which play a pivotal role, ushering in economic transformation, easing mobility, and promoting regional integration. But large-scale projects are often praised for their macroeconomic benefits, greater GDP growth, higher trade volume, and more investment inflows; less is known about their social effects, especially for poor and marginalized groups. Integrating infrastructure development with pro-poor policies can diminish spatial inequality, augment access to services, and set new employment opportunities in motion. Nevertheless, due to the absence of such intentional alignment, most of these benefits may pass opportunities by for communities that need them the most, worsening existing inequalities or opening the door to new types of poverty.

This paper steps in precisely to fill the missing link in the literature on the BRI and poverty: through examining the lived realities of poverty alleviation in three major BRI corridors in Africa, the paper can assess the degree to which the TAZARA Railway, the Addis Ababa–Djibouti Railway, and the Port of Djibouti have met their promise of inclusive development. It explores tangible results, such as jobs and incomes created, as well as less direct impacts, ranging from mobility enhancement to empowering local actors and structural transformations in the local economies. By highlighting these aspects, this paper shifts the focus from overall economic indicators to community effects. It thus sheds light on the unexploited potential of infrastructure as a force not only for trade and geopolitical advantage but also for justice and sustainable development. However, this article discusses that while adopting the BRI concept allows China to create an appearance of alleviating poverty via building long-distance travel infrastructures such as railways and ports, these lengthy projects in essence fail to deliver direct and sustainable mitochondrial improvements in the lives of the poorest populations. Although macro-level benefits from trade and connectivity are evident, the import and export benefits are usually short-lived and mostly end up benefiting powerful politicians and local elites, foreign contractors, and the developed urban centers. In Africa, the rural poor and marginalized groups who would be expected to benefit from these wealth-generating and poverty reduction policies usually remain mostly absent from decision-making processes, and their efforts towards achieving these goals are undermined by a lack of connections to the resources, such as money, that could help them out. That being said, many of these projects do not work for flipping these inequalities or creating new ties of dependency that could lead to new projects staying with poverty.

This paper integrates the pro-poor tourism and development literature, reports at regional levels, and recent policy discussions, in order to scrutinize the existing gap between what the BRI delivers in theory and in actual practice. It not only confirms the best ideas incorporated in actual investments but also reveals that the prevailing structural obstacles to equity are still in place and retain global investment reform capacity. While placing the discussion within the case studies of TAZARA Transport Tanzania, Zimbabwe and Zambia railways, and the Addis Ababa–Djibouti Railway and Port of Djibouti, this analysis demonstrates that if the unequal historical and institutional contexts are ignored, mere technical infrastructure can easily magnify these inequalities. Critical discussions are conducted on both cases where pro-poor concerns are subordinated for the purposes of

efficiency, debt servicing, or geopolitical leverage, and the situation where pro-poor concerns are lacking from the projects. This paper, therefore, maintains the stance that all future BRI projects should be redesigned so as to bring poor communities meaning and not only mention them in brochures printed in English, but involve them mechanistically. The recommendations that are offered have their emphasis on the development of governance systems, participation of people, vocational training, and the institution of clear accountability mechanisms. These functional levels alone can allow infrastructure investment to be the real controller in the positive and long-term development of the regions affected by the endemic poverty if its orientation is done in this way. Therefore, the research question for this paper is: “To what extent do China’s Belt and Road Initiative (BRI) transportation infrastructure projects in Africa directly contribute to poverty alleviation among the most marginalized communities, and what structural or governance barriers hinder their effectiveness?”

Most poverty-reduction studies maintain that with proper planning, infrastructure can be pro-poor and act as a stimulus in the fight against poverty, provided that it is associated with more markets, better access to employment, and increased mobility of people and populations who need it the most. According to Ashley et al., “while tourism and infrastructure development should be witnessed by the poor, by virtue of their sufficient nature, these sufferings should stimulate local livelihoods and spatial poverty traps.” In a similar context, the Asian Development Bank ^[1] says, “the presence of physical infrastructure, especially in the transport sector, provides the fundamental requirement for the development of the private sector, agriculture, and trade at the community level,” and these are the areas of poverty alleviation.

2. Theoretical framework and literature review

China’s BRI has seen considerable scholarly attention pour into its manifold dimensions, especially on the issue of exporting the development by financing infrastructure. While a number of studies admit BRI’s chances for economic boost, connectivity, and visibility of trade, there are increasing doubts about the BRI’s power to directly tackle poverty, especially in African countries with systemic inequality and political fragility. This study engages this debate by examining the effects of BRI transport infrastructure in combating poverty through a multi-dimensional approach drawing on literature from Pro-poor Policy and Pro-poor Development Economics Literature.

The development policy supports the idea that infrastructure can be a significant driver of poverty alleviation by facilitating access to markets, providing the opportunity for more mobility, and reducing restrictions of isolation. As a World Bank report mentions, transport infrastructure has high potential for poverty reduction only if it is coupled with accessibility points in rural areas, supportive feeder service, and inclusive pricing. The importance of complementarity of investments and social policies is necessary for such resources to reach the intended beneficiaries; otherwise, these investments will remain bypassing the very people they are intended to help.

Literature on the inclusivity and equity concerns over BRI projects is reflected in a wide range of publications. China’s investments received an overwhelming welcome in Africa because of their magnitude and speed. However, he noted that many poor communities did not benefit from their investments because of inadequate safeguards and low enforcement capacity. This divide, therefore, of infrastructure expansion and poverty alleviation is hindered by a lack of transparency and a lack of public participation. Given in particular the arguments made by Hillman, debt sustainability concerns, low transparency, and engaging only state-owned Chinese firms weaken local ownership

and reduce the developmental significance of these projects. These critiques indicate that infrastructure under BRI may bring about a boost in GDP or trade volume, but without targeting often-low-income populations, and with no chance of sustainable development.

A nurturing setting for this is what is perceived as the “elite trap,” whereby elites, foreign investors, and urban centers become those that chiefly benefit from development projects ^[2]. This is one scenario in which development initiatives designed to benefit the poor unwittingly manifest as more support to those already positioned to benefit under circumstances where governance is weak, and corruption is an integral part of the development worldview ^[2], who assert that without full inclusion of locals, the reality of the unfair distribution of resources, which end up institutionalizing inequality is a common feature of tourism development. Such observations can be taken to highlight the need for including local communities in the decision-making process, and by extension, they highlight the vital role of participatory planning and community engagement as a basic building block of equitable infrastructure development.

Although BRI projects are known to be very ambitious, there are still considerable gaps in the literature in relation to how the poorest communities are affected by these projects in their daily lives. This is the gap Githaiga et al. analyzed by exploring the BRI trends across the African regions. They reveal that the infrastructural component of the BRI ^[3], although both transformative in scope and depth, lacks a mechanism for equitable share and long-term equitable development ^[4]. Similarly, as Foster and Briceño-Garmendia reminded us, there are limits to what infrastructure alone can deliver in terms of an inclusive society, for without policy interventions, the poorest people remain invisible from the main corridors of transport.

Importantly, all these studies reveal a common pattern: even though BRI’s focus on Africa’s landscape with its scale and ambition has most commentators praising it, the social aspects are rather mixed. Infrastructure is not a pro-poor tonic in its own right. Its ability to contribute to poverty reduction can be better guaranteed if such complementary infrastructure reforms are undertaken, besides a clear governance framework and community engagement. This paper follows this line of thinking to document and analyze three of BRI’s strategic projects—TAZARA, the Addis Ababa–Djibouti Railway, and the Port of Djibouti to investigate how these initiatives help in alleviating poverty directly. Specifically, this paper will fill an existing gap by reversing the broad filter of academic work that looks at macroeconomic

indicators and moving toward an impact analysis at the community level.

3. Case studies and impact analysis

3.1. The Tanzania-Zambia Railway (TAZARA)

The Tanzania-Zambia Railway (TAZARA), constructed between 1970 and 1975 with massive financial and technical aid from the Chinese government, was initially perceived as a gigantic infrastructure project that would promote trade linkage among the regions while liberating Zambia is no longer reliant on apartheid countries’ trade routes. The 1,860-kilometer railway that links Kapiri Mposhi in Zambia, with the port of Dar es Salaam in Tanzania, was pivotal in connecting the communities that use these countries as a trade route to the foreign markets. Locally, TAZARA fostered employment creation and offered rural farmers, who would otherwise have no access to markets, an opportunity to sell their produce, leading to agricultural diversification and small income generation. Rogerson claimed that transport infrastructure such as TAZARA ^[4], “diversifies rural economies and reduces poverty through linkages to markets, employment, and services,” particularly when it links people at the

edges of disadvantage to the centers of growth.

TAZARA also acted as a catalyst for some local development, such as settlement creation, small-scale trading establishments, and the erection of utilities like water supply plants and mills. Thus, a bottom-up economic activities upheaval took place, which went well with pro-poor development expectations during the period. Nevertheless, the railway's transport capacity has been greatly limited due to chronic financial underfunding, poor mismanagement, and dilapidated infrastructure. However, Githaiga et al. maintained ^[3], "BRI-related infrastructure projects, while transformational in scope, often face sustainability concerns that compromise long-term developmental equity," leading to reduced reliability in services and freight movement, which constrained the functionality of TAZARA and was gradually making it irrelevant to the poor economy, especially to smallholder farmers and informal traders. This aligns with Hillman's critique that BRI infrastructure projects often lack transparency and long-term planning structures, which undermines their sustainability and weakens developmental outcomes.

However, the benefits of TAZARA's economic linkages were not well spread. Urban concentrations and individuals who had capital to invest or connections to those who could help them benefited more than the majority of people in the disconnected rural areas, who remain disconnected from the decision-making processes. They also remain cut off from the downstream benefits. This is in support of De Beer and De Beer's argument that, without inclusive Planning ^[5], infrastructure projects may become "vehicles of exclusion rather than empowerment," offering dividends to the privileged people while the marginalized, poor, and sick remain at the bottom of the socio-economic pyramid.

Appreciating its strategic importance as well as symbolism, but more importantly, as a path to people-to-people integration, China, Zambia, and Tanzania signed a trilateral agreement in September 2024 to revamp the TAZARA Railway and travel. Their plan to modernize the railway entails transforming the railway corridor into an important rail-ocean transport corridor in East and Southern Africa. If the project is implemented, it signals the revival of regional transport linkages and supports economic recovery. However, its poverty-reducing potential can only be realized if accompanied by committed governance reforms, local employment quotas, and rural servicing integration. Ashley et al. warned that infrastructure alone cannot suffice. "It must be embedded in broader pro-poor strategies for the 'poor' to be active participants in the process of development rather than passive recipients." Should the TAZARA Railway be bereft of integration with such poverty eradication, it may once again not be able to deliver on its promise of poverty reduction.

3.2. Addis Ababa–Djibouti Railway

The Addis Ababa–Djibouti Railway is an electrified standard-gauge railway, commissioned in 2016, which stands as a flagship BRI initiative in East Africa. Covering some 752 kilometers in a direct line between Addis Ababa and the Port of Djibouti, the main port of entry and exit for over 95% of Ethiopia's imports and exports—the railway dramatically slashes transit times from several days to around 12 hours. This improvement in transit time leads to lower transportation costs for traders and farmers, especially for those within the corridor. The 2007 Asian Development Bank emphasizes that "transport investments have a strong pro-poor impact when they improve rural connectivity and reduce market isolation," which the railway ultimately achieved by allowing people and goods to move more freely.

Independent of these poverty-alleviating prospects, the corridor has promoted small-scale tourism and agriculture-related seasonal work mobility by providing better accessibility between urban and peri-urban areas.

The mobility improvements made possible by the corridor also presented opportunities for the growth of informal trade, local hospitality enterprises, and a rising tide of interregional labor migration. Spenceley et al. argued that “access to infrastructure is often a critical enabler for local entrepreneurship, especially when supported by complementary policy and training measures.” But these conditions have not been systematically created along the Addis Djibouti corridor.

Thus far, however, the railway’s poverty-reducing benefits have remained limited and patchy. The key difficulty for Ethiopia is in assuming a massive debt burden because its self-financed centerpiece was taken out through loan contracts with China. Githaiga et al. noted that “while the promise of BRI infrastructure may hold out long-term rewards ^[3], there is a rising worry that debt sustainability is the key issue in assessing BRI development legitimacy in Africa.” Furthermore, the Chinese contractors and engineers who dominated the project’s building and early functioning left only small numbers of local workers to do low-skill tasks, resulting in minimal capacity-building prospects. Dollar highlighted that the absence of local capacity-building in many BRI projects leads to missed opportunities for economic Empowerment ^[6], particularly when high-skilled roles are filled by foreign firms.

Foster and Briceño-Garmendia similarly argued that infrastructure must be embedded in complementary local systems like feeder roads and local labor policies to generate pro-poor outcomes.

Accordingly, although the Addis Ababa–Djibouti Railway reduced trade costs and presented options for regional economic diversification, its role in poverty alleviation has been indirect and ephemeral, with little longer-term empowerment of Ethiopia’s poorest communities. An encompassing governance mechanisms, highlighting local employment, skills transfer, and pro-poor orientation of interventions is crucial for this infrastructure to deliver on its revolutionary promise.

3.3. Port of Djibouti

Located at the point of convergence of the Red Sea and the Gulf of Aden, the Port of Djibouti, a regional maritime platform for Africa, the Middle East, and Asia, connects the three sectors. China, in the framework of the Belt and Road Initiative, has strongly committed to the renovation and enlargement of the port capacity and, simultaneously, the adjacent facilities of the Doraleh Multipurpose Port and Free Trade Zone. Changes have improved the port’s position as one of the top-level Africa logistical centers, boosting cargo turnover for Djibouti and landlocked Ethiopia. Hence, the site becomes an unrivaled venue for regional commerce. Chin and Gallagher argued that such placements as “China’s strategy in Djibouti is not only about trade efficiency, but about embedding itself into the architecture of global connectivity through logistics and finance” ^[7].

From an economic perspective, the financial resources allocated for the construction and development of the logistics and ancillary services stimulate some level of income generation for the locals. Similarly, the prospect of more cruise tourism with better port access has piqued the interest of foreign investors, and this has offered an opportunity for development in the hospitality and service industries. As Winter observed, “heritage tourism infrastructure linked to BRI logistics platforms could become a strategic tool for inclusive economic participation, provided it is locally anchored.” Despite such scenarios, the impact achieved in poverty reduction remains minimal.

However, one major concern area is the deep linking of the local economy with the port industry. Most of the activities and control in the port are dominated by the Chinese state-owned enterprises, with hardly anything transferred from the Chinese setup to the Djiboutian community vis-à-vis training or ownership. This situation led

to a state of dependency while depriving the nation of the value capture. De Beer and De Beer stated that “external control over strategic assets can inhibit community agency and prevent equitable development”^[5], which may be the case with Djibouti as well. This shows the structural concern raised by Dollar and Hillman^[6], who both mention that BRI projects often replicate dependency rather than foster autonomy, especially when ownership remains external and governance opaque.

As for the money already spent on the port extension, mostly debt financing through the Chinese loans, it has caused disputes on the issue of financial sustainability. Githaiga et al.^[3] stated that “geopolitical entanglements and debt dependence may ultimately undermine the sovereignty of small African states under BRI,” in reference to Djibouti being more exposed to the Chinese strategic power.

On the one hand, the Port of Djibouti has considerably improved macroeconomic statistics and connectivity of the region. However, these effects are only superficial as long as no institutional changes are initiated that give labor access to local communities, transparently govern the system, and share the benefits equally. As to BRI projects, for leveling up the reduction of poverty, the initiative must go beyond the tangible infrastructure and reach the intangibles of personal development, social participation, and economic independence.

4. Key challenges identified

Although the development of transport infrastructure within the framework of China’s Belt and Road Initiative (BRI) has a significant potential to alleviate poverty in African countries, serious difficulties still prevent its effective implementation in similar environments. Equally important, the lopsided focus on technical aspects in planning has deprived local communities, particularly vulnerable groups, of their legitimate roles in the decision-making processes concerning prioritizing projects. Subsequently, this scenario leads to the practical consequences of investments in infrastructure are being oriented outwards and being dominated by foreign or even national actors, who are not in tune with the developmental needs of the area. As De Beer and De Beer contended^[5], if the deprived people are excluded from the planning procedures, “development is going to be something that happens to them rather than with them,” and due to that they become more dependent instead of being empowered.

Another principal issue is the distribution of the advantages; they are not equally shared among all members of society. Some infrastructure investments, which lack adequate social frameworks, are skewed in favor of political elites, urban centers, and foreign companies that may be taking on construction and operations. In this sense, the situation has been observed through all three cases, in such a way that high-skilled jobs, procurement contracts, as well as governance influence, were in many cases largely reserved for Chinese firms or local elites at the expense of poor communities. In the view of Rogerson^[4], only deliberate pro-poor orientation would alleviate the prevailing imbalances, while envisaged infrastructure can end up intensifying the existing disparities.

One more crucial obstacle is the question of debt sustainability, which is the main concern when financing BRI projects. Most African states have incurred intolerable debts, which are required to be settled in time; these, in turn, weaken the country’s financial capacity to expand other areas such as healthcare and education. Githaiga et al. warned that “high debt exposure is linked to BRI participation... diverts... public funds away”^[3], especially in the event of defaults on loans being prioritized over internal spending. On the one hand, this can serve as the structural pillar for governments to be trapped in and, in the end, unable to implement protectionist policies or effectively deal with local development issues.

In conclusion, these difficulties show the relevance of changing the approach to building infrastructure,

involving the community, and striving for economic growth, which will countermeasure poverty alleviation among African nations.

5. Recommendations

For BRI transportation infrastructure to fulfill its role in poverty alleviation across Africa, it is necessary to adopt a more inclusive and socially responsible implementation. First, infrastructure investment should be linked directly to poverty alleviation goals through job guarantees, local procurement requirements, and civil works programs/Community Development. Provided that railway line areas and ports of call are favorable, disadvantaged populations must be the primary focus when operating and planning projects, especially when these projects generate meaningful economic opportunities. Infrastructure that can only be reached by connecting people to markets and services will not improve living standards without these policies, which were designed to target marginalized communities.

It is also imperative to provide local capacity building through vocational education and technical training. One of the main criticisms of the case studies, particularly the Addis Ababa–Djibouti Railway, is the failure to transfer any significant technical information to the local workers. However, when a host country spends time and resources on workforce development and training, it can be assured that new infrastructure projects will bring about not only temporary jobs for local people but also long-term employment and management opportunities for them. Beyond that, it increases the sustainability of new infrastructure projects and reduces dependency on overseas operators. As Dollar noted ^[6], without local skill development and labor participation, infrastructure investments risk becoming isolated from domestic economic empowerment.

Further, the principles of governance transparency and independent evaluation should be introduced at all stages of project planning and implementation. Data collection of social and economic indicators, such as job creation, income growth, and essential services, with financial indicators, should be integrated into the monitoring systems. The infrastructure projects can thus be regulated by independent bodies, ideally with the participation of local civil society organizations, to ensure that they serve the local population instead of only the interests of politicians and big corporations. This is consistent with Hillman, who said that the absence of accountability, transparency, and oversight has undermined the developmental value of many BRI projects.

And lastly, the collaborative partnership approach is a primary strategy that should be adopted. Through the involvement and participation of governments, NGOs, development agencies, and local communities in all decision-making processes, and in what they get as a benefit, almost everything can be accomplished. As Chin and Gallagher observed ^[7], inclusive frameworks not only add to the effectiveness of development but also scale up its legitimacy. Similarly, Rogerson and De Beer and De Beer both stress that participatory governance and bottom-up planning are essential for infrastructure to truly support marginalized groups and avoid elite capture ^[4,5]. Additionally, by introducing the possibility for joint responsibility, the future BRI initiatives will be more likely to concern themselves with overcoming the problems of poverty and achieving the fair development of all regions of Africa.

6. Conclusion

In this paper, I undertake a critical assessment of how much, if at all, China's Belt and Road Initiative (BRI) transportation infrastructure efforts in Africa. TAZARA Railway, the Addis Ababa Djibouti Railway, and the

Port of Djibouti play a direct role in alleviating poverty for the continent's most disadvantaged and poor groups. Even though transporting goods and people across the BRI countries has been hailed for its vast scale and trade potential, there are still many instances where the BRI's outcomes are not pro-poor or inclusive. According to the results reported in this study, there seems to be a gap between the infrastructure sector development and the real-world conditions of the poor and informal economies of rural Africa.

On a different but related note, these big transport infrastructure projects, notwithstanding their mandate of trade facilitation and regional migration, have continuously neglected the low-income segment in the communities in their design, implementation, and long-term management. The TAZARA Railway, hailed as a symbol of liberation and economic integration, has unfortunately fallen victim to a lack of international support and the marginalization of rural populations. Nevertheless, while the Addis Ababa Djibouti Railway has helped to lessen the travel time and bolster trade, it was mainly built and operated without the establishment of the local workforce development and knowledge transfer. In the same way, even if the Port of Djibouti transformed into a major logistical ground, but it could not definitely prove to be a key factor in effectively improving the economy or alleviating poverty in the neighboring areas. In these three cases, decision-making processes and economic benefits have reached mainly the foreign firms, the urban elites, and the state actors.

Infrastructure alone is not automatically pro-poor, as the examination of the literature added further evidence on this matter. The suitability of transport systems to tackle poverty can only be achieved through the connection of these systems with other complementary policies comprising rural access roads, vocational training, local procurement mandates, and participatory governance. A group of researchers such as Dollar^[6], Hillman, and Foster & Briceño-Garmendia particularly emphasized the role of social measures, mapping out impressive inclusive planning and accountability.

As for the future of BRI infrastructure projects in Africa, it is recommended that they adapt from the current top-down, state-to-state model to a people-centered approach. Such transformation, in particular, should encompass incorporating community needs into the planning and budgeting process, ensuring local representation in decision-making, and establishing tracking and monitoring mechanisms. This can include not only connectivity for long-term local ownership and capacity building but also equitable access. BRI's BRI campaign may end up being a replication of the inequalities that it claims to combat if it does not reform these systems.

The bottom line is that if BRI is to be a real driving force of inclusive development in Africa, then it has to render more than just linkages. BRI should ideally not only provide connectivity but also empowerment, equity, and sustainable transformation on the side of the continent's poverty.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Asian Development Bank, 2007, *Tourism for Pro-Poor and Sustainable Growth: Economic Analysis of Tourism Projects* (Technical Note No. 20), viewed May 20, 2025, <https://www.adb.org/sites/default/files/publication/29863/tn-20-tourism-pro-poor.pdf>
- [2] Manyara G, Jones E, 2007, *Community-Based Tourism Enterprises Development in Kenya: An Exploration of Their Potential as Avenues of Poverty Reduction*. *Journal of Sustainable Tourism*, 15(6): 628–644.

- [3] Githaiga NM, Burimaso A, Bing W, et al., 2019, The Belt and Road Initiative: Opportunities and Risks for Africa's Connectivity. *African Journal of International Affairs*, 19(3): 22–45.
- [4] Rogerson CM, 2007, Tourism: A Viable Option for Pro-Poor Growth in Africa? *GeoJournal*, 67(2): 155–166.
- [5] De Beer A, De Beer F, 2011, Reflections on Pro-Poor Tourism in South Africa: Challenges of Poverty and Policy in the Search for a Way Forward. *Journal of Contemporary Management*, 8: 591–606.
- [6] Dollar D, 2015, China's Investment in Africa, Brookings Institution.
- [7] Chin GT, Gallagher KP, 2019, Coordinating China's Belt and Road Initiative in Africa: The Role of the AIIB and the Silk Road Fund. *Global Policy*, 10(3): 346–358.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

China's Responses and Strategies in Participating in International Digital Trade Rules Negotiations

Jingfan Zhu, Sujie Wei*

School of Economics, Guangxi University, Nanning 530000, Guangxi, China

**Author to whom correspondence should be addressed.*

Copyright: © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: Against the backdrop of profound reshaping of the current international landscape and the unprecedentedly rapid iteration of digital technologies, the global digital economy landscape and international trade rule system are entering a new era full of changes. Digital trade rules have emerged as a prominent focus in this field. Firstly, through a comprehensive review of sample data such as the WTO e-commerce proposals under the current multilateral framework, we can gain a profound insight into the negotiation practices of major economies regarding digital trade rules. In this context, China has demonstrated strong defensive interests in the “emerging” issues of digital trade, aiming to safeguard national data security and promote the healthy development of the digital economy. Therefore, when participating in the formulation of global digital trade rules, China needs to accurately strike a balance between offense and defense, contribute Chinese wisdom and solutions, and promote the construction of a fairer, more reasonable, and inclusive international digital trade governance system.

Keywords: Digital trade; Trade rules; Business negotiations

Online publication: October 14, 2025

1. Introduction

Driven by the wave of technological revolution and industrial transformation, the digital economy is developing at an unprecedented speed, and digital trade is facing an unprecedented historical opportunity. Focusing on the Chinese market, the China Digital Trade Development Report states that in 2023, China's import and export volume of digitally deliverable services reached 385.9 billion US dollars, a year-on-year increase of 3.5%, hitting a new historical high. To keep up with the pulse of the times, the Opinions on the Reform, Innovation and Development of Digital Trade issued in December 2024 emphasized promoting digital trade development through innovation and accelerating the construction of a strong digital trade country, reflecting China's proactive actions and strategic vision in promoting trade model innovation and reform of the global governance system. However, the rapid expansion of digital trade has also posed severe challenges and new requirements to the existing international trade rule system. A unified and coordinated rule system has not yet been formed globally^[1]. Therefore, this paper conducts an in-

depth analysis of the current international dynamics of global digital trade rules and the core issues of concern, and further explores and puts forward strategic suggestions for China in participating in digital trade rules negotiations, aiming to contribute wisdom and solutions to the healthy development of China's and global digital trade.

2. Literature review

In the academic exploration of international business negotiations on digital trade rules, the primary issue focuses on an in-depth analysis of international trade negotiation rules under the frameworks of GATT and WTO. It particularly emphasizes the core role and widespread recognition of GATT and WTO in promoting the smooth progress of international trade negotiations and resolving trade disputes^[2]. However, the current regulations of the WTO are facing dual challenges from technical barriers and political interference, thus calling for necessary supplementation, optimization, and innovative reforms to the WTO rule system to adapt to the needs of the times. In-depth exploration of international trade negotiation methods constitutes another key dimension in this research field. In the context of e-commerce negotiations between major powers, the simplification of the structure of negotiating members can often significantly improve negotiation efficiency and bring more favorable negotiation results to all participants; on the contrary, at the negotiating table with multiple participants, although small countries have no significant market advantages, they can benefit from broader international cooperation and promote the improvement of global total welfare^[3]. Studies on trade negotiations based on specific cases have profoundly revealed the interweaving of complex domestic and foreign political and economic factors behind negotiation results, including national interest games, dynamics of international relations, international institutional frameworks, etc. These factors interact to jointly shape the complex ecology and final direction of international trade negotiations^[4].

3. Development trend of global digital trade rules

3.1. Parallel operation of the WTO framework and the APEC framework

WTO plays a key role in promoting international trade prosperity and the construction of rule systems. However, the diversity and differences in interest demands among member states have seriously hindered the smooth progress of negotiations. Nevertheless, the signing of the Consolidated Text of the WTO Joint Statement Initiative on Electronic Commerce indicates that the construction of digital trade rules under the WTO framework is gradually deepening. The international rule system that balances the interests of all parties has laid a solid foundation for the prosperity and sustainable development of global digital trade^[5].

As one of the most important economic cooperation mechanisms in the Asia-Pacific region, APEC has played an active role in promoting negotiations on digital trade rules in recent years, such as in cross-border data flow and data protection, e-commerce rules, and digital intellectual property protection^[6]. Currently, digital trade has become an important area of economic cooperation among APEC members. The negotiations on digital trade rules under the APEC regional framework aim to formulate rules and standards adapted to the development trend of the digital economy through consensus, so as to promote the liberalization, facilitation, and standardization of digital trade within the region^[7].

3.2. American and European models

3.2.1. American digital trade framework

The American digital trade model advocates "market liberalization." It has enriched the global layout in the field

of digital trade through participation in TPP, USMCA, and UJDTA, etc.^[8]. In view of the blank state of digital trade rules under the WTO multilateral framework before 2015, negotiation activities on digital trade rules at the regional and bilateral levels increased significantly, becoming an important way to fill this gap^[9]. Among them, the signing of TPP marked an important milestone in the development of digital trade rules, consolidating and expanding the global influence in advantageous digital trade fields such as social networks and search engines. Although the United States later withdrew from TPP, CPTPP, as an extension of TPP, has ensured the continuity and development of core issues related to digital trade.

3.2.2. European digital trade framework

The European Union has constructed a European-style framework for digital trade rules based on integrating its unique values and institutional advantages. This model is unique in global digital trade governance, and TPP has had a profound impact on the EU's digital trade framework^[10]. The EU has borrowed and adopted many core provisions from TPP in a series of trade agreements it has signed, especially in the field of digital trade. This reflects that while maintaining its own characteristics, the EU also actively absorbs advanced international experience to improve its digital trade rule system.

3.3. Asia-Pacific model

As one of the most economically active regions in the world, countries in the Asia-Pacific region have gradually formed a digital trade rule model with Asian-Pacific characteristics on the basis of seeking to balance the interests of liberalization, security, privacy protection, intellectual property protection, and other aspects. Asian-Pacific countries are jointly promoting the formulation and implementation of digital trade rules by strengthening regional cooperation and coordination^[11]. The conclusion of regional agreements such as DEPA and SADEA has built a solid institutional foundation for the vigorous development of digital trade in the Asia-Pacific region. The digital trade rules of the Asia-Pacific model advocated by these agreements significantly emphasize the core values of diversity and inclusiveness, aiming to balance and meet the complex and diverse interests of countries in the region through a flexible design framework.

4. Key areas of China's participation in digital trade negotiations

4.1. Cross-border data flow and data security

Cross-border data flow is one of the core elements of digital trade, involving the transmission, storage, and processing of data between different countries and regions. Data security is an important prerequisite for ensuring that data is not illegally obtained, tampered with, or leaked during cross-border flow. Cross-border data flow and data security are key areas in digital trade regulatory negotiations. Countries often have different laws, regulations, and standards in this regard, which require consensus through negotiations^[12]. China often includes relevant provisions on cross-border data flow and data security in bilateral or multilateral agreements signed with other countries to ensure the legality and security of data in the process of cross-border transmission.

4.2. Rules for digital service trade

Digital service trade is an important part of digital trade, covering multiple fields such as telecommunications services, computer and information services, and royalties for intellectual property^[13]. The formulation of rules for digital service trade involves WTO basic principles such as market access, national treatment, and most-favored-

nation treatment, as well as new issues arising from the particularity and complexity of digital services. As China's first local regulation in the field of digital trade, the "Hangzhou Digital Trade Promotion Regulations" were formally implemented on June 1, 2024. The introduction of this regulation provides legal protection and policy support for the development of digital trade in Hangzhou and even the whole country.

4.3. Digital taxation and anti-tax avoidance

The rapid development of digital trade has brought challenges to the traditional tax system, making digital taxation and anti-tax avoidance important topics in international negotiations. Digital taxation involves issues such as tax jurisdiction, determination of tax base, and setting of tax rates for transnational digital enterprises; anti-tax avoidance aims to prevent transnational enterprises from evading tax obligations through digital means^[14]. China actively participates in international negotiations in this field and promotes the establishment of a fair and reasonable digital taxation system. Internationally, China supports the efforts of international organizations such as the OECD in the field of digital taxation and promotes the formulation of unified global digital taxation rules and standards. Domestically, it strengthens domestic tax legislation and law enforcement work and improves the capacity of digital tax collection and management.

5. China's proposals for participating in international digital trade rule negotiations

5.1. Flexible combination of negotiations: Promoting open cooperation and market access

In international digital trade rule negotiations, countries flexibly combine different negotiation strategies based on their own interests and negotiation goals, aiming to maximize negotiation interests. China's proposal emphasizes promoting open cooperation in the field of digital trade and advancing the building of an open world economy. The digital trade chapter in RCEP reflects China's concept of promoting open cooperation, where member states strengthen cooperation in areas such as e-commerce, data flow, and information security to facilitate the liberalization and facilitation of intra-regional digital trade. China has established multiple free trade pilot zones and implemented a series of innovative digital trade policies and systems, providing a more convenient investment and trade environment^[15].

5.2. Phased negotiations: Ensuring data security and privacy protection

Phased negotiations break down complex negotiation issues into multiple stages to advance the negotiation process step by step, which helps improve negotiation efficiency and gradually build trust and consensus. In international digital trade rule negotiations, due to the numerous and complex issues involved, countries first negotiate on issues that are relatively easy to reach a consensus on. After achieving certain results in these issues, they then gradually move on to more complex ones. China's proposal emphasizes the importance of ensuring data security and privacy protection. It has initiated and promoted the "Belt and Road" Data Security Cooperation Initiative, advocating for joint responses to data security challenges while promoting cross-border data flows.

5.3. High-risk, low-cost negotiations: Driving rule innovation and technological development

High-risk, low-cost negotiations refer to situations where one or both parties face high uncertainty or potential losses in the negotiation process, but the input costs are relatively low. This negotiation method is common in emerging fields or industries with rapid technological iteration, such as international digital trade rule negotiations. China's proposal advocates that, in light of the rapid development of digital technologies and the

continuous innovation of business models, countries should fully consider the characteristics and needs of new technologies, new formats, and new models when formulating digital trade rules. The digital yuan (DC/EP) launched by the People's Bank of China is an important innovation in the field of digital currency. It not only helps improve payment efficiency and reduce transaction costs but also provides an important opportunity for China's international cooperation and rule-making in the field of digital currency.

6. Conclusion

Against the backdrop of global digital economy transformation and the reshaping of trade rules, digital trade rules have become the core of the game in the international economic order. This paper finds that the WTO multilateral framework and regional mechanisms such as APEC and CPTPP jointly form a pluralistic rule pattern, and the interest games among countries around core issues such as cross-border data flow, digital services, and digital taxation continue to deepen.

As an important participant in global digital trade, China has shown strong development momentum relying on its scale advantage, but it still faces challenges such as insufficient experience and standard connections in the formulation of international rules. Its defensive demands in the fields of data security and digital sovereignty reflect the dual considerations of development stage and national interests.

To this end, China needs to uphold the concept of openness and win-win cooperation strategically, and flexibly use tactics such as "combined negotiations," "phased advancement," and "breakthroughs in innovative fields" tactically. It should contribute to rule solutions based on domestic practices, promote the construction of a fair and inclusive new global digital trade governance system, and inject impetus into the sustainable development of the world economy.

Funding

This article was one of the achievements of the 2025 Guangxi Degree and Graduate Education Reform Project on Artificial Intelligence Empowering International Business Master's Teaching Innovation Research (JGY2025036).

Disclosure statement

The authors declare no conflict of interest.

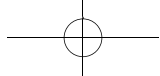
References

- [1] Wei L, Huang X, Huang Y, 2024, Global Digital Trade Governance: Rule Differences and Strategic Choices. *International Trade*, (02): 5–17.
- [2] Li C, Zhao M, The Choice and Effectiveness of International Trade Dispute Settlement Mechanisms: Theory and China's Choice. *Finance & Trade Economics*, 2011(5): 86–91.
- [3] Xu X, Lin K, 2022, The Politicization of International Economic Agendas and the Dilemma of WTO Reform. *World Economics and Politics*, (10): 101–129 + 167–168.
- [4] Quan Y, 2023, The Reconstruction of International Economic and Trade Rules and the Prospects of WTO Reform. *Economist*, (01): 109–118.

- [5] Suh J, Roh J, 2023, The Effects of Digital Trade Policies on Digital Trade. *The World Economy*, 46(8): 2383–2407.
- [6] Burri M, Callo-Muller MV, Kugler K, 2024, The Evolution of Digital Trade Law: Insights from TAPED. *World Trade Review*, 23(2): 190–207.
- [7] Sen N, 2018, Understanding the role of the WTO in International Data Flows: Taking the Liberalization or the Regulatory Autonomy Path? *Journal of International Economic Law*, 21(2): 323–348.
- [8] Yue Y, Huo P, 2021, WTO E-Commerce Negotiations and the Game of Digital Trade Rules. *Journal of International Business Studies*, 42(01): 73–85.
- [9] Gao J, Sheng B, 2023, Digital Trade Rule Negotiations and China’s Interests. *World Social Sciences*, (04): 171–187 + 246.
- [10] Zhang G, 2024, Research on China’s Game Strategy to Enhance Discourse Power in Digital Trade Rules. *Northern Economy and Trade*, (07): 29–33.
- [11] Zhang X, Hou J, 2022, Digital Trade Rules: “American Template” and the Construction Strategy of “China-ASEAN Plan.” *Academic Forum*, 45(04): 83–92.
- [12] Wolfe R, 2019, Learning about Digital Trade: Privacy and E-Commerce in CETA and TPP. *World Trade Review*, 18(S1): S63–S84.
- [13] Mattoo A, Meltzer JP, 2018, International Data Flows and Privacy: The Conflict and Its Resolution. *Journal of International Economic Law*, 21: 769, 776.
- [14] Mishra N, Valencia AMP, 2023, Digital Services and Digital Trade in the Asia Pacific: An Alternative Model for Digital Integration? *Asia Pacific Law Review*, 31(2): 489–513.
- [15] Huang X, Zhou L, 2024, Comparison, Challenges and China’s Response Strategies of Global Digital Trade Rules - From the Comparative Perspective of CPTPP, DEPA and RCEP. *Social Science Front*, (01): 44–53.

Publisher’s note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Integrated Services Platform of International Scientific Cooperation

Innoscience Research (Malaysia), which is global market oriented, was founded in 2016. Innoscience Research focuses on services based on scientific research. By cooperating with universities and scientific institutes all over the world, it performs medical researches to benefit human beings and promotes the interdisciplinary and international exchanges among researchers.

Innoscience Research covers biology, chemistry, physics and many other disciplines. It mainly focuses on the improvement of human health. It aims to promote the cooperation, exploration and exchange among researchers from different countries. By establishing platforms, Innoscience integrates the demands from different fields to realize the combination of clinical research and basic research and to accelerate and deepen the international scientific cooperation.

Cooperation Mode



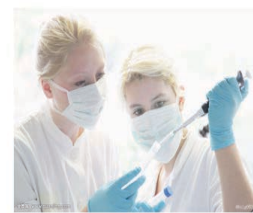
Clinical Workers



In-service Doctors



Foreign Researchers



Hospital



University



Scientific institutions

OUR JOURNALS



The *Journal of Architectural Research and Development* is an international peer-reviewed and open access journal which is devoted to establish a bridge between theory and practice in the fields of architectural and design research, urban planning and built environment research.

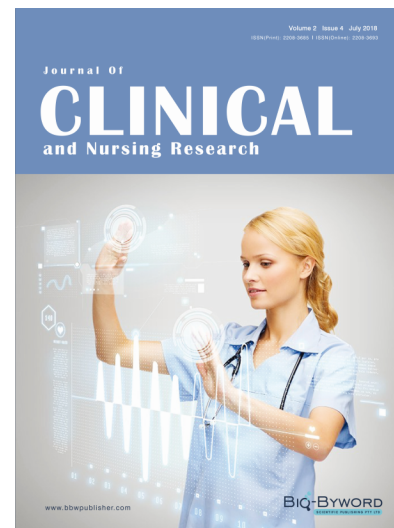
Topics covered but not limited to:

- Architectural design
- Architectural technology, including new technologies and energy saving technologies
- Architectural practice
- Urban planning
- Impacts of architecture on environment

Journal of Clinical and Nursing Research (JCNR) is an international, peer reviewed and open access journal that seeks to promote the development and exchange of knowledge which is directly relevant to all clinical and nursing research and practice. Articles which explore the meaning, prevention, treatment, outcome and impact of a high standard clinical and nursing practice and discipline are encouraged to be submitted as original article, review, case report, short communication and letters.

Topics covered by not limited to:

- Development of clinical and nursing research, evaluation, evidence-based practice and scientific enquiry
- Patients and family experiences of health care
- Clinical and nursing research to enhance patient safety and reduce harm to patients
- Ethics
- Clinical and Nursing history
- Medicine



Journal of Electronic Research and Application is an international, peer-reviewed and open access journal which publishes original articles, reviews, short communications, case studies and letters in the field of electronic research and application.

Topics covered but not limited to:

- Automation
- Circuit Analysis and Application
- Electric and Electronic Measurement Systems
- Electrical Engineering
- Electronic Materials
- Electronics and Communications Engineering
- Power Systems and Power Electronics
- Signal Processing
- Telecommunications Engineering
- Wireless and Mobile Communication

